Technology adoption, cooperation and trade and competitiveness policies: Re-examining the uptake of Renewable Energy Technologies (RETs) in urban Latin America using systemic approaches

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ABSTRACT

Many conventional approaches to Renewable Energy Technology (RET) adoption in developing countries generally stress economic and technical factors; often relying on rural contexts. Systemic approaches are an alternative lens, attempting to include social and economic factors at various scales, but to date there is little evidence supporting their application. Based on empirical analysis in Mexico and Brazil, this thesis asks: What are the most important factors affecting RET adoption in the urban developing world?

Insights were explained using three systemic approaches on RET adoption at the meso-level. While systemic approaches are useful in highlighting larger social and policy trends, they are not without their limitations; rather, history and context are important.

Specifically, awareness of energy conservation in combination with previous experience (versus just awareness) also affects technology uptake. Moreover, longer established networks were seen to be more institutionalized, with knock-on affects on RET use. Dynamics *within* stakeholder groups were also observed to help explain RET adoption. One source of divisions was trade and competitiveness policies, where in Mexico there is a major divide between foreign and domestically-owned firms.

International influences (e.g. climate change) have also prompted networks in both places - but in Brazil, over time, the key drivers for action on climate change were domestic verses foreign. These facets are arguably happening as a result of Brazil's trade and competitiveness approach which yielded more opportunities for developing technological capabilities, therefore positively impacting on RET uptake.

Although research is recent, the general consensus is that trade liberalization can lead to more RET use in developing countries. However, the findings of this study show that under certain conditions a provisionally open trade and competitiveness regime can also increase RET use. This is because technology use is also linked to local technology cooperation dynamics, and not just to trade and competitiveness policies.

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ACRONYMS

Acronym	Spanish or Portuguese	English
ABRAVA - DASOL	Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação e Aquecimento - Departamento Nacional de Aquecimento Solar	Brazilian Association of Refrigeration, Air Conditioning, Ventilation and Heating - National Department of Solar Heating
ANEEL	Agência Nacional de Energia Elétrica	Brazilian Electricity Regulatory Agency
ANES	Asociacion Nacional de Energia Solar	Mexican National Association for Solar Energy
CANACINTRA	Camara Nacional de Industria de Transformacion	Mexican National Chamber of Industry of Transformation
CCGT		Combined Cycle Gas Turbine
CDM		Clean Development Mechanism
CENBIO	Centro Nacional de Referência em Biomassa	Brazilian Reference Centre on Biomass
CETESB	Companhia Ambiental do Estado de São Paulo	State of Sao Paulo Environmental Company
CFE	Comision Federal de Electricidad	Mexican Federal Electricity Commission
CIE	Centro de Investigaciones de Energia	Centre for Energy Research, UNAM
CIETEC	Centro Incubador de Empresas Tecnologicas	Incubator Centre for Technical Businesses, USP
CONAE	Comision Nacional para la Ahorro de Energia	Mexican National Commission for Energy Conservation
CONACYT	Consejo Nacional de Ciencia y Tecnología	Mexican National Commission for Science and Technology
CONUEE	Comision Nacional para el Uso Eficiente de la Energia	Mexican National Commission for Energy Efficiency
CUT	Central Única dos Trabalhadores	Brazilian Central Workers Union
GHG		Greenhouse Gas
IEE	Instituto de Eletrotécnica e Energia	Electrotechnical and Energy Institute, UNAM
IEE	Instituto de Investigaciones Electricas	Mexican Electric Research Institute
INMETRO	Instituto Nacional de Metrologia, Normalização e Qualidade Industrial	Brazilian National Institute of Metrology, Standardization and Industrial Quality
IPN	Instituto Politecnico Nacional	Mexican National Politechnical Institute
IPR		Intellectual Property Right
IPT	Instituto de Pesquisas Tecnológicas	Institute of Technology Research, USP
LAFRE	Ley para el Aprovechamiento de las Fuentes Renovables de Energía	Law for the Advancement of Renewable Energy Sources in Mexico

Acronym	Spanish or Portuguese	English
LPG		Liquefied Petroleum Gas
LyFC	Luz y Fuerza del Centro	Central Light and Power
MMA	Ministerio de Meio Ambiente	Brazilian Ministry of Environment
MCT	Ministerio de Ciencias e Tecnologias	Brazilian Ministry of Science and Technology
NAFTA		North American Free Trade Agreement
NAMA		Non-Agricultural Market Access
NORMEX	Nacional Organismo de Normalizacion y Certificacion de Mexico	National Organism (Organization) of Normalization and Certification of Mexico
PEMEX	Petroleos Mexicanos	Mexican Petroleum
PROALCOOL	Programa Brasileiro de Alcool	Brazilian National Alcohol Fuel Program
PROCEL	Programa Nacional de Conservação de Energia Elétrica	Brazilian National Program for Electricity Conservation
PROINFA	Programa de Incentivos às Fontes Alternativas de Energia	Brazilian Incentive Program for Alternative Energy Sources
RET		Renewable Energy Technology
SEHAB	Secretaria Municipal de Habitação	São Paulo Municipal Housing and Urban Development Department
SEMARNAT	Secretaria de Medio Ambiente y Recursos Naturales	Secretary of the Environment and Natural Resources
SENER	Secretaría de Energía	Secretary of Energy
SVMA	Secretaria do Verde e Meio Ambiente de Sao Paulo	Municipal Secretary of Green (issues) and Environment
SWH		Solar Water Heater
UAM	Universidad Autonoma Metropolitana	Autonomous Metropolitan University, Mexico City
UNFCCC		United Nations Framework Convention on Climate Change
UNAM	Universidad Nacional Autnoma de Mexico	National Autonomous University of Mexico
USP	Universidade de Sao Paulo	University of Sao Paulo
WTO		World Trade Organization

CHAPTER 1: INTRODUCTION

1.1. The renewable energy challenge for growing cities

Global energy demand is expected to grow by 55% from 2005 to 2030, with the majority of this increase (74%) coming from developing countries (IEA 2007). To meet this need, research, support and interest in renewable energy technology (RET) options for developing nations is growing. A number of advantages have been highlighted espousing their use. For instance, academics, policy makers and practitioners increasingly view the use of these technologies as a way to address global climate change. One avenue for developing countries to do this is the Clean Development Mechanism (CDM). In the CDM, countries of the industrialized world taking part in the global climate change process[1] that have exceeded their greenhouse gas (GHG) emissions allowance "pay" developing countries for undertaking projects that reduce GHG emissions, by placing a price on these emissions that were mitigated through projects.

RETs are also considered attractive options to reduce local and regional environmental impacts, such as air pollution in urban areas, mainly due to the burning of fossil fuels. Furthermore, the use of RETs in developing countries is considered a means through which to increase technological capacity, or those aspects that contribute to technological change at the level of a firm, country or region (Rogers 2003b). Adopting more renewables is also viewed as a way to increase energy security (see Mason and Mor 2009) for a comprehensive overview on energy security and renewables in the Middle East for instance) as many renewable energy sources are

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[1] The Kyoto Protocol, developed in 1997, and which came into force in February 2005, is an international environmental agreement that commits industrialized countries to reduce their greenhouse gas (GHG) emissions in the timeframe 2008-2012. The majority of industrialized countries are parties to the treaty, with the major exceptions of the United States and Australia. Canada, although a party to the agreement, has indicated that they will not be able to meet their commitments. Also, developing countries do not have targets.

available domestically[2] (e.g. sun, wind, biomass), thus reducing developing countries' dependency on fossil fuels. Even those countries that have fossil fuel reserves domestically are interested in renewables as a way of reducing domestic consumption (and therefore freeing up more fossil fuels to be exported) (Massabié 2008), and to reduce vulnerability to price fluctuations of fossil fuels.[3]

The use of renewables is steadily increasing, but progress is slow. For example although renewables are expected to increase in use by 60% from 2002-2030, in 2002 these sources only accounted for 1% of global energy consumption (Renewables 2004: 6). In other words, while there is increasing research, support, interest and use for RETs, they continue to remain on the margins of more conventional energy choices.

At the same time, the world is becoming increasingly urban. According to the United Nations Population Foundation (UNPFA), as of 2008, more than half of the world's population lived in cities (UNFPA 2007). By 2030, it is estimated that over 60% of the world's population will live in cities, and over four-fifths of this number will reside in developing country cities (WRI 2005). Urban areas are argued to be responsible for about 80% of annual global carbon dioxide emissions (UN-HABITAT 2007: 4), although on a per capita basis, GHG emissions from city dwellers are often less than their rural counterparts (Dodman 2009). This recognition has prompted a small but growing body of literature examining cities and energy and environmental issues, including renewable energy policies. This literature has mainly drawn from evidence in industrialized nations (e.g. Nijkamp and Pepping 1998; Capello et al. 1999; Cherni 2002) with some examples from the developing world (e.g. Cherni 2001), or both (Dhakal 2008). In the area of climate change and developing countries, research on cities focuses on health impacts and adaptation (e.g. Campbell-Lendrum and Corvalán 2007; Bicknell et al.

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[2] Although many equate energy security with decreasing imports and increasing production of domestic energy resources but there are other aspects to energy security. For instance, threats to energy supplies can come from domestic sources too -see Wang, T. and J. Watson (2009). China's Energy Transition - Pathways for Low Carbon Development. Brighton, UK, Science and Technology Policy Research (SPRU). This has been demonstrated in Western Canada where ecoterrorists hindering the development the oil and gas sector in that region are purported to be Canadian. See Bright, A. (2008). Bombings of Canadian pipelines spark ecoterrorism fears. Christian Science Monitor (CSM).

[3] As an example, the price of oil was almost US$150 per barrel of oil in July 2008, versus about US$68 in July 2009.

2009; Heinrichs et al. 2009; Lapitan et al. 2009). Studies on developing country cities and the adoption of renewables, and in Latin America in particular,[4] are sparse.

Conventional approaches aimed at increasing renewable energy technologies (RETs) in developing countries, stressing barriers and ways to overcome them, often neglect the urban context and place too much emphasis on technical and economic attributes. Systemic models have been proposed as an alternative approach as they try to include social and economic factors at various scales to explain RET adoption, but to date there is little evidence supporting their application. An important research question is thus:

"What are the most important factors affecting RET adoption in the urban developing world?"

To answer this question, the dissertation focused on the following three sub-research questions:

- How can systemic approaches help to explain RET adoption in the urban developing world?
- What are the reasons SWHs and biogas to produce electricity technologies are being used or not in Mexico City and São Paulo?
- To what extent do trade and competitiveness policies explain RET adoption in the urban developing world?

The dissertation argues that systemic approaches can be effective tools to explain RET adoption because in addition to accounting for factors affecting adoption noted in conventional approaches (e.g. cost, direct incentives), they highlight larger social and policy trends. Yet, while systemic approaches are useful, they are not without their limitations when applied to real world examples. Rather, history and context are important, which put some assumptions into question when applying these approaches

[4] Some exceptions include the studies done by Quintanilla, J. and P. Mulas (1998). Use of Solar Energy in Mexican Urban Areas to Substitute for Liquified Petroleum Gas (LPG). 17th World Energy Congress. Houston: 1-10.; Quintanilla et al. (2000). Uso Masivo de la energia solar en sustitucion de combusitbles fosiles en la Zona Metropolitana de Vale de Mexico: Sectores residencial, hospitalario, hotelero, y de banos publicos. U. N. A. d. M. U. Programa Universitario de Energia. Mexico City, UNAM.; Ferrel-Mendieta, M. (1999). the Use of Solar Water Heaters in Mexico City. Masters thesis - Architecture. Montreal, McGill: 134.

to Mexico City and São Paulo. Each approach on its own, with its strengths and weaknesses, can explain part of the story, but in combination, they represent a more complete understanding.

Specifically, I found that classical explanations for RET use (such as those emphasizing cost, awareness and incentives) can help to explain adoption rates in each location, but were unable to adequately account for differences between the two settings. I found that awareness of energy conservation in combination with previous experience with a technology also affects uptake, rather than just awareness of the actual technology stressed by most adoption studies on RETs.

Secondly, conventional approaches focus on interactions between stakeholder groups. But more attention is needed on the nature of these relationships. In my research I found that networks in São Paulo that had been around longer were more institutionalised and the stakeholders groups more mobilized, and that more links existed between various sectors, positively affecting RET use.

I also found that dynamics *within* stakeholder groups, affected by international influences, such as divisions uncovered at the meso-level, help explain RET use. One reason behind these divisions can be traced to trade and competitiveness policies, where in Mexico there is a major divide between foreign and domestically-owned firms.

Also, international influences have prompted and / or strengthened these networks in both locations, such as with climate change, but in Brazil, over time, the key drivers advocating climate change are domestic verses foreign. I argue that these three facets are happening as a result of their trade and competitiveness approach – in Brazil there have been more opportunities for developing technological capabilities, therefore establishing more indigenous capacity and more 'ownership' of the technology cooperation process, which in this case plays a positive role on uptake.

Although research in this area is recent, the general consensus is that trade liberalization can lead to more RET use in developing countries (World Bank 2008a; Cosbey 2007). However, my findings show that under certain conditions a provisionally open trade and competitiveness regime can also increase RET use. This is because technology use is also linked to local technology cooperation dynamics, and not just to trade and competitiveness policies.

Many studies on renewable energy in the developing world use evidence from rural environments (e.g. Forsyth 1999; Wilkins 2002; Cherni et al. 2007), and often use information at the micro level or use countries, rather than cities, as case studies (e.g. Milton and Kaufman 2005; Rodrigues and Matajs 2005). In the developing world, there is little evidence based on the meso-level, including the experience of cities and renewable energy options. Analysis at the meso-level in the context of RET adoption in developing countries can represent an arena for a new methodological approach.

The meso-level centres attention on a system, as discussed in section 1.2. I view the cities of Mexico City and São Paulo and their surrounding areas as systems under scrutiny and place analysis at the meso-level through examining relationships between actors and the technologies and the environment. The meso-level focuses on social networks. Another reason the meso-level was chosen to centre analysis was to capture the potential effects of actions at various levels. Organizations that operate at this level link efforts undertaken in community / neighbourhoods with national and state level policies.

The dissertation focused on processes and networks occurring at the meso-level, which may yield some unique insights into the question – "what are the most important factors affecting RET adoption in the urban developing world?" Stakeholders operating at the meso-level were identified as being key players that operate within the solar water heater / biogas / renewable energy sectors and that are involved in the technology cooperation process (sellers, buyers and intermediaries) at the meso-level (i.e. the municipal level). A common basis for the term stakeholder comes from (Freeman 1984), who considers stakeholders to be those affected by or can affect a firm's objectives. This definition is broadened however in this thesis, to include other organizations and institutions, not just firms. A good example is Reed (2008) where stakeholders are viewed as "those who are affected by or can affect a decision…those who hold a stake (whether directly or indirectly)…rather. …than the wider public" (Reed 2008: 2420). A common way in which to distinguish stakeholders is through social units of organization that function within a system, such as a city. Attention was therefore placed on technology developers, producers, users and intermediaries (e.g. government agencies, Non-Governmental Organizations (NGOs), trade associations, firms) that operate at this level.

The adoption of RETs in urban settings of developing countries must be an essential component of global, national or sub-national energy sustainability strategies, as we move increasingly toward a carbon-managed world. Urban areas can be defined a number of ways. Some consider them to be centres of economic activity, using certain criteria based on economies of scale and density (Capello et al. 1999). In the developing world, urban areas can be considered locations with high concentrations of population and low service capacity. This dissertation however is looking more at citywide impact of renewable energy technologies. However, examining their uptake is particularly complex because more often than not, RETs are newer technologies in developing countries, and “evidence suggests that new technologies still have a very slow rate of diffusion in developing countries” (Tomlinson et al. 2008: 59).

1.2. Key concepts

Before answering the research question, it is important to establish what constitutes a systemic model, technology adoption, and renewable energy.

1.2.1. Systemic models - are those frameworks, approaches or perspectives that are applied to a system. A system can be defined in a number of ways. For instance, a system, also termed a structure, can be viewed more generally, as a set of elements, which interact and are independent, forming a more complex whole. Jay Forrester, a scholar, with initial training in engineering, applied a system to human situations. He was a pioneer of systems dynamics, which argues that the structure of any system — the many circular, interlocking, sometimes time-delayed relationships among its components — is often just as important in determining its behavior as the individual components themselves (Forrester 1961).[5] Carlsson et al. (2002) view a system as

[5] For a more extensive review of systems perspectives used in the social sciences please see Carlsson et al. (2002). " Innovation systems: analytical and methodological issues." Research Policy **31**: 233–245

consisting of components, relationships and attributes. Components are operating parts (actors, institutions, physical artifacts), relationships (links between the components and feedback loops, where the components and relationships change as the components interact), and attributes (the properties of the components and the relationships). In this vein, I consider a location, such as a city, as a system. Mexico City and São Paulo, the two cities under scrutiny, can be considered 'global' or 'world' cities, which are not isolated, but rather key axis points, intertwined in the capitalist system.[6]

While some consider a system to be "components interacting within boundaries" (Metcalfe 2004: 19 cited in Watson 2008) it is often difficult to pinpoint exactly where the boundary of one system begins and another ends. Boundaries – like a system -- are fluid and often change over time. Furthermore, influences on the system are found within and outside the system – but with links to it.

One distinguishing feature of this approach is that by taking a systems perspective, these approaches incorporate decision-making processes with their interaction with the environment; in other words technologies, along with the actors, policies and institutions are considered (Enos 1991; Watson 2008). It is important to point out that systemic models as defined here are based in qualitative studies, distinct from how a system and a model are defined in econometrics[7].

1.2.2. Technology Adoption - One way to define technology adoption is when an individual, household or organization selects and uses a technology (Carr 1999). In the context of RETs, the concept of use, uptake and adoption taken is a broad one, as it implies that an end user can also improve or adapt a technology (whether domestic or foreign in origin) in order to make more suitable to their circumstances (Wilkins 2002). Adoption is defined here as actual use of renewable energy technologies by individuals, households and organizations over a sustained period of time. Users of these technologies can range from individuals who integrate novel goods, processes and / or knowledge into their daily lives and routines and their local context, or firms,

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[6] For a more further discussion of global or world cities please see Cherni, 2002, pp. 8-9

[7] For further information on energy models for energy systems applied in developing countries please see Urban et al. (2007). "Modelling energy systems for developing countries." Energy Policy **35**: 3473–3482.

governments and / or research institutions that incorporate new products, processes or knowledge to produce different technologies (Sauter and Watson 2008).

This is distinct from technology diffusion, which is a process through which actors learn about an innovation through various communication channels (Rogers 2003a). Technology transfer, another key concept of the thesis, will be discussed further in Section 1.4 and Chapter 2.

In order to determine if technology adoption has occurred, studies must be conducted over time. This is because time:

a) will affect the process of diffusion and adoption through the amount of time between users first being exposed to a technology and deciding to use it;

b) will distinguish between early adopters (tend to be more innovators) versus later adopters (more mainstream); and

c) will affect the rate and scope of adoption (e.g. often, if the technology has only been recently introduced, less people will be likely to adopt it right away) (McMaster et al. 1997).

1.2.3. What is renewable energy?

While an increasing number of people agree that the uptake of renewables is good, arguments remain as to the definition of renewables in the context of energy. Renewable energy has been defined a number of ways. Very simply, they are those sources of energy that may be replenished, versus those sources of energy that are finite (NREL 2003). Renewables are generally viewed as a part of Environmentally Sound Technologies (ESTs), or those technologies that "protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes" (UNCED 1992, Paragraph 34).

Broader definitions of renewables include conventional biomass (e.g. fuelwood, charcoal)[8] (Bourdaire and Ellis 2000) and / or large-scale hydro (Renewables 2004).

[8] In fact, including fuelwood makes biomass the most prevalently used renewable and the fourth largest energy source globally, accounting for about 15% of energy supply (Boudaire and Ellis 2000: 853).

The United Nations Environment Programme (UNEP)'s Division for Technology, Industry and Economics (DTIE) includes all biomass but excludes large-scale hydro (UNEP / DTIE 2000). While biomass and large-scale hydro are *renewable* (sources of energy that can be replenished), they are associated with a number of major social, health and environmental problems such as respiratory illnesses, displacement or large-scale alterations of human and / or animal populations, and sediment deposits (IPCC 1996). Thus, there is increasing consensus to exclude these forms of energy in the definition of renewables.

Some divide renewable energy sources into classes. Rowlands (2005) terms some renewable sources "light green", which he considers all forms of hydro and biomass, and some "dark green", which includes wind and solar. For instance, the European Union allows large-scale hydro (above 10MW) to be included in EU countries' national renewable energy targets, but only allows smaller-scale hydro schemes (below 10MW) to qualify for support for renewables (Rowlands 2005). However, the problem with this classification is that other issues, including the location of these RETs, are not considered. For example, although debates regarding the carbon footprint accruing as a result of producing ethanol abound[9], it is generally agreed that the carbon footprint is higher when using ethanol from corn (where the United States dominates world production) versus sugarcane-derived ethanol (where Brazil is the world production leader).[10] Furthermore, while biomass and large-scale hydro are *renewable* (sources of energy that can be replenished), they are associated with a number of major social, health and environmental problems such as respiratory illnesses, displacement or large-scale alterations of human and / or animal populations, and sediment deposits (IPCC 1996; Bruce and Pickering 2000; Rowlands 2005). Thus, there is increasing consensus to exclude these forms of energy in the definition of renewables.

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[9] See for example, Searchinger et al. (2008). Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change. Science. **319:** 1238 - 1240. who argue that corn-based ethanol grown and produced in the United States nearly doubles greenhouse gas emissions for the next 30 years.

[10] Sugarcane derived ethanol is considered more efficient because it is already a sugar versus corn, which is a starch that first must be converted into a sugar (where often fossil fuels are used in this process) Garrett, L. (2008). Food Failures and Futures. A Maurice R. Greenberg Center for Geoeconomic Studies Working Paper. Washington, D.C., Council on Foreign Relations: 16).

The dissertation also uses a more narrow definition of renewables, or the definition adopted by the Brazilian Energy Initiative, termed "new" renewable energy sources. These sources consist of "modern biomass, small hydropower (generally defined by power output – hydro is considered small often up to 10MW)[11], geothermal energy, wind energy, solar energy (including photovoltaics) and marine[12] energy. Modern biomass excludes traditional uses of biomass such as fuelwood and includes electricity generation and heat production, as well as transportation fuels, from agricultural and forest residues and solid waste" (Goldemberg 2002: 1-2). However, one clarification is that the only solid waste considered a renewable energy source is waste that is digested anaerobically rather than simply burned or left decomposing openly. This is consistent with the definition of renewables as indicated in the Conference Paper for the global conference on Renewables, held in Bonn, June 2004, which states that renewables also include the "biodegradable part of waste…only if it is provided and used in a sustainable manner" (Renewables 2004: 9).

This thesis examines the experience of two RETs in Mexico City and São Paulo. The main technologies under scrutiny in this dissertation are solar water heaters (SWHs) and biogas, or landfill gas, to generate electricity. I am examining the physical object and the broader processes associated with their adoption (e.g. installation, operation, maintenance, tacit knowledge). These technologies were chosen as they were deemed some of the most economically viable RETs (White and Hooke 2004; Houri 2006) - including in urban environments. Chapters 4 and 5, which examine the case studies in detail, will provide further details on the specifics of these particular technologies used in Mexico City and São Paulo, but some attention to landfill gas will be paid here.

There are various types of technologies and methods used with respect to biogas. For instance, the gas can come from agricultural sources with bacteria added (e.g. a pig

[11] This upper threshold varies in organizations and countries, including Canada and Brazil, which consider up to 30MW small hydro. There are often sub-categories too. In one Brazilian rural renewable energy United Nations-sponsored project eligible renewable hydro projects included small (defined as 1-30 MW), mini (100kW-1MW), micro (10kW-100kW) and pico (up to 10kW). (BREED), Brazilian Rural Energy Enterprise Development. (2007). "Various Information." Retrieved March 19, 2009, from http://uneprisoe.org/BREED/DecentralizedEntrepreneursBrazil.pdf

[12] This includes energy from tides, waves and Ocean Thermal Energy Conversion (OTEC), which seeks to convert water warmed through solar radiation into electricity.

farm) or it can come from municipal waste (e.g. a landfill). This dissertation examines biogas from municipal waste, or landfill gas.

Generally speaking landfill gas consists of:

- 50 per cent methane (CH_4);
- 47 per cent carbon dioxide (CO_2);
- 2-3 per cent chlorine, benzene, non-methane organic compounds (NMOCs) (UNESCAP 2007: 15).

Methane is the major component of landfill gas, especially in developing countries. There are two main uses for landfill gas in the climate change context. The first is flaring, where instead of being passively released, by flaring the methane, it becomes mainly CO_2, which is not as powerful a GHG as methane. The second is through generating electricity (described below). This dissertation focuses on the latter process.

The use of methane, or landfill gas, as a renewable energy source remains controversial. First of all, some Non-Governmental Organizations (NGOs) claim that including landfill gas as a renewable energy source is an incentive to create waste, rather than reducing it, and that attention should instead be focused on composting, recycling and reduction. Secondly, they are also concerned that municipal, or household, waste, in addition to organics, includes other components such as plastics which when burned can form toxic chemicals. Burning landfill gas (whether to run a motor or through flaring) can also form toxic chemicals when methane and some non-methane organic compounds (NMOCs) (which constitute less than 1% of landfill gas in the United States by weight) are mixed (Ewall 2008). Thus, some countries exclude landfill gases in their definition of renewables (Haas 2001). Critics also suggest that any policies that include "waste to energy" projects as renewable energy sources compete with wind and solar (Ewall 2008; Grassroots Recycling Network 2008). Methane is a greenhouse gas (GHG) 25 more times powerful than carbon dioxide in terms of global warming impact (IPCC 2007). In addition, the energy content of biogas (as well as a number of other biomass sources) is roughly half that of coal; in other words, twice the amount of biogas versus coal[13] is needed to produce the same amount of energy (Rubin 2001: 214).

[13] It is important to note that this is a rough estimate, as this number varies depending on the type of coal used – sub-bituminous, bituminous, lignite, anthracite, etc.,

Those that support the use of landfill gas as a renewable argue that if this methane gas is recovered and combusted to run motors, it can be used to generate heat or create electricity through non-fossil means, and carbon dioxide rather than methane is released into the atmosphere. This can be especially important in instances where the landfill gas replaces fossil fuels as electricity (Pipatti and Savolainen 1996). There are also those who argue that by combusting landfill gas in an engine, it will lead to the destruction of other harmful chemicals (UNESCAP 2007) (See Table 1.1 below).

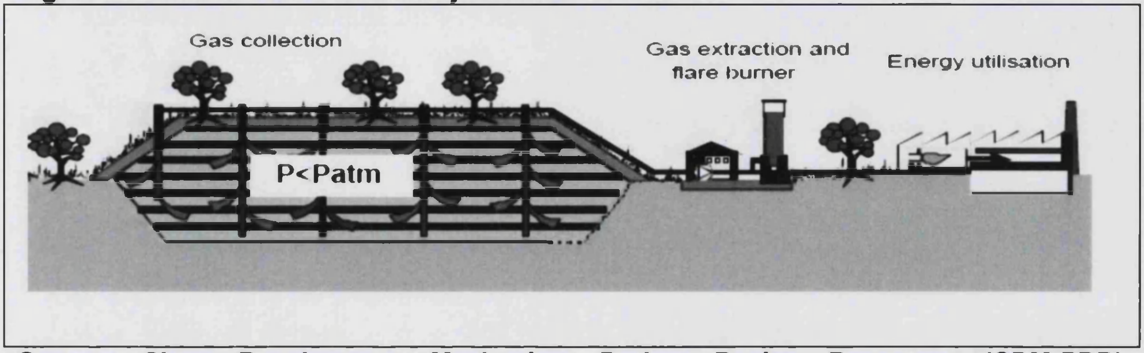
Table 1.1 - Observed landfill gas engine destruction efficiencies for functional groups

Functional group	Minimum (%)	Maximum (%)
Methane	96.0	99.6
Alkanes	70.2	>99.9
Alkenes	50.1	>99.6
Alcohols	84.1	>99.8
Aldehydes	>42.4	95.9
Ketones	>87.4	99.9
Aromatic hydrocarbons	92.0	>99.9
Terpenes	-	>99.9
Halogenated hydrocarbons	>70.1	>99.7
Sulphur compounds	>8.7	>96.6

Source: UNESCAP 2007, p. 17

This dissertation considers landfill gas to produce electricity in some landfills in developing countries as a RET because the content of landfill gas in developing countries can be very different than in the developed world. Also, in locations where the temperatures are warmer and more humid, like São Paulo, these processes occur more rapidly. In landfills, bacteria breakdown organics anaerobically (when in an oxygen-free setting) which forms methane gas. These bacteria tend to particularly thrive in landfills where there is high moisture content, which is the case in a number of developing country landfills (Zerbock 2003). In the industrialized world, organics generally constitute about 30-40% of waste, but the amount of organic waste, or waste deriving from plant or animal elements (i.e. with carbon), in developing country landfills is much greater (e.g. some figures put it at 70-80% although this data comes from a study done in 1982) (Thomas 2006). Rather than being passively released, the landfill gas, which is mainly made up of methane, is directed through tubing to an electricity generating plant. The gas is treated (cooled down and then heated again) to enable it to be used as a fuel for electricity generation.

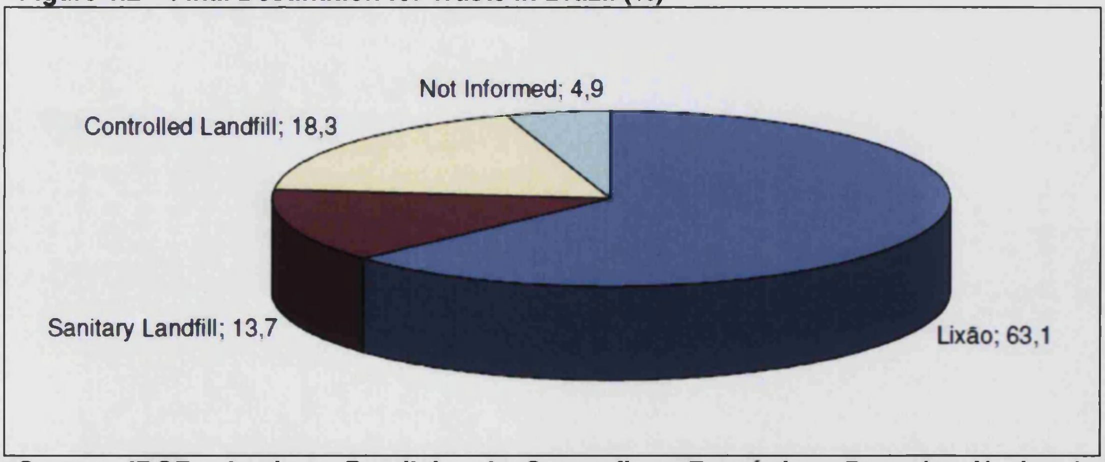
Figure 1.1 Landfill Gas to Electricity Generation Process



Source: Clean Development Mechanism Project Design Document (CDM-PDD) Bandeirantes 2005, p. 5

Furthermore, as indicated above, only solid waste that is decomposed using anaerobic methods will be considered. Brazil and Mexico, the two case studies under consideration, possess landfills that are equipped with what have been termed sanitary landfills, or those that have contemporary technology and comply with those countries' most stringent environmental and health regulations. Bandeirantes and São Joao, the two landfills in operation outside of São Paulo being considered, are sanitary landfills. **Figure 1.2** below provides details on waste in Brazil. *Lixão* means open-air garbage dumps.

Figure 1.2 – Final Destination for Waste in Brazil (%)



Source: IBGE - Instituto Brasileiro de Geografia e Estatística. *Pesquisa Nacional de Saneamento Básico*, 2000 taken from Bandeirantes CDM PDD, p. 8

Numerous landfill sites, including Bandeirantes and São Joao in Brazil, have been assessed in terms of technical and economic feasibility for landfill gas projects in these countries by the United States Government (USG) since 1998 (USG 2006). Furthermore, one study on biomass combustion, examining landfills equipped with these requirements, indicated that air toxic emissions were typically very low due to various mechanisms in place (e.g. high temperatures and good air-fuel mixing (Demirbas 2005). Another advantage of landfill gas in Brazil is that although the country is currently heavily reliant on hydropower for its electricity, governments at various levels are seeking out alternatives for electricity generation, especially to help the system in peak times. This search increased after the apagão of 2000/01. Generally speaking, thermal power plants – using especially natural gas but oil too – are the most favoured option. This is a part of Brazil's strategy to increase their energy mix, such as through the New Petroleum Law of 1997 (Román 2007).

1.3. The Renewable Energy Experience in Developing Countries – Conventional Frameworks to Explain Their Uptake (or Lack of)

Various approaches found in technology adoption literature are used to explain the reasons for RET adoption in developing countries. Two of the most dominant types, and variations of them, stem from economics and public policy One way in which to term them is by grouping them as "push / pull" models and "barriers- or policy-oriented" models. The general thrust of these frameworks examines the adoption of RETs as being hindered by a series of barriers. The models suggest ways to overcome these barriers. A number of these models generally view renewable energy technologies as being used as a reflection of cost or technical features, or similarly, viewed as a question of supply and demand according to economics – in other words, much emphasis is placed on economic and technical features. Recent variations also consider other aspects which may have a role, including barriers to awareness and institutional barriers, suggesting that the government must take on more of an active role, by implementing building codes and allowing for alternative infrastructure more conducive for RETs. However, as is explored below, one concern with these approaches is that they tend to neglect social and / or larger policy trends which may impact RET adoption.

1.3.1. Push / Pull models

Models to explain environmental technology adoption in developing countries abound. For instance, many economists examine "push" (i.e. the supply side, including the actions of technology suppliers, research and development (R&D) activities) and "pull" (i.e. the demand side, including the aspects influencing the actions of technology buyers) factors. Studies focus on the level of a firm, a sector, or a country and generally characteristics of firms and the technology (e.g. (Jaffe and Stavins 1994; Blackman 1999; Mueller 2006; Nemet 2007).

However, these models place most of their attention on economic aspects. Furthermore, they are often applied in the case of firms, rather than individual people, families, other institutions (e.g. schools, hospitals) or communities, which have different characteristics and motivations than firms. Barriers-oriented or policy-focused frameworks are broader than these economic models, accounting for other aspects such as institutions and political dynamics.

1.3.2. Barriers-oriented or Policy-focused Frameworks

These conventional approaches target barriers, compartmentalizing them into various aspects. They focus on identifying barriers (technical, economic, institutional, among others) and ways to overcome these barriers, such as through providing financial incentives and training, mandatory policies, among others (e.g. Wilkins 2002, Renewables 2004), to ensure that RET adoption is successful. For instance, in Israel,[14] where there is a 95% penetration rate of SWHs for houses, the government made it mandatory to use SWHs in households since 1980. The main premise for this policy was for security reasons (Mor 2008).

These types of approaches tend to centre on five classic explanations for RET adoption, or a lack of, in the developing world. These include: economic problems such as 1) little financing options available, and 2) the high cost of RETs in general and versus their alternatives, 3) technical problems, such as not being able to perform as hoped due

[14] which is arguably not a developing country, although not classified as an Annex 1 nation, or a nation with a quantifiable GHG emissions target under the Kyoto Protocol (See Ayalon, O. (2009). Sustainable 'Green' Rural Municipalities. Renewable Energy in the Middle East: Enhancing Security Through Regional Cooperation. M. Mason and A. Mor. Dordrecht, the Netherlands, Springer.: 112)

to climatic conditions, 4) a lack of awareness and / or access regarding the RET, and 5) institutional issues including the fact that existing infrastructure often favours conventional energy sources (Martinot 2002; Wilkins 2002; Dorian et al. 2006). Many classify these obstacles under groupings as types of barriers – including economic, technical, knowledge and institutional, although factors can be considered various types of barriers at the same time.

Economic barriers

The most prevalent explanations accounting for a lack of sustained RET use in developing countries fall under the grouping of economic barriers. Specifically, the key economic barrier proposed by many scholars to be the biggest obstacle for RETs in the developing world, is their high cost -- in general and versus their alternatives (Dorian et al. 2006). Many RETs are characterized by having high up front costs for the purchase and installation of equipment, even if one does not have to "pay" for the source of energy (e.g. sun, wind) (Martinot 2002). By contrast, technologies for traditional energy sources are often either very inexpensive (e.g. basic stove using wood as fuel, electric showerhead) or significantly cheaper than their RET counterpart. Others also purport that the "true" cost of using fossil fuels is not reflected in their price as the health and environmental impacts involved in their use (e.g. respiratory illnesses, acid rain and global warming) is not incorporated (termed "externalities" by economists) in their price. They assert that internalizing these externalities will make renewables the most "cost effective" option (Bourdaire and Ellis 2000; Edinger and Kaul 2000). Some studies also talk about the economic barrier termed 'split incentives' where owners versus renters and, for new buildings, property developers are not interested in saving energy as the benefits will be accrued by future occupants (Philibert 2006).

Moreover, although a number of studies indicate over time that in the long run the RET is cheaper than its counterpart, many people in the developing world find it easier to pay for the cost of fuel month by month (a common practice for traditional energy sources) rather than everything at once (Quintanilla and Mulas 1998). For this reason, long term credit schemes, where consumers pay a certain fee every month, have been identified as a mechanism to increase RET uptake (Martinot 2002; UNDESA 2005: 48-49).

Although this idea remains popular among experts examining renewable energy's impasse in the developing world, in practice, little financing options are available for those interested in RETs. This is the second most common barrier identified in a number of studies on renewable energy in the developing world. Investors are often reluctant to allocate funds in this sector in general, and especially in the developing world. Many find that offering credit to potential developers, producers, dealers and / or consumers of RETs to be too risky – because possible financiers know little about the technology or the business, and / or have doubts about the ability for potential lendees to repay the loan. Further concerns arise among potential investors with respect to facets common in developing countries (not just RETs) – whether perceived or real --including the prevalence of sub-optimal products and processes, a lack of standards for these technologies, or political and economic instability (Muntasser et al. 2000, Martinot 2002, Wilkins 2002).

In addition, little in-roads have been made with established lenders in the developing world. Traditional banks often find RET investments too risky. Even in those cases where established developing country credit or micro-credit institutions have expressed an interest in looking at RETs as a part of their portfolio, not much progress in this area has been made because their experience is different (e.g. lending small amounts of money rather than the larger amounts many RETs cost) [15], or their requirements are too stringent (e.g. high credit rates and weekly payments; a potential lender must be a member, paying a membership fee) for much of the population in developing world (UNDESA 2005; Rodrigues and Matajs 2005).

Technical barriers

A number of studies also underscore technical barriers. Technical barriers, as viewed here, focus on the "nuts and bolts" of 'hardware' as well as the details of 'software'. Martinot (2002), speaking of Photovoltaics (PV) in developing countries, states that "...historically, the reasons for failure of solar home systems projects included poor quality products, poor installation and maintenance, and systems being "oversold"

[15] Pramana, V. (2006). Commercializing Renewable Energy in India (CREI) A. Mallett. Washington, D.C., personal communication, speaking about his experience on the Commercializing Renewable Energy in India (CREI) project

(marketing claims that raise expectations higher than the technology can deliver)" (Martinot 2002: 52). Jafar's (2000) study on RETs in the South Pacific echo the reasons identified above, as well as inappropriate design, for the failure of a number of RETs in this setting.

Knowledge barriers

A third challenge faced by those interested in increasing RET adoption in the developing world – awareness -- is highlighted under knowledge barriers. In this context, knowledge of a technology centres on being aware of its existence, how to access the technology and how it works. Conventional studies focus on how a lack of awareness about and / or access to the technology by the government, industry, investors, and the general population affect the adoption of renewables. According to Muntasser et al. (2000), examining the potential for the photovoltaic (PV)[16] industry in developing countries, the lack of knowledge of the product and processes can be the most attenuating barrier faced by those interested in increasing the uptake of RETs. As these technologies are often not prominent vis-à-vis conventional energy sources, little information is available about them including quality, performance expectations, and maintenance and upkeep – let alone the principles behind the technology. Even if people have rudimentary or in-depth knowledge about RETs, they often do not know how to obtain the products, the necessary components, or information about processes regarding the technology (Wilkins 2002).

Furthermore, there is a lack of information regarding the potential market, thus deterring possible investors, developers or producers from entering this area. More specifically, Wilkins (2002) argues that failures regarding the transfer of climate technologies to developing countries can be traced to the fact that foreign firms possess little knowledge of local settings (e.g. culture, language, purchasing habits, needs of population) or did not pay enough attention to how to adapt their technology to make it better suited for the developing country environment.

[16] Photovoltaic describes the process that converts sunlight into energy. There are two basic solar technologies, solar cells and solar collectors. Solar cells convert solar insolation into electricity while solar collectors convert insolation into heat. Mallett et al. (2009). UK- India Collaboration to Overcome Barriers to the Transfer of Low Carbon Energy Technologies: Phase II. SPRU. Brighton, UK, SPRU, University of Sussex.

But this definition of knowledge often equates knowledge to information and neglects a third, critical component of knowledge termed "know why" knowledge, or "principles knowledge" where people begin to understand not only what the technology is and how to use it, but the principles behind the technology (Bell 1990; Lall 1995; Lall 2000). This can have implications for adoption, as the more people understand a technology, it enhances their ability to adapt it to their particular situation, making them more apt to use it.

In addition, prior conditions which can affect knowledge, must also be taken into account (Rogers 2003a). For example, previous experience with the technology may negatively influence RET adoption more than lack of awareness. This is because a negative experience with a technology can do far more damage to its diffusion and use than a positive experience can to increase diffusion and adoption (Frewer et al. 1998).

Institutional and Legal Barriers

A rich body of literature exists regarding the definition of institutions[17]. Most studies on renewables are not clear how an institution is defined. However those that do make this clarification indicate that they are different than organizations, such as government departments and community groups. Institutions are rules which govern behaviours and / or the organization of a social grouping (Breukers and Wolsink 2007). Some suggest that the government must incorporate renewable energy sources into various applications including designing, retrofitting and constructing buildings, for generating electricity (Houri 2006). These requirements can be mandatory or encouraged through a series of directed incentives. Furthermore, as the infrastructure is often in place for conventional energy sources, it is sometimes difficult for architects, buildings, and producers of alternative energy sources to obtain the necessary permits, licenses, access to the grid, etc. (Rodrigues and Matajs 2005; Philibert 2006).

A series of proposals have been put forth to effectively address these barriers. For instance, the World Bank has proposed framework aimed at increasing the use of RETs

[17] A well-known example is North, D. (1990). Institutions, Institutional Change and Economic Performance. Cambridge, Cambridge University Press. Under New Institutional Economics, the view distinguishes between organizations (groups of people and structures they create for governance) and institutions, which are the rules, both formal and informal, which govern their behaviour, decisions, organization, etc.

in developing countries. This is called a Renewable Energy Toolkit (REToolkit), which consists of a website and an Issues Note to assist World Bank staff members and others to design and implement renewable energy projects, particularly in developing countries.[18] The Issues Note examines relevant policy, economic and financial issues regarding renewable energy systems. More specifically, the Note provides a comprehensive examination of various policy frameworks worldwide to encourage the use of renewables including feed in tariffs, renewable obligations, tax credits, the Clean Development Mechanism (CDM), among others. Moreover, the Note also includes a technology chapter that provides technical details regarding a number of renewable energy technologies, such as hydropower, wind, biomass, geothermal, and solar photovoltaic (PV).

However, little attention is placed on social issues as well as larger indirect policy directions and their potential implication. For instance, in a 174 page document the World Bank does indicate the importance of community organizations and engagement (2008b: 28, 53-54, 81, 94-96) for RET adoption in rural applications, but the thrust of the framework stresses potential economic, legal and regulatory barriers and tools to overcome these barriers. Furthermore, the Bank emphasizes the need for training of technical and / or business skills, and not on the dynamics of communities and what the implications will be for the community should a particular technology be pursued, aspects which are also key (e.g. see Cherni et al. 2007).

Numerous other proposals have been put forth to increase RET adoption in developing countries including those noted in an issues paper for the Renewables Conference in 2004[19] (Renewables 2004), and the United Nations Industrial Development

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[18] World Bank (2008b). "REToolkit: A Resource for Renewable Energy Development " Retrieved March 21, 2009, from http://go.worldbank.org/OWJW3JRYJ0 .

[19] Here, emphasis is placed on a policy framework that increases access to finance (especially for women and the rural poor), increases knowledge about RETs (through research and development and capacity-building) and institution building. The paper suggests that policies focus on decreasing subsidies for conventional energy sources and internalizing costs involved in using energy sources that are often not incorporated (thus 'leveling the playing field' between RETs and other conventional energy technologies) through the creation of "smart subsidies', or those that target the poor to help them finance renewable options, tax incentives, feed-in-tariffs, green certificates, etc.

Organization (UNIDO)'s, Service Module 6: Sustainable Energy and Climate Change.[20]

More often than not, experts develop these guidelines, often from outside of the developing world; there is little engagement of communities and the public (whether from urban or rural areas), who could be acutely impacted by the implementation of any proposed RET adoption scheme. As an example, UNIDO notes that in developing this package, they engaged with stakeholders through workshops / conferences held on more macro-level topics, such as "Energy and NEPAD/Africa" and "Biomass gasification and South-South cooperation" (UNIDO 2005) but there are no details on who these stakeholders are or how they were identified.

While these barriers are important, their existence or lack of does not fully explain RET adoption in developing countries. The problem with these frameworks used to explain RET adoption is that they often place too much emphasis on technical and economic attributes and / or generally offer only immediate, or shorter term, policy options. Also, while some pay attention to the dynamics among different stakeholder groups or organizations, there is less attention placed on the nature of these relationships and on the differences within stakeholder groups. In addition, they often neglect to examine dynamics occurring beyond the level of scrutiny, such as international influences, which can impact RET use.

For example, one suggestion to address economic barriers, such as the high cost for some of these technologies, is through subsidies. This is an area of considerable debate in RET studies in developing countries. One view claims they are good for increasing RET use in developing countries, arguing that conventional energy sources receive subsidies (e.g. coal, oil and natural gas received $US151 billion in subsidies from 1995-1998), which has helped encourage and maintain their usage (Muntasser et al. 2000; Goldemberg 2006). Others suggest that, over time, those renewables that were subsidized are often not sustainable (Douthwaite 2002; Pramana 2006; UNEP 2006).

[20]Regarding renewable energy, this module mainly targets energy for productive use in rural environments, provide a generic "package" of services and products.

Further debates arise regarding who should receive the subsidy. Some claim that a blanket subsidy for fossil fuels (e.g. cheaper gas) ends up benefiting the wealthy more than the poor. For instance, in Mexico, where subsidies on fuels are sometimes used, wealthier residents are more likely to own vehicles and / or a gas boiler / gas stove (Quintanilla et al. 2000). In India, subsidies on the price of electricity (and fertilizer) have often been criticized as helping wealthy agrobusiness rather than family farms, which often do not have electricity connections (Vedavalli 2007). Some also have concerns in India with that government's feed in tariff law aimed at encouraging the use of photovoltaics (PVs) in that country, is favour large scale solar farms, which only wealthy investors have the necessary capital to start up a project, rather than smaller, decentralized options (Mallett et al. 2009)[21].

As another example, Forsyth (1999), highlighting an experience from the United Nations Development Programme (UNDP) in the 1970s, stresses the importance of local context, providing examples of failed biodigesters in India. Two of the main reasons for its failure were because the supply of dung was over-estimated and conflicts arose once dung went from being a common good to a commodity. He also examines biomass gasifiers in the Philippines, which failed as the pumps were meant for more intensive forms of farming and because they were perceived by farmers to be less reliable than waiting for rain.

Moreover, a number of these conventional approaches downplay key aspects including social well-being, the user's wishes, needs and strengths, and local livelihoods. These are just as important as technical and economic attributes in any renewable energy decision-making process. Cherni et al.'s (2007) study demonstrates this, applying a multi criteria decision making model incorporating priorities identified by community members, including those noted above, alongside those of experts (e.g. climate change, poverty alleviation) including local and regional government officials.

Furthermore, in some contexts, factors termed as 'barriers' may be 'drivers' in another, and may change over time. For instance, Montalvo (2008) notes that for one

[21] Also, for further details on the specifics of these policies please see Mallett et al. (2009). UK- India Collaboration to Overcome Barriers to the Transfer of Low Carbon Energy Technologies: Phase II. SPRU. Brighton, UK, SPRU, University of Sussex.

technology in one market in one moment in time, consumers may be drivers for environmentally friendly products, but in another setting or at a different time consumers may deter firms from investing in cleaner technologies if they do not perceive any existing or potential market demand. By not taking a nuanced, longer-term view, approaches based on barriers mean that more often than not, the uptake of these technologies is not sustainable, and RETs are discarded. In addition, these approaches do not account for the role that other, seemingly unrelated, indirect policies can have on RET adoption. In other words, these "end of tailpipe" solutions in environmental policy jargon or "band aid" solutions in development policy jargon are important but insufficient in and of themselves to effectively increase RETs. Another problem with this approach is that these barriers are often interdependent and their existence can be traced back to policies formulated at the macro-level. Thus, addressing one, several, or all of the barriers does not necessarily equate with an increase in technology adoption.

Some have turned to the international technology transfer process as a way to increase the use of RETs in developing countries.

1.4. Technology Transfer Approaches – International Climate Change

Probably the best-known approach proposed to increase the uptake of RETs in developing countries through technology cooperation at the international level, is through the United Nations Framework Convention on Climate Change (UNFCCC) of 1992 and the Kyoto Protocol of 1997. Article 4.5 of the UNFCCC is the most cited article in support of the use of low carbon technologies in developing countries through technology transfer. Here, developed countries

> "shall take all practical steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement provisions of the Convention" (UNFCCC 1992, Article 4.5: 11).

Since that time, the success of the Convention in achieving this has been widely questioned with many developing nations left feeling frustrated at the lack of progress that has been made in achieving technology dissemination, development and use in practice[22] (Khor 2008).

Another mechanism designed to encourage the uptake of RETs in developing nations through technology transfer is through Article 12 of the Kyoto Protocol. In the Kyoto Protocol industrialized nations are required to limit their carbon dioxide emissions to specific targets, using a 1990 baseline, during the 2008-2012 period. Article 12 of the Protocol contains details of the Clean Development Mechanism (CDM). The CDM "allowed the north to support emission reduction projects in the south – including industrial gas capture, renewables, energy efficiency and forest plantations – in return for credits towards [their] Kyoto obligations and provided a small fund for adaptation through a tax on transactions." (Liverman 2009: 293). Often these projects, involving organizations in northern and southern countries, have a technology transfer component. The CDM was designed as a way to counter some of the criticisms of its predecessor Activities Implemented Jointly (AIJ), which was a pilot phase for climate change investment after 1995. AIJ activities tended to favour certain regions (Latin America versus Africa) and certain types of projects – carbon sequestration through forestry and land use activities, rather than those fostering industrial technology transfer (Forsyth 2009).

Supporters of the CDM emphasize economic benefits for developing countries due to the potential for generating funds through carbon credits through CDM projects (Castro Negrete 2005; Milton and Kaufman 2005; Rodrigues and Matajs 2005). According to a study on the benefits of CDM in Small Island Developing States (SIDS) conducted by Duic et al. (2003), where a price of 25 Euros / tonne of carbon equivalent abated was assumed, renewable energy projects were made that much more economically feasible when used as a CDM project (e.g. in Cape Verde, in 2012, they projected a cost of electricity of 8.7EU cents/kWh for combined cycle + wind versus 8.2 EU cents/kWh for combined cycle + wind + CDM potential). For a number of renewable energy projects, the CDM is argued to be a necessary tool; making those RETs that are nearly economically feasible become viable (Duic et al. 2003).

[22] A lack of effective technology transfer to the developing world (and particularly least developing countries) is not limited to low carbon technologies. See Foray (2004) cited in Oliva (2008) which looks at technology transfer to least developed countries more broadly, within the context of the World Trade Organization (WTO).

But, economic benefits associated with CDM projects are not always clear as some scholars and practitioners avow that the CDM process is long, convoluted and riddled with bureaucracy, thus making projects more expensive by increasing transaction costs and reducing the Internal Rate of Return (IRR) (e.g. Personal Communication, comments at a stakeholder forum with CDM executive board, Carbon Expo, May 2005).

In addition, with respect to technology, the main purpose of the Kyoto Protocol was to increase investment in national capacity to address climate change rather than to encourage technology transfer and adoption of low carbon technologies. The hope was that developed countries would meet some of their emissions through the transfer of new, clean technologies to developing countries through the CDM (Grubb et al. 2001; Ravindranath and Sathaye 2002), but the extent to which this has happened continues to be a subject of debate. For example, Schneider et al. (2008) argue that in addition to making potential projects commercially viable, actors involved in the projects increase access to information and access to capital – thus encouraging technology transfer. On the other hand, they note that CDM projects do not improve the institutional framework of countries, arguing that domestic and international policy makers encourage CDM country specific measures to improve investment conditions.

In another example, an assessment of plans for technology transfer in CDM projects in 2006, the plans varied significantly by project type and host country. In India, for instance, only 7.3% of CDM projects planned to involve some element of technology transfer compared to 55.1% in China and much as 83.3% in Malaysia (Haites et al. 2006).

Furthermore, it is not clear that these studies at the macro level provide an accurate reflection of what is really occurring. For instance, more recent analyses by Seres et al. (2007) and Seres and Haites (2008) report the shares of technology transfer for equipment only, knowledge only, and both knowledge and equipment. Knowledge is measured "only through training and the engagement of foreign experts" (Seres et al. 2007: 12), but is this an accurate reflection of 'knowledge'?

Measuring knowledge using these proxies (e.g. number of training sessions, foreign experts, etc.) is very difficult. Debates regarding 'what is knowledge' have been around for many, many years. What is distinct about knowledge is that it is information that has been processed in the minds of individuals and that this individual's prior understandings, experiences and environment will shape how this information is processed (Alavi and Leidner 1999). Many technology studies view information as synonymous with knowledge. But, people will process information given about a technology - what it is, how it works, etc. – differently. Schneider and Ingram Schneider and Ingram (2007), speaking about policy spaces (e.g. climate change, drug use) where people galvanize around an issue, argue that these issues will be impacted by "ways of knowing" as people interpret aspects in this space and relationships between them.

Furthermore, even if one were to use this narrow definition of knowledge, if technology is considered 'knowledge' and 'equipment' only, how are processes accounted for? Also, these numbers and questions aside, as the CDM is so recent, it is not clear how technology cooperation, in instances where it is happening, is leading to their uptake in developing nations.

Some suggest that for more effective technology cooperation, the CDM consider the 'development dividend', which is generally considered social and developmental benefits accompanying these emissions reduction projects. Forsyth (2007) and Morsink, Hofman and Lovett (in review) propose that cross-sectoral partnerships, or those between investors, public sector actors and citizens (e.g. through NGOs, community groups) where all are engaged in the designing and / or implementing of the investment, could be one such way to increase the development dividend and technology transfer, alongside the CDM.

In sum, the reasons behind the lack of RET adoption in developing countries are interdependent and vary depending on the circumstances. Scholars continue to look for commonalities, with some developing tools to assist policy makers and practitioners to increase the success of RET adoption in developing countries. Despite these efforts, there still is not a definitive basis why certain renewables are being adopted and not others in the developing world. One key aim of this dissertation is to contribute knowledge in this area through answering the question – *What are the most important factors affecting RET adoption in the urban developing world?*

The dissertation does this conceptually by integrating technology adoption, cooperation and trade and competitiveness frameworks, and propose a new framework, urban technology cooperation, to better reflect RET use in developing country cities; methodologically by focusing my study on the meso-level; and empirically through applying three systemic approaches to the urban developing country context in Mexico and Brazil.

1.5. Explaining RET Adoption Using Systemic Approaches – Technology Adoption and Cooperation, and Trade and Competitiveness Regimes

This dissertation also answers three sub-research questions in order to answer the overall research question – ***What are the most important factors affecting RET adoption in the urban developing world?***

The first sub-research question is: ***How can systemic approaches help to explain RET adoption in the urban developing world?*** As noted earlier systemic approaches have been proposed as alternative frameworks to explain RET adoption as they try to incorporate economic and social facets at various scales. However, the bulk of the literature on systems and technology comes from innovation studies (Nieuwenhuis et al. 2003; Hekkert and van den Hoed 2006; Watson 2008). Some scholars, focusing on transitions and systems innovation view a system as a society, arguing that forces that have the potential to transform the system are found within and outside the system. Research on systems innovation focus on large-scale transformations of how societies function, including how they address the need to feed, house, and transport themselves, and communicate with others. The focus of these theories is on the regime, or the dominant aspect of society, as well as change originating from niches, or subsystems within the overall system (Frantzeskaki and de Haan 2008; Berkhout 2004 et al.; Geels

2004). This view has been applied to the context of energy. Changes affecting energy systems, defined as those affecting on a societal scale, range from shifts to new or improved technologies in key sectors such as power generation, transportation and how energy is being used (Geels 2004).

In other innovation studies, a system is considered at the level of a country through the concept of National Innovation Systems (NIS)[23] (Lundvall 1992; Nelson 1993; Patel and Pavitt 1994) or those processes surrounding a particular technology or group of technologies (Hekkert and van den Hoed 2006).

In fact, there are relatively few instances in which systems perspectives have been applied to the adoption of renewables in developing countries. Two examples however include 1) the Intermediate Technology Development Group (ITDG)'s approach to energy and sustainable livelihoods, and 2) a software tool developed by Imperial College combining both quantitative and qualitative criteria, based on multi-criteria analysis called Sustainable Rural Energy Decision Support System (SURE-DSS). A key premise of these perspectives is to incorporate the views of people (e.g. a community) into the analysis. These two different frameworks provide valuable insights, aimed at providing a comprehensive view towards understanding RET adoption. However, studies using these frameworks are based on rural experiences in South Africa and Colombia (Cherni et al. 2007; Brent and Kruger 2009). These systems approaches are useful because they, along with a few others (e.g. Ockwell et al. 2007), integrate technology transfer and adoption.

The second sub-research question is ***"What are the reasons SWHs and biogas to produce electricity technologies are being used or not in Mexico City and São Paulo?"***

As indicated above, the majority of approaches focusing on RET adoption focus on identifying barriers and ways to address these barriers. But, they generally focus on economic and technical factors, which, while important, do not adequately explain why technologies are being used or not. Systemic approaches have been proposed as

[23] See (OECD), (1997). National Innovation Systems. OECD. Paris, OECD. http://www.oecd.org/dataoecd/35/56/2101733.pdf for further details

alternative perspectives through which to assess RET adoption in developing countries, but there is little application of them to date.

This dissertation centres around three key themes – technology adoption, technology cooperation, and trade and competitiveness approaches. Although numerous systemic frameworks within these themes could have been examined, the dissertation honed in on three of those deemed to be some of the most relevant in the case of RETs in developing country cities.

These approaches will be described in further detail in Chapter 2. The first systemic approach comes from adoption literature. Everett **Rogers' Diffusion of Innovations (2003a)** is a technology adoption model that views the decision of whether or not to adopt a technology in stages. This model, recognizing the importance of underlying conditions, helped to explain how previous conditions in combination with awareness of energy conservation in general, rather than just awareness of the technology itself helped explain RET adoption. It is an agent-centric framework[24] that focuses on the attributes of innovations, considering social and economic / technical aspects, and it highlights the role "change agents". These agents can be people directly or indirectly involved in the development, production, distribution and / or use a technology.

There are a few examples of this model being applied in developing countries and / or renewables, including switching from wood to natural gas as a fuel in small scale industry in Bolivia (van Oosethout et al. 2005), a machine to ease food preparation tasks in Mali and the United States' Million Roofs Initiative, aiming to have photovoltaics (PV) on one million roofs by 2010 (Rogers 2003a), but not renewables in developing countries specifically.

The second systemic approach, **urban technology cooperation**, comes from technology transfer literature. Technology transfer is a principal channel through which developing countries adopt Renewable Energy Technologies (RETs). It is an integral part of technology adoption. Technology as defined here includes processes (e.g. organizational and management practices, production processes), knowledge (tacit and

[24] An agent-centered, or actor-oriented, framework focuses on the role of people, or organizations (populated by people) in shaping decisions and outcomes.

codified) and products (e.g. physical equipment, artefact), also termed "software" and "hardware" (Lall 1995; IPCC 1996; Teece 2005).

Looking at evidence from the environmental and climate change arenas, one criticism is that many technology transfer models do not adequately reflect needs at the local level (Forsyth 2005) or the differences that can occur within groups or among individuals– they are often lumped together as the interests and influences on a "stakeholder". In addition, the majority of technology transfer models stress the one way nature of flows. The word "transfer", whether implicitly or explicitly, implies that it is a one-way, linear process in which one actor (the donor / active player / expert) provides technology (physical products and know-how) to another (the recipient / passive player / non-expert).

There are a number of critics of the term transfer (e.g. Shove 1998; Barton 2006) prompting some researchers to suggest an alternative concept, technology cooperation, to better reflect the two or more way exchange between participants (Heaton et al. 1994; Martinot et al. 1997). But it is not clear that these notions of technology cooperation include non-experts as stakeholders in the process. Also, Heaton views technology cooperation as "mutually beneficial joint undertakings by institutions in the developed and developing worlds to encourage, develop, adapt, and deploy technology" (1994: 39). Exchanges between the North and the South remain the centre of focus.

Like these scholars, I also support the use of an alternative term - urban technology cooperation. It builds on the previous technology cooperation work, highlighting the two or more-way nature of flows of knowledge, processes and equipment. But it also provides some clarification as developers, producers, distributors, intermediaries and end users, including non-experts, are viewed as necessary active players in the process. Emphasis is placed on cooperation with all stakeholders involved. Furthermore, the concept attempts to recognize the heterogeneity within stakeholder groups. One assumption of this concept is that in order for technology cooperation to be sustainable, it must be part of a larger process of technological capacity, where firms, organizations and communities acquire knowledge and expertise as well as physical equipment.

This assumption is based on a number of other pivotal studies in this area that have demonstrated this link (e.g. Ockwell et al. 2007, Bell 1990).

The term urban was applied to properly account for cities, which are often central nodes "in a national, and increasingly international, society linked by means of networks" (Capello et al. 1999: 5). Also, drawing from the national systems of innovation literature, there is some evidence that supports cities as being regional or metropolitan innovation centres, which can positively affect the rate of technology development and use (Lundvall 1992; Doloreux and Parto 2005). Scholars in this vein highlight the role of proximity and communication occurring within a system. It also draws from the work of Porter (1990), who argues that firms and institutions operating in clusters, which in developing nations can often be found in cities, have competitive advantages. Other studies from Latin America also highlight that personal contacts, including face-to-face meetings, and relationships are key. Personal relationships are important everywhere, but even more critical in this setting, as emails and letters are seen as being too impersonal. Fostering personal relationships among various technology cooperation players in a city is easier due to proximity. Some Latin American researchers suggest that many Latin Americans lie somewhere in between Euro-American individual values (focusing on what is within people) and Asian collectivism (focusing on relationships between people) (Corral-Verdugo and Pinheiro 2009). Discussions with key informants while conducting interview-based research in various developing country cities in Latin America and Asia (Mexico City and São Paulo for my PhD research, Santo Domingo for my masters research, and New Delhi, India for my research fellowship), also confirm this view.

The third systemic approach chosen comes from the **trade and competitiveness** literature. This is because these policies are some of the most important policies that shape technology transfer processes occurring at the systemic level. The third sub-research question therefore is: ***to what extent do trade and competitiveness policies explain RET adoption in the urban developing world?***

This question relates more to the national and sub-national level of policies, versus the first and second sub-research questions, which tend to relate to various scales.

Debates regarding trade and competitiveness policies – including their definition and which types are more effective in bringing about economic development, innovation and successful technology transfer and adoption – abound. Chapter 2 will explore these issues in further detail.

Although there has been much research conducted on domestic and international trade and competitiveness policies in the developing world, including the multilateral World Trade Organization (WTO) system (e.g. Trade-Related Aspects of Intellectual Property Rights (TRIPs), these studies generally focus on their role in economic development and innovation (see Kim 1998; Lall 2000; Grieve 2004; Wade 2004; Shadlen 2007 for example), and less so on their role in technology adoption, especially in the area of renewables. In the past, work on technology transfer in the area of renewable energy tends to overlook these policies, but is linked to national competitive and technology policies (see Forsyth 1999 for instance).

Competitiveness issues that have been raised in climate change research mainly focus on industry, where certain carbon emitters subject to a price and certain allocation of carbon (e.g. those firms involved in the European Union's Emissions Trading Scheme (ETS)) would become less competitive to those carbon emitters not subject to any carbon constraint (e.g. a firm in China). The fear is that some firms, especially energy intensive ones, would source from or relocate to different areas where there is no such requirement on carbon in order to reduce costs. Specific industries include steel, aluminium and cement, as they are rather carbon intensive. Also, "these sectors also have some degree of product and process uniformity; consumers tend therefore to be indifferent to where products were made, provided they are less expensive" (Reinaud 2009: 6). While recognizing the empirical limitations of these insights (as the ETS has only been in place since 2005), preliminary analysis of those potentially vulnerable firms in the ETS indicate that there was no major changes in trade flows or production during the three year time period under scrutiny (Reinaud 2009). This is supportive of Kuik, Tol and Grimeaud (2003), who stress that although the IPCC indicated a plausible carbon leakage rate between 5-20% in their Third Assessment Report based on models, projections of models have their limitations.

Work is just beginning on the potential role that trade and competitiveness policies may have on the adoption of low carbon technologies in developing countries, of which renewables are a part – one focus is on linking the World Trade Organization and climate change negotiations (e.g. Cosbey 2007). This research is particularly focused on the role that Intellectual Property Rights (IPRs) may have on the transfer of climate technologies to developing countries (See World Bank 2008a; Littleton 2008; Mallett et al. 2009; Ockwell et al. in review). Highlighting the lack of success within the WTO to address environmental issues, Kernohan and De Cian (2007) look to regional trade agreements, such as those within the European Union framework, which are often "more far-reaching than multilateral trade negotiations in [their] coverage of domestic measures and environmental regulations, [they] might represent a reasonable opportunity for strengthening the credibility of controversial climate-related measures" (2007: 75).

Of those studies looking at the relationship between cooperation of low carbon technologies and trade and competitiveness policies, some scholars claim that an open trade regime, or policies that emphasizes trade liberalization, will increase the adoption of low carbon emitting technologies (Cosbey 2007; World Bank 2008a).

Research from other technologies in the developing world also makes this argument. Emphasis is placed on the market, centring on investor and consumer choice (Markusen and Venables 1999). Thus, foreign direct investment (FDI), exports, trade liberalization, and indirect government involvement are stressed. Technology cooperation under this approach is mainly characterized by shorter-term, more integrated methods (e.g. acquisitions / subsidiaries, direct purchasing of foreign technologies) with one participant serving as the key player. The claim is that these forms of technology cooperation are more effective as the process happens more quickly (Pietrobelli 2000). The market will decide which technologies are most viable for the environment in which they are to be used. With a single leader driving the process, providing coherent information to the public, and often possessing the means for quicker deployment, there is a greater likelihood that these technologies will be used. They argue that this form of technology cooperation is the most common version of this tool (namely internal, such as between a Multinational Corporation (MNC) and one of its subsidiaries), and the reason it is widely used is because it will lead to the most rapid diffusion and adoption of technology (Pietrobelli 2000).

Others suggest that a conditionally outward approach to trade and competitiveness is most conducive to increasing technology development, adoption and dissemination. In this view, while the presence of foreign investors is also encouraged, they have less of a `free reign' in the local market. For instance, the government tends to take on a more direct role through creating legislation, mandatory requirements, and direct involvement in technology development, production, dissemination and adoption (Lall 2004b). However, in current renditions, the government does not drive the technology cooperation process, but rather, is one of a number of key players. Emphasis is placed on building up indigenous capacity to absorb and adapt technologies. Some claim that technologies often work better in settings in which they are developed rather than those imported from elsewhere (Heaton et al. 1994), while others argue that foreign and local technologies are sources to draw from (Bell and Pavitt 1993). However, there is a lack of empirical evidence to support these claims in the context of renewables in developing countries.

These three themes – technology adoption, technology cooperation and trade and competitiveness regimes, including variations on the approaches and why these particular approaches were chosen, will be explored in further detail in Chapter 2.

1.6. Research Design

Processes and networks occurring at the meso-level can provide innovative insights into the research question noted above– ***What are the most important factors affecting RET adoption in the urban developing world?*** This dissertation tackles this question by answering the three sub-research questions, indicated in the section above, using evidence from two cities which serve as case studies.

The dissertation turns to the experience of Latin America, the most urbanized part of the developing world (Cherni 2001), to answer these questions. Specifically, it looks at two dynamic and growing countries in the region and their largest and arguably most significant cities – Mexico City, Mexico and São Paulo, Brazil. In-depth research and analyses were conducted within these cities to determine how Roger's diffusion of innovations approach, urban technology cooperation and trade and competitiveness policies can influence technology adoption in the urban developing world.

Both cities have large populations, active civil societies, major discrepancies between the urban wealthy and poor, a high-energy demand, and high technological capability (TC), or assets (e.g. human resources, technical and scientific skills and infrastructure) held by a firm, region or country to bring about technological change (Rogers 2003a). The study examines RET use in these cities beginning from the mid-1970s to 2007, with a particular focus on the 2000 – 2007 timeframe. This time period was chosen as important events occurred globally and locally which can help to understand the context of RETs in Mexico City and São Paulo. These facets include increased interest in renewable energy, major shifts and yet relative continuity at the political level (except for local politics in São Paulo), and similar yet different trends occurring regarding paths pursued for economic development.

For example, both Mexico and Brazil were affected by the first oil shock (October 1973). This happened when the Arab nations of the Organization of Petroleum Exporting Countries (OPEC) increased the price of oil, reduced oil production and issued an oil embargo on numerous Western countries. These actions lead to subsequent interest and research in the renewable energy sector in many countries as a way of decreasing dependency on these foreign sources of fossil fuels, but stopped or slowed down after 1980. As a general trend, interest and research on RETs further waned worldwide once Saudi Arabia increased their production of oil in an attempt to reverse decreasing global demand for oil in 1986. But, interest and research on RETs has been steadily increasing again since the 1990s – and especially in the mid-2000s due to environmental factors along with energy security reasons. For example, now alternative energy is viewed as a way of addressing climate change and local pollution, as well as decreasing dependence on foreign fossil fuel sources (EIA 1998).

Another contextual consideration for these cities has to do with their approach to economic development. The 1990s saw some major shifts regarding trade and competitiveness policies in both countries, explored further in Chapter 2. Numerous state-run companies were privatized, and both Mexico and Brazil began to liberalize their trade and competitiveness regimes, although Brazil did so to a lesser extent (Baer 1996; Political Risk Services 2002; Cunha 2004; Shafaeddin 2005). More information on the case studies is in Chapters 4 and 5. The information collected is mainly qualitative, which was augmented with some quantitative information. Detailed information on research methods is in Chapter 3.

1.7. Thesis Overview and Objectives

The nature of the study dictates an interdisciplinary approach. As noted in this chapter, a rich body of literature exists to explain technology adoption and cooperation (explored further in Chapter 2) – including approaches found in economics, political economy, to approaches that emphasize social contexts, such as constructivist literature and actor oriented frameworks. The most prevalent type of frameworks to examine RET adoption stem from barriers-oriented or policy-focused models.

I found that conventional approaches to RET adoption are often limited as they do not account for the effects that indirect policies may have on RET adoption, nor the interdependent nature of actors, technologies and policies operating in a system. I turned to several systemic approaches to determine how effective they are at explaining RET adoption.

The thesis also contributes to knowledge in this area through putting forth a new concept and a new methodology. To begin with, I propose the concept *urban technology cooperation* as a systemic approach to explain RET adoption in developing country cities. Technology cooperation is a pivotal channel for the uptake of RETs in developing countries, and it is these debates that the thesis turned to. The concept is a two-or more-way iterative, non-linear approach; it reflects all stakeholders involved in the process; and it is relevant for urban environments, recognizing their distinct features. Chapter 2 will explore the thesis themes further, examining the various debates underway in the areas of technology adoption, technology cooperation, and trade and competitiveness regimes, to provide more theoretical grounding, assessing their applicability in explaining what is occurring in urban Latin America.

I also chose a new methodological tool by examining the meso-level. This level was chosen because it focuses on a system, social networks and attempts to assess the affects found at various levels.

Chapter 3 will to inform the reader about the methods and analysis used in the dissertation. The first section of this chapter will explain the research methods used for the study, including why case studies were chosen to explain the adoption of RETs in the urban developing world. This will include information on how the outcome (technology adoption) was "measured". The metric used for the technology hardware is m2 / 100 inhabitants, while the metric used for biogas to produce electricity is MWs, or the capacity of the electricity generator. The complexity of attempting to measure technology software will also be addressed in this chapter. This section will also explain some of the methodological challenges involved in data / information collection for the case studies.

Chapter 3 will also turn to why I chose these particular methods to answer my research question: What are the most important factors affecting RET adoption in the urban developing world? – And the sub-research questions that include: How can systematic models help to explain RET adoption? What are the reasons that SWHs and biogas to produce electricity technologies are being used or not in Mexico City and São Paulo?, and under what conditions, if any, do trade and competitiveness policies impact RET adoption? The second section of Chapter 3 will turn to the tools used to assist in the analysis of the results from the data and information collection, including why I chose Atlas ti, a Computer Assisted Qualitative Data Analysis Software (CAQDAS) program to assist in determining findings.

Chapters 4 and 5, regarding Findings in Mexico City, Mexico and São Paulo, Brazil, will each be divided into four sections. The first two sections will focus on the results of the outcomes – namely technology adoption, measuring hardware and software. There will be one section on Solar Water Heaters and another on biogas to produce electricity. The second half of the chapter will turn to the results of the most important factors potentially affecting RET adoption as identified by the key informants, using

Atlas ti to help determine common themes and trends. They will be sub-divided by the two technologies examined, SWHs and biogas to produce electricity.

From there, Chapters 6, 7 and 8 analyze the findings of the two case studies, using the three approaches identified earlier at the meso-level, assessing their strengths and limitations – Rogers' diffusion of innovations model, urban technology cooperation, and trade and competitiveness approaches.

Chapter 9 will bring all of these insights together, providing the discussion of the thesis by answering the sub-research questions – How can systemic approaches help to explain RET adoption in the urban developing world? Why are SWHs and biogas to produce electricity technologies being used or not in Mexico City and São Paulo, and to what extent do trade and competitiveness regimes play a role on RET adoption? By answering these questions using evidence from urban Latin America, this dissertation seeks to

1) test three systemic approaches;
2) apply a new methodological approach in the area of RETs and developing country cities by focusing research at the meso-level;
3) provide more empirical evidence on the areas of trade and competitiveness policies and the adoption and cooperation of low carbon energy technologies; and
4) develop and test my own approach (urban technology cooperation)

Chapter 9 also concludes the thesis, bringing the discussion back to answering the overarching research question – ***What are the most important factors affecting RET adoption in the urban developing world?***

1.8. Conclusion

To summarize, although there is a general consensus that renewable energy technologies should be a part of developing countries' energy portfolio, they remain on the margins. On the other hand, this sector is growing globally, including in the developing world.

Conventional approaches aimed at increasing renewable energy technologies (RETs) in developing countries, stressing barriers and ways to overcome them, are useful in that they emphasize economic, technical and institutional aspects regarding RET use.

However, as indicated above, there are a number of problems with the above conventional frameworks. First of all, similar to other scholars critical of conventional RET approaches applied in developing countries (e.g. Cherni et al. 2007), I argue they tend to place too much emphasis on economic, technical, and institutional aspects, which, while paramount, neglect other aspects, including sociocultural dynamics, which can be just as important to potential users. In other words, 'cut and dry' business principles are often applied to explain renewable energy technology adoption, tracing it to "customer satisfaction, affordability, dealer profitability, and effective supply and service chains" (Martinot 2002: 42). These aspects are important but one must also look at "...the attitudes, values, beliefs and needs of potential users; for any innovation that goes against an entrenched custom in a community is unlikely to be adopted" (Troncoso et al. 2007: 5). These approaches often fail to adequately account for context.

Secondly, the 'remedies' offered are often short-term, reactive solutions. Because of this, these approaches do not account for the role that other, seemingly unrelated, indirect policies can have on RET adoption. These barriers are often interdependent and their existence can be traced back to policies formulated at the macro-level. Thus, addressing one, several, or all of the barriers does not necessarily equate to an increase in technology adoption. In other words, these models do not focus enough on integration.

Third, current approaches to knowledge tend to take a literal approach, viewing it as information, but knowledge is more than just information, it is also dependent on their people's previous understandings, experiences and environment.

Moreover, of those conventional approaches that focus on relationships, emphasis is placed on the dynamics between stakeholder groups (e.g. government agencies versus firms versus community groups) rather than *within* stakeholder groups. Also, more information is needed on the nature of these relationships. Finally, these models tend to be applied at the micro or macro-level; the meso-level which can offer some unique insights is neglected. Systemic approaches are an alternative tool as they try to include social and economic factors at various scales to explain RET adoption, but to date there is little evidence supporting their application. Chapter 2 assesses their appropriateness to explain RET adoption in the urban developing world.

CHAPTER 2: FRAMEWORKS OF TECHNOLOGY ADOPTION, COOPERATION AND TRADE AND COMPETITIVENESS REGIMES

2.1. Introduction

The focus on Chapter 2 is on debates surrounding the key themes of the thesis – namely those frameworks used to explain technology adoption, technology transfer and trade and competitiveness policies. The first purpose of the chapter is to assess the applicability of some alternative approaches, systemic frameworks – in particular Rogers' diffusions of innovations, urban technology cooperation, and trade and competitiveness regimes – to help explain RET adoption in the urban developing world.

Conventional frameworks do a good job at highlighting economic and technical factors affecting the uptake of RETs in developing countries. However, the problem with these approaches is that they are based on short-term objectives, emphasizing economic and technical issues, and generally rely on experience from rural applications. Moreover, they tend to treat information and knowledge the same. They also do not scrutinize enough the nature of relationships between and within stakeholder groups and neglect the potential role that intermediaries can have on uptake. They are also often applied at the macro or micro-levels; the meso-level is neglected.

Systemic approaches have been proposed as an alternative lens to examine RET adoption as they account for larger social and policy considerations as well as economic and technical concerns.

Rogers' Diffusion of Innovations (2003a) model was considered a useful approach because it recognizes that knowledge is shaped by underlying conditions and that it consists of principles knowledge, or knowledge on why a technology works rather than just what technology is or how it works. Social aspects, as opposed to mainly economic and technical issues also feature prominently. The model also considers technologies over time and the importance of change agents, or those people who influence others to use or not use as technology.

On the other hand however one could also say that the model does not take the dynamics between and within stakeholder groups into account enough. Also, it is not clear from the framework how certain aspects within the system or external but with links to the system (in this case the city) play a role on adoption. To clarify, as is shown from the study results, some of the change agents, technologies and drivers were more foreign in Mexico City, whereas in São Paulo, they were more domestic. How, if at all, these origins play a role on adoption was explained using urban technology cooperation and trade and competitiveness approaches rather than Rogers' model.

The second framework considered is urban technology cooperation. This alternative concept is in contrast to orthodox technology transfer models which are often linear, stress the one-way nature of flows and do not account enough for the dynamics between and within stakeholder groups, as well as non-experts. Urban technology cooperation focuses on the unique features of cities, emphasizes the role of technological capacity building in impacting use and is applied at the meso-level.

Some criticisms of this model include the fact that the meso-level is difficult to define as a 'space', that use of the term technology cooperation may downplay the power dynamics between participants, that it is too city-centric, and thus not useful elsewhere, and that models attempting to engage the public may be favoured in theory, but in practice have been plagued by difficulties.

The third type of systemic approach considered is trade and competitiveness policies. Although research on this area is recent, the general consensus is that trade liberalization can lead to more RET use in developing countries. However, the problem with this claim is that it is based on studies at the macro-level. A more appropriate question is under what conditions, if at all, do trade and competitiveness policies affect the use of RETs in developing country cities.

2.2. Alternative Technology Adoption Approaches – Systemic Frameworks

2.2.1. Rationale and Criteria for the Three Systemic Approaches

There are a number of perspectives through which to answer the research question: what are the most important factors affecting RET adoption in the urban developing world? I chose to concentrate research efforts on systemic approaches for a number of reasons. First of all, centring attention at the meso-level led the focus of research to be on stakeholders and networks versus individuals or macro-level institutions. Systemic approaches, which have been applied at the meso-level, and which attempt to include social and economic facets at various scales were felt to be an appropriate lens through which to assess how RET uptake occurs on a city-wide scale. Secondly, through answering the research question, the dissertation deemed it crucial to understand how choices and decisions can impact adoption through assessing the motivations, experiences and contexts of agents. Systemic approaches, examining networks, relationships and interactions, were deemed suitable to undertake this task.

The criteria and rationale to determine which specific systemic models to employ in the dissertation analysis were also decided upon. Criteria included whether or not the approach captured prominent factors that key informants identified as being pivotal in RET adoption in these developing country cities; whether or not the approach attempted to capture alternative factors, beyond the classical explanations for RET adoption, and whether or not the approach would be appropriate if applied at the meso-level: in other words, would it be able to capture the potential affects of choice and decision making by stakeholders versus individuals, or macro-level institutions.

Specifically, as noted above, I examined the case studies of Mexico City and Sao Paulo and the use of Solar Water Heaters and biogas technologies to generate electricity using Rogers' diffusion of innovations model, a new concept termed urban technology cooperation and trade and competitiveness policies.

It is important to note that these models represent only a few lenses through which to explain these changes. Other approaches stress the role of energy transitions (e.g. Geels 2004, Frantzeskaki and de Haan 2008; Berkhout et al. 2004), examining political institutions (Noble 1998) on ruling parties and industrial policy), or gender and renewables (Clancy et al. 2004). The potential contribution of these alternate approaches include:

- energy transitions – serves as a way in which to understand changes occurring at a societal level. This approach focuses on niches (changes happening within or outside of the system such as the use of RETs, car sharing, organic farming) and regimes (the dominant aspects of societies such as conventional energy sources, individual or one-family car ownership, etc.). Scholars avow that a transition has occurred "when the societal system functions in a different way…the composition of the societal system had to change fundamentally…changing its structures, cultures and practices" Frantzeskaki and de Haan 2008: 4);
- political institutions and ruling parties (Noble 1998) – through this approach, the tactics of governing parties, to create incentives to support industrial policies and to actively seek out coalitions and alliances with other parties maintain these policies, are assessed; and
- gender and renewables (Clancy et al. 2004) - provides an avenue to assess the impact that energy use has on women versus men (e.g. women in rural environments in developing countries are generally responsible for providing fuel within the household thus while reduction of energy subsidies for fossil fuels is often cited as being necessary to promote energy efficiency and environmental protection, these more expensive energy prices will have negative implications for poorer households)

The main rationale for choosing the three approaches was based on the criteria developed partially on what I was seeking to research before conducting fieldwork, and also based on results obtained from the fieldwork. For instance, before conducting interviews I knew that previous research in this area using conventional approaches indicated a number of crucial factors to consider. At the same time, I was interested in exploring the notion that more indirect policies and technology cooperation may play more of a role of technology adoption than conventional approaches would indicate. For those reasons, Rogers' diffusion of innovations model was chosen at it focuses on classical explanations for RET use (including economic and technical features) but also attempts to capture social aspects. The concept of urban technology cooperation was chosen as the technology cooperation process is an integral part of adoption, especially in developing countries when the origins of technologies are often (at least partially) – but not always – from abroad. The idea of 'urban' was a way in which to capture unique features of cities, which could also have an impact on RET use. Moreover, I thought that trade and competitiveness approaches – intrinsically linked to technology development, production and use but often neglected in RET studies – warranted a closer examination.

Ultimately however, results from discussions with key informants in the case studies reinforced the use of systemic approaches. For instance, as explored in further detail in Sections 4.7, 4.8, 5.7 and 5.8 trade and competitiveness policies and networks (or a lack of) featured prominently in responses as factors affecting RET use.

As another example, the issue of how the use of RETs affect women in particular did not really come up in discussions with key informants. That said, if a different study had been undertaken, such as a household-level survey comparing a wealthier and poorer neighbourhood in one of these cities, the issue of RETs and their impact on females in particular would likely have been a prominent theme. In addition, although the use of SWHs and biogas technologies has slowly been increasing, in both of these cities, at present their use remains on the periphery, although this may change, causing a large-scale shift at a societal level, making the transitions approach more relevant. Moreover, for the majority of the time period under scrutiny (mainly 2000 – 2007), at the relevant political levels in Mexico City (federal and local), the same political leaders were in power (2000-2006).[25] Basically, Mexico had a more conservative, right-leaning party at the federal level, and a more socialist, left-leaning party

[25] In 2000 the federal government of Vincente Fox of the Partido de Accion Nacional (PAN) or National Action Party (considered right-leaning), came to power, thus ending the 71 year rule of the Partido Revolucionario Institucional (PRI) or Institutional Revolutionary Party. Mexico City, or the Distrito Federal (D.F.), does not have a state-level government as it is under different jurisdiction that the State of Mexico (the area surrounding Mexico City). In the 2006 federal elections of Mexico, Felipe Calderón, also of the PAN won (although very narrowly with a less than one percent lead). At the municipal level, in 2000, Andrés Manuel López Obrador of the Partido de la Revolucion Democratica (PRD) or Party of the Democratic Revolution (left-leaning party) was elected as the Head of Government at the municipal level in Mexico City (he resigned in 2005 to run in the federal election). Marcelo Ebrard, also of the PRD, was elected mayor of Mexico City in July 2006 (Informal discussions, various informants, November 2005-January 2006)

controlling Mexico City. In Sao Paulo, there was relative stability at the federal and state level (left leaning party from 2002-2009 and centrist party at the state level).[26] At the local level, there were shifts from right to left governing parties during the time of scrutiny[27], but as indicated in Chapter 5, at the time of writing (2009), the main policies supporting SWHs and biogas technologies were still being implemented.

2.2.2. Contextualizing Technology / Socially-Embedded Frameworks

Contrasting the above techno-economic / policy approaches, are those that suggest the above models do not assess technology adequately. Based in science and technology studies, in contrast to those purporting orthodox technology adoption and transfer frameworks, these scholars emphasize context and define technology quite broadly. For instance Ursula Franklin who considers technology to be both practices and a system that "involves organization, procedures, symbols, new words, and most of all, a mindset" (Franklin 1990: 12). Scholars of this view argue that technology is implied to be positive or neutral, and treated separately from the social context in the above models. They claim instead that technology is the result of power relations, politics and hegemons, and vice versa. These hegemons determine why certain sets of technologies are the only ones deemed scientific (e.g. Western technologies versus non-Western technologies) (Stewart 1977; Jasanoff et al. 1995; Shove 1998; Miller 2001). I view technology as products, processes and knowledge and recognize that technology has a symbiotic relationship with the social context – in other words, they are dynamic and influence each other.

2.2.3. Actor-Oriented Approaches

Ultimately, agents are core to the technology adoption and (as discussed further below) the cooperation process. Ideas, knowledge, management practices, equipment, etc. can

[26] In 2002, Luis Inácio "Lula" da Silva, of the Partido dos Trabalhadores (PT), or Workers Party, (left-leaning party) was elected president. He was re-elected president in 2006. At the state

[27] Celso Pitta of the Partido Progressista do Brasil (PPB) or Brazilian Progressive Party (now called the Progressive Party (PP)) (right-leaning party) was mayor from 1997-2000 (excluding a period of a few weeks in May / June where he was ousted by a decision from the State of Sao Paulo supreme court, and then reinstated when that decision was reversed), then Marta Suplicy of the PT was mayor from 2001-2004. Jose Serra, of the PSDB, became mayor in 2005 until March 31, 2006, but then his deputy Gilberto Kassab, from the right-wing Democratas, or Democrats, political party, took over as mayor when Serra decided to run for the governorship of the State of Sao Paulo (Prefeitura de Sao Paulo, 2007).

be exchanged, but not effectively if some participants do not understand the technology. More recent approaches to technology also stress the importance of agents – active within the context they operate in; thus influencing their decisions (Shove 1998; Biswas et al. 2001; Barton 2007).

Norman Long (1990), criticizing modernization and neo-Marxist approaches for being too reliant on external factors to explain social change, argued that the conduct of various actors diversified "even where structural conditions and types of external impulses are relatively constant." (Long 1990 cited in Schuurman 1993: 18). The ability to effect change by individuals and groups on a smaller scale are thought to be better explained with this analysis, as actors are the centre of focus in this approach.

Actor-oriented approaches are often linked to Actor Network Theory (ANT) but there are important differences. ANT uses the term actant, which is an element in a system – whether physical equipment, text, people or organizations (Latour 1987).

I take a more narrow approach, in that I view actors, or agents, as being individuals, organizations, and groups that can influence the technology cooperation process. In other words, there must be some human aspect involved in these groups. Examples relevant for this dissertation include NGOs, various levels of government, trade associations, consultants, end users, etc.

However, defining actors is difficult because the notion is an arbitrary one, used as a tool by researchers to delineate how different groups and / or individuals affect social change. Also, in the real world, people and groups can be considered various agents or actors simultaneously. For instance, in Mexico City, one consultant I spoke with had recently left the Mexican federal government at the time of our interview after having worked there for many years. He also had purchased a solar water heater for his home. So, he could be considered a representative of a consultancy, a recent government representative and an end user all at the same time.

Actor-oriented approaches were considered relevant to assess technology cooperation and adoption as number of studies examining technologies in developing countries have linked sustainable technology cooperation to strong networks between various actors involved in these technologies over time (Bunders et al. 1999; Douthwaite 2002; Briggs and Matsaert 2004).

Research on technology diffusion and adoption can focus on the attributes of agents, communities or organizations, or the technologies themselves. For example, as noted earlier, Cherni et al. (2007) examine the attributes of communities using a multi-criteria approach. They suggest that they have a number of assets or resources - social, natural, physical, human and financial. This approach draws from sustainable livelihoods, which is an agent-centric framework, where actors that will potentially use the RETs are active participants in decision-making process. It is a model that quantifies both qualitative and quantitative attributes – termed capital (human, physical, financial, natural and social) in a community, assigning a 1.0 to capital that is considered ideal, and comparing this with what really could be achieved by implementing a new technology. This model was applied at the micro-level and assumes that "[g]iven that the needs were very similar in every household surveyed, it made sense to provide a common energy solution to the community" (Cherni et al. 2007: 1497).

These alternative approaches emphasize socio-culture factors as well as economic and technical facets. I view culture as a dynamic process, which changes over time and space. (Skelton 1997) suggests that it is "socially constructed and so an individual's experience and creation of culture is determined by such social factors as gender, race, class, sexuality, age, geography. ..[and] history and contemporary social, economic and political factors" (1997: 73). Culture is a form of social organization, a way of life, which affects a person's viewing of the world.

Although not exhaustive, Table 2.1, provides a list of some major theoretical frameworks used to explain renewable energy or other environmental technology adoption in industrialized and developing countries.

Table 2.1 Selected Examples of Approaches to Explain the Adoption / Diffusion of Renewable Energy Technologies[28]

Type	Main Disciplinary direction	Description	Some Authors / Organizations	Proposed Evidence and / or scale of scrutiny
Economic	Economics	push and pull factors (technology suppliers and R&D) focus is on rate of adoption and why some firms adopt more than others	Blackman 1999, 2002	Level of firm, sector and country Developing countries
Barriers-Oriented / Policy focus	Economics and public policy	Economic, technical, political, social, institutional	Wilkins 2002 UNFCCC 1992 / Kyoto Protocol 1997 Renewables 2004 RETooIkit 2005	Developing countries – Southeast Asia Global / developing countries Europe / global Developing countries
Actor-oriented approaches; Behavioural Models; Asset or Resource Models	Communications, sociology, political science	Integrated 'socio-technical potential'	Cherni 2007 Shove 1998	Latin America Australia
Contextualizing Technology and socially embedded approaches	Science and technology studies	Neo-Luddites / Technology critics Technology as a social construct Science (technology) – who defines? Technology as a mindset / practice	Mills 1998 Jasanoff 1995 Miller 2001 Franklin 1990	Industrialized and Developing countries

Source: Author

2.2.4 Rogers' Diffusion of Innovations

Another actor-oriented approach is from Rogers' Diffusion of Innovations (2003a). This approach was chosen as a way to help explain RET adoption for various reasons. First of all, it is a systemic model, recognizing the dynamics of technology and its social context. Also, in addition to accounting for economic and technical aspects, Rogers takes sociocultural factors into consideration. Moreover, Rogers' model

[28] Please note that this table provides a general idea of the main thrust of these approaches, some of which overlap

recognizes the potential impact that people, or what he terms 'change agents', may have on the uptake of technologies. Rogers model will be broken down further below, using evidence from other RET studies, especially those in developing countries, to determine how well it can explain RET adoption in urban Latin America.

Rogers can be applied looking at the attributes of agents and / or technologies. When referring to the attributes of agents, he names them innovators, early adopters, late adopters, and laggards. I chose instead to apply aspects of Rogers' actor-oriented approach that examines the attributes of a technology rather than attributes of the individuals or organizations that are potential or actual adopters (Rogers 2003a). Although determining attributes of technology and actors can be very subjective, there is often less controversy with certain aspects of a technology (e.g. the price of equipment or services – even if debates continue about whether or not all costs that need to be have been captured in the price) rather than an agent. Rogers also recognizes the limitations in these catergorizations of agents, noting that he had defined a farmer in Iowa as a 'laggard' who did not adopt the new hybrid variety of corn (reliant on pesticides for its survival) because there were no more songbirds. Rogers further concedes that he reframed this farmer years later as an early adopter, when referring to the organic food movement in the United States (Rogers 2003a).

Rogers essentially views technology adoption as "a process of stages that occurs over time" (2003a: 197). It is a decision-making scheme; a process that a potential user must go through in order to make the decision whether or not to use a technology. His model consists of stages: knowledge, persuasion, implementation and confirmation. In his model, an actor (e.g. individual, organization), once aware of a technology makes a decision on whether or not to use the technology -- what he labels as the "persuasion stage" -- based upon several attributes. The first factor is whether or not the technology is perceived to have relative advantages (e.g. economic, social). The second concept is what Rogers terms 'complexity' – or how well potential users understand how the technology works and the principles behind it. The third factor that affects the persuasion stage is triability, or whether or not a potential user can "try out" a technology before fully committing to it. The actor then implements the decision (whether or not to use the innovation), and finally confirms this decision (either to continue using (or not use) the technology, or to change their mind). These stages all occur within a ''social system'' (i.e. the context in which the decision takes place) and are informed by "prior conditions" (Peter 2002; Rogers 2003a).

Knowledge – Like those RET studies (e.g. Wilkins 2002, Muntasser et al. 2000) that examine knowledge barriers, Rogers also pays attention to knowledge. As noted in Chapter 1, what distinguishes Rogers from these other frameworks is that the model recognizes the importance that underlying conditions may have on RET uptake. Actors can be passive- in that they happen to come across a technology – or more active – in that they are aggressively seeking out ways to address a need. Furthermore, his definition of knowledge considers not only awareness of the technology (defined as knowing it exists) and how it works, but also what can be considered principles knowledge, or what Lall (1995) refers to as 'know why' knowledge – where people understand why the technology works. This is important because adapting RETs to local environments – in addition to increasing uptake -- can also lead to indigenous technological developments, which can increase self-reliance and even lead to exporting this technology (physical equipment and expertise) abroad (Kalogirou 2004; Ockwell et al. 2007; Mallett et al. 2009). Cherni et al. (2007) also stress the importance of knowledge by recognizing in their model that communities need to understand the potential implications involved in using a renewable energy technology.

That said, Rogers is not exactly clear on how he defines knowledge. Knowledge and information mean different things to different people. As noted in Chapter 1, knowledge is more than just information; it can also include norms and assumptions. Actors process information differently based on their experiences, understanding and unique attributes.

Persuasion - The majority of RET studies in developing countries focus on what Rogers terms the persuasion stage. The first aspects within this stage are relative advantages. Many RET studies emphasize a number of these advantages, applied at the micro or macro levels, arguing for their adoption in developing countries (e.g. United Nations Environment Programme / Division of Technology 2000; Renewables 2004).

Like those studies noted in Chapter 1 that emphasis economic barriers, Rogers also notes that RETs must be seen as ***relatively economically advantageous*** for their adoption to occur. A number of scholars and practitioners argue that poverty reduction can occur with RET use. For example, studies demonstrate that poorer people (especially women) are often burdened with the task of finding conventional energy sources, such as fuelwood (which can take up to several hours per day), and so they are left with little or no available time; they argue that RET adoption – through freeing up time -- can help to improve the socio-economic situation of poorer people (Biswas et al. 2001). Along these lines, studies show that RETs can lead to job and income-generation (Kaufman et al. 1999) and, looking at a more macro-level, provide more employment per unit of electricity generation versus non-renewable energy sources (Moody-Stuart and Clini 2001). For instance, one study shows that "up to 188 worker-years are created locally for every megawatt of small solar electric systems" (United Nations Environment Programme / Division of Technology 2000: 7). Another study on the link between employment and RETs in the United States indicates that wind and PV energy provide 40% more jobs per dollar than coal, and that these jobs often require higher skills (Singh 2001). Other economic benefits, such as those at the national level, can also be accrued through using RETs. According to Biswas et al's (2001) study, economic competitiveness at the national level in Bangladesh is compromised when examining the "cost" of using fossil fuels, accounting for 9% of import costs and 15% of export earnings in the early 1990s.

Rogers' model also considers ***political advantages***, which can be applied at various levels (micro, meso and macro). For example, a country or region can consider the use of more RETs as decreasing dependence on fossil fuels. As noted in Chapter 1, even those countries that are large fossil fuel exporters consider RETs to be advantageous as their use domestically, frees up more fossil fuels for export, creating more opportunities for foreign exchange (Massabie 2008). For example, Venezuela's state-owned oil company Petroleos de Venezuela S.A. (PDVSA), is investing in a 100 MW wind energy facility.[29] Energy security arguments could also be considered here, as supporters are quick to claim that the majority of the world's fossil fuel resources that are technically and economically 'easiest' to extract are in unstable parts of the world (e.g. Middle East, Russia, Nigeria)[30] (Edinger and Kaul 2000).

[29] Renewable Energy World.com, 2008

[30] Although Alberta, Canada is second only to Saudi Arabia in terms of proven oil reserves (175 billion barrels versus Saudi Arabia's 224 billion barrels), this oil comes from the tar sands (or oil sands), which

In contrast to many conventional approaches however, Rogers also talks about the importance of technologies being considered ***socially advantageous*** compared to alternatives to increase adoption. Some researchers assess health and environmental impacts as an economic advantage by putting a monetary value on them (e.g. through measuring days of work lost due to respiratory illnesses) (e.g. Edinger and Kaul 2000, Bourdaire and Ellis 2000). But, they can also be viewed as relative social advantages – with attempting to assess their impact in a monetary value. Some of the health benefits are highlighted in Biswas et al.'s (2001) study on the potential for biogas use in Bangladesh and Milton and Kaufman's study on SWHs (2005), arguing that renewables decrease problems (especially for women), that are associated with fuel currently used for cooking and heating (e.g. wood) in rural environments such as respiratory illnesses from smoke inhalation, low birth weights and lung cancer (Ezzati and Kammen 2002). Energy expert Jose Goldemberg further stresses that other conventional energy sources (namely fossil fuels) are associated with health problems. Specifically, he notes that "...energy-related emissions from fossil fuel combustion, including the transportation sector, particulate matter, sulphur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide and other pollutants are major contributors to urban air pollution, which is thought to be responsible for about hundreds of thousands deaths annually around the world." (2006: 2186). Studies also focus on the environmental improvements that can occur as a result of using RETs. They demonstrate the links between fossil fuel use and acid rain, ozone depletion and global warming (Kalogirou 2004; Edinger and Kaul 2000).

Another feature in Rogers' (2003a) persuasion stage is ***complexity***, or how well potential users understand the technology (how it works and / or the principles behind it). Unlike some conventional approaches to technology uptake, Rogers' model examines technology adoption over time. Complexity is a part of an actor's familiarity

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is a more viscous, "dirtier" oil source. The process to extract this oil source into synthetic crude is expensive and environmentally-damaging. This can be done through open-pit mining (70 metres or less below the surface) or through extracting oil "in situ" which involves generating steam from natural gas into deep deposits of bitumen to enable it to flow to the surface (the majority of Alberta's tar sands are deeper and so this process must be used) (CAPP), C. A. o. P. P. (2006). IS Oil Sands Backgrounder. Calgary, CAPP.

and experience with the technology. The adopter becomes more comfortable and adept with the technology (Douthwaite 2002). Assessing these facets over time is important in understanding adoption. This has important implications for RET use because as people become more comfortable with a technology, they are more likely to adopt technological "cousins", where there are mainly incremental changes between the previous and newer technologies versus taking on a completely new technology. A drawback of this however is that it may lead to "path dependency", where entities become "locked-in" to a particular set of technologies that they understand, have the infrastructure for, etc. (Oyelaran-Oyeyinka and Lal 2004).

The other aspect that can persuade someone to use (or not to use) a technology is ***triability***, or the ability for someone to temporarily use a technology (Rogers 2003a). Here, a potential user has the ability to use an innovation on a trial basis – either for a limited time period, or as a complement to conventional system (i.e. they do not have to rely solely on the RET for their energy needs).

Implementation is the next stage -- when the user decides to actually use (or not) the technology. This can be on a trial run (as noted above), or for a longer – if not permanent – period of time.

Confirmation is the final stage. It is the decision to keep using (or not using) a technology, or to change the previous decision made at the implementation stage. This is an important aspect that a number of studies on RETs in developing countries often downplay. For instance, Donna Green's study assessing the Thailand government's solar battery charging programme indicated that 60 percent of them were no longer used over time due to several limitations including the fact that these batteries only ran on direct current (DC), rather than supplying the alternating current (AC) that most electrical appliances require, a lack of communication among stakeholders, little training given to villagers, among others (Green 2004).

Throughout the decision making process, change agents influence how actors make decision.

In sum, the model is a systemic approach that recognizes the interactions between RETs and their social context. This model builds on conventional approaches through various ways. First of all, knowledge is recognized as being shaped by underlying conditions and is not the same as information. Furthermore, Rogers' recognizes that understanding not only what a technology is and how it works, but why a technology works plays a role on adoption.

Another strength of the approach is that in addition to economic, technical and political aspects, social aspects are also considered. Furthermore, the model examines technologies over time, including a stage of confirmation, where an individual or organization chooses to keep using a technology or not. Finally, Rogers' approach accounts for the role that change agents may have on adoption.

However, there are certain shortcomings of this model. First of all, not enough attention is placed on the dynamics between and within the stakeholder groups. Dynamics between and within stakeholder groups, occurring throughout the stages, can play a major role on adoption. Green (2004)'s study on solar battery chargers in rural Thailand showed that in this instance many technicians and trainers only spoke Thai rather than the local languages spoken by the ethnic minorities in the northern part of the country (where the majority of that government programme was implemented). This meant that many villagers without knowledge of Thai (e.g. women, elderly) had to rely on certain villagers learn about the RET. This communication problem occurred throughout the decision making process, which had implications for the confirmation stage.

Secondly, as is noted in Chapter 6, a distinction should be made between these change agents. For instance, in the case of biogas technologies, the main change agents were domestic in Brazil but foreign and domestic in Mexico.

Thirdly it is not clear using this approach how indirect policies and other influences with links to the system (in this case the cities and surrounding areas of Mexico City and São Paulo), but not necessarily a part of it, can affect adoption.

To address these shortcomings, the dissertation also turned to technology transfer debates, an integral part of the adoption process, to better explain the uptake of RETs in Latin American cities. In essence, this dissertation will explain RET adoption by integrating adoption and innovation literature.

2.3. From Technology Transfer to Technology Cooperation

International and domestic technology transfer are essential parts of technology adoption, especially in developing countries. It is an important channel in which Renewable Energy Technologies (RETs) are acquired in the developing world. This can be done in order to obtain technology directly, to obtain components, or to encourage domestic innovation through absorption and adaptation to the local environment.

2.3.1 Historical approaches to technology transfer

In the past, technology transfer of energy technologies in the development context meant the transfer of equipment from industrialized countries – whether governments, aid agencies, industry, or Non-Governmental Organizations (NGOs) to the developing world. In the 1950s and 1960s it was often "parachuted in with little attention given to building domestic capabilities to operate and maintain the equipment" (Wilkins 2002: 42). Often, this meant the transfer of modern, capital-intensive equipment and large-scale production process methods, requiring more capital and less labour into countries who were characterized by having the opposite (little capital and a lot of labour) available to them (Akubue 2000). Stewart (1977) also asserts that in the past many technologies from the industrialized world to developing countries were not appropriate for these contexts; suggesting that the technologies (often capital intensive) were often better suited to the domestic elite and / or export markets rather than the domestic economy (often labour intensive).

Many argued that attention must also be placed on transferring skills and not just physical equipment in this process. The transfer of technologies in the renewable energy sector also saw a shift from transferring not only products, but also skills after the oil crisis in the 1970s, where the need to develop the technical skills of local staff and to use indigenous inputs and / or end-products was recognized (Wilkins 2002).

2.3.2 Current Renditions of Technology Transfer

Characteristics of Technology Transfer

While noting some important exceptions such as Schumpeter (1911 cited in Teece 2005) and (Arrow 1962), who recognized that technology was ever-evolving and technological change occurred as the result of a cumulative process, historically "technology" was viewed as something material and / or static that could be moved to other countries, companies, etc.

Proponents of technology transfer argue that the definition of technology had changed. They recognize technology to be processes (e.g. organizational and management practices, production processes), knowledge (tacit and codified) and products (e.g. physical equipment, artefact), also termed "software" and "hardware" (Lall 1995; IPCC 1996; Maskus 2003; Teece 2005).

For instance, Practical Action, a NGO, based out of the United Kingdom, formerly called the Intermediate Technology Development Group (ITDG), considers technology to be "physical infrastructure, machinery and equipment, knowledge and skills and the capacity to organise and use all of these" (Practical Action 2006).

However, a number of people continue to view the concept in economic terms. For instance, (Schnepp et al. 1990), focusing on expertise and knowledge rather than physical equipment, stress that technology transfer occurs when it is passed from one person to another for economic gain. As I have argued in Chapter 1, although economic considerations are important, other aspects such as socio-cultural are just as relevant consideration.

Technology transfer in developing countries is characterized by a number of features. It can be integrated, where the originating body (e.g. Multinational Corporation (MNC), large domestic firm, academic institution) maintains the ownership of the technology. Or, it can be less integrated, where the actor in the local context can own and / or manufacture the technology. Some also call this vertical (relocation of technology through licenses or subsidiaries) or horizontal (less integrated) (Forsyth 1999). Others (e.g. Ockwell et al. 2007) consider vertical technology transfer to be technology moving from the lab to commercialisation, while horizontal technology transfer is technology from one geographic location to another. Technology transfer can also be short term, or longer term. Moreover, technology transfer can be internal, where one firm shares technology to a subsidiary company or through a Joint Venture (JV), or external, where one entity sells the technology and / or issues a license for others to use the technology. It can be formal (e.g. agreements, Memorandums of Understanding) or informal (e.g. personnel movement, publications, conferences, network discussions) (Pietrobelli 2000), or contain a mixture of both. It can be in the public or private domains (UNFCCC 1992). Finally, it can be through commercial (e.g. FDI, joint ventures) or non-commercial (e.g. scientific exchanges, foreign aid) mechanisms (Able-Thomas 1996). These differing features are considered to be pathways or channels (IPCC 2000).

2.3.3. Conventional Technology Transfer Models

A dominant model of technology transfer is the linear one. This is a model that occurs in stages, beginning with research and development, demonstration and deployment, and finally market penetration – sometimes termed vertical technology transfer (Bush 1945). This feature is common to a number of approaches used in the context of low carbon energy technologies. For instance the feedback model is another version of technology transfer noted by the Intergovernmental Panel on Climate Change (IPCC). This model also occurs in stages: assessment, agreement, implementation, evaluation and adjustment, replication, which then feeds back into the assessment stage. Analysis of the interests and influences on various stakeholders occur at each stage in order to determine success (IPCC 2000). While not looking exclusively at renewables (e.g. case studies include in addition to wind energy a rice harvester technology used in Myanmar), Douthwaite (2002) also recognizes that as more use a technology, they will feedback into the technology development, production and use process through their experiences.

Many low carbon technology transfer scholars and practitioners advocate barriers-oriented / policy-focused models, similar to those used in addressing technology adoption. Wilkins (2002) also compartmentalizes barriers into economic, technical, institutional, political aspects.

Some conventional low carbon energy technology transfer models operate at a systemic level in an attempt to account for influences at the micro and macro levels. For instance, the IPCC uses a "technology / innovation system" framework of analysis in their technology transfer study, where governments, research institutes and the private firms work with financial institutes, NGOs and International Governmental Organizations (IGOs) in the flow of knowledge, products, processes and practices ((IPCC) 2000). This focus on system has occurred as scholars have argued "it is the overall system and the quality of interconnections within it which effect success technology transfer" (Bessant and Rush 1995: 101).

2.3.4. Alternative Technology Cooperation Frameworks

These frameworks provide important insights into the transfer and adoption of renewable energy technologies as current renditions often take a longer-term approach to assess these processes. However, there are several shortcomings with these approaches.

First of all, the technology cooperation process is a more interactive approach, rather than isolated from stage, to stage, to stage – consisting of networks, communication and relationships (Walter 2000). While a few conventional models recognize this non-linear process (e.g. IPCC 2000), most do not. It is important to examine all of the relationships of the organizations or individuals involved in technology cooperation (Harmon and al. 1997 citing Auster 1990: 425). This notion also has elements from the triple helix model in innovation studies where industry, the academic sector and governments at various levels (nation, region / state, and local) collaborate to develop and produce innovations. The argument is that those projects with more sources of leadership and support will be more than likely to succeed (Etzkowitz and Mello 2004).

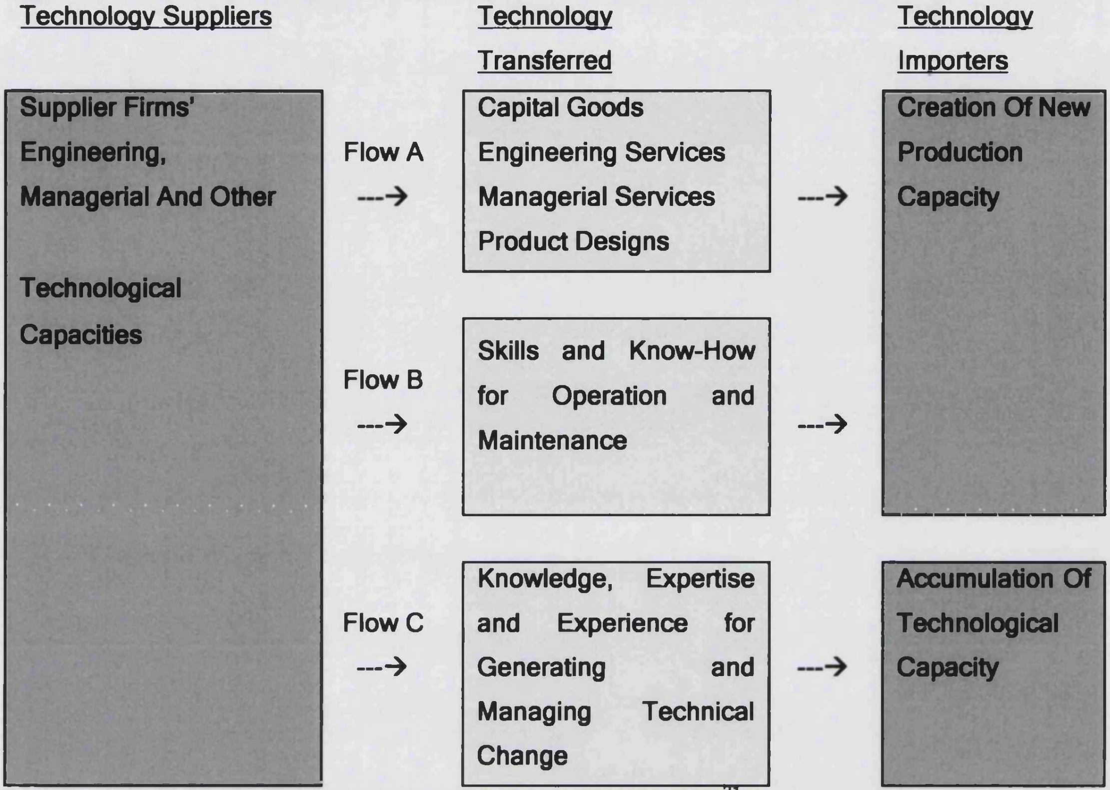
Secondly, most conventional technology models often neglect to incorporate the views of the non-expert as well as other stakeholders. For instance, the IPCC recognizes that private sector firms are the main buyers of technology, but that state-run enterprises, individual entrepreneurs, and governmental agencies can also be purchasers (IPCC 2000). However, other actors can also be technology purchasers, including communities, private or state-run organizations – not enterprises per se (e.g. hospitals, sports groups), local community groups, or non-expert individuals. Also, the framework highlights NGOs and international government organizations (IGOs) as intermediaries but what about community groups, trade associations and other actors?

Third, these models do not adequately reflect needs at the local level, or the differences that can occur within groups or among individuals (Forsyth 2005) – they are often lumped together as the interests and influences on a "stakeholder". Kremic (2003) examining the technology transfer process that occurs in government agencies versus the private sector also argues that individuals can play an important role in ensuring its success.

Finally, there are a number of weaknesses similar to conventional technology adoption models. For instance, they often treat knowledge and information similarly, they tend to neglect sociocultural dynamics, they do not capture the potential affects that indirect policies may have on technology transfer and adoption, and they tend to rely on evidence from the macro level or micro levels (often in rural versus urban settings).

Influenced by the work of Martin Bell (1990), Ockwell et al. (2007) also identify a series of transfer barriers in the context of low carbon energy technology transfer. Bell (1990) stated that technology transfer can be viewed as a series of flows – Flow A consisted of goods and equipment, Flow B were skills and know-how regarding how to operate, maintain and fix these technologies, and Flow C was the knowledge and expertise needed to make some technological developments, or what Lall refers to as "know-why" skills, when agents understand the principles behind the technology (Lall 1995).

Figure 2.1. The technological content of international technology transfer



Source: Adapted from Ockwell et al. 2007, p. 11 based on Bell[31]

Bell's argument was that in many technology transfer processes, Flow C transfers were downplayed, which were critical to developing technological capacity (TC) or capability, or "those aspects, both embodied and non-embodied (e.g. human resources, infrastructure, technical and scientific skills) that cause technological change" at the level of the firm, country, region, etc. (Rogers 2003b: 9).

But even these models, as well as those noted above, stress the one-way nature of flows. A few exceptions exist. For instance, looking at technology transfer more generally, Mansfield in his 1984 study with Romeo noted that new technology flows were occurring to the US from US subsidiaries abroad, a process they term "reverse technology transfer" (Diamond 2003: 1611).

Table 2.2 provides an overview of some of the major technology transfer and innovation models.

[31] Bell, M. 1990. Continuing Industrialisation, Climate Change and International Technology Transfer. SPRU, University of Sussex

Table 2.2 Selected Examples of Innovation / Technology Transfer Models

Type	Main Disciplinary Direction	Description	Some Authors	Proposed Evidence and / or Scale of Scrutiny
Technology Transfer / Innovation Linear Models	Economics / Policy	Development, production, deployment, use Donor / recipient Active / passive	Bush 1945	U.S. Developing countries 1950s / 60s
Technology Learning / Change	Economics	Technology as dynamic	Schumpeter 1911 Arrow 1962	
Technological Capacity / Essential Knowledge Flows	Economics / Policy	Products and processes, knowledge Flows A, B and C	Lall 1995 Bell 1990	Developing countries Developing countries
Innovation – feedback loops	Economics, Policy, Innovation	More circular process, feedback loops	Douthwaite 2002 IPCC 2000	Developing countries
Triple Helix / Quadruple Helix		University, public sector and private sector (+ public and intermediaries) Different partners with different skills, experiences and perspectives Increased understanding	Nichols 2003 Lall 2005 Juma and Yee-Cheong 2005 Bunders et al. 1999	Developing countries Global Bangladesh
Technology Transfer – other facets (e.g. communicatio n)	Technology Studies	Importance of communication in collaboration – builds trust, helps create perception of 'ownership'	Walter 2000	Argentina
Technology transfer – non-linear	Science and technology studies, innovation	Networks Tech transfer / Innovation system Process between participants Intermediaries	Auster 1990 IPCC 2000 Wilkins 2002 Bessant and Rush 1993	Industrialized and Developing countries Southeast Asia UK
Technology cooperation	Policy	Two or more way process Inputs and insights by all players – active players	Heaton et al. 1994 Martinot et al. 1997	

Souce: Author

2.3.5 Urban Technology Cooperation

By addressing these shortcomings, urban technology cooperation is proposed as an alternative framework to help explain RET adoption in the developing world. The concept developed through a combination of deductive and inductive research. Initial formulation of the approach stemmed for pre-field research and was refined after collecting and assessing findings found using evidence in Mexico City and Sao Paulo. Urban technology cooperation differs from transfer in several aspects, which will be explained in further detail below:

- Sustainable technology cooperation includes technological capacity building
- It is an iterative two- or more-way process where all participants are active players, inputting into the technology cooperation process;
- cohesive and continuous communication between technology cooperation participants – developers, producers, distributors, intermediaries, and ideally, end users;
- It operates at the meso-level – focusing on links existing between networks across levels – from the global to the local, better capturing the potential affects of policies and events at the macro-level that may affect the urban experience;
- It attempts to recognize the heterogeneity of stakeholders; and
- It focuses on the importance of cities

The first characteristic of urban technology cooperation is the notion that it can only be sustainable if it "takes place as part of a wider process of technological capacity building" (Ockwell et al. 2007: 8). In other words, technology cooperation must include opportunities for learning among players - adoption is linked to innovation (Douthwaite 2002). But opportunities for learning are not in and of themselves enough to ensure successful cooperation, players must also be able to assimilate and make use of this new knowledge, termed absorptive capacity (van den Bosch et al. 2003).

However, in Bell's International Technology Transfer model, the flows are often represented as one-way. In contrast, urban technology cooperation is a two- or more-way process which is the second feature of the concept. Use of the term cooperation implies that all stakeholders – each possessing unique skills and expertise to exchange with others -- are active participants in the process (Heaton et al. 1994). Akin to those researchers working on other or similar environmental issues (e.g. Glasbergen (ed.) 1998; Forsyth 1999; Mason 1999), it draws from cooperative environmental governance and global environmental democracy, where stakeholders, bringing various expertise and local knowledge to discussions, shaping environmental preferences through open communication. The view is that these deliberations "are more likely to lead to durable commitments to environmental sustainability insofar as decisions significantly affecting community interests are 'owned' by those involved" (Mason 1999: 212). Urban technology cooperation is an iterative approach, emphasizing communication, interactions and relationships between various participants (Walter 2000; Harmon et al. 1997), rather than a linear approach. It can be viewed as a series of networks.

Urban technology cooperation emphasizes the importance of cohesive and continuous communication between actors to ensure these players have a voice and so more players – to a certain extent – can lead to increased collaboration and thus RET adoption. This concept examines the nature of relationships between and within stakeholder groups further to determine how, if at all, they impact adoption. In contrast to this view, some scholars purport that technology adoption is less likely with more players involved in the technology cooperation process. Pietrobelli (2000) suggests that with more actors 'under the tent', there is less chance of coordination. In this view, the plethora of partnerships leads to increased transaction costs, conflicting agendas, etc. and so a single or dominant partner is more conducive to increasing uptake of technologies (Pietrobelli 2000).

In addition, similar to others working on technology, urban technology cooperation recognizes that the process can be facilitated or hindered through the actions of intermediaries (Wilkins 2002; UNFCCC 1992; Able-Thomas 1996; Bessant and Rush 1993) -- or those actors who do not directly exchange technologies but may facilitate the process and / or have an interest in them. Urban technology cooperation attempts to incorporate the views of users and intermediaries, which many technology transfer models downplay.

Also, urban technology cooperation operates at the meso-level, as discussed in Chapter 1. Participants form networks and provide information amongst each other. As more information is exchanged and as links strengthen and grow, the technology itself and these networks are ever changing (Schenk et al. 2007). The meso-level was chosen to better reflect this reality rather than the traditional linear technology transfer process, which begins in the research lab, then goes to commercialization, to market, to use.

The meso-level accounts for indirect policies, which are often generated and have implications at the systemic level, to determine their potential role on technology adoption. Other researchers also examine the links between the various levels, including Mulder (2005)'s study of technology adoption and diffusion patterns at the micro-level and how they impact sectoral energy consumption. However, the meso-level was also chosen as the place for analysis because by virtue of its location of scrutiny it often has more direct links to the local, national and international levels. In other words, by focusing on the meso-level it affords the ability to assess how relationships between stakeholders play out in the real world, including the different dynamics between and within stakeholder groups (as discussed in detail in Chapter 7).

Capello et al. (1999) examining energy policies and sustainable cities in Europe, is one example of a RET adoption at the meso-level. They suggest a Pentagon prism of critical success factors to address barriers for renewable energy technologies. The pentagon points are hardware (equipment), software (knowledge and processes), orgware (institutional and managerial efficiency in the urban energy and environmental sector), finware (cost saving and financial aspects of energy initiatives), and ecoware (urban social and quality of life conditions involved in the implementation of new energy initiatives) (Capello et al 1999: 45).

Urban technology cooperation, applied in these two case studies, examines stakeholders, rather than individuals. What is different about this concept rather than other meso –level approaches used in energy research which "acknowledges the mutual coherence of groups of actors" (Schenck et al. 2007: 1508), is that urban technology cooperation also attempts to recognize the heterogeneity of stakeholders. It draws from alternative approaches that account for differences between individuals or organizations within a "stakeholder" or "actor", including Mulder (2005) who notes that there will be persistent heterogeneity among agents, as each person understands something differently. For instance, how can a "community" or a "developing country government" be expected to have a unified stance on renewables (Shove 1998, Barton 2006; Forsyth 2005)?

But, it is important to consider what exactly is meant by 'heterogeneity'. As noted above, each person understands things differently, and has different experiences and motivations. On the other hand, at the other extreme, often positive-based approaches, attempt to model the behaviour of actors using a similar premise – that actors are 'rational' agents, seeking profit maximization. Yet, there are a host of other factors which also impact choices. My view is that individuals are different but at the same time, one of the main premises for groups coming together is due to some 'common ground' – whether this be a shared culture, language, community, etc., and so the dynamics within these groups are iterative, changing over time.

The final aspect of urban technology cooperation lies with the term "urban" and its implications for RET adoption. The focus on cities was chosen for two reasons. First of all, as noted earlier, with limited exceptions (e.g. Quintanilla and Mulas 1998; Quintanilla et al. 2000), there is little evidence on the experience of RETs in developing country cities. Secondly, cities often serve as regional / metropolitan innovation systems which in turn impact the rate and scope of technology adoption, diffusion and development (Lundvall 1992; Doloreux and Parto 2005). Aligned with this is the notion that proximity between potential partners (e.g. universities, industry) also impacts the effectiveness of the technology cooperation process (Lindelof and Lofsten 2004). The term urban also attempts to capture Porter's (1990) geographic 'clusters' effect in a city, sometimes referred to as agglomerations in urban areas. A cluster is "a group of companies and other institutions in related industries that are co-located in a specific geographic region" (Ketels et al. 2006). Using evidence from around the world including the Silicon Valley for information technology, and the British Midlands for car racing, the argument is that location is important for companies in helping them have competitive advantage over their counterparts. In this view, geographic proximity to other firms, institutions and resources gives firms competitive advantages because as these industries are grouped together, there are closer relationships, common local knowledge, and these groups are subject to similar incentives (Porter 1990). Similar to the triple helix model, these clusters drive innovation and the productivity of firms located within these clusters, which can assist adoption as they work together to tackle various challenges their industry is subjected to.

In other words, the term 'urban' was applied to bring out these unique features of developing country cities. For example, as noted in Chapter 1, in developing countries, generally clusters of research and development (R&D) and innovation occur in cities, as they often serve as hubs for various institutions (firms, academic institutes, government agencies, community groups). These institutions tend to gravitate towards cities as there are – generally speaking – better access to resources (e.g. infrastructure, services, electricity, etc.). This is not to say that innovation centres are not in rural areas in developing nations, but that they tend to be more prolific in developing country cities, acting as clusters for technology development and production. Another unique feature of developing country cities is based on the premise that continuous face to face interactions, while important globally, are particularly important in Latin America. As many sector representatives of both SWH and biogas technologies industries are congregated in and around Mexico City and Sao Paulo, social networks have formed in both places. Of course social networks are just as important in rural settings – and in fact even more so as day to day contact likely happens more frequently and amongst a small population 'pool' – but in the case of these two particular RETs, many of those that develop and produce the technologies are located in cities (whether big or small) versus rural settings. For example, even the NGO Grupo Solaris, operating out of the USP campus focusing on agricultural research at Piracibaba, takes place close to that city, which has a population estimated to be between 300 000 - 400 000.[32]

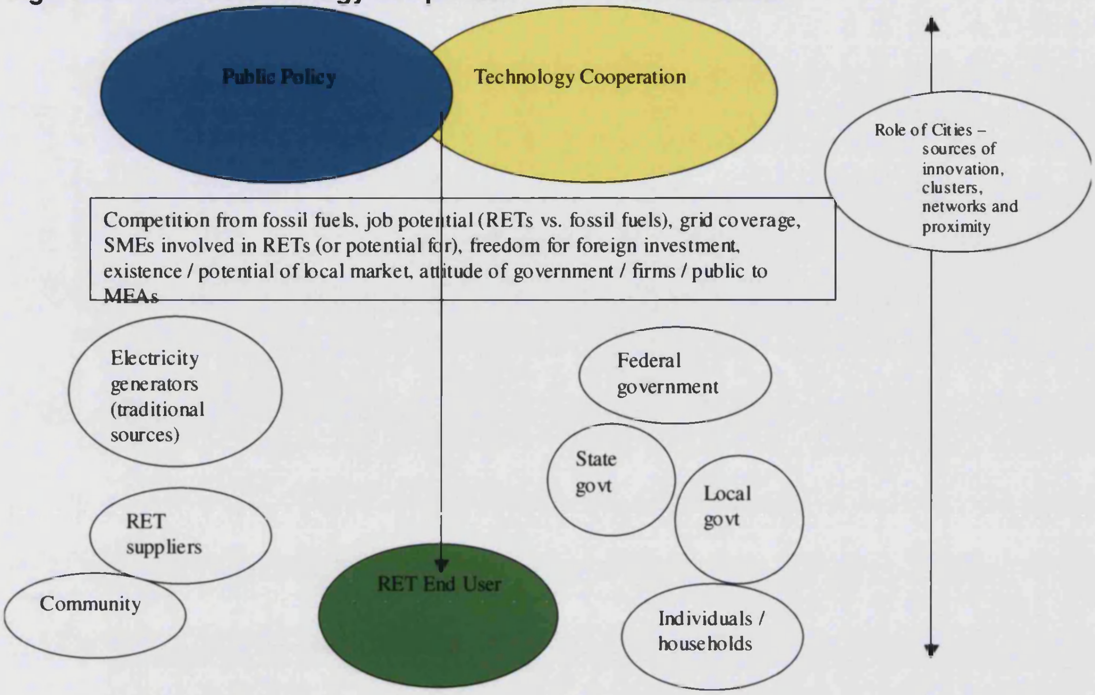
While the effects of this agglomeration will be difficult to "test" in this dissertation, as both case studies are urban environments, it is important to point out that agents interacting in a common regional space (e.g. city) remain a key element in fostering knowledge, information exchange and collaboration, an important part of technology cooperation (Walter 2000). Although networks and exchanging information are also occurring across regions and national borders, personal contacts within a certain geographic setting remain especially important in the developing world. In sum, cities pose a unique perspective as they can serve as centres of innovation, from which technology cooperation players have an increased ability to interact due to proximity to each other.

[32] Interview, one NGO, April 2007

It is important to understand that these insights above were the result of a constantly involving process as I embarked on this dissertation research.

Figure 2.2 is a graphic representation of how the urban technology concept was being formulated. Through this concept I was trying to capture the effects that public policy, technological capacity and cooperation have on the various factors that have been identified in conventional and other alternative approaches as affecting RET use in developing countries. In addition, as there is a research gap with respect to cities and RET uptake in the developing world, I wanted to understand what unique role cities can play on affecting RET use – examining literature focusing on innovation in cities looking at clusters, cities being a nexus for innovation, proximity to innovation sources and sources networks (e.g. in many developing countries, the use of a technology is often encouraged or discouraged through word of mouth, etc.), and how these aspects affect uptake. While Figure 2.2 below is more abstract, Figure 7.1 (p. 279) represents a more detailed portrayal of the urban technology cooperation concept through being applied to the case of SWHs and biogas technologies to generate electricity in Mexico City and Sao Paulo. The concept hones in on players at the meso-level. The model also captures links between players operating mainly at other levels (macro and micro) with those at the meso level.

Figure 2.2 Urban Technology Cooperation – Pre-Field Research



Source: Author

Some criticize approaches based on the meso-level as the scale and the action needed is not clear. For instance, the meso-level is generally referred to as the level of analysis between the national economy and the level of individuals, firms and households. However, some suggest it is difficult to try and define the meso-level as a "space". For example, (Genus and Coles 2008) argue that Geels' (2004) energy transitions model (with the meso-level being considered a 'regime') does not properly identify or analyze what the meso-level is. For this study, I view the meso-level as the cities of Mexico City and São Paulo and their surrounding areas, with the aim of having a citywide impact. The boundaries of this space are not definitive, and are dynamic, but rather the above (these cities and their surrounding areas) serve more as guideposts to the researcher.

Another criticism is that power dynamics are bound to play out in these relationships, with some players being more dominant that others in all, or different aspects of the technology cooperation process; thus, suggesting that technology transfer is a more accurate way to characterize what is happening (Stirling 2008).

But the word "transfer", whether implicitly or explicitly, implies that it is a one-way, linear process in which one actor (the donor / active player / expert) provides technology (physical products and know-how) to another (the recipient / passive player / non-expert). Like others uncomfortable with the terms transfer (Heaton et al. 1994; Martinot et al. 1997), the dissertation asserts that by virtue of using a different term, cooperation, provides an opportunity for participants to view themselves as partners.

A further criticism of this approach is that by focusing on specific features of cities reduces the applicability of this framework to other settings including towns and rural areas in developing nations. I argue that many conventional approaches to technology adoption and transfer do not account for context enough – their focus is on creating a framework at a macro, general level, to be applied as way to increase the use of renewable energy technologies in developing countries. Developing country cities have unique aspects, requiring a distinct approach.

Another criticism is involved with attempts to incorporate non-experts - some suggest that although deliberative approaches to technology and environmental governance decisions are to be applauded, in practice, attempts at incorporating the views of non-experts have been difficult (Mason 1999; Ockwell 2008). These are valid considerations, and so an important task of the dissertation is to evaluate the three systemic approaches purported to examine RETs in these settings.

Sections 2.2 and 2.3 have provided an assessment of systemic technology adoption and cooperation frameworks as ways to explain the uptake of RETs in developing country cities. However, when these systemic approaches are applied to real world situations, the above claims may not hold true. To do so, the dissertation will hone in on two types of systemic policies – trade and competitiveness – which often have profound effects throughout a country, region or city – to focus on the other sub-research question examined: under what conditions, if at all, different trade and competitiveness regimes have an effect on RET adoption in Latin American cities?

2.4. Trade and Competitiveness Regimes and RET Adoption – Key Debates

As noted in Chapter 1 and expanded upon in the following sections, many historical renewable energy technology adoption and transfer approaches overlook the potential influence that macro-level systemic policies can have on these processes. Trade and competitiveness policies are one such area. Speaking about technology more broadly however, one branch of trade and competitiveness suggests that an increase in technology development, adoption and dissemination mainly occurs through a principally outward approach – emphasis is placed on the market, centring on investor and consumer choice. Another trade and competitiveness strategy suggests that a conditionally outward approach is most conducive to increasing technology development, adoption and dissemination. In this view, while the presence of foreign investors is also encouraged, they have less of a `free reign' in the local market. Although research examining the potential role of trade and competitiveness policies may have on the uptake of renewables is recent, the general consensus is that trade liberalization can lead to more RET use in developing countries.

2.4.1. Defining trade and competitiveness

These policies have been defined in a number of different ways. The WTO's Trade Policy Review classifies trade policies and practices by measure, with the aim of determining the effects of these actions on trade. This system divides measures into three different types 1) those that directly affect imports (e.g. policies dictating rules of origin, quantitative restrictions and controls, etc.), 2) those that directly affect exports (e.g. restrictions on exports, or assistance for exports), and 3) other measures that affect production and trade (subsidies, trade-related intellectual property rights) ((UNCTAD) 2006): 3-4).

Regarding competitiveness policies, although a number of definitions also exist, the majority are rooted in terms of economic, technical, and / or business attributes. For instance, one definition focusing on firms suggests that competitiveness is "the ability of firms in a region / country to work in close cooperation amongst themselves and with other organizations (at home and / or abroad) to design and implement strategies for increasing their shares in the global market of goods and services" (Villaschi 2004). The World Economic Forum which has a Global Competitiveness Index, suggests that competitiveness encompass "the set of institutions, policies and factors that determine the level of productivity of a country" (Barro and Sala-I-Martin 1995). This focus on productivity however is too narrow. In addition, it is not clear what exactly is meant by productivity or how it is measured over time. Take the example of ethanol production in Brazil, for example. In the 1970s and 1980s, Brazilian sugar mills were reliant on subsidies to make ethanol competitive with gasoline.

Initially, learning by using resulted in some temporary losses on production process as actors learned to use new technology (Mulder 2005). Over time, due to learning by doing or experience (when sugar mill operators learned more about producing ethanol rather than sugar), the price of producing ethanol decreased substantially from about US$ 100 per barrel in 1980 to current ranges of US$25 - $50 per barrel in 2007 (Goldemberg et al. 2004; Skeer 2007). At present, little would dispute that Brazil is the world leader in this technology, and yet the sugar mills would not have been profitable without the government subsidies in previous decades; i.e. for a long time, their productivity declined.

Some countries / firms / organizations seek competitive advantage in basic products and services[33], while others expend their efforts on increasing technological capability or technological learning to develop more complex goods and / or services (only or concurrently with more basic goods and services). In other words, competitiveness is broader than the objective of increasing market share would imply. Increasing competitiveness can also lead to increases in education (e.g. literacy, basic arithmetic to tertiary education), which may not impact a country's Gross Domestic Product (GDP) or a firm's market share, but which can be reflected in a country's Human Development Index (HDI)[34].

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[33] This can be defined as those products and services that are, arguably, less knowledge- and learning-intensive (e.g. cash crops, basic tourism services).

[34] See the Human Development Reports of the United Nations Development Programme (UNDP), developed by a group of scholars including Mahbub ul Haq on the Human Development Index (HDI), which incorporates information on life expectancy, literacy rate and infant mortality, among others, for example. http://hdr.undp.org/en/humandev/,

Competitiveness policies can be viewed as government actions to encourage various actors, such as firms (whether state-run or private), research institutes, etc. to work together and / or to increase knowledge and / or expertise among actors. For the purposes of this study, those trade and competitive approaches that emphasize gaining skills in technological capability will be examined as they are often closely linked into technology cooperation and adoption processes.

2.4.2. Inward-looking trade and competitiveness policies

The first view – quite popular in Latin America - was influenced by dependency theory, informed by the structuralist economics of Argentine economist Raul Prebisch, and expanded upon by economists at the United Nations Economic Commission for Latin America (ECLA) such as Celso Furtado in Santiago, Chile, among others such as Andre Gunder Frank. This theory argued that colonialism and international trade led less to economic development for the developing world and more to a core-periphery relationship where developing countries exported raw materials for the manufactured products of the industrialized world; thus creating a situation where these nations were dependent on developed countries (Kay 2005). Import Substitution Industrialization (ISI), a state-led, inward-oriented development strategy, was particularly popular in Latin America from the 1950s-1970s/80s (although Brazil and Mexico began ISI in the 1930s and 1940s as a result of the Great Depression) (Kay 2005; Shadlen 2007). ISI viewed state enterprises as key to economic development and industrialization. Governments conducted a series of policy actions under ISI. Generally speaking, these actions included, among others, protection from foreign goods and services through tariffs, controls on imports and foreign exchange, and the creation of development banks to provide finances to domestic or state enterprises (Baer 1996). Domestic rather than foreign trade was emphasized in order to build up industrialization through indigenous sources– an extreme version of this position advocates complete self-sufficiency; an autarky. Sectors central to economic growth and industrialization, such as steel, electricity and natural resources, often became state enterprises in order ensure a continuous supply of cheap inputs (Baer 1996).

Variations of this view exist with respect to how much government should be involved in the economy, but all agree that government involvement is an integral part in the industrialization process. Using empirical evidence from the Asian Tigers, attention focused on macro-level government action, targeting sectors to assist businesses to innovate and develop human capital skills, and the institutional framework needed to do so effectively (Kim 1997; Kim and Nelson 2000). In addition to these grand scale schemes, actions pursued at a smaller scale, termed "below-the-radar" aspects of industrial policy by (Wade 2004) (e.g. In Taiwan, Industrial Development Bureau officials encouraged foreign enterprises to use domestic rather than foreign suppliers) also play an important role in developing technological capability. According to Shafaeddin, "...with the exception of Hong Kong, no country has managed to industrialize without infant-industry protection" (2005: 1148-1149).

However, over time, support for this approach waned as a number of state-run enterprises became inefficient because they had a monopoly over their respective sector. They also often employed more people than necessary and as a result of their losses, forced the government to give them subsidies in order to continue operating (Baer 1996).

2.4.3. Conditionally-outward looking trade and competitiveness policies

Some contend that a conditionally outward approach (rather than inward approach) to trade and competitiveness is most conducive to increasing technology development, adoption and dissemination. In this view, while the presence of foreign investors is also encouraged, they have less of a `free reign' in the local market. For instance, the government tends to take on a more direct role through creating legislation, mandatory requirements, and direct involvement in technology development, production, dissemination and adoption (Lall 2004b). In current renditions, the government does not drive the technology cooperation process, but rather, is one of a number of key players. Emphasis is placed on building up indigenous capacity to absorb and adapt technologies.

Under a conditionally outward trade and competitiveness approach investors (foreign and / or domestic) must often form partnerships with local firms, use local suppliers, share their intellectual property rights (IPRs), and / or agree to train local people.

Technology cooperation tends to be longer term and collaborative – with more indigenous input and where partners have more equal footing (termed horizontal technology cooperation). Other countries use vertical technology cooperation as the principle method to acquire foreign technologies, but with horizontal aspects aimed at encouraging the development of local technological capabilities. This form of technology cooperation is increasing in the private sector, such as through joint ventures (IPCC 2000). Some argue that these forms of technology cooperation are more effective as they become more adapted to local conditions (Westphal 2001). For instance, the technology can be made less expensive, less complex, more applicable to the local climate, or in sync with the local culture (Westphal 2001).

2.4.4. Outward-looking trade and competitiveness policies

Another view, particularly dominant in the late 1980s and 1990s, as a part of the Washington Consensus,[35] was that less government involvement was needed in order to achieve economic development and industrialization. This view espoused "competitiveness, deregulation, privatization, and the restriction of public intervention economic processes." (Hettne 1995: 38).

Greater increases in the GDP and / or industrialization of developing countries were linked to trade liberalization, privatization, deregulation and openness (e.g. for example see Clark et al. 1999 on industrialization and outward-oriented trade policies). Critics argue that often these actions lead to further wealth concentration and deepened regional disparities already in place in developing countries (Baer 1996; Sanchez-Reaza and Rodriguez-Pose 2002).

Regarding technology some research suggests that mainly outward trade and competitiveness policies will increase technology development, adoption and dissemination – emphasis is placed on the market, centring on investor and consumer choice (Markusen and Venables 1999). Thus, foreign direct investment (FDI), exports, trade liberalization, and indirect government involvement are stressed. This view is

[35] The Washington Consensus, was a term originally applied to a series of economic policy prescriptions by John Williamson to be used by international financial institutions (IFIs) such as the World Bank and the International Monetary Fund (IMF). See http://www.cid.harvard.edu/cidtrade/issues/washington.html for further information

based on evidence which indicates that openness to trade and Foreign Direct Investment (FDI) levels have facilitated technological diffusion (Tomlinson et al. 2008: 61).

Technology cooperation under this approach is mainly characterized by shorter-term, integrated methods (e.g. acquisitions / subsidiaries, direct purchasing of foreign technologies) with one participant serving as the key player. The claim is that these forms of technology cooperation are more effective as the process happens more quickly (Pietrobelli 2000). The market will decide which technologies are most viable for the environment in which they are to be used. With a single leader driving the process, providing coherent information to the public, and often possessing the means for quicker deployment, there is a greater likelihood that these technologies will be used. They argue that this form of technology cooperation is the most common version of this tool (namely internal, such as between a Multinational Corporation (MNC) and one of its subsidiaries), and the reason it is widely used is because it will lead to the most rapid diffusion and adoption of technology (Pietrobelli 2000).

2.4.5. Trade and Competitiveness Policies and the Uptake of Low Carbon Energy Technologies

The nexus between trade and competitiveness policies and environmental issues has been well documented (e.g. Anderson and Blackhurst 1992; Esty 2001; Brack and Gray 2003; Nuemeyer 2002), including research in developing countries, where some claim that openness leads to access to state of the art technologies, and to the extent that these technologies are 'cleaner' there can be environmental improvements as well as economic competitiveness gains by firms, and others which argue that openness does not necessarily mean that firms will choose these 'cleaner' often more expensive imported options, and that incentives are needed (See Rock and Angel (2005)'s study on several industries in East Asia for one example).

Discussions on the environment continue within the World Trade Organization (WTO)[36] context. For instance, on the one hand, the environment is considered an area

[36] The WTO is an international entity established in 1995 to govern trade rules at the international level. The basis of its philosophy is support for free trade between countries, supporting the reduction of tariffs

of general exception to the free trade rubric in that countries are allowed, under Article 20 of the General Agreement on Tariffs and Trade (GATT), the international treaty the WTO is based on, trade restrictive measures towards goods and services considered harmful to human, animal and plant health, as well as those depleting natural resources (Mason 2007). Under the Non-Agricultural Market Access (NAMA) negotiations however, a number of Northern and Southern countries (e.g. Australia, Japan, the United States, Thailand, the Philippines, India, etc.) are challenging national legislation, labelled non-tariff barriers (NTB) put in place for health, environment and local economic development reasons (Friends of the Earth 2007).

Furthermore, the Doha Ministerial Declaration of 2001 agreed that environmental goods and services should be an area targeted for faster liberalization. But, the WTO has yet to agree on a definition for what constitutes an environmental good or service. Areas of concern in the case of goods include how to deal with: a) single versus dual-use goods, b) relativity and evolving technology (e.g. something considered an environmental good now but may not be in the future as technology changes, and how to compare, e.g. cars based on a fuel cell versus those running on alternative fuels such as compressed natural gas (CNG), versus those running on 'clean' diesel, versus those running on regular diesel), c) implications for developing countries – their ability for domestic manufacturing and export, and d) dealing with environmental agricultural products, such as biofuels. Many developing nations assert that discussions of these goods and services focus on high-technology products, where there are currently less opportunities for them to export – Brazil for instance has pushed to have biofuels included as environmental goods. There are also debates regarding WTO rules and their compatibility with obligations under certain Multilateral Environmental Agreements (MEAs), where trade is restricted for certain goods and services (Bernasconi-Osterwalder and Sherman 2005; World Bank 2008a; Kojima et al. 2007).

There are a number of studies that examine the link between trade and climate (Brack 1999; UNEP 2009), and investment and climate (Forsyth 1999). Some investigate links between the World Trade Organization (WTO) and the climate regime (Kuik et

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and other barriers to trade. Mason, M. (2007). WTO. Encyclopedia of Environment and Society. Robbins. London, UK, Sage: 1990-1991.

al. 2003), with some arguing that regional trade agreements, such as that under the European Union, may be a better way to address climate issues, as they can serve as a 'bottom up' approach to encourage regulatory measures at more global levels (Fujiwara and Egenhofer 2007; Kernohan and De Cian 2007).

Studies looking at trade and competitiveness in the climate literature also focus on the impacts on firms of a cap on carbon emissions vis a vis those firms not subject to a cap (e.g. Reinaud 2009 as noted in Chapter 1). Mongia et al (1994) also suggest that those trade and industrialization policies favouring energy-intensive production (e.g. aluminium, cement) set tariff levels to reflect the 'real' economic costs of energy supplies.

There are few studies regarding the potential link between trade and competitiveness policies and the uptake of low carbon energy technologies however, although interest and research is growing. Recent research has focused particularly on the potential role of intellectual property rights (IPRs) on technology cooperation in developing countries (e.g. Middleton 2008, Mallett et al. 2009, Srinivas 2009). Discussions on IPRs are linked to the WTO because a stipulation for accession to the organization was also to join Trade Related Aspects of Intellectual Property Rights (TRIPS)[37]. IPRs are legal rights over ideas, creative processes and products. They include copyrights, trademarks, and patents – where holders can prevent the use of these technologies; thus patents are likely the most important type of IPRs within this context (Harvey 2008).[38] To date, evidence regarding whether or not IPRs have been a barrier to technology cooperation in low carbon energy technologies is mixed.[39]

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[37] TRIPS, or the agreement on Trade Related Aspects of Intellectual Property Rights, aims to create uniform IPR protection across developed and developing countries. It is administered by the WTO and has brought IPRs into international trade negotiations for the first time. Developing countries were given longer to conform to the agreement than industrialized countries and least developed countries have until 2013 to conform, and 2016 for pharmaceutical patents.

[38] Other IPRs include copyrights, which could be particularly relevant in the case of software used for low carbon energy technologies and Plant Variety Protection, relevant for both mitigation (e.g. biofuels) and adaptation (e.g. drought-resistant varieties of crops) Abbott, F. (2008). Innovation and Technology Transfer to Address Climate Change: Lessons from Global Policy Development on Intellectual Property and Public Health. Conference of the Parties 14- United Nations Framework Convention on Climate Change,. Poznan, Poland.

[39] For further discussion on these debates please see Ockwell, D., R. Haum, A. Mallett and J. Watson (in review). "Intellectual Property Rights and low carbon technology transfer: the two polarities of diffusion and development." Global Environmental Change (in press).

Other research is broader. For example, Cosbey states that "if barriers to trade in low emissions goods are lowered, there will be increased uptake, and increased incentives to invest in those technologies and goods (Cosbey 2007: 2). One World Bank study examining trade policies and the use of biofuels also purports that the removal of "barriers to biofuel trade would increase competition, which should in turn help improve efficiency, bring down costs, and enable the world's most efficient producers to expand their market share" (Kojima et al. 2007: 74). Another World Bank study also indicates that reducing tariff and non-tariff barriers to trade can increase technology diffusion, based on the results of their study of four clean energy technologies including wind, solar, clean coal and efficient lighting in 18 of the high-GHG emitting developing countries. Here, the authors note that removal of these barriers will result in an increase of trade volumes of up to 13 percent. This view also argues that streamlining Intellectual Property Rights (IPRs), investment rules and other domestic competitiveness policies will encourage the diffusion of low carbon energy technologies in developing countries (World Bank 2008a: 13-14 and 53).

However, there are a number of problems with these assertions. First of all, they are based on macro level analysis. Secondly, it is difficult to make such an overarching statement (i.e. that open trade and competitiveness policies lead to RET adoption) because trade policies encompass a number of features including – in addition to taxes and Intellectual Property Rights (IPRs) where attention is generally focused – privatization and foreign investment rules. It is more appropriate to ask, under what conditions, if any, do trade and competitiveness policies influence RET adoption – the sub-research question of this dissertation.

2.4.6. Trade and competitiveness approaches in Latin America

As mentioned previously, in order to determine which trade and competitiveness approach, if any, is most conducive for RET adoption, two case studies in Latin America were chosen. The trade and competitiveness policies of Latin America are particularly interesting due to their historical experience in this area. For instance, the "hang over" from the ISI experience in the region, as well as the prominence of the Washington consensus has seen an unprecedented openness to foreign investment and technologies in the region – a shift that is particularly pronounced in countries like

Brazil, who was one of the most keen on developing indigenous technologies, while discouraging technology imports from abroad (Gibbons et al. 1994, OECD 2004; Villaschi 2004; Hemais et al. 2005; Kostoff et al. 2005). Trade and competitiveness approaches used in Mexico and Brazil is discussed in Chapters 4 and 5.

2.5. Conclusion

Systemic approaches have been proposed as an alternative tool to examine the uptake of renewables in developing countries as they account for larger social and policy considerations as well as economic and technical concerns. But to date, there is little evidence supporting their application. I chose to apply three systemic approaches to the cases of the adoption of two RETs in Mexico City and São Paulo.
Section 2.1 provided a brief overview of systemic technology adoption approaches, while honing in on Rogers' (2003a) diffusion of innovations model in particular.

Rogers Diffusion of Innovations model was considered a useful approach because it considers social aspects as well as economic and technical issues. It also takes a broader view of knowledge, assessing how previous experiences can play a role on awareness, and indicates that 'know why' or principles knowledge is also important. The model also considers technologies over time and the importance of change agents, or those people who influence others to use or not use as technology.

But, the model does not take the dynamics between and within stakeholder groups into account enough. Furthermore, the model does not address the potential affects involved when the origins of change agents or technologies are different (domestic, foreign or both), which may have implications for RET uptake.

Section 2.3 argues that conventional technology transfer models are useful approaches to explain RET adoption because they take a longer-term view. However, the problem with many of these conventional approaches is that they suggest that this process happen in a series of stages. They also often neglect to incorporate the views of the non-expert as well as other stakeholders. These models do not examine closely enough the differences that can occur between and within groups or among individuals.

Orthodox technology transfer frameworks also possess number of weaknesses similar to conventional technology adoption models. For instance, they often treat knowledge and information similarly, they tend to neglect sociocultural dynamics, they do not capture the potential affects that indirect policies may have on technology transfer and adoption, and they tend to rely on evidence from the macro level or micro levels (often in rural versus urban settings).

To address these shortcomings, a new concept urban technology cooperation was posited as an alternative framework to explain the uptake of RETs in Mexico City and São Paulo. In addition, it stresses the iterative non-linear process of cooperation and the two or more way nature of relationships. It accounts for features of cities and focuses on the dynamics between and within stakeholder groups and operates at the meso-level. However, some concerns with this approach are that meso-level not clearly identified (e.g. Genus and Coles 2008), but the meso-level here is defined as the cities and their surrounding areas. Others (e.g. Stirling 2008) suggest that that use of the term technology cooperation may downplay the power dynamics between participants. However, this dissertation argues that the dominant discourse centres on the term "transfer', which neglects the two or more way nature of these relationships, and immediately implies that one person is a donor and the other is a recipient. Another critique could be that this model, centring on cities is not relevant for rural situations. But developing country cities are distinct, thus warranting a unique perspective. Finally, some (e.g. Ockwell 2008) assert that models attempting to engage the public may be favoured in theory, but in practice have been plagued by difficulties.

The third approach considered is trade and competitiveness regimes. Although research on this area is recent, the general consensus is that trade liberalization can lead to more RET use in developing countries. However, the problem with this claim is that it is based on studies at the macro-level. A more appropriate question is under what conditions, if at all, do trade and competitiveness policies affect the use of RETs in developing country cities.

Finally, when embarking on Chapters 6, 7 and 8 it is important to keep in mind when using these systemic approaches is that they are each different styles or manifestations of the systems perspective, which influences the explanations stressed as well as their interpretation. Table 2.3 provides a quick overview of these differences.

Table 2.3 Comparing three systemic approaches to assess RET adoption in developing country cities

	Strengths	Limitations
Model/Approach: Rogers Diffusion of Innovation		
Analysis (Decision)	Attempts to understand rationale for why people use technologies or not	May not always be cognitive
Frame of reference (Individual, organization)	Attempts to assess how actors influence change	Less emphasis on dynamics between relationships
System (Norms, degree of interconnectedness)	Recognizes role of values, connections	Does not capture the fact that system is dynamic, changes over time
Issues (attributes of people and technology)	Recognizes technology attributes have different implications depending on actor, system, etc.	Attributes of people is arbitrary and can change (farmer and songbirds)
Worldview (Agency, structure to a lesser extent)	Attempts to understand motivation and choice	May not take history and context into account enough
Model/Approach: Urban Technology Cooperation		
Analysis (Processes)	Assesses mechanics behind a phenomenon	May not place enough attention on the implications of an outcome
Frame of reference (Stakeholders, participants)	Recognizes that stakeholders and participants change over time	By stressing cooperation and participation can downplay role of hegemons, power
System (Networks, Relationships)	Focuses on the importance of dynamics between actors in shaping choices	Can downplay importance of individual behaviour in making decisions
Issues (dynamics between and within groups)	More emphasis on dynamics between relationships	Can over-emphasize the role of these dynamics on an outcome
Worldview (Agency, Structure to a lesser extent)	Attempts to understand motivation and choice	May not take history and context into account enough
Model/Approach: Trade and competitiveness		
Analysis (Policies)	Emphasizes the role of politics and policy	Can neglect the role of other facets
Frame of reference (Institutions - government, industry)	Important components of a system	Often downplays dynamics within these organizations
System (Country, state, region, city)	Underscores the role of governments	Can downplay role of non-governmental actors
Issues (effects of policies)	Assesses the implications of policies at varous levels	By stressing dominant political forces, sometimes downplays dynamics within
Worldview (Agency or Structure)	Attempts to understand motivation and choice or effects of system	May over- or under-emphasize effects of a decision on system

Source: Author

CHAPTER 3: RESEARCH METHODS AND ANALYSIS TECHNIQUES

3.1. Introduction

The purpose of this chapter is to inform the reader about the research design, methods and analytical tools and parameters of the dissertation. The first section of this chapter focuses on debates regarding methods at a more general level, suggesting that one's ontology shapes how research is conducted, including concepts and methods chosen.

The second consideration posits that one problem with previous studies on RETs in developing countries is that they often centre attention on the micro and / or macro level, and rely on rural settings. Research at the meso-level and in urban environments offers a new methodological approach, which can shed further insights into this area of study.

The third part of the chapter focuses on the research methods and analysis used for this study, which was largely based on qualitative methods, but augmented with quantitative statistics where applicable. I chose to base my research from evidence obtained through qualitative interviews and codes for a number of reasons. First of all, these approaches are exploratory, and emphasize the importance of context and setting. Secondly, by capturing numerous aspects in a setting – economic, technical, as well as social and cultural, they provide a deeper understanding of phenomena. In addition, by using these techniques, researchers are more equipped to develop concepts that recognize differences in settings. This approach is distinct from a hypothesis drive quantitatively based approach, seeking to determine general laws.

Although some critics of this approach argue that they are too anecdotal, using this approach is further support for the view that many assertions regarding RETs – whether they are based in quantitative and qualitative techniques – are dependent on context, history and technology. Large quantitatively based studies comparing indicators from developing countries are considered advantageous as they are less costly and more efficient. But, the problem with this technique is that data collected from developing countries is often questionable (e.g. a number of United Nations (UN) agencies rely on data provided by developing country governments to populate their statistical studies), and inferences about local level dynamics made from data aggregated at the macro level often do not reflect the reality on the ground.

I chose to 'measure' uptake of equipment through m^2 for Solar Water Heaters (SWHs) and Megawatts (MW) for biogas technologies, similar to other studies on these two particular technologies. While recognizing the difficulty involved in attempting to measure knowledge and processes, one way to provide an indication is through examining the organizations, capacity building efforts and other activities underway regarding their use in Mexico City and São Paulo, which I have done.

Finally, I used Atlas ti to help me identify and assess prevalent themes identified by key informants.

3.2. Methods Used to Examine Renewable Energy Technologies (RETs) in the Developing World – Impact of Worldview

Positivism versus Interpretivism

Another fundamental debate prevalent in the social sciences rests with a researcher's ontology or worldview. Understanding this worldview is essential for research studies, as it will influence the researcher's choice of methods and theoretical frameworks. One key debate in the social sciences lies with positivism versus interpretivism, where hermeneutics is the philosophy of interpretation. People suggest that positivists also 'interpret', but rather interpretists tend to recognize that people have different ways of understanding the social world. One common view is that positivists tend to view the researcher and their environment / subject of scrutiny as being separate, while interpretists stress the fact that the researcher and the environment and subject of scrutiny are all the same. Those who are considered positivist tend to support quantitative methods of study, such as large surveys with a random sample size (Silverman 2006). For example, turning back to Tables 2.1 and 2.2 in Chapter 2, examining some technology adoption and cooperation frameworks, one can see that some approaches favoured by economists and policy makers could be considered positivist (including push and pull factors, focus on barriers in the adoption literature and linear, stages approaches in the technology transfer / cooperation literature).

But as this dissertation argues, the problem with these conventional approaches, are that they generally over-emphasize economic and technical factors, which, while important, tend to neglect other aspects, such as sociocultural considerations that these other analysts assert are just as relevant. That said, the methods and analysis used to understand the world are based on my preconceptions of the world, which have occurred as a result of my own experiences. So rather than belabouring the question – am I a positivist or an interpretist? I think a more appropriate question is to determine which methods would be most effective in answering my research questions?

In some circumstances, a more quantitatively based assessment would be useful to answer a certain research question, but in my case, I turned to systemic approaches to answer my research questions because they help to understand how motivations, agency and context explain choices. I decided that qualitative methods, augmented with quantitative aspects, would be able to address these above points, rather than macro-models, using economic data

Qualitative methods, which seek a more comprehensive sense of understanding, were also considered an appropriate means through which to apply actor-oriented approaches. This is because actors have differing perceptions, opinions, assumptions and experiences, which can be better captured using qualitative tools.

One reason for the shortcomings often found in conventional technology adoption and cooperation frameworks is because the basis for these approaches stem from the notion that individuals and groups are motivated by orthodox notions of self interest, and hence seek to act 'rationally', in accordance with principles such as profit maximization. But as Schneider and Ingram (2007: 21) point out:

> "…a great deal of physical and social science research suggests that human motivations are much more complex, that moral, aesthetic, intuitive, inspirational, empathetic, and other influences have important roles."

Also, as Fischer (2003) asserts, the formation of policies is just as much based on perceptions, assumptions, and is subjective, versus the espoused technocratic view emphasizing a more objective reality.

That said, an increasing number of scholars, such as Ron Weber (2004) working on information systems, question whether this schism is so stark. A course on research methods at the University of Queensland in Australia, where Weber teaches, lays out the basic differences between the two approaches.

Table 3.1 – Differences between Positivism and Interpretism

Metatheoretical Assumptions About	Positivism	Interpretivism
Ontology	Person (researcher) and reality are separate.	Person (researcher) and reality are inseparable (life-world).
Epistemology	Objective reality exists beyond the human mind.	Knowledge of the world is intentionally constituted through a person's lived experience.
Research Object	Research object has inherent qualities that exist independently of the researcher.	Research object is interpreted in light of meaning structure of person's (researcher's) lived experience.
Method	Statistics, content analysis.	Hermeneutics, phenomenology, etc.
Theory of Truth	Correspondence theory of truth: one-to-one mapping between research statements and reality.	Truth as intentional fulfillment: interpretations of research object match lived experience of object.
Validity	Certainty: data truly measures reality.	Defensible knowledge claims.
Reliability	Replicability: research results can be reproduced.	Interpretive awareness: researchers recognize and address implications of their subjectivity.

Source: Ron Weber, MIS Quarterly, 2004, p. iv

Despite these assumptions laid out above, sometimes these distinctions are not as clear-cut as the above would suggest. For example, Ron Weber points out that researchers who would fall under the 'positivist camp' based on the above criteria "understand fully that their culture, experience, history, and so on impact the research work they undertake and thus the results of their work" (2004: iv). Yet, explanations put forth through positivist means only– narrow and often emphasizing the role of one or two factors to explain something -- are found wanting. I suggest that in certain circumstances, positive methods are effective at assessing certain attributes. (e.g. in the case of Solar Water Heaters (SWHs), how pipes made from different materials – such as copper and aluminum -- affect water temperature reached), but are not the most effective tools for assessing human contextual aspects, such as the technology cooperation and adoption processes. Like other scholars (e.g. Danermark et al. 1997), rather than advocating a positivist versus interpretist "either-or" approach, I advocate the notion that a "both-and" approach can be useful (i.e. drawing on both traditions), as they each have strengths and limitations.

Structure versus Agency

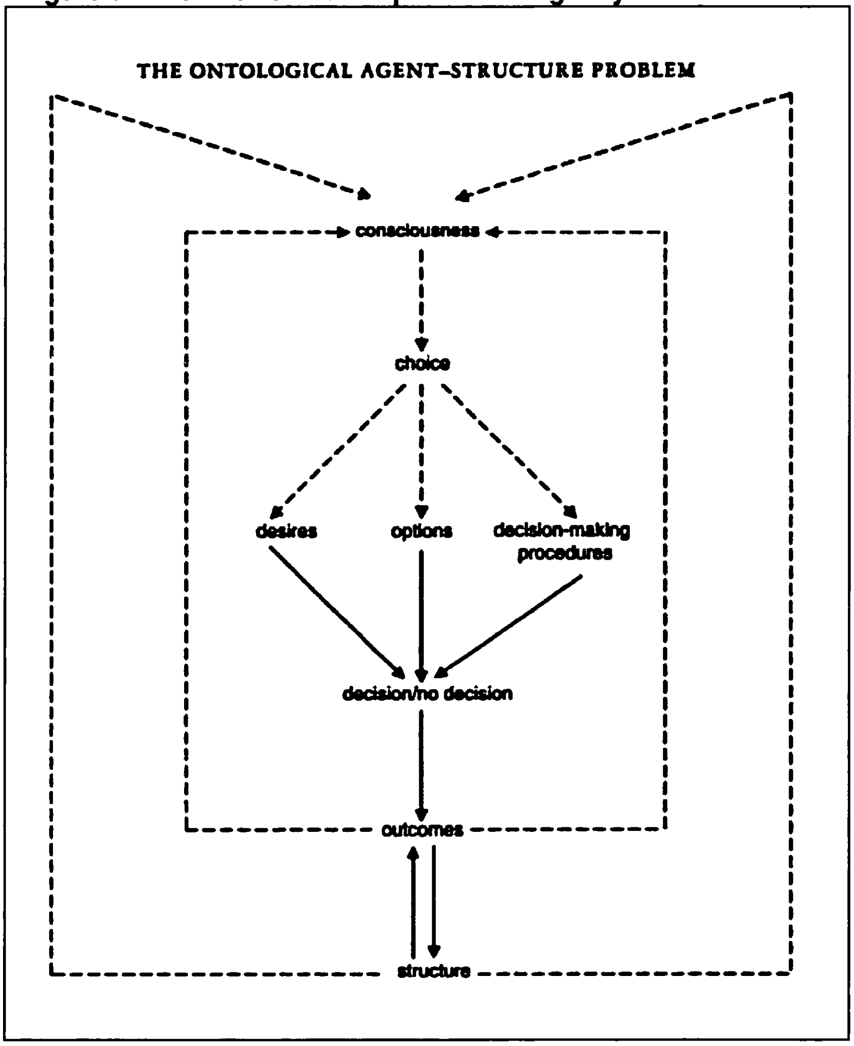
Some of the most prevalent debates also lie between structure versus agency. A brief overview of these two views and how they shape frameworks, research and results, used to explain RET adoption is warranted.

Those theories emphasizing agency, focus on people and their ability to make choices and actions. Those scholars stressing structure however emphasize that an individual and / group of people's choices are rooted in their context – including culture, religion, previous experiences, etc. Agency and structure are linked, both influencing each other. While most recognize these linkages, many scholars emphasize either agency or structure as being more powerful, depending on their worldview. This in turn has implications for how concepts are defined.

Similar to the contrast between positivist and interpretist views, in some cases these distinctions are also not as easily made. For example, applying Friedman and Starr's (1997) exploration of these debates in international relations to discussions about technology, shows how technologies, agents and the environment all interact. Technologies are "filtered through an agency's consciousness" (1997: 38), and they formulate perceptions, and from there agents undertake choices and actions. By the same token, these technologies – ones used, ones discarded, constantly re-assessed --

are the result of actions and choices taken by one or a group of agents (Friedman and Starr 1997).

Figure 3.1 the Interrelationship between Agency and Structure



Source: Gil Friedman and Harvey Starr, 1997. Agency, Structure and International Politics – From Ontology to Empirical Inquiry, p. 39

In the context of this study, although the use of renewable energy technologies (RETs) is viewed as the outcome, examining the processes that have the potential to affect their use, it is important to recognize that these outcomes and processes influence each other. In other words, causality flows are not unilinear.

I will put this more clearly, using one technology of the study, Solar Water Heaters (SWHs), which have been used in these countries for decades. As is shown in Chapter 4, previous experiences with SWHs in Mexico City, plagued with problems due to improper installation and use, or inappropriate settings, led to negative perceptions of the technology among former users – telling their friends, relatives, colleagues, etc. of their experience, which has impacted the use of the technology in that city. These negative perceptions have meant less interest among Mexicans in this technology, and I suggest that the SWH industry is likely smaller than would otherwise be the case (although a small but very committed group continues to thrive). As is discussed in Chapters 4, 6, and 8 this had led to less coordination in that country, including no nationally-sanctioned standards, and continued negative perceptions of this technology despite the major technical advances that have occurred during the past two decades.

3.3. Missing Areas of Scrutiny – the Meso-level and Urban Environments

As indicated in Chapter 1, many studies on renewable energy in the developing world use evidence from rural environments (e.g. Forsyth 1999; Wilkins 2002; Cherni et al. 2007), and often use information at the micro level or use countries, rather than cities, as case studies (e.g. Milton and Kaufman 2005; Milton and Kaufman 2005; Rodrigues and Matajs 2005).

Furthermore, even if implicit, there is little distinction of scale of analysis. Scale can be referred to as "the spatial, temporal, quantitative, or analytical dimensions used by scientists to measure and study objects and processes" (Gibson et al. 2000: 219). Although the term level is often used interchangeably with scale, levels can be considered locations along a scale (e.g. regions such as macro, meso and micro-level, or time) (Gibson et al. 2000).

The meso-level is often described as the level that connects the micro (firm, interpersonal level) and the macro-level (general, larger-scale, e.g. a region, country). However others point out that this 'space' is difficult to define. Similar to debates regarding "what is a system," (e.g. are there defined boundaries? does it change over time?) noted in Chapter 1, the meso-level is not something necessarily tangible; it is dynamic and shaped differently between contexts.

Meso-level organizations, due to their ability to link macro and micro-level facets, have also been identified by some development agencies (e.g. the Dutch international cooperation agency) as being "critical agents in the fight against poverty and the improvement of governance" (Ubels and Gronden 2004: 3). One unique attribute of analysis at the meso-level is that it attempts to capture the interdependencies occurring within a system, which changes the dynamics of the overall system, rather than aggregating individual system elements. The meso-level involves the linking up of technologies and groups of actors, and examines these interactions (Schenk et al. 2007). The meso-level is associated with systems analysis and also incorporates aspects from the micro and macro levels. One example of the meso level applied to an energy system is analysis from Schenk et al. (2007), who examine the electricity sector, noting that a mixture of renewables and conventional energy power plants may make the electricity system more or less efficient, depending on the amount of renewables vs. conventional power sources being used relative to electricity demand.

As indicated in Chapter 2, cities were chosen as the focus of scrutiny for two reasons. First of all, there have been little studies to date on RETs in developing country cities. Secondly, cities can serve as regional and metropolitan innovation systems (Lundvall 1992; Doloreux and Parto 2005), as actors living in close proximity can affect the technology cooperation process (Lindelof and Lofsten 2004).

Cities have also been identified as a key area of bearing for multilevel analysis in the areas of environment, renewables and climate change. This is because they often have significant control over relevant aspects including energy consumption, transportation use, infrastructure, waste management, etc. (Setzer 2009).

3.4. Research Methods

3.4.1. Research Design

Several methods were used when conducting research for this dissertation. Information was obtained through previous studies and relevant literature in this area, as well as other sources (e.g. company, government and NGO reports, websites and papers). The diversity of people and contexts involved in this study made it advisable to pursue a number of methods for research. For example, some participants preferred to meet in person, while others preferred to respond over email, which gave them an opportunity to answer the questions over a longer period of time if needed.

The information drawn from these sources was largely qualitative collected through the qualitative data collection techniques explained below. This was augmented with some quantitative information, which provided information for some descriptive statistics where applicable (e.g. number of metres squared installed).

There are a number of merits to using qualitative research. For instance, quantitative research tends to focus on numbers to explain what is happening, whereas qualitative researchers focus on words to understand trends in social settings. Furthermore, "whereas a typical quantitative research project identifies and investigates the impact of only a few variables, qualitative research attempts to explore a host of factors that may be influencing the situation" (Hancock and Algozzine 2006: 8).

Qualitative research also relies on multiple methods as it is based on the notion that there is no one objective "reality", but numerous ways in which reality is interpreted. By using various methods, sometimes referred to as 'triangulation', the researcher attempts to have a more in-depth understanding of what is happening by gathering these different interpretations – the idea is an alternative perspective to traditional notions of 'validity', focusing on the accuracy of information to measure what you have set out to argue (Denzin and Lincoln 2008). In other words, the definition of validity is defined more through integrity and quality rather than "the rhetoric or norm of objectivity for its justification" (Gill 2000: 188).

The economist Mansfield suggested that qualitative research was needed to capture important nuances based on his experiences. He collected information directly from firms and other organizations "carefully tailored to shed light on the problem at hand, rather than to try and adapt readily-available general purpose data" (Diamond 2003: 1613). This type of research assumes the value of context and setting, and searches for a deeper understanding of the participants' lived experiences of the phenomenon

(Marshall and Rossman 1999). Through qualitative methods a researcher is better able to develop context-sensitive concepts (Bennett and Elman 2006).

On the other hand, one critique of qualitative research purports that it is too anecdotal and insights are unable to be generalized (e.g. when Cheek (2008) refers to the experience of some qualitative researchers whose project was rejected by ethics committees on this basis). In other words, qualitative methods are too context-based and thus not as readily 'transferable' to other contexts. But as has been discussed in Chapters 1 and 2, applying an approach based more on numbers to a different setting might also overlook the importance of context and history in explaining key events or trends. My view is that all approaches have insights to share but that qualitative methods offer a more comprehensive, in-depth view of an intricate social question. This more profound examination is useful for researchers working in other areas (e.g. different regions / countries, different technologies) because it forces them to take a thorough look at their own specific research context and assess commonalities and distinct features.

The claim is that quantitative methods relying on statistics and large random samples provide a more accurate view of what is occurring, attempting to limit biases and subjectivity. But others point out that biases and subjectivity are inherent in all studies, whether consciously or not. Many statistics are singled out selectively depending on the objective. For instance, the United States only keeps track of the number of U.S. soldiers killed in Iraq since 2003; data on Iraqi citizens killed since then have not been published (Silverman 2006). This sends a message to assuage U.S. voting family and friends of soldiers killed that their comrades played an important role and will not be forgotten, while, by not noting the amount of Iraqis killed, downplaying the casualties involved in the war.

Furthermore, positive-based studies tend to centre on hypothesis testing, often using quantitative methods, which makes for too narrow of a frame of reference for the researcher. By using this approach, researchers tend to "neglect other aspects of theory development, such as the formation of new hypotheses or new questions to study" (George and Bennett 2004: 12).

Quantitatively-based methods, such as Cross National Analysis (CAN), where statistics of different metrics (e.g. income per capita, rate of literacy) are analyzed, largely based on secondary sources such as the United Nations, have several advantages including low cost and time saved, and its efficiency (Herkenrath 2002). At the same time however a number of studies indicate that inferences at the individual level based on aggregate level data, lead to false understandings. One such study from Germany showed that at the individual level people more likely to be involved in right wing extremism were students and the employed, even though at the aggregate level, there were studies that indicated that states with higher levels of unemployment tend to have higher rates of right wing extremism (Herkenrath 2002).

Also, one problem with large quantitatively-based studies using data from developing countries is that the data is not there, questionable in terms of accuracy and or massaged / highlighted to make a certain point (which also happens globally too) (Herkenrath 2002). Qualitatively based studies, through interviews and discussions with key informants, provide avenues through which to collect information, recognizing the subjectivity involved in people's responses, perceptions and opinions, through which a study can ascertain and assess findings.

The answers to the research questions were based upon a comparative analysis of two cities: Mexico City, Mexico and São Paulo, Brazil. In order to provide adequate comparability, while at the same time allowing for national / city level nuances, the two most economically viable[40] RETs in these settings were examined: namely biogas to generate electricity technologies and passive solar water heaters in São Paulo and solar water heaters Mexico City (White and Hooke 2004). The technologies used in both places are comparable in terms of temperatures reached (e.g. 25 degrees Celsius for hot water being used to shower).

However, there is one difference regarding the 'hardware' of SWHs. Bearing in mind the differences between showers in different places and in different households and institutions (e.g. a 3 minute shower on average by family members may be the norm in

[40] Defined by price of technology and price of electricity produced vis-à-vis their counterparts.

one household, versus 10 minutes in another family), in São Paulo, a larger tank for water is needed for families in Brazil, as part of the local culture in São Paulo is to take two showers per day – one in the morning and one in the evening. In Mexico City people tend to take one shower per day (although not surprisingly some people were perplexed when asked the question ' how many showers per day and / or week do you take'?)

The main research tool to be employed is the Case Study. The two case studies, termed collective case studies by some, chosen are the cities of São Paulo, Brazil and Mexico City, Mexico. The advantages of the case study include the fact that a researcher can undertake a variety of research methods and use multiple sources of data. The case study also tends to be favoured by social scientists that are studying something they have little control over, and that are based on phenomena happening in the real world (Yin 2003). Furthermore, a key goal of the case study is to "allow investigators to retain the holistic and meaningful characteristics of real-life events" (Yin 2003: 2). This type of research tool allows for interdisciplinary, in-depth, multi-level analysis over time - which, when examining the links between global energy challenges and local development, is key (Mitchell 1983; Creswell 1998; Denscombe 1998).

I chose two case studies to provide a balance between comparison and detailed analysis because "the more cases an individual studies, the greater the lack of depth in any single case" (Creswell 1998: 63). I chose only to focus on two because although qualitative studies are 'rich' in information and peculiarities, as more case studies are added, these large amounts of information become unmanageable (Munoz 2002). These cities were chosen because they possess a number of similar traits such as large populations, an active civil society, major discrepancies between the urban wealthy and poor, major sources of investment and a large energy demand. In addition, while these cities have distinct cultures, languages and societies, they are both in Latin America, thus share some similar experiences (e.g. members of regional organizations such as the Organization of American States, former colonies of southern, heavily Catholic, European nations). These cities represent excellent opportunities for renewable energy technologies and energy policy and development. As well, like many mega-cities, they are both major hubs of technological learning, and, as large economies, are major greenhouse gas (GHG) emitters. I chose to compare case studies because "there is a growing consensus that the strongest means of drawing inferences from case studies is the use of a within-case analysis and cross-comparisons within a single study or research program" (George and Bennett 2004: 18). This research could be labelled qualitative comparative research, which is argued to account for conjunctural outcomes, or accounting for causal factors occurring in groups (i.e. that these factors alone may not be responsible for an outcome) (Munoz 2002).

Critics of the case study technique however claim that one cannot generalize through the use of one (or a few) examples (Denscombe 1998; Yin 2003). Also, some would say that each country is unique, and social processes develop interdependently with these unique cultures, structures and historical experiences, termed the historical singularizing perspective (Herkenrath 2002). But, as Mitchell (1983) highlights, a case study is not meant to suggest that it represents an overall social phenomenon. In my research, the goal of this comparison is to examine similarities and differences, not suggesting that these two cases are exactly the same. Each case is unique, but there are a number of similarities (e.g. large populations, significant increasing demand for electricity) between the two case studies chosen as noted earlier and other important urban centres in developing countries (e.g. New Delhi, India; Beijing, China) that face similar situations.[41]

Primary source methods included face to face interviews, telephone interviews, self-administered questionnaires through email, and informal discussions. These mixed modes to collect information were chosen in order to account for different settings and to ease the comfort level of the interviewee. Potential interviewees were all given the option to meet in person[42], to have a phone conversation, or to reply to a short questionnaire through email.

The technique known as triangulation was used (Hancock and Algozzine 2006), where "a number of different methods are used to measure the same thing, in order to achieve

[41] With respect to Brazil for instance, it is a part of BRIC (Brazil, Russia, India and China), which are expected to form a part of the world's ten largest economies by 2050. Wilson, D. and R. Purushothaman (2003). Dreaming with BRICs: the Path to 2050. Global Economics Papers. G. Sachs, Goldman Sachs. In 2007, Goldman Sachs updated their BRIC to include Mexico and South Korea, termed BRIMCK. See O'Neill, Jim, BRICs and Beyond, Goldman Sachs, November 2007 for further details.

[42] Except for the last few as I was unable to be in Mexico and / or Brazil at that time

reliable findings" (Outhwaite et al. 2007: 506). Specifically, I used information obtained through interviews and questionnaires, primary documents (e.g. firm and government websites), or secondary sources (e.g. previous studies conducted in this or related areas), and observations written down as field notes obtained while living in each setting for two and a half months. Also, there were some follow up discussions over email with a number of participants, asking some of the same and / or similar questions.

According to Dillman, "...few survey undertakings are as difficult as defining, sampling, contracting, and obtaining responses to self-administered questionnaires from businesses or other organizations" (2007: 323). For this reason, my primary objective was to conduct face-to-face interviews or have phone conversations, and to use an electronic questionnaire as a "back up" (i.e. when respondents preferred to use that method rather than the first two options).

A series of interviews and questionnaires, as well as informal discussions with relevant stakeholders were held with key informants in the renewable energy technology sector in each city (66 individuals in total) – specifically those involved in SWHs and biogas from solid waste. Interviews (whether in person or through the phone or internet telephony) were formal meetings with prearranged agendas and often tape recorded answers. Informal discussions occurred over a longer period of time where I was able to spend a fair amount of time talking with a number of informants in a variety of settings (e.g. a training session, in the office, etc.).

How respondents were selected is discussed below. I purposely sought out a particular person to target, rather than send a generic electronic letter where possible in order to increase response rates. This is in line with other studies, such as one undertaken by a university research centre in the United States. Although researchers only achieved an average response rate of 51% for 26 surveys, when broken down, the response rate was 72% for surveys addressed to individuals within companies / organizations compared to only 40% when surveys were addressed to only the company (Dillman 2007).

Furthermore, as well as relying on 'common sense', I adhered to some typical surveying principles when soliciting information from businesses and other organizations. These principles include planning at the start for a mixed-mode design and having the first interviews serve as "trial runs", where the questions were altered, deleted or added as appropriate depending on the type of organization being approached, and the effectiveness of getting responses (Dillman 2007).

3.4.2. Influences on Responses

According to Marshall and Rossman, whether a researcher undertakes a longer-term ethnography, or a study largely based on in-depth interviews, where the researcher often stays in a setting for a briefer amount of time, but interacts with participants, "the researcher enters the lives of participants. This brings a range of strategic, ethical and personal issues that do not attend quantitative approaches" (1999: 79).

Some factors assisted in bringing about a frank exchange between respondents and me. These factors included the fact that in both Brazil and Mexico the interviews were conducted in the first language of the respondents, the fact that I was associated with two reputable organizations working in and around these cities for quite some time (UNEP / ROLAC (1972) in Mexico City and Vitae Civilis (1989) in São Paulo), the fact that I was living with a Mexican and Brazilian in each place, and the fact that I also had professional and academic experience in this field (working for the Organization of American States (OAS) and for the Canadian government on international energy and environmental issues). In addition, the fact that I was a part of a university, played a role on responses – especially in the private sector, where anything they revealed was not considered confidential (unless they explicitly told me they wished it to be so). At the same time, being from a university, I was not considered to be working for a competitor, interested in gaining insights into the business (Dillman 2007).

My age, gender and situation may have worked against me (early thirties, female, a foreigner, and noticeably pregnant in Brazil), but generally, I found that most respondents (about 80% male, 20% female in Mexico and 90% male, 10% female in Brazil) were open and treated me professionally (if not a little surprised that I was undertaking this alone and while pregnant!). On the other hand, it offered me a way to "break the ice" with participants who spoke about their children and families.

Finally, some such as (Bessette 2004) argue that a shorter stay in the field can hinder trust, as time is needed for respondents to get to know the researcher and become more open; they advocate for Participatory Action Research, where the researcher works directly with the community to identify problems, conduct research and develop answers to research questions together. A variation of this approach is when the researcher studies 'those in his or her own backyard', or settings in which the researcher is already intimately involved. However, one challenge with these approaches is that the researcher, whether inadvertently or not, is perceived to be more aligned with (and / or manipulated by) one or more particular groups (Cleaver 2001); in other words, the researcher is viewed as being not as impartial. This may affect responses by having some informants withhold information or provide knowledge which could be particularly sensitive to an 'insider' researcher (Creswell 1998). For instance, in Brazil, although I explained that while there I was doing some work for Vitae Civilis from São Paulo, I found informants to be quite frank with me. This is probably because I also explained that I was rather independent because the NGO is located in a city 1 hour outside of São Paulo and it was not easily accessible for me to get to without a vehicle and so I did some desk-based research from them from the home of my host family in São Paulo, i.e. I did not interact with NGO members on a day-to-day basis.

A shorter stay also allowed me to remain steadfastly focused on the goal at hand (to obtain as much information as possible to answer the research questions while in each location). For instance, some organizations in Brazil and Mexico spoke very candidly about divisions that existed between various groups (e.g. in Mexico firms that were owned by foreigners and those owned by Mexicans and firms considered to be "in the club" (i.e. those always being awarded the government contracts) and those "outside the club"; organizations that were a part of the trade association ABRAVA in Brazil, and those not). One could argue that these groups would not have been so forthcoming if I had longer-term relationships built up with one or more of the opposing groups.

3.4.3. Interview Techniques

The principle qualitative research method used was in-depth interviews and questionnaires, based on a series of questions and responses. The interviews were semi-structured; purposely designed to be "fluid". In other words, the questions provided "signposts" for the discussion, while at the same time allowing for a good conversation flow. The ordering of questions was also conducted to provide more ease for the interviewee / respondent – with basic questions (e.g. number of employees, number of years in existence) first and opinion questions last, and ensuring a flow between questions and sections. Moreover, interviews / questionnaires / questions asked were tailored to the specific organization providing information.

The interviews were designed so as to avoid 'embeddedness bias', or asking the questions in such a way as to obtain preconceived responses. To avoid this, interviews were constructed to broach topics as broad themes where discussion was open-ended allowing discussants to highlight topics they found relevant. Discussion began around basic information about the company or organizations, the industry and market in general, and then moved on to themes the dissertation was particularly interested in including classical explanations for RET adoption, technology cooperation and trade and competitiveness policies. The idea was to present the themes more generally, gauging the relevancy of these themes in explaining RET adoption through the responses of interviewees rather than asking them pointed questions (e.g. how do taxes affect the use of SWHs or biogas technologies?)

These types of interviews and questionnaires are often criticized as being too influenced by researchers through ways in which questions are phrased and which words are used (Ockwell 2008).

One alternative suggestion is the narrative interview where the interviewee tells a story. The idea of the narrative interview is to allow the speaker to increase their comfort level, by generating a story, to provide a more accurate account from the interviewee's perspective. The interviewer acts more as a listener that is unaware of the event, thus interested in all information; a critique of the conventional "question-response schema of most interviews" (Bauer 1996: 2). But, there are a number of criticisms to this approach. First of all, the informant may emphasize certain parts of the story he / she would like the respondent to focus on, highlighting his or her role positively, etc., termed strategic communication. Also, as the interviewer conducts more and more interviews, he or she is bound to learn more about the event. "The credibility of the attitude [that the interview knows little or nothing on the topic] reaches its limits. The interviewer's informedness cannot always be hidden" (Bauer 1996: 10).

People who were involved in this investigation did so voluntarily. They were all made aware of the objectives of my thesis – looking at RET adoption, paying particular attention to the role of trade and competitiveness policies and examining the technology cooperation process. This was done briefly over the phone or through email, where I was met with a "gatekeeper", or was directly in touch with the relevant person, and then more extensively in the interview. Using these techniques allowed the companies and organizations themselves to decide who would be best to respond to my queries. They all had the option to provide their responses anonymously or not, and to choose whether or not to have the interview tape-recorded. In addition, respondents were made aware up front that should they wish to change questions, or emphasize something else missed, they could do so. Furthermore, all had the opportunity to add to the interview / questionnaire. I varied the questions somewhat, depending on who was being interviewed (e.g. a firm versus a government agency, NGO or consultancy). An example of the questions asked in the interviews and via questionnaires can be found in **Annex 1.**

I chose to focus on interviews and questionnaires rather than other qualitative research tools, such as visual data, through photographs for instance, as well as interactive analysis through focus groups for various reasons. First of all, with respect to visual data, a number of informants were not comfortable with their offices / companies being captured on film. In addition, one problem noted by other scholars is that in some research "photographs have been misunderstood as constituting forms of data in their own right...[rather than as] a means of preserving, storing, or representing information"

(Emmerson 2004: 251). In other words, visual data is similar to code sheets, audio recordings, transcriptions of interviews, etc. Because of the reluctance of some informants regarding visual information, I chose to focus on those other tools noted above.

With respect to focus groups, some advantages cited by researchers include the fact that in a group setting, respondents build on each others' responses, therefore providing a more detailed account of something that may likely not have occurred in individual interview settings (Wilkinson 2004). I did not use this method for practical reasons (e.g. it would be more difficult to accurately transcribe the often fast-paced discussions in Spanish and Portuguese, and hard to get these people together) and I also felt that in a group setting, respondents might be less willing to open up to me.

This is important because it was through these individual interviews that people spoke candidly about the divisions occurring within stakeholder groups. For example, I had the opportunity to attend meetings between technology cooperation members already taking place (e.g. in Mexico City I was invited as an observer to discussions underway regarding the proposed mandatory standard for SWHs on new buildings by the municipal Secretary of Environment). There I was able to make observations at the meeting regarding the interactions between these participants. I was able to get a sense of some tensions between these groups, but specific clarity on what was causing these divisions and what the tension points were, were captured in the individual interviews (e.g. the divide found between domestic and foreign SWH companies in Mexico City, and the fact that some SWHs companies felt like outsiders from 'the club').

Another question that arises is whether or not this research constitutes discourse analysis, but this classification is tricky because as Gill (2000) points out, there are likely more than 57 variations termed 'discourse analysis'. On the one hand, in the sense that I assumed informants spoke a 'similar language' referring to technologies (although I spoke about technology meaning not only equipment but also knowledge and processes, informants generally considered technology to be 'hardware' only), institutions working on renewable energy, etc., a discourse analyst might suggest that not enough attention was played on the subtleties and different interpretations involved in these words. Yet, on the other hand, this dissertation examines the power of discourse as it tried to understand how perceptions, assumptions and experiences shape people's decisions, technologies, etc.

3.4.4. Selection of respondents

The selection of participants for this study are similar to a number of other studies examining energy, environmental and policy issues in the developing world that use a political science / policy implementation approach (e.g. Purkitt's study (2002) of environmental security in southern Africa, Green's (2004) study of solar home systems in northern Thailand, Márquez et al. (2008) study on household solid waste generation in Mexicali, Mexico among others). Those interviewed were from a purposeful sample, also called a convenience sample, or a pre-defined structure selection, compiled in 2004-2005, which served as a basis before undertaking field research. I chose this approach because the research focuses on a phenomenon (the adoption of certain RETs in two cities), which is not as constrained by either place or population. Studying phenomena requires the researcher to "determine a sampling strategy that is purposeful and representative" (Marshall and Rossman 1999: 68).

This list of key informants was built upon while in these locations (2005-2006), in consultation with the organizations I was affiliated with (UNEP / ROLAC and Vitae Civilis) and other active players working in these sectors in both locations. Termed snowball sampling, additional study participants are identified through information given by the first group of individuals. This approach is often used when participants are not as readily identified through conventional sampling methods (Kagee 2004). This approach was considered appropriate for this dissertation because there were some instances where some companies did not have websites and the lists were not as updated and experts were known through "word of mouth". Some people suggest that "care should be taken in making generalizations from a non-random sample" (Purkitt 2002: 119). Alternatively, a non-random sample can be advantageous because by ensuring players considered relevant are involved, it can help provide insights into the broader issues which the researcher is trying to understand (Bryman 1989).

As noted in Chapter 1, a system consists of components, their relationships and attributes. I consider a city to be a system. For this reason, I used a pre-defined structure selection (purposeful sample) in order to ensure that relevant parties involved in the technology cooperation process were accounted for. .

I contacted key informants with the help of several in-country experts identified beforehand and while there; individuals who were very knowledgeable and active in these cities in these particular RETs. Interviewees were also identified through direct calling / emails from me courtesy of lists provided by Energy Source Guides (www.energy.sourceguides.com) for both countries, the National Commission to Save Energy, or Comision Nacional de Ahorro de Energia (CONAE) and the National Association of Solar Energy, or Asociacion Nacional de Energia Solar (ANES) in Mexico, and the trade association, the Brazilian Association of Refrigeration, Air Conditioning, Ventilation and Heating - National Department of Solar Heating, or Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação e Aquecimento - Departamento Nacional de Aquecimento Solar, ABRAVA-DASOL in Brazil. Informants identified through these various means directed me to other relevant players.

In Mexico there are over 50 companies that distribute and / or make SWHs. In Mexico City and the surrounding area (such as Cuernavaca, and Puebla), about 20 active companies were identified that make and / or distribute or sell SWHs in Mexico City[43], and a number of government officials at the national, regional, and local levels working in this area exist. In addition, there are three universities working on this form of solar energy in and around Mexico City, as well as few NGOs and consultancy firms, such as the National Association for Solar Energy, or Asociacion Nacional para Energias Solares (ANES). There are two consultancies investigating biogas for electricity in Mexico City. Information was formally collected through interviews and questionnaires conducted in Spanish from 15 SWH companies, two biogas companies, three universities (five representatives from one university), one public research institute, three consultancies, one NGO, and seven government agencies. In addition, two energy experts familiar with the renewable energy sector in Mexico City also

[43] Older lists of SWH companies in Mexico City were also used, but after various attempts at communication (e.g. phone numbers and emails that did not work, and asking around), I was informed that about every year in Mexico about three or four SWHs companies went under and another three or four were created. (Interview, one SWH company and one government agency, November – December 2005).

provided insights through more informal conversations occurring at various times in the research process (Total = 35).

In Brazil, there are over 140 companies that produce and / or distribute SWHs (ABRAVA 2007). In São Paulo and the surrounding state, there are about 23 companies that produce, distribute and / or sell SWHs in São Paulo. Many of these companies are members of ABRAVA – DASOL. In addition, a number of government officials at the federal, state and local levels are working in this area (SWHs in São Paulo). Also, there is one university working on this form of solar energy in and around São Paulo, as well as few NGOs and consultancy firms, such as Vitae Civilis and Sociedade do Sol. With respect to biogas, there is one company (actually a consortium of companies), one university, two government agencies, and a number of consultants in São Paulo working on biogas to produce electricity in São Paulo. Information was formally collected through interviews and questionnaires conducted in Portuguese from 14 SWH companies, one biogas company, one alternative energy company, one energy company, three NGOs, two consultancies, one trade association, one university (four representatives), and three government agencies. Informal discussions were also held with the Canadian consulate in São Paulo (Total = 32). Some interviewees were comfortable with being quoted directly, others were fine with indicating they participated in the study but not with directly attributing quotes to themselves, while others wished to remain anonymous. After careful consideration, it was decided to keep all interviews anonymous with respect to who said what. In places where the interviewee wished to remain anonymous (or indicated their first name only) it was written in **Annex 2** as such. End user information was obtained informally through discussions with a number of end users / potential end users (institutions (e.g. a hospital)), individuals (about 20)) and through the experiences of other players involved in the technology cooperation process (over 50 individuals). Specific details about the interviewees (names, organizations, dates of interviews) can be found in **Annex 2.**

3.4.5. Language

The majority of the information was obtained in the (likely) native (and sometimes only) language of the Mexicans and Brazilians involved in this study -- Spanish in

Mexico (one interviewee wished to conduct his interview in English) and Portuguese in Brazil (some informal conversations were held in English – e.g. those with the Canadian consulate in São Paulo). I learned Spanish in Cuba and the Dominican Republic in 1998, becoming fluent and took two more formal courses in Canada. I studied Portuguese in London and São Paulo and was able to communicate at an intermediate level with interviewees.

3.4.6. Factors Affecting RET Adoption

Information from interviews and questionnaires as well as other secondary sources including government and company websites shed light on factors affecting RET adoption in Mexico City and São Paulo. The experiences of those involved in the technology cooperation process (e.g. technicians and other industry representatives (a little less than half of the respondents in each location), government officials, Non-Governmental Organizations (NGOs), trade association representatives, consultants) formed the basis of this investigation. What is distinct about asking these people for information is that the main objective of the interview or questionnaire is to garner a sense of organization itself, which they represent (Dillman 2007), although some personal opinions were asked. At least one representative from each organization, and ideally more, were consulted to reflect differences between and within groups of stakeholders, such as "firms" or "government agencies" (and sometimes individuals within an organization) and to better capture sub-groupings within groups of stakeholders (e.g. domestic firms versus subsidiary firms) to establish trends.

Questions began with a request for basic information about their company or organization and the market for renewable energy sources (especially SWHs and biogas) and specifics about the technology (hardware and software), including the cost of the technology in general and vis-à-vis alternatives. Interviewees also gave their opinion on the perceptions of the technology by different stakeholders at the end of the discussion. Respondents also answered questions relating to possible energy and / or environmental mechanisms (incentives) with which to assist the adoption of RETs in these cities.

From there, participants were asked questions regarding trade and competitiveness policies, and how they affected buying and selling patterns of the technology under scrutiny – if at all.

Moreover, questions about their technology cooperation process were asked, including how their technologies were developed, produced, bought and sold. These questions were asked to determine if they worked with other companies or organizations to design, produce, sell or buy technology and the nature of their relationship (e.g. subsidiary versus a joint venture, formal contract versus informal (often oral) agreement).

These questions were asked for two reasons. As noted in Chapters 1 and 2, the technology cooperation process is characterized by being of different types, including integrated forms, where the ownership of the technology often belongs to one actor (e.g. the headquarters of a multi-national corporation and subsidiaries in developing countries), often found in open trade regimes, or less integrated forms of technology cooperation, where the ownership of technologies is shared (e.g. through joint ventures, memorandums of understanding), often found in conditionally open trade regimes. These questions were also asked to get a sense of the relationships that were occurring between the stakeholder in question and other participants involved in the process.

"Measuring" RET Use in Mexico City and São Paulo

The sciences, including social sciences, tend to rely on empirical evidence, or experiences and observations, to validate claims made. One reason for this is that empirical evidence serves as a proxy to help to understand what is happening in the world.

There are various ways to 'measure' the adoption of renewable energy technologies (RETs). This thesis examines *actual* use of a technology rather than potential use, or intent to use. One reason for this decision is due to the difficulty involved when trying to measure an actor's "intension to use" a technology, especially in the developing world. For example, some studies use willingness to pay (e.g. Wustenhagen and

Bilharz 2006) as a way of determining intent to use or to assess existing market potential in the industrialized world. One can determine willingness to pay by asking potential end users if and how much of a premium for "green" energy sources they would be willing to pay. Having said this, looking at WTP might not be as applicable in the developing world due to a number of reasons which can be more pronounced in these countries, such as a potential lack of environmental awareness and / or lower household income. Moreover, there may be a "long way from declaring a willingness to pay to taking the actual purchasing decision" (Wustenhagen and Bilharz 2006: 1690).

As a specific example, a survey on micro-generation technologies in the United Kingdom (which include micro-wind generation, solar water heaters and photovoltaics for household use), showed a difference of 90% of survey respondents that indicated renewable energy is a good idea versus only 20% who indicated they were likely to install any of these micro-RET options (Ellison 2004, cited in Watson and Sauter 2007: 2776). Actual use of a technology is more appropriate to measure rather than intent to use because there may be differences between how the technology actually works and how the technology was expected to work (Rogers 2003a: 181).

I measured the **adoption of Solar Water Heaters**, the first technology under scrutiny, through various features. The hardware was measured by metres squared (m^2). Furthermore, to account for potential differences due to population, the dissertation adopted the metric of m^2 / 100 inhabitants – a metric found in many studies on SWHs worldwide (See for example, Houri 2006: 670; Milton and Kaufman 2005: 6; Milton 2004: 8; Nahar 2002: 631; Philibert 2006: 12).

A number of SWH studies (or parts of SWHs studies) focus more on energy use, and utilize kWs or kW/h as a measurement of energy use. Energy use is calculated as a way of measuring energy savings to determine payback period, reduction in fossil fuel or electricity use, carbon or other pollution abatement or potential income generated through the Clean Development Mechanism (CDM)'s Certified Emission Reductions (CERs) (e.g. Rodrigues and Matajs 2005: 53; Headley 1998: 258; Perlack and Hinds 2001: 5; Nahar 2002: 633; Milton and Kaufman 2005: 23).

In line with those studies examining SWH usage, I use m^2 to measure SWH use but will refer to kW or kW/H when looking at energy use – when applicable. Ultimately however, when measuring "technology adoption", I chose the metric m^2 to measure SWH use because this data was more readily available – the majority of companies and organizations had this information on hand. In this context, SWH use was assessed through metres of SWH panels that are installed and working / being used (when this information was available).[44] Other information, such as number of installations, number of individual systems sold, etc. will also be provided when available to better understand SWH adoption.

Market growth – to help give a better indication of SWH use trends -- was measured through examining various aspects involved in the technology cooperation process over time. Like other studies, such as Houri (2006), examining the market growth of SWHs, aspects to measure market growth include changes in technology sales (whether physical products or services), installations, production and capacity.

Data limitations for SWH use

As noted above, the main metric used to determine how many SWHs are being used in both cities is m^2 / 100 inhabitants. However, at present, no reliable numbers exist on m^2 of SWHs in Mexico City and São Paulo. More detailed information on number of m^2 of SWHs is expected to be available some time soon in Brazil, but at the time of writing, this information is still unavailable.[45] For this reason, information on m^2 in Mexico City and São Paulo was estimated using two sources of data 1) data provided by the companies themselves and 2) m^2 at the national level and dividing by the population in those metropolitan areas. Fortunately a previous global study (Weiss et al. 2004) on SWHs included Mexico as a case study and estimates on what percentage of the SWH market Mexico City constitutes were provided.

[44] This last part is particularly important in Mexico and Brazil, as the market for SWHs also includes poor quality versions or poor installations (even if the quality of the equipment is good) (Interviews, 12 informants-Mexico, November 2005-January 2006; 4 informants-Brazil, March – May 2006). . Previous studies conducted on SWHs in Mexico and Brazil also confirm this fact Fernandez and Martinez, A. a. J. (2003). Mexico's Advances With Regard to Climate Change, 2001 - 2002. R. a. G. P. General Directorate for Research in Urban. Mexico City, Federal Ministry of the Environment and Natural Resources, National Institute of Ecology: 80. and Brazil (Rodrigues and Matajs 2005).

[45] Interviews, one NGO, December 2005, and one trade association, May 2007; personal communication, one trade association, February 2008

Several challenges involved with the collection of data from local sources included the fact that a few companies were unwilling to provide me with this data, while other companies were able to give me an estimate but were not able to pinpoint with precision the final point of sale of their products (i.e. if they were within the borders of Mexico City or elsewhere), and a few more were not able to give me an estimate of the m^2 they had sold and knew or assumed (because of no complaints) were working. In addition to this, sometimes the logistics involved in tracking down these companies and figuring out how to get to these various places using the public transit system also proved to be a daunting task in and of itself!

To ensure more accuracy, these numbers were compared by using information that existed at the national level. In the case of Mexico, m^2 information is given annually by the National Association on Solar Energy (or ANES in Spanish). The NGO requests these numbers from all SWH companies in the country every year. Although not completely precise (about 3-4 SWH companies go out of business and the same number start every year on average), ANES makes these estimates to the best of their knowledge. Furthermore, because no one could say with certainty what percentage of the SWH market in Mexico, el Distrito Federal represented, I used the previous study (which used data from Mexico City up to 2000) (Weiss et al. 2004: 33) for this estimate.

In the case of Brazil, similar to Mexico, companies are asked to provide their annual sales of m^2 to the national trade association for SWHs (among other technologies), ABRAVA. However, in São Paulo, the Sociedade do Sol's SWHs, even though their project to disseminate this technology had yet to "take off" at the time of research, the hardware of this technology is considered of too low quality to receive the PROCEL stamp, or ABRAVA affiliation and so they are not included in ABRAVA's total. To account for these differences, sensitivity analysis was conducted when generating numbers, to provide a range of plausible numbers in which the mean was eventually used and compared with the numbers obtained from these local sources.

The **use of biogas to produce electricity** however was measured in MW, a number more easily obtained. This metric (MW) is used like other studies on (or the potential of) this same technology (See for example Katinas and Skema (2001: 815) on Lithuania; Shin et al. (2005: 1261) on Korea; Wanichpongpan and Gheewala (2007:1822) on Thailand; and Aitchison (1996: 1113) on the United Kingdom). Information in MWs was readily available, and so provided a single form of measurement that could also take other technology use measurements into account. These other technology use measurements include the number and capacity of motors in place, the amount of biogas to be combusted to generate electricity daily, etc.

However, technology is both "hardware" and "software". Thus, SWH and biogas use was also measured by examining activities occurring in both cities regarding these technologies. These less tangible forms of technology are more difficult to measure. For instance, Park and Park (2005) note that technological knowledge is difficult to measure because it is often is comprised of heterogeneous and multidisciplinary sources, it is often tacit and thus difficult to quantify, and it is often subject to certain differences between sectors. Nevertheless, they and other researchers measure knowledge through a number of proxies such as research and development (R&D) expenditure, number of researchers, patents, or types of patents, among others (Hu and Jaffe 2003; Park and Park 2005). This thesis looks at knowledge and processes generally however for two reasons. First of all, as indicated earlier, knowledge is more than just information, it is also shaped by experiences, assumptions and values and so it is not clear how adequate these proxies are to determine knowledge. Secondly, there was also a lack of precise information available about money spent on research and development and the specific amount of researchers for SWHs in Mexico City and São Paulo.

Patents will be explored in Chapter 8, which examines Trade and Competitiveness Approaches. However, this was not used as a proxy to measure technology adoption as there were some inconsistencies regarding how they were perceived. For instance, in both locations there was a general consensus that SWHs were in the 'open domain' and that no patents existed on these technologies. However, some companies claimed they did have a patent or "trademark" on their technology, while one NGO claimed that to seek a patent was counterintuitive to their philosophy – which was to make their technology be developed by all.[46] In the case of biogas to produce electricity, all informants indicated that the patents for the hardware of a lot of the patents were held by other countries (namely companies such as Caterpillar in the Unites States, as well as Canadian and Dutch and Swiss firms). In addition, the majority of studies use patents as a proxy to measure innovation (e.g. Hu and Jaffe 2003; Park and Lippoldt 2008), rather than adoption. The subject of patents will be treated instead as one of a number of potential factors affecting technology adoption, rather than as a way of measuring adoption.

Other factors can also be indicators of knowledge and / or processes. These factors include formal and informal capacity building efforts and the number of organizations working on solar water heaters (SWHs). An indirect way of learning about SWH use is through examining the awareness, or what some call knowledge, of the technology amongst the population. But, as I argue in Chapters 1 and 2, this view of knowledge tends to equate it with information. However, this thesis views "awareness" as also being a factor that can help to explain the "why" the technology is or is not being adopted. For this reason "awareness" will be investigated in Chapter 6, which deals with the question of "why SWHs and biogas into electricity technologies are or are not being used in Mexico City and São Paulo".

Some other proxies used to measure aspects such as knowledge and processes include number of courses on solar water heating, number of installers (whether certified or not certified), number of organizations working on SWHs, among others (e.g., in Tunisia the number of SWH suppliers doubled and number of installers quadrupled in four years following a UNEP program encouraging their use in that country (Volans 2009). This study includes this information where obtainable. However, as indicated above, some "official" information that other studies have used as proxies to "measure" technology use was not available for Mexico City or São Paulo, or was considered unsuitable for this study. For this reason, interviews and discussions with key informants, as well as information obtained from other sources (e.g. government, NGO and company websites) helped to glean insights in this area.

[46] Informal discussions and Interviews, three informants Mexico, November 2005-January 2006; and Informal discussions and interviews, six informants Brazil, March – May 2006

3.5. Analysis Techniques

This information was mainly analyzed through an in-depth evaluation and interpretation of information supplied through these primary and secondary-sources. As discussed in Section 3.4, information was collected with the objective of answering the research and sub-research questions:

What are the most important factors affecting RET adoption in the urban developing world?

- How can systemic approaches help explain RET adoption in developing country cities?
- What are the reasons that SWHs and biogas to produce electricity technologies are being used or not in Mexico City or São Paulo?
- To what extent do trade and competitiveness regimes affect the uptake of RETs?

One option was to transcribe interviews and examine completed questionnaires, looking for trends and common themes with no software programs. Another alternative was to use a Computer-Assisted Qualitative Data Analysis Software (CAQDAS) program, such as Atlas-ti. This program allows the researcher "to manage, extract, compare, explore and reassemble meaningful segments of large amounts of data" (Atlas-ti 2008) in order to identify common themes and trends in the qualitative data and to link these insights to conceptual analytical frameworks. The software is based on four premises – termed the VISE principle, offering opportunities for Visualization, Integration, Serendipity, and Exploration of information in the study process (Atlas-ti 2008). One other advantage of using a CAQDAS program is that it counts the number of times themes are revealed, which can reinforce the prominence of themes identified qualitatively. As there was a large amount of information to consult – over 60 interviews and questionnaires in Spanish and Portuguese, sometimes translated in English - it was deemed suitable to use a CAQDAS program.

Atlas-ti was the CAQDAS program chosen. There were a number of reasons why I chose this program rather than other CAQDAS programs (e.g. Nvivo, ALCESTE). First of all, the program allows for a verbatim record to be kept of the interviewee's responses and that the frequency and word usage can help to determine patterns and themes from this information (Yin 2003). Also, Atlas-ti allows visual as well as textual data to be incorporated into the analyzed documents. This function allowed for the possibility of including information in other forms – such as charts and tables if necessary to be assessed. Furthermore, one of the other programs, ALCESTE, has all of the commands in French. Although I have fair knowledge of French, I thought it would be best to use a program in English – especially important as the interviews themselves were in Spanish and Portuguese. Finally, at the time of deciding which program to use (early 2007), one other CAQDAS program under consideration, Nvivo, was expected to come out with a newer version and it was not clear how compatible these two versions would be.

After transcribing the interviews, I came up with about 30 or so pre-selected codes based on my research questions and the themes that came up consistently during the interviews. From there, I coded the interviews manually using these pre-selected codes, as well as adding further codes revealed when going through the textual information thoroughly again when coding versus transcribing. This approach of developing codes at the start of data analysis and then modifying them is similar to other studies that also use this tool (including Kagee 2004: 627; Grunwald and Kieser 2007: 380, Zhang 2005: 68, among others). If deemed applicable, text from the interviews was associated by more than one code (e.g. if the text touched on issues to do with trade policies and networks, the text had these two codes associated with it). I initially had over 100 codes, and then narrowed them down to about 40. From there, I undertook a second order of analysis, taking these 40 codes and grouping them into four code families to do with RET adoption and cooperation, to determine how best to explain these factors using the theoretical guideposts indicated in Chapters 1 and 2: 1) conventional explanations 2) Rogers' Diffusion of Innovations, 3) Urban Technology Cooperation, 4) Trade and Competitiveness Regimes

Using Atlas-ti proved to be a learning process in and of itself – not only becoming familiar with the software, but also learning some strategies to 'step out of the weeds' – one example is by linking codes that were initially separated but closely related together (e.g. patents and Intellectual Property Rights) – See **Table 3.2 and Figure 3.2** for details on how the trade and competitiveness regimes code family was established. In sum, by using this software tool, I was better able to identify trends and themes and common threads between these various concepts.

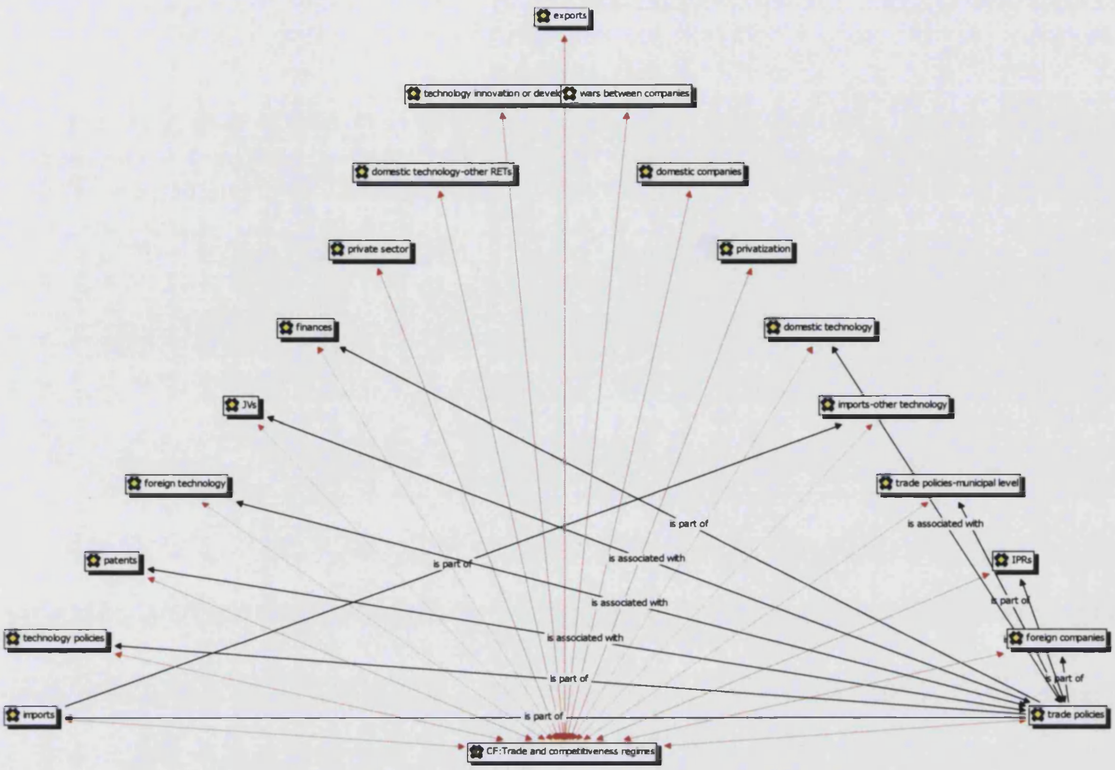
Table 3.2 Constructing the trade and competitiveness index

- I examined all the codes developed (over 100 in total)
- I went over the codes and looked for similar codes and decided to amalgamate certain codes into one larger code. In this instance I had some information about trade and competitiveness policies under this heading. I also had information from other related codes – including patents, intellectual property rights, imports, etc. I decided to amalgamate these codes into a larger code called "trade and competitiveness regimes." Other codes which did include some information about trade and competitiveness regimes sometimes, but not always (e.g. Mexican electricity sector) were not included, as the relevant text had already been captured in another code related to trade and competitiveness regimes (e.g. privatization). Here I had about 40 codes in total
- I then created code families, through further linking of related themes. I established one code family called "trade and competitiveness regimes"

Source: Author, August 2009

Figure 3.2 represents a graphic interpretation of the relationship between various codes and amalgamating them into one code family. The diagram also helps the researcher to examine the links between particular codes that fall within one code family. For example, in the figure below arrows link text that falls under "imports", "imports-other technology", and "trade policies". These sub-themes within the code family were extremely helpful in developing the analytical chapters, as they helped to determine exactly how conventional and alternative explanations could determine the most important factors affecting RET use in developing country cities.

Figure 3.2 - Trade and competitiveness regimes code family



Source: Author, Based on Atlas ti Analysis, June 2008 and updated August 2009

3.6. Conclusion

To summarize, this chapter explained the research design, methods and analysis used in the study and the basis for choosing them. Conventional technology adoptions often overlook the importance of context and the connectivity between actors. I therefore turned to systemic approach, which have been proposed as an alternative lens through which to understand RET uptake, but to date there has been little application of them in practice in this area, to answer my research question – What are the most important factors affecting RET adoption in the urban developing world?

In answering this question, I chose qualitative approaches because they provide a better way in which to understand how choices and decisions impact uptake through the motivations, experiences and contexts of agents. Qualitative techniques also offer a number of advantages including a more in-depth view of phenomena, and better reflect the subjectivity involved when conducting research.

Specific techniques used include probability and snowball sampling in order to ensure that relevant players involved in the technology cooperation process were considered. Furthermore, while some researchers would criticize my fieldwork approach as being too short (staying roughly 2.5 months in each location), in that not enough time was given to develop and establish trust, on the other hand, by being in each place for a shorter time, I felt there was less chance of me being perceived as being aligned with any one particular interest.

I chose to 'measure' uptake of equipment through m2 for Solar Water Heaters (SWHs) and Megawatts (MW) for biogas technologies, similar to other studies on these two particular technologies. In order to account for data limitations, especially with m^2, I used a number of sources 1) information from the companies themselves, 2) information provided by two important agents at the national level, 3) information provided by other studies conducted in this area.

Finally, I chose to use Atlas ti, a computer based program to help qualitative researchers analyze large quantities of data. I found this program extremely helpful in identifying, amalgamating and conceptualizing key themes as discussed by informants.

CHAPTER 4: SOLAR WATER HEATERS AND BIOGAS TECHNOLOGIES IN MEXICO CITY

4.1. Introduction

The study looks at trends regarding these two technologies from about the mid-1970s to the present (2009), with most information collected between 2005-2009. As noted in Chapter 1, Mexico City and São Paulo provide fascinating backdrops for this research. Both cities have large populations, active but unique civil societies, major discrepancies between the urban wealthy and poor, a high-energy demand, and high technological capability (TC), or the ability of firms, regions, countries, etc., possessing various assets including human resources, technical and scientific skills and infrastructure, to cause technological change. As well, akin to many mega-cities, they are both major hubs of technological learning, and, as large economies, are larger greenhouse gas (GHG) emitters. One distinct difference between the two places is that they possess differing trade and competitiveness approaches. Details about São Paulo are discussed in Chapter 5.

The main purpose of this chapter focuses on the sub-research question ""*What are the reasons SWHs and biogas to produce electricity technologies are being used or not in Mexico City?*" The focus of this chapter and Chapter 5 is on the findings from Mexico City and São Paulo. Chapters 6, 7 and 8 analyze these findings using the three systemic frameworks as guidelines for their explanation. This chapter provides details about the situation for both technologies – Solar Water Heaters (SWHs) and biogas technology to produce electricity in Mexico City. It is divided into five sections. The first section provides information about Mexico City. The next two sections focus on information about these two RETs in Mexico City, including segments are using them, where they are being used, and most importantly, how much they are being used. The latter part of the chapter consists of the other two sections. It turns to the factors affecting their uptake in Mexico City, teasing out common patterns and themes, as identified by informants and other secondary sources.

This chapter shows that in comparison with other nations with similar attributes (e.g. insolation patterns, population), Mexico has a lower than average rate of SWH use. However, this rate is higher in Mexico City versus other parts of the country. It also shows that, to date, there are no biogas technologies to generate electricity being used in Mexico City, despite the fact that there are a number of these projects being planned as Clean Development Mechanism (CDM) projects in other cities in Mexico, as well as a project underway in Monterrey.

Similar to other studies examining the adoption of SWHs in developing nations (e.g. Muntasser et al. 2000, Headley 1998, Milton and Kaufmann 2005), this chapter shows that in the case of SWHs in Mexico City, respondents also noted direct environmental policies (2nd most prevalent theme noted) and awareness (4th most prevalent theme noted) as key factors affecting RET use. An interesting finding of this chapter however, is that in contrast to many studies emphasizing direct economic and technical aspects, two of the most prevalent themes identified by participants as having the potential to affect RET use in Mexico City are trade and competitiveness regimes (1st most common) and networks (or a lack of them) (3rd most common).

Apart from some World Bank, and joint World Bank / consultant assessments of the Bank's Monterrey biogas project (e.g. Bartone et al. 2005; Roth and Grajales-Cravioto 2005; Vergara 2005), the majority of studies of biogas technologies to produce electricity in Mexico are Project Design Documents (PDDs) of the CDM (EcoSecurities 2006a; EcoSecurities 2006b; EcoSecurities 2007; Juarez 2007), which are plans assessing the potential for these technologies, rather than an analysis of their uptake, or lack of uptake in certain settings. That said, other studies examining biomass (e.g. Goldemberg 1998) indicate the importance of direct environmental policies. Similar to these studies, I found that direct environmental policies were the most common theme cited by interview responders. However, an interesting trend is that, similar to the SWH results but different than many RET studies in developing countries, trade and competitiveness regimes were also noted as being important (2nd most common theme) and networks (4th most common theme). These findings lie outside of the classical explanations of RET adoption, centering on costs, access to finance, technical problems, awareness and institutional issues.

4.2. Mexico City – Context

Mexico City is the capital of Mexico. The city has a large population – almost 10 million in the city proper, and over 19 million when the outskirts are included. Mexico, a country with a large degree of openness in international trade, practices an outward-oriented trade and competitiveness approach. Emphasis is placed on encouraging Foreign Direct Investment (FDI) and free trade, and increasing technological capability through the manufacture and supply of foreign-designed technology. For instance, in 2007, Mexico had the largest amount of Free Trade Agreements (FTAs), with 43 countries worldwide (ANIERM 2007). Furthermore, the Mexican renewable energy market in 2003 was estimated to be about $US 241 million, with imports of $US 216 million – or almost 90 %. In Mexico, end-users of RETs tend to buy integrated products, therefore Mexicans only become engaged in the construction / engineering aspects at the RET implementation stage (Dessommes 2004).

Electricity used in Mexico City is generated by the federally-owned Comision Federal de la Electricidad (CFE) and the Electric Power Utility Law (revised in 1992) limits private participation. For instance, Independent Power Producers (IPPs) must consume their electricity generated or sell it to CFE at long term (25 years), fixed low prices (Dessommes 2004; Estrada 2005). In Mexico City, electricity is distributed by another state-owned enterprise (SOE) Luz y Fuerza.

As noted earlier, the two technologies under scrutiny are Solar Water Heaters (SWHs) and biogas to generate electricity technologies. SWHs used in both cities are on a large-scale (e.g. institutions) and a smaller scale (e.g. household level). Biogas technologies to generate electricity being considered or in use in both cities are generally used at a larger-scale (e.g. landfills for large cities). For these reasons, it is important to examine the amount of disposable income and access to credit available for residents of these two cities and access to credit available to larger institutions.

The first point to be examined is disposable income, relevant for SWHs for household use. According to David Morillon, president of ANES in 2005, there are about 23 million residences (which includes houses and apartments) in the Federal District and surrounding area, but of the people living there, "which ones can realistically purchase a SWH?"[47]. To answer this question, I turned to Quintanilla et al.'s (2000) study on SWH use in Mexico City. That study assumed that the monthly income of a home would need to be at least four times higher than minimum wage to afford a SWH for use in homes in the Federal District (taking other factors such as monthly expenditure, etc. into account). He estimated that 43% of homes in and around Mexico City or homes where the monthly income was at least four times higher than the minimum wage, could afford a SWH.

For a more recent estimate, I examined statistics from 2005. In Mexico City, the Mexican National Institute of Geography Statistics and Computer Science, or Instituto Nacional de Estadistica Geografia and Informatica (INEGI) has data on almost 4 million people employed in Mexico City in 2005 of the 8 721 000 that lived in Mexico City in 2005.[48] According to INEGI, of this number, more than 1 480 000 people made in and around four times the minimum wage or higher in Mexico City in 2005. The minimum wage in Mexico City for the year 2005 (from January 1 – December 31) was 46.80 pesos / day or about US$4.35 dollars / day[49]. Using these estimates, one can assume that ***at least* 17%** of the population in Mexico City could afford a SWH in 2005.

However, this is a very conservative estimate because 1) the information from INEGI is calculated per person, whereas generally speaking, there are about four people in the average home in Mexico City[50] and 2) some larger scale SWHs for use in apartment buildings would require less upfront costs for potential users, and 3) the monthly income for a Mexican home can also come from sources other than formal employment such as informal employment activities and remittances from family members abroad. Taking this information into account, Quintanilla's estimate that about 43% of homes in and around Mexico City could afford a SWH seems plausible too. There are no credit schemes in place to help families or institutions purchase a SWH in Mexico City. Institutions have better access to credit versus individual families, which can help them

[47] Interview, one NGO, December 2005

[48] (INEGI), I. N. d. E. G. y. I. (2007). "Various information from website." Retrieved September 16, 2007, from www.inegi.gob.mx.

[49] using an exchange rate of US$ 1 = 10.78 pesos December 31, 2005, www.oanda.com

[50] Informal discussions, November 2005 – January 2006; However, Quintanilla et al (2000: 10)'s study indicated that on average about five people lived in homes in Mexico City at that time.

come up with the capital needed to purchase a SWH. Some photos of Mexico City are included in **Figures 4.1** below. The purpose of these photos is to give the reader a flavour of the city. The first tries to capture how large the city is it (as this photo represents only a very small portion of the city) and also tried to demonstrate that the city is a modern hub, linked globally to other global cities, regions and countries. Furthermore, the photo shows that the city is situated in a valley, which means that some environmental problems, such as air pollution, are more pronounced.

The second photo shows the central part of Mexico City, called the Zocalo. It is a large square, where people congregate for various reasons (celebrations on holidays, a protest site, such as during the 2006 elections by supporters of López Obrador when he lost the 2006 federal elections by about 1%, etc.). The purpose of the photo is to indicate that daily face to face interactions among people and providing a space for these interactions is an important part of Mexican cities.

The third photo shows a girl walking in Bordo Poniente, Mexico City's one main landfill site (at the time of research as the city is currently in the process of closing this one down and allocating other landfill sites to address the city's waste). The purpose of this photo is to show that there are stark contrasts between wealth (as can be surmised in the first photo) and poverty (as indicated in the third photo). The photo also shows that communities exist, eking out a living (through finding recyclables to resell, etc.) within Bordo Poniente (versus Bandeirantes in Sao Paulo, where there are communities near the landfill site, but not directly within / adjacent to it). As is discussed further in this chapter in Section 4.8, the fact that people live directly within the current Mexico City landfill will have some implications should any potential biogas technology to electricity project using waste from Bordo Poniente come to fruition. A positive outcome could be providing electricity for these communities and training, employment for some community members to work on the project.

Figures 4.1 Views of Mexico City

Source: www.istockphotos.com

Source: www.istockphotos.com

Permission to use © Milan Klusacek

Source: www.istockphotos.com

The greenhouse gas (GHG) emissions of Mexico City are largely caused by fossil fuels (especially oil and natural gas), which the city is heavily reliant on for its electricity and transportation needs – for instance, daily energy consumption is about 44 million litres of gasoline equivalent (Plan Verde 2009). Various studies conducted calculating GHG emissions in that city, such as the 2004 "Local Climate Action Strategy of Mexico City", range from estimates of about 34.9 million tonnes of CO_2 equivalent in 1996, to about 60 million tonnes of CO_2 equivalent in 2000, and 62.6 million tonnes of CO_2 equivalent in 2004. Some reasons for these discrepancies include the fact that some studies include emissions from aviation and solid waste[51] while others do not and that very few official inventories exist (Dodman 2009; Gobierno de Districto Federal 2004).

[51] When assessing GHG emissions and removals, the IPCC is concerned with "methane produced from the anaerobic microbial decomposition of organic matter at solid waste disposal sites" (IPCC 2006, Chapter 8: 33) - CO_2 is accounted for separately, but whether or not these sites include municipal and / or industrial waste depends on the actual landfill. See IPCC (2006). Chapter 8: Reporting Guidelines and Tables. Guidelines for National Greenhouse Gas Inventories. I. P. o. C. C. (IPCC). Cambridge, Cambridge University Press.

4.3. Solar Water Heater (SWH) Use in Mexico and Mexico City – the hardware

The first step when answering the sub-research question "*what are the reasons SWHs and biogas to produce electricity technologies being used or not in Mexico City?*" is to establish exactly **how much** of these RETs are being used. This is important, as a key goal of the dissertation is to determine if there are acute differences between the two locations in terms of how much these RETs are being used and potential factors that may affect RET adoption, in which more general deliberations can be established. As noted in Chapter 3 on Research Methods, the use of RETs will be measured by examining technologies that are considered hardware (physical equipment) and / or software (knowledge and processes).

4.3.1. Mexican SWH Industry – The government and non-governmental organizations (NGOs) confirmed that although small, the SWH industry has firm, long-standing roots in the country – it has been in existence in Mexico for over 40 years[52]. In addition, the technology itself has been in existence for a long time – according to one SWH company - for 85 years[53]. In Mexico there are over 50 companies that distribute and / or make SWHs[54]. Both government officials and industry firms indicated that in Mexico City and the surrounding area (e.g. Puebla, Cuernavaca), about 20 active companies were identified (2005-06) that made and / or distributed or sold SWHs in that area[55]. A number of government officials at the national, regional, and local levels working in this area exist. According to one company in Mexico City that used to produce SWHs, before there were around 70 companies making SWHs in Mexico, but now, he claimed there were only about 10 – 15 that were producing good

[52] Interviews, two NGOs, and one government official, November 2005 - January 2006
[53] Interview, one SWH company, December 2005
[54] Interview, one NGO, December 2005
[55] Older lists of SWH companies in Mexico City were also used, but after various attempts at communication (e.g. phone numbers and emails that did not work, and asking around), I was informed that about every year in Mexico about three or four SWHs companies went under and another three or four were created. (Interview, one SWH company and one government agency, November – December 2005).

quality SWHs[56]. Sources from all sectors of the SWH industry indicated that companies are either wholly Mexican, Mexican but with imported products, or subsidiaries of international firms.[57] In addition, there are three universities and one technical institute working on this form of solar energy in and around Mexico City, as well as a few NGOs and consultancy firms, such as Energia, Tecnologia y Educacion (ENTE), the National Association for Solar Energy, or Asociacion Nacional para Energias Solares (ANES) and Consultoría y Servicios en Tecnologías Eficientes (CYSTE).

At the national level, the SWH industry is generally centred around three areas of the country. In the 1950s, there were a number of immigrants that came to the state of Jalisco (in and around Guadalajara) and so the first place that the Mexican SWH industry developed was there.[58] The two other places where the industry is concentrated are in Morelia and the area in and around Mexico City (especially Cuernavaca – a city located about 80 km south west of the City). Sources from the private sector, as well as a NGO and consulting firms stressed that the main reason the Mexican SWH industry is concentrated in these locations is due to climate. For instance, Cuernavaca is also known as the "city of eternal spring" and the city claims to have the most pools in the world – according to one source, about 35, 000 – 40, 000 pools[59].

Key informants from a broad range of SWH industry actors noted that when looking at Solar Water Heater (SWH) use in Mexico, SWHs represent only a small portion of the technologies used in Mexico to heat water. The main technologies used to heat water are natural gas and Liquefied Petroleum Gas (LPG), which is used in Mexico City. Electric and diesel water heaters are used very little[60]. For example, (Quintanilla and Bauer 2001) call the Metropolitan Area of Mexico City (MAMC) – an area which includes the Federal District and 51 of the surrounding localities located to the north of the Federal District, in the State of Mexico – "the world's largest LPG market" (2001:

[56] Interview, one former SWH company, December 2005
[57] Interviews, three SWH companies, three government representatives, one consulting firm, and one NGO, December 2005
[58] Interview, one consulting firm, January 2006
[59] Interviews, one SWH company, one NGO and two consulting firms, November and December 2005
[60] Interviews, one consultancy, three SWH companies, four university representatives, three government representatives, November 2005 - January 2006

1). Regarding specifics, in 1992, about 43% of LPG use in Mexico City was used to heat water; however, at the time only 54% of residential dwellings had any water heater (Bauer, Quintanilla et al. 2000: 284) – so this number is likely higher.

4.3.2. SWH equipment use in Mexico - In 2006 there were about 840, 000 m^2 of solar water heaters installed in Mexico (ANES 2007). This number is an increase from a little over 650, 000 m^2 in 2004 (CONAE 2007: 13) and 2005, which was approximately 740, 000 m^2. While this growth may seem impressive on the surface (about 100,000 m^2 per year), when comparing Mexico to other countries with a similar climate, Mexico's rate of SWH installation is rather low. For example, Turkey, with an estimated population of almost 70 million in 2005 versus Mexico, with an estimated population of over 107 million in 2006 (Population Resource Center 2007; CIA 2007), saw an *annual* SWH installation increase in 2003 of about 630, 000 m^2 (Milton and Kaufman 2005: 12).

To provide another comparison, some forecasts have put Mexico on par with the BRIC countries, or Brazil, Russia, India and China, projected to account for the majority of global Gross Domestic Product (GDP), economic growth and investment opportunities by 2050, with some coining the term BRIMCs. [61]

Another of the BRIMCs, with a large growing economy and increasing GHG emissions, is China. This country is the world leader in SWH use. For instance, in 2006, there were around 20 million additional m^2 installed – therefore making the total almost 100 million m2 of SWH installed in China in 2006 (REN21 2008: 12). However, as the population of China was estimated to be about 1 314 million in 2006 or about 1 330 million as of July 2008 (CIA 2008), or about 12 times higher than Mexico's, a more comparable rate would be m^2 / inhabitant. When couched in these terms, using data from 2006, China's rate would be a little over 7.5 m^2 / 100 inhabitants

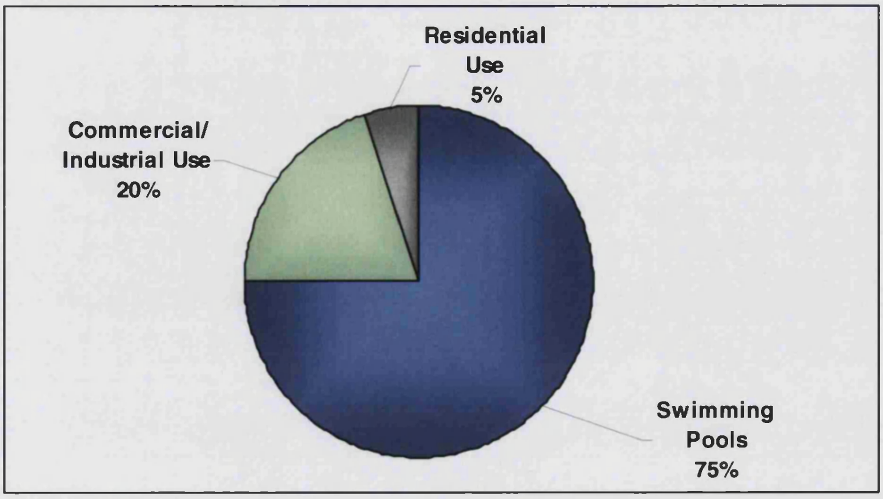
[61] The term Brazil, Russia, India, Mexico and China (BRICs), stem from a 2001 and later 2003 Goldman Sachs report where these four countries were singled out in forecast scenarios to account for the majority of global GDP, economic growth and investment opportunities by 2050. In a 2005 Goldman Sachs paper, Mexico was also projected to have rates similar to the rest of these countries O'Neill et al. (2005). How Solid are the BRICs? Global Economics Paper. G. Sachs. New York, Goldman Sachs: 1-24. (O'Neill et al. 2005: 4), leading to the term BRIMCs but as noted in Chapter 3, this was further updated to include South Korea O'Neill, J. (2007). BRICs and Beyond. G. Sachs. New York, Goldman Sachs: 1-272.

versus Mexico's less than 0.8 / m^2 per inhabitant. This is particularly striking when one looks at the potential for solar energy in Mexico, which some informants indicated is one of the highest in the world[62]. Other studies, such as Hoyt et al. (2006) and Torres Roldán and Morales (2006), indicate that Mexico has an average insolation rate, or rate of solar radiation, of about 5kWh/m^2/day, also highlight this point. For comparison, New York, New York has an average insolation rate of 3.53 kWh/m^2/day.[63]

4.3.3. SWH Market in Mexico - Generally, SWHs in Mexico are used to heat swimming pools (between 70 and 80%). The rest of the market is for SWHs used in commercial / industrial heating water applications and SWH for home use (mainly for bathing / washing purposes). Residential clients (whether using hot water for personal pools or for other purposes) are often wealthy or middle class. Large clients, whether for pools or heating water for other purposes, make up more than half of the SWH market[64]. Commercial and industry clients include hotels, sports clubs, hospitals, and various companies who need to heat water for industrial purposes[65]. According to ANES, SWHs for commercial and industry use represents about 20% of the industry.[66] All informants indicated that the market for SWHs for residential use was "very marginal"[67] in Mexico. Some informants indicated that SWHs for residences represented about 1% of the market[68], while others noted this market was about 5% to 8%[69].

[62] Interviews one consultant, two university officials, November 2005- January 2006
[63] This yearly average was obtained using 10 years of data (1990-2000) Whitlock et al (2000). Release 3 NASA Surface Meteorology and Solar Energy Data Set. Renewable Energy Industry Use. Rise & Shine 2000, the 26th Annual Conference of the Solar Energy Society of Canada Inc, Halifax, Nova Scotia, NASA. See http://www.apricus.com/html/insolation_levels_usa.htm
[64] Interview, one university representative, December 2005
[65] Interviews, one SWH company, one NGO and two university representatives, November and December 2005
[66] Interview, one NGO, December 2005
[67] Interview, one university representative, December 2005
[68] Interviews, two SWH companies, December 2005
[69] Interviews, three SWH companies, November-December 2005

Figure 4.2 Estimated Market Share of SWHs in Mexico (approx.)



Source: Author, based on estimates provided by key informants November 2005-January 2006

The majority of other studies examining SWHs in Mexico have numbers regarding SWH use similar to the ones noted by informants. But, there are some discrepancies with respect to household use of SWHs. For example, Milton (2004: 5) indicates about 1% in 2003 were used. Other studies suggest that SWHs for residences in Mexico are generally closer to the higher numbers provided by respondents. For example, one study notes that in 2003, 78% of the SWH market was for swimming pools, 14% for commercial / industrial applications, and 8% for domestic use (Hoyt et al. 2006: 11). Quintanilla et al. indicated that, in 1999, SWH for residences was about 9% of the market (2000: 46).

Some respondents noted that interest in renewables was increasing in Mexico. In addition, the general view among all stakeholders within the SWH industry indicated that the SWH market in Mexico has generally been increasing steadily – and especially since 2000[70]. Other studies also confirm this trend. For example, in 1990, there were around 150, 000 m^2 of SWHs installed in Mexico, increasing to around 370, 000 m^2 in 2000, 430, 500 m^2 in 2001 and 574, 000 m^2 in 2003 (Castro Negrete 2005: 21; Weiss et al. 2004: 6; Milton 2004: 64). Previous reports indicate that annual installations of SWH remained relatively constant at about 12,000 m^2 from 1990 – 1996 (Castro Negrete 2005: 21), or around 20 000 m^2 in the 1990s (Quintanilla et al. 2000: 45). In the 2000s, yearly installations ranged from about 45,000 m^2 in 2000 to over 50 000 m^2

[70] Interviews, six SWH companies, three government officials, one university official, and one consultancy

in 2002 (Fernandez Zayas and Valle 2005: 5). This number had increased to almost 100, 000 m^2 installed per year in 2005 and 2006 (Heliocol 2007).

A broad range of stakeholders noted that increases were not as pronounced in the housing sector but more in the industrial and commercial sectors – especially institutions such as hotels and sports centres[71]. Another company saw the market shifting more towards the residential sector and less towards pools in terms of growth patterns based on recent trends within their company (e.g. a 300% increase in SWHs for homes, but 50% less for pools in 2005)[72].

4.3.4. Types of SWHs in Mexico - As shown in **Table 4.1** below, the principal SWHs used in Mexico differ in price, size, and form. The Table lays out the SWH forms from least expensive to most expensive forms. The cheaper versions are used to heat pools, while the most expensive forms are used to heat water for commercial or industrial purposes, although one expensive version of the SWH available in Mexico (made by Genersys, a company from the United Kingdom (UK)) can also be used in houses.

[71] Interviews six SWH companies, three government officials, one university official, and one consultancy, November 2005-January 2006
[72] Interview, one SWH company, December 2005

Table 4.1 Principal Types of SWHs Used in Mexico

SWH Type	Cost in US$ (equipment + installation)[73]	Details	Main Use
Plastic with no covering	400.+	Varies – $3m^2$, $9m^2$+	Residential swimming pools
Plastic with covering	700.	Varies – $3m^2$, $9m^2$	Residential water heating (single family) Residential swimming pools
Copper with glass covering	800-900.	2-3 m^2 about 150 litres about 30 – 60 degrees Celsius depending on climate / conditions	Residential water heating (single family)
Crystal Tubes with glass covering	920.	Up to 80 degrees Celsius depending on climate / conditions	Residential water heating (single or multifamily) Commercial, industrial water heating (e.g. hospitals, hotels)
Copper with glass covering	1000.	6 m^2	Larger sized swimming pools (e.g. hotels, sports clubs)
Copper with glass covering	2000+	10 m^2 +	Commercial, industrial water heating (e.g. hospitals, hotels) Residential water heating (Single or multiple)

Sources: Interviews with 13 SWH companies, November 2005 – January 2006, September 2007. Some information confirmed from Hoyt et al. 2006: 29 and Heliocol website, 2007
NOTE: 1 US dollar = 10.6 pesos in January 20006, www.finance.yahoo.com

As indicated in **Table 4.1** above, an average SWH system for domestic water heating use for a family in Mexico (150 litre tank and 2-3 m^2 of panels) would cost about US$800-900. Depending on family size, one may need a tank holding more water or more m^2 (e.g. 200 litres or $4m^2$)[74]. This is consistent with other studies, such as Torres and Gomez, which state that in Mexico, generally flat solar collectors cost about US$ 242 per m^2 installed (2006: 62). This is generally considered to be on average, or a little higher, than the average costs for this technology globally (Hoyt et al. 2006: 2).

In Mexico, one can find many types of solar water heaters, from sophisticated systems that force water circulation, to ones that use natural circulation to move water, including cheaper, more simper versions of SWHs[75] – according to Ubaldo Inclan of

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[73] This is the average number based on information provided by key informants when in Mexico. However, even within certain types of SWHs, the price range can vary greatly.
[74] Interviews, five SWH companies, November 2005 – January 2006
[75] Interview, one SWH company, November 2005

SENER, "the differences in prices [for SWHs] is enormous"[76]. It is difficult to say which material for SWHs is the most popular in Mexico after interview discussions and consulting the literature. A number of interviewees noted that plastic (whether covered in a glass panel or uncovered), because it was the cheapest, was the most popular form of SWH[77]. However some informants indicated that the traditional type made from copper and covered with a glass panel was the most popular[78].

Imported technology (hardware), mainly finished products but some components, consists of about 70% of the SWH market, although national production is increasing[79]. According to Mexican energy expert Odon de Buen, the majority of components for SWHs made domestically are from Mexico – although the copper used in certain forms of SWHs is from Chile[80].

To summarize, there is significant variation with respect to SWHs in Mexico – ranging from differences in price, style, size, materials used and origins of the hardware. General trends include the fact that this technology is steadily increasing in use within the country but that when compared to other developing countries with similar climates, the adoption rate is rather low. While the above is important to provide context, the chapter will specifically turn to SWH use in Mexico City.

4.3.5. SWH Equipment Use in Mexico City - According to a number of informants engaged in this sector, the above pattern of market segments for SWH use in Mexico (e.g. percentage of SWHs used in commercial processes, homes) in Figure 4.1 is similar in Mexico City[81]. In Mexico City, like the rest of Mexico, SWHs can generally be divided into two groups – a) those of plastic, either uncovered or covered by glass (imported or locally-made) which are used to generate lower water temperatures, often used to heat swimming pools (around 25-30 degrees Celsius); and

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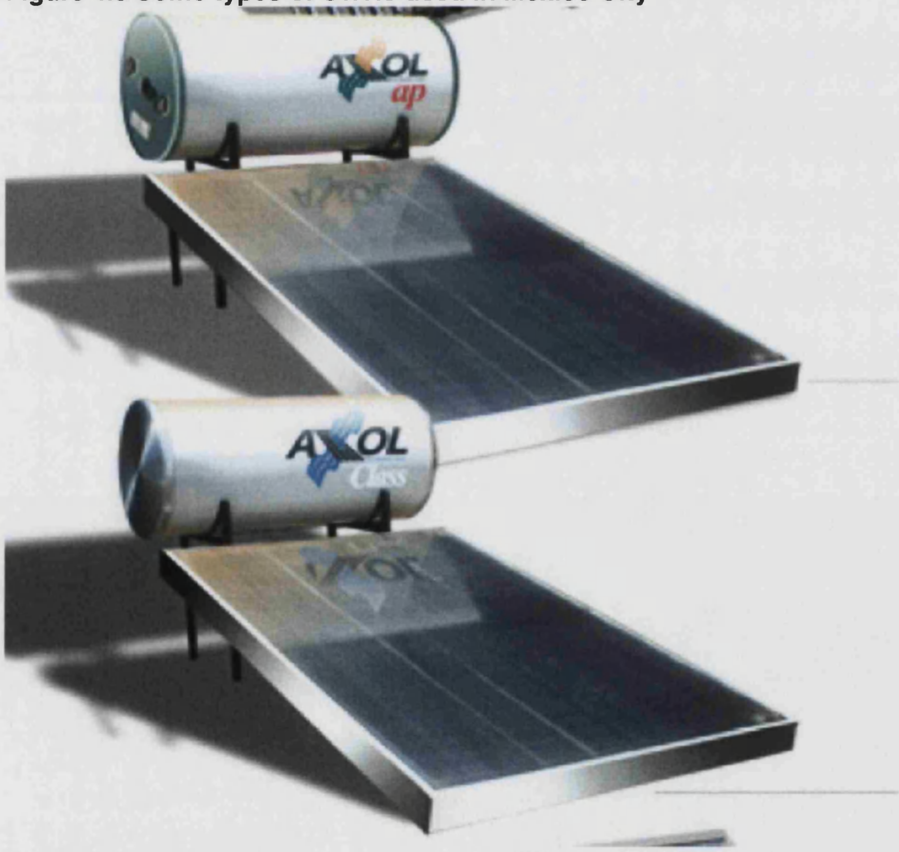
[76] Interview, one government representative, November 2005
[77] Interview, three SWH companies, November and December 2005
[78] Interviews, one university representative, two SWH companies, November - December 2005
[79] Although respondents were aware that I was defining technology as both hardware and software, here they are referring to physical equipment. Interviews, one SWH company and one government representative, December 2005
[80] Interview, one consultancy, January 2006
[81] Interviews, three SWH companies and one organization, November and December 2005

b) those made from copper, aluminum, glass tubes, among other materials, often covered with glass, made to generate higher water temperatures (e.g. around 70 degrees Celsius), used in industrial / commercial processes, or other uses (e.g. hot water use for hotels / hospitals / etc.) on a large scale. Some plastic SWHs that can reach temperatures of 40-48 degrees without problems were also included in this group[82].

In terms of style of systems used in households in many developing countries, SWHs can be characterized three ways – namely, a basic version in which the storage tank and heat collector are integrated, a version in which the tank (which is insulated therefore allowing for hot water in the evening and on cloudy / cooler days) and panel are adjoining, and a third version in which the heat collector is separate from the storage tank, also insulated (Milton 2004). In Mexico City and the surrounding areas, the second version is often used (where the tank and solar panel are adjoining).

Figure 4.3 Some types of SWHs used in Mexico City



Source: Modulo Solar, Cuernavaca, Mexico. The top one uses copper piping, while piping in the bottom one is made up of an alloy made from aluminum.

[82] Interviews, 13 SWH companies, and one consultancy, November 2005 – January 2006

It was difficult to determine what percentage of the Mexican SWH market Mexico City represents, as official statistics do not exist at present. For this reason, a number of methods were used to calculate the amount. With respect to statistics at the national level, ANES indicated that in 2006, 840 000 m^2 of SWHs were used nationally. A high level statistic was used because figures for Mexico City from other studies do not provide enough information. For example, Weiss et al., who did a global study of SWHs, representing about 85-90% of the SWH market in 2001 (2004: 4), have figures for the Mexico City SWH market for single family homes and larger institutions but only those SWHs for hot water or bathing, i.e. not pools. They indicate that the Federal District represented 28% of the market for single family SWHs and 72% of the market for multifamily or industrial-scale SWHs in 2001 in Mexico (2004: 30-31). However, it is not clear how much of the SWH market for pools (which is about 75% of the overall SWH market in Mexico) is in Mexico City.

In order to calculate the approximate amount of metres squared of SWHs in Mexico City, I used ANES' number of approximately 840, 000 m^2 in 2006. As noted previously, discussions with key informants indicated that SWHs for houses range from about 1 - 10 % of the overall SWH market. However, the amount of SWHs used in houses in Mexico City is only for single-family dwellings. For this reason, I will estimate that 5% of SWHs are used in single-family dwellings in Mexico, rather than numbers at the higher end of this range. Assuming 5% then, the number of SWHs for residential use in Mexico in 2006 was about 42 000 m^2 and Mexico City is 28% of this number, or about 11 760 m^2 for SWHs for one family dwellings.

Respondents indicated that SWHs for pools represent between 70-80% of the SWH market. Using a number in the middle of this range, or 75%, this would be equal to 630 000 m^2 in 2006. It is difficult to determine exactly how many metres squared for pools are in Mexico City, as there is no official number. Numerous inquiries to determine a ballpark figure did not reveal confident results. I was told that the majority of SWHs for pools in Mexico are in the Cuernavaca, Acapulco and Cancun areas; Mexico City represented a smaller portion of this market. So, using a range of between 10 – 20% of this 75%, one could estimate that there were about 63 000 - 126 000 m^2 of SWHs for pools used in Mexico City in 2006.

Interviewees indicated that SWHs for commercial and / or industrial purposes make up the rest of the SWH market. Including SWHs used in multifamily dwellings, this would represent about 20% of the SWH market in Mexico. In 2006, this would be 168 000 m^2 and Mexico City is about 72% of this number, or about 121 000 m^2. Therefore, in total, it is estimated that there were approximately 144 500 m^2 of SWHs not including pools in Mexico City, or between 207 500 m^2 - 270 500 m^2 including pools in the Federal District, as of the end of 2006.

The latest accurate data on the population of Mexico City is from the Mexican National Institute of Geography Statistics and Computer Science, or Instituto Nacional de Estadistica Geografia and Informatica (INEGI) in 2005, states that the population of the city was a little under 8 721 000 in order to determine m^2 / 100 inhabitants. Using the same calculations shown above, and using a population figure of about 9 million for Mexico City in 2006, it was determined that there were approximately 1.6 m^2 / 100 inhabitants (not including pools) in Mexico City, or 2.3 – 3 m^2 / 100 inhabitants using SWHs, which, is significantly higher than the national average of 0.8 m^2 / 100 inhabitants using SWHs.

Table 4.2 Estimates of SWH Use by Market Segment in Mexico City - 2006

	Market Share Nationally	**Market Share in Mexico City**	**Amount of SWHs used in Mexico City (m^2)**
Residential (single family)	5%	28%	11 760
Swimming Pools	75%	10-20%	63 000 - 126 000
Commercial / Industrial or Residential (multifamily)	20%	72%	121 000
TOTAL			207 500 - 270 500

Source: Author, based on assumptions indicated above

In sum, depending on the assumptions made when determining the percentage of the SWH market in Mexico City, the majority of SWHs used in this region, measured by m^2, are used to heat swimming pools. These SWHs often made from black plastic panels and plastic tubing, versus a glass plated aluminum panel and copper tubing, or glass vacuums also covered in glass, are generally cheaper, making them an attractive option for many Mexicans. This finding – that cheaper versions of RETs would be more widely used in developing countries -- is similar to those studies on SWHs and other RETs that emphasize price as a critical factor affecting adoption (e. g. Matajs and Rodrigues 2005: 7; Nahar 2002: 623, Iniyan and Jagadeesan 1997: 316, among others).

The next largest segment of the SWH market in Mexico City is the commercial and industrial sectors, ranging from about 58% to 44% of the market in the Federal District, depending on the assumptions made regarding SWHs for pools. These findings are consistent with those studies on RETs that focus on the need for financing options to encourage RET adoption (Matajs and Rodrigues 2005: 9; Painuly 2001: 79), especially for residential use, as the industrial and commercial sectors often have more access to capital and credit, especially in developing countries.

However, when these figures that have been broken down into market segments are compared with another location, these findings become interesting. As will be shown in Chapter 5, they are **significantly different than those results on SWH use in São Paulo**, another mega-city in Latin America with similar traits such as percentage of population with disposable income available to purchase a SWH at current prices and the credit available to the commercial and industrial sectors.

4.3.6. SWH market growth in Mexico City – Representatives from a NGO, the government and a consultancy also noted that there is a large potential for the SWH market to grow in Mexico City[83]. Previous studies also confirm this potential. For instance, as noted earlier, a 1998 comprehensive study on the possibility of using SWHs for residential hot water use in Mexico City indicated (using data from the Mexican INEGI 1992 survey) that "private houses where the family income exceeds four minimum salaries accounted for 47 percent of the total number of dwellings [in the Metropolitan Area of Mexico City]; these are considered [as having] sufficient income to invest in a solar water heating system" (Quintanilla and Mulas 1998: 3). In Quintanilla and Mulas' (1998) study they did not include the possibility of SWHs substituting gas heaters in apartment buildings in MAMC. Other studies indicated that urban, wealthier Mexicans are considered to be one of the top potential market areas for SWHs in the country (Ferrel-Mendieta 1999: 68). Similar to market trends in Mexico, some saw market growth for SWHs in Mexico City occurring in all areas – pools,

[83] Interviews, one NGO, two government representatives, one consultancy November - December 2005

industrial and commercial applications, and residential applications[84]. Others predicted growth would occur more in SWHs for industrial or commercial applications[85].

The final aspect regarding the SWH market to be considered is the climate in Mexico City. The amount of savings of a SWH can provide in Mexico City vis-à-vis a fossil fuel counterpart are less than in other parts of the country (e.g. Cuernavaca, Acapulco). For instance, Jorge Davila, of the SWH company Sunway, noted that plastic SWHs (generally used to heat swimming pools) would only provide 35% of savings versus using their fossil fuel counterparts in Mexico City. Solar panels made from copper and covered in glass would provide up to 80% of savings in Mexico City, rather than 90% of savings in other places with a warmer, sunnier climate in Mexico versus using their fossil fuel counterparts.[86] Another SWH company representative also pointed out the differences in efficiency, thus providing a variety of temperature ranges, between Mexico City (water temperatures up to 30 degrees Celsius) and Acapulco (water temperatures up to 90 degrees Celsius) using the same SWH.[87]

Some informants avowed that one is not likely to rely on a SWH to heat their water year round. Specifically, there are periods where there is rain during afternoons (the rainy season is from about June - September in Mexico City), and there is also a "cold" season in Mexico City (generally considered December – February). Because of these seasons, one would likely need to have a "back up" system (e.g. LPG or natural gas)[88].

Although some other studies indicate the same (see Ferrel-Mendieta 1999), a survey on the potential for SWHs conducted in two Federal District neighbourhoods in 1989 by the National Institute of Funds for Workers' Housing or Instituto del Fondo Nacional para la Vivienda de los Trabajadores (INFONAVIT), the largest public mortgage lender in Mexico, showed that 97% and 90% of respondents supported the use of SWHs in those locations, while only 3% and 10% of respondents did not support SWHs for various reasons; the main one being the need for a gas water heater during the cold season (Quintanilla et al. 2000: 48).

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[84] Interviews, three SWH companies, November – December 2005
[85] Interviews, one SWH company, one university representative, one government official, December 2005
[86] Interview, one SWH company, December 2005
[87] Interview, one SWH company, January 2006
[88] Interviews, two government officials, November – December 2005

Detailed information regarding how often this back up would need to be used was unavailable. Quintanilla's study showed that in the worst month for SWHs in Mexico City (December) the SWH systems of all of the seven SWH producers interviewed could provide a maximum of 60 litres per person per day of water greater than 50 degrees Celsius if four panels were used (using one or two panels would only yield a maximum of 15 to 32 litres per person per day of water – indicating the need for a back up in this time period) (Quintanilla et al. 2000: 134). Alternatively, one could purchase a sophisticated SWH (e.g. like those models common in colder climates like northern Europe and Canada) (very expensive for many Mexicans)) to heat their water.

4.4. SWH Use in Mexico and Mexico City – the software

In addition to "hardware" other forms of technology use were examined. These include knowledge and processes – also known as the "software". As noted in Chapter 3, other studies use proxies such as research and development (R&D) expenditure, number of researchers, patents and types of patents to measure technological knowledge and processes. In the case of SWHs in Mexico City, research and development expenditure, as well as number of researchers working on SWHs was difficult to determine quantitatively, due to a lack of availability of data. Companies generally did not have an allocated budget for R&D, nor specific staff or staff time devoted to R&D, but incremental innovations were occurring, mainly with respect to the production process, over time[89]. Other organizations, such as governments and universities, were unable to provide a specific figure for budgets, although some were able to provide an approximation of staff.

Another proxy used to "measure" knowledge is through patents or types of patents as noted in Chapter 3. However a number of interviewees indicated that there were no formal patents in Mexico on the SWH technology[90], making this indicator difficult to determine. According to one university representative, the technology is in the public

[89] Interviews, two SWH companies, and informal discussions November – December 2005
[90] Interviews, two SWH companies, one university representative, November – December 2005

realm[91]. Another source noted that the technology is simple[92], making it difficult to have a patent in place. This is not to say that informants were not concerned about Intellectual Property Rights (IPRs) and other propriety issues involved with their technologies – something that will be explored further in Chapter 8, when the effects of trade and competitiveness policies on the adoption of these technologies are assessed.

In addition, as noted in Chapter 1, the problem with using these proxies as ways to measure knowledge is that they do not account for the distinction between just information (e.g. number of patents applied for and received, R&D dollars) and knowledge (information and how this information is processed and interpreted). While recognizing these limitations, one way to measure the software is to examine those organizations working on SWHs in Mexico City.

4.4.1. Organizations working on SWHs in Mexico City

There was a general consensus among stakeholders that the main organization undertaking capacity building efforts for solar energy in Mexico and Mexico City is ANES[93]. This organization, which has been in existence since 1980[94] undertakes various activities, including coordinating yearly conferences and providing intermittent workshops and seminars to discuss developments in solar energy, their applicability to Mexico, etc.)[95].

In addition to ANES' activities, many informants spoke about the networks that ANES had built up over time and were maintaining between industry and academics, and more recently, their engagement with the government – especially at the local level in Mexico City. In addition, respondents indicated that dynamics within ANES were influencing SWH use in that city and country in a positive way. They specifically indicated that in the past, key positions in ANES were taken up by academics, but that recently the organization was incorporating more industry representation into the NGO,

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[91] Interview, one university representative, November 2005
[92] Interview, one consultancy, December 2005
[93] Interviews, three university representatives, one NGO, three consultancies, three government representatives, three SWH companies, November 2005-January 2006
[94] However, the first meeting of specialists working on renewable energy in Mexico – which formed the basis for ANES - took place in 1977 (ANES 2007)
[95] Interviews, one NGO and one SWH company, December 2005

not only academics. Because of representation from both the academic and industry communities, the NGO's actions were viewed as being more 'in tune' with what was needed to encourage adoption – e.g. not only seminars focusing on cutting-edge lab research in Mexico and elsewhere, but particularities – including opportunities and challenges -- of the Mexican SWH market.[96]

Another more recently created organization working on renewable energy, operating out of Cuernavaca, is the Association of Renewable Energy Suppliers, or la Asociacion de Proveedores de Energias Renovables (AMPER). This organization is a trade association. However, only two respondents mentioned AMPER[97], which is quite new (officially created in October 2004) and its main activities are centred on photovoltaic energy[98]. Other organizations working on SWHs in Mexico City are the consultancy firms ENTE and CYSTE.

In and around Mexico City, formal capacity building efforts also includes those regarding technological development on renewables, which mainly occurs through various universities. In addition, the Electricity Research Institute, or Instituto de Investigaciones de Electricidad (IIE) in Cuernavaca, an arms-length organization created by the federal government in 1975 also conducts research on RETs in Mexico, although they conduct little work on SWHs[99]. With respect to solar thermal technology, there are a number of key universities in and around Mexico City that conduct work on Solar Water Heaters. These are the Universidad Nacional Autonoma de Mexico (UNAM) – particularly its Centre for Energy Research, or Centro de Investigaciones en Energia (CIE) in Cuernavaca and its Engineering Institute and Observatory for Solar Radiation, Geophysical Institute in the Federal District; the Universidad Autonoma Metropolitania (UAM); and the Iberoamericana University. In addition, the Instituto Politicnico Nacional (IPN) also works on SWHs (15 people), including running various tests on SWHs through a laboratory. Government institutes working on SWHs in Mexico City include SENER (1 person) and CONAE (2 people),

[96] Interviews, one NGO and four SWH companies, November-December 2005
[97] Interviews, one consultancy and one SWH company, December 2005
[98] The organization works to certify companies that sell photovoltaic energy in Mexico, as well as to promote renewable energy in schools and universities (CONAE 2005).
[99] Personal Communication, one research institution, November 2005 and October 2007; Interviews, four university representatives, and one government representative, November - December 2005

and a number of people within the Secretary of Environment of the Federal District[100]. More recently the German aid agency, GTZ and the consultancy, Econergy Mexico have become involved in SWHs in Mexico. The Global Environment Facility (GEF) also has a global SWH project, of which Mexico is one of the case studies. The aim is to have 2.5 million m^2 of SWHs installed by 2011.[101] Having said this, the majority of capacity building regarding solar energy occurs through experience gained on the job[102], also termed learning by doing[103].

But, one factor hindering the use of this technology in Mexico City and the country is the fact that there is no school in place to certify potential developers, producers, and / or installers of SWHs in Mexico. In fact, in Mexico, there is no government-run, national-level certification program or school available for people to develop, produce and / or install SWHs[104]. Sources from the private sector, universities and a consultancy indicated that people are certified through individual companies which provide courses / training, or not at all. Other organizations that provide courses on solar energy in Mexico are ANES and AMPER and SYS-CON but these last two mainly focus on photovoltaics (PV)[105]. One company highlighted a course on SWHs and solar energy in Spain[106]. People were concerned about this as they felt that without at least one national school and / or –accredited nationally certification program on SWHs, there was no common vision to rally around and / or critique. Others noted that no certification program or government-sanctioned standards program opened the door to bad quality products on the market.

[100] Interviews, six university representatives, and four government officials, November – December 2005
[101] Personal Communication, UNEP representative,, Lebot, B. (2006). Information regarding global SWH project at GEF. New York and confirmed (GEF), G. E. F. (2008). "UNDP/UNEP Solar Water Heating Market Transformation and Strengthening Initiative - Mexico." Retrieved September 16, 2009, http://www.thegef.org/uploadedfiles/07-01%2008%20ID2939%20Global%20SWH%20Final.pdf
[102] Interviews, two university representatives and two SWH companies, November – December 2005
[103] Learning by doing is when producers, through experience, are able to carry out activities using less time, resources and energy (This concept comes from Kenneth Arrow's work on endogenous growth theory, recognizing that firms also innovate internally, Cortright, J. (2001). Reviews of Economic Development Literature and Practice: No. 4. U. S. D. o. Commerce. Portland, OR, Impresa Consulting: 1-40.: 23).
[104] Interviews, two SWH companies, November - December 2005
[105] Interviews, three SWH companies, two university representatives, one consultancy, November-December 2005
[106] Interview, one SWH company, November 2005

Chapters 7 and 8 explore the reasons behind this lack of coordination – which are traced to three factors – the nature of these relationships between stakeholders, dynamics within stakeholder groups, and trade and competitiveness policies.

In sum, the SWH market in Mexico City is increasing, and at 1.6 m^2 / 100 inhabitants or 2.3 – 3 m^2 / 100 inhabitants, it is higher than the national average of 0.8 m^2 / 100 inhabitants in 2006. Compared to other countries with similar climates and populations, both the national average and Mexico City's average are rather low. Many different types of SWHs are available – consisting of a wide range in price, materials and layout. Characteristics of SWH use in Mexico City – that cheaper versions of the technology are more prevalent in general, and that those with more capital available to them (businesses, hospitals, sport institutes, etc.) are using SWHs more than households are similar to classical explanations of RET use in the developing world. However, when compared with results for São Paulo in Chapter 5, these findings become very interesting and some factors affecting uptake do not fall into these conventional explanations.

Regarding the 'software', with about eleven organizations (including three government agencies) actively working on SWHs in and around the context of Mexico City, an active group of players exists, attempting to increase the use of this technology in the Federal District. Informants indicated that ANES was by far the most effective and active champion for SWHs in the city and country, and that internal dynamics were beneficial to their use. On the other hand, respondents were concerned about the lack of Mexican courses, schools and certification programs in this area. Chapters 7 and 8 – using two systemic frameworks -- explore why this is the case.

How does this situation compare with that of another RET deemed viable for Mexico City - biogas to generate electricity? Section 4.5. examines this RET.

4.5. Biogas Use to Produce Electricity in Mexico and Mexico City – the hardware

Another potential renewable energy source for urban areas in Mexico is biogas. Specifically (as noted in Chapter 1) the RET examined is the production of electricity through landfill gas. This technology was chosen based on previous research done in this area, arguing for its potential. For instance, using municipal solid waste (MSW) to produce electricity from the ten main cities in Mexico (which includes Mexico City), "could lead to the installation of 803 MW and generate 4, 507 MWh/year" (Torres and Gomez 2006: 65). Representatives from the private sector and government indicated that this technology is attractive in Mexico and Brazil, as well as other developing countries, due to the make up of waste in many of these countries, which consists of a higher organic to inorganic ratio.[107]

4.5.1. Biogas to produce electricity equipment use in Mexico

At the time of writing, there was only one biogas to produce electricity project up and running in Mexico. This project produces about 7 MW of electricity. It is located in Monterrey, Mexico, and was established through partial funding from the Global Environmental Fund (GEF) of the World Bank. Sistemas de Energia Internacional S.A. de C.V. (SEISA) is the company that implemented the project along with the municipality of Monterrey. The idea of this project is to serve as a pilot in order to replicate this endeavour in other parts of the country[108]. As of late 2007, there were four landfill gas to energy projects in the CDM pipeline managed by Ecosecurities and another five in the development stage proposed by other companies.[109] In the Monterrey project, the equipment used is foreign (motors to generate electricity which normally use natural gas, diesel, or some other fuel, which are adapted to use biogas as a fuel); however Mexican expertise is utilized[110].

4.5.3. Biogas to produce electricity equipment use in Mexico City

[107] Personal communication, interviews, two biogas company representatives and one government official in Mexico, December 2005-January 2006 and one government official and one engineering consultant in Brazil, March 2006
[108] Interview, one government representative, December 2005
[109] Personal Communication, one research institution, October 2007
[110] Interviews, two biogas companies, one government representative, December 2005 – January 2006

Informants confirmed the viability, in technical terms, of this RET as an option to produce electricity for Mexico City, although to date there is no project. Discussions with these experts indicated that any biogas to electricity project in Mexico City would likely be similar to the Monterrey project – namely a joint effort between foreigners and Mexicans, using foreign hardware (the Swiss and Dutch have expertise, and a Canadian company was also identified) and foreign and domestic knowledge and processes[111].

4.6. Biogas Use to Produce Electricity in Mexico and Mexico City – the software

Like SWHs, it is important to examine the "software" involved in biogas from solid waste to produce electricity. In addition to the problems noted earlier with equating information to knowledge, there were other problems involved with using proxies used to measure knowledge by other studies. For instance, research and development (R&D) expenditure and number of researchers – when it was occurring -- was very difficult to determine as this was mainly occurring abroad. In addition, companies were unwilling to share this information. Other sources conducting studies did not have this information available. Also, patents were deemed inappropriate indicators to measure knowledge of this technology in Mexico City as the patents are foreign[112].

4.6.1. Organizations working on biogas to generate electricity in Mexico City

With respect to number of organizations working on this technology, at present, the companies Ecosecurities and MGM International are interested in exploring this potential in Mexico City and so were starting to conduct studies.[113] In addition, several government agencies, such as Environment and Natural Resources Secretariat or Department, or Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT), and National Institute of Ecology, Instituto Nacional de Ecologia (INE) (within

[111] Interviews, one consultancy, two biogas companies, five government representatives, November 2005 – January 2006
[112] Interviews, two biogas companies, four government representatives, November 2005 – January 2006
[113] Interviews, two biogas companies, December 2005 - January 2006

SEMARNAT), the Energy Secretariat or Department, Secretaria de Energia (SENER) and the National Commission to Save Energy, or Comision Nacional para el Ahorro de Energia (CONAE) (within SENER) are also conducting studies on the possibility of this technology within the country, of which Mexico City would be a part[114]. In addition, the government sponsored research institution, the Institute of Electricity Research, or Instituto de Investigaciones Electricas (IIE) is conducting a study on this possibility in the Federal District[115]. However, there is little knowledge amongst the general public of this technology in Mexico, let alone technical personnel available to work on this area[116].

There are a number of companies such as Ecosecurities, MGM International, Conestoga, Biotermica, among others[117], conducting studies regarding the potential for landfill gas in Mexico. Most of these companies are foreign or a subsidiary, but there are also a few Mexican or joint foreign and domestic ones. Some of these studies are assessing the possibility of generating electricity through biogas. However, the majority are assessing the potential to flare one of the main by-products of landfill gas, methane, so it is converted into CO_2 before being released into the atmosphere, which, as noted in Chapter 1, is 25 times less harmful in terms of global warming potential (IPCC 2007).[118]

Although this facet did not come up often, interestingly, in contrast to a number of studies examining biogas, such as some in Asia, where generating electricity rather than carbon credits was more important (see Forsyth 1999 and 2005), some informants indicated that because of the structure of the electricity market in Mexico (monopolized by government-run agencies with some opportunities for Independent Power Producers (IPPs) to sell electricity to the CFE but at terms considered unfavourable to investors and plagued by permits, various forms and subsequent delays) these types of projects (i.e. those to generate electricity rather than just flaring methane) were too cumbersome

[114] Interviews, four government representatives, November 2005 – January 2006
[115] Personal Communication, one research institution, November 2005 and confirmed in October 2007
[116] Interviews, two biogas companies, December 2005 – January 2006
[117] Interview, one biogas company, January 2006
[118] Some consider methane flaring to be a "low hanging fruit" or those projects, which are the most economically viable, but may not have the greatest environmental or social benefits Muller-Pelzer, F. (2004). the Clean Development Mechanism. HWWA Hamburg Report. Hamburg, Hamburgisches Welt-Wirtschafts-Archiv (HWWA) - Hamburg Institute of International Economics: 27). However, this thesis specifically looks at biogas to generate electricity.

and too costly to interest investors. That said, I did not find any NGO or community group working on this issue in Mexico City at the time of research (2005-06) despite various prodding of informants working on biogas technologies, or working on environmental and climate change issues more generally.

To summarize, this technology is relatively unknown in Mexico City, although the landfill gas to energy project in Monterrey is starting to become known amongst technical experts within the country. There is increasing interest in biogas for electricity as a potential energy source for urban areas (although methane flaring remains the principal area of interest) and so a number of companies – mainly international – are exploring this possibility in the country and within the Federal District. It was stated by both private sector and government representatives that the major impetus for these companies getting involved, as well as piquing the interest of the municipal government, is due to climate change – they see it as a way to obtain carbon credits through the Clean Development Mechanism (CDM). Thinking on this however was sparse on specifics as examples of who would sell or purchase these credits were hypothetical (e.g. the municipality and / or the landfill owner or industrialized nations).[119] However, as noted above, there are no biogas to energy projects up and running in Mexico City at the time of writing (2009) – although as noted in more detail in Section 4.8, there are more recent plans to undertake some biogas projects. The reasons for this are explored in Section 4.8 and also examined further in the subsequent chapters, when we explore the "why" involved in technology adoption for RETs in urban Latin American settings. To begin this task, we will turn to results regarding why SWHs and biogas for electricity are or are not being used, based on evidence from Mexico City.

4.7 Factors Affecting SWH Use in Mexico City

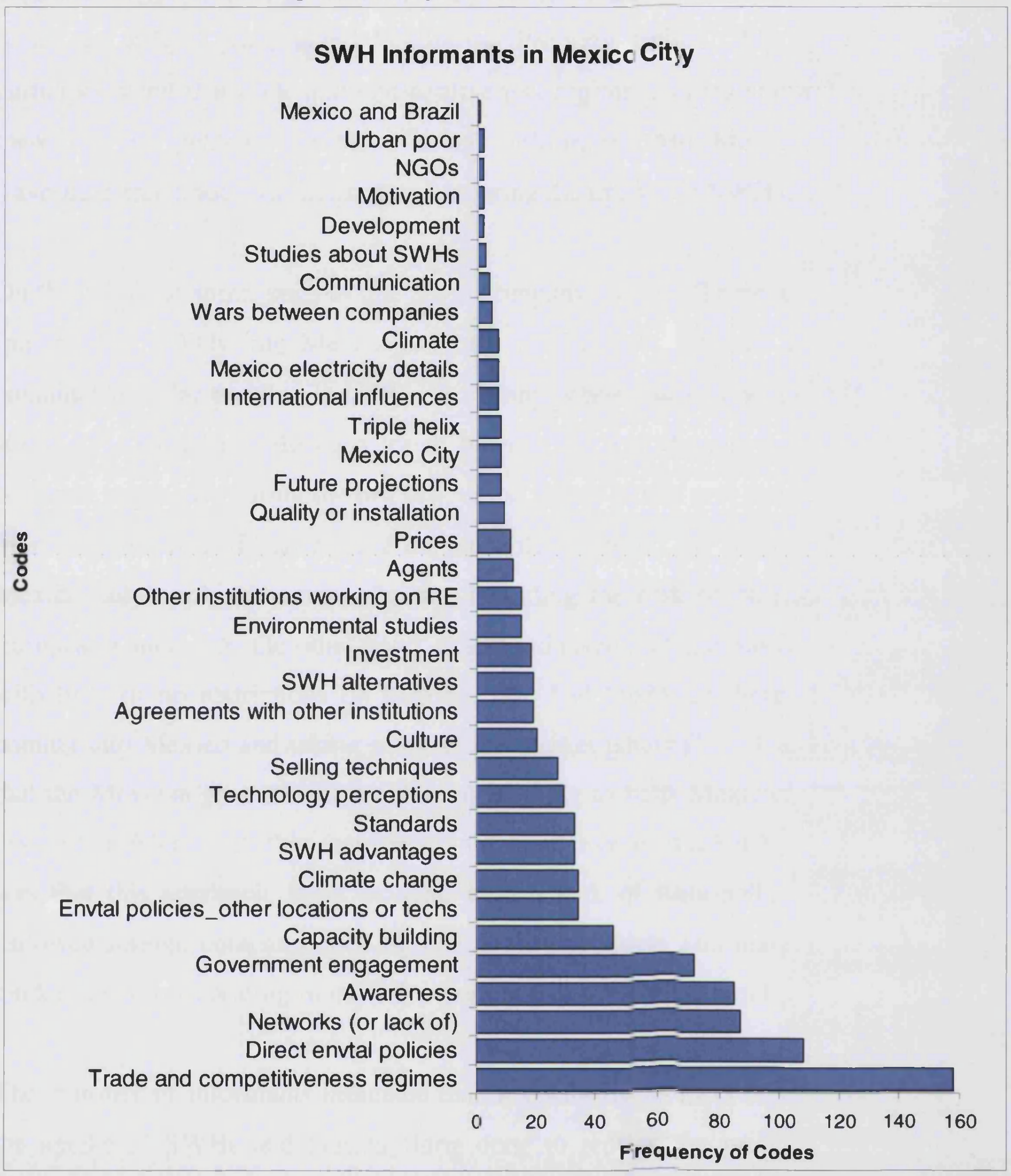
To help ascertain which factors had the most impact on the use of SWHs and biogas to produce electricity in Mexico City, I turned to Atlas ti, a computer assisted qualitative

[119] Interview, one government representative, November 2005 and two biogas firms, December 2005-January 2006

data analysis software (CAQDAS) program, as discussed in Chapter 3. Codes were themes identified by respondents, with some based on predetermined topics to serve as guideposts, during the discussions. As noted in Chapter 3, after transcribing the interviews, I came up with about 30 or so pre-selected codes based on my research questions and the themes that came up consistently during the interviews. From there, I coded the interviews manually using these pre-selected codes, as well as adding further codes revealed when going through the textual information thoroughly again when coding versus transcribing. The final step was amalgamating some codes, which spoke about similar themes. For example, I originally had separate codes for patents and taxes on imported products and services, then I grouped these together into "trade and competitiveness regimes".

The graph below represents the frequency that processes were discussed by informants – namely those factors having an impact on the uptake of these RETs. It is important to point out that these codes do not respond to a 'per person' basis. In other words, if one person spoke about various aspects of trade and competitiveness policies six times, then the frequency was noted as six for that person, and not one. While recognizing that people will tend to emphasize and come back to certain themes more than others, these responses were scrutinized thoroughly to ensure that the themes presented represented a broader view (i.e. that a number of people shared this view, rather than – say -- one overly enthusiastic policy maker promoting their specific policy or program, thus mentioning direct environmental policies 34 times). (See Tables 4.3 and 4.4 for responses on a per person basis for the four code families noted in Chapter 3 – Conventional approaches, Rogers' diffusion of innovations, urban technology cooperation and trade and competitiveness regimes).

Graph 4.1 Factors Affecting SWH Adoption in Mexico City



Source: Author, Atlas ti analysis, July 2008, updated August 2009

As noted in the graph above, themes identified by respondents ranged from trade and environmental policies to motivation and the urban poor. This chapter on findings will explore the most prevalent themes affecting the uptake of these RETs, as identified by key informants.

The most frequent theme noted by respondents was **trade and competitiveness regimes**. Specific topics identified include privatization, joint ventures, taxes, whether the technology was foreign or domestic, as well as the role of customs, transportation issues, as well as patents and Intellectual Property Rights (IPRs). Although many participants felt that trade and competitiveness regimes played some role on adoption, there was no general consensus among informants that Mexico's current regime (favouring free trade) was helping or hindering the uptake of SWHs.

On the one hand some, such as one SWH company, noted, "There are no restrictions on imports [for SWHs into Mexico]...I call my friend in Florida and he sends me a container of solar panels via UPS".[120] Many echoed this view such as another who stated, "NAFTA has reduced a lot of barriers for exports and imports within North America, especially during the last few years. [Now tariffs are] practically 0%; nothing more than the cost of transporting the technologies here".[121] These lack of tariffs into Mexico only apply to certain regions, including the rest of North America and the European Union. On the other hand, others indicated that the SWH market in Mexico, with little or no restrictions on imports, also had "risks as there are big companies coming into Mexico and taking more of the market [share]"[122] Those of this view felt that the Mexican government was "doing nothing to help Mexican companies"[123] and that one problem with this easy entry into the Mexican market by foreign companies was that this approach, hand in hand with a lack of nationally certified standards, "allowed foreign companies selling bad quality products and installations"[124] into the market, therefore creating more bad experiences among actual and potential users.

The majority of informants indicated that any subsidy to LPG or natural gas hindered the uptake of SWHs and that anything done to reduce the price of SWHs, whether purposely or inadvertently (e.g. reducing tariffs from foreign finished products and / or components following trade liberalization) would increase SWH use in Mexico City. In addition, domestic companies highlighted the fact that they were "a Mexican company making Mexican technology".[125] Foreign companies too were quick to point out their local expertise – e.g. making adaptations to the installation to make it suitable

[120] Interview, one SWH company, November 2005
[121] Interview, one SWH company, December 2005
[122] Interview, one SWH company, November 2005
[123] Interview, one SWH company, December 2005
[124] Interview, one SWH company, December 2005
[125] Interview, one SWH company, December 2005

for Mexico City[126], and their efforts to create a Mexican production factory, using 90% of Mexican components[127]. A prevalent view was that the Mexican SWH industry "has a strong national component but companies need to take advantage of all technologies".[128]

This theme, the most prevalent, is particularly interesting as it falls outside the five classic explanations for RET use or a lack of use in other developing country studies as indicated in Chapter 1 (high cost of RETs, little financing options available, technical problems, lack of awareness and institutional issues, such as infrastructure favouring non-renewables), stressed by conventional models.

The second most prominent theme identified was the role of **direct environmental policies**; or, those policies put in place for the purpose of increasing the uptake of renewable energy sources – either generally but which could include SWHs, or policies targeting this RET in particular – which were deemed influential in increasing, or decreasing, the adoption of these RETs. In the case of Mexico City, these were government policies at the municipal and federal levels. A subset of this theme identified was **climate change**. Related to this area were **environmental policies in other locations or for other renewables**, where respondents noted success stories or failures with other RETs or in other settings.

Many informants spoke about work being done to promote renewables and / or specifically Solar Water Heaters, such as discussions for the Law for the Advancement of Renewable Energy Sources in Mexico, Ley para el Aprovechamiento de las Fuentes Renovables de Energía (LAFRE) (which was passed November 28, 2008). Another program noted is one by the National Commission to Save Energy, or Comision Nacional para el Ahorro de Energia (CONAE) in Spanish, an arms-length organization of the Mexican Ministry of Energy, begun in 2002, to promote the sale of SWHs in homes. However, there was a broad consensus among stakeholders that the challenge with this program appears to be a lack of promotion, a change in leadership within CONAE and little coordination amongst the public, the government and the private

[126] Interview, one SWH company, December 2005
[127] Interview, one SWH company, November 2005
[128] Interview, one consultancy, January 2006

sector. For instance, even if one manages to find out about the program (which due to little promotion was rare), one must express an interest in the program through the internet and wait for a response regarding a proposal to install a SWH in their home. However, when a response is received, it is often very complicated and onerous (e.g. the potential user had to calculate their current energy usage and expenses), and unclear – thus, not making this program very successful to date. Furthermore, there are no financial incentives provided to potential participants who must calculate the amount of natural gas or Liquefied Petroleum Gas (LPG) used and money spent per year in order to compare it with accrued savings through the SWH[129]. After the time of field research (2005/06), CONAE also created a National Solar Water Heating Program – Programa de Calentadores Solares de Agua (PROCASOL) in 2007, with funding from the GTZ, the German development agency, targeting industry, low income housing and buildings with the aim to increase SWHs to 1.8 million m^2 by 2012 (IEA 2008). Also, with the entry into force of LAFRE November 28, 2008, CONAE became the National Commission for Energy Efficiency, or Comision Nacional para el Uso Eficiente de la Energia (CONUEE).

Many stakeholders also highlighted the municipal government's requirement for Solar Water Heaters in the Federal District, which makes it mandatory for new buildings in the city with 50-100 or 100+ employees have 30% of their water heating come from SWHs. One of the main rationales for this program is climate change. The government estimates that by 2012, with the implementation of this law, that a little over 350 000 tons of CO_2 equivalent will be abated (Sheinbaum and Vasquez 2006). At the same time, representatives from the private sector, government, universities and consultancies reflected that these efforts were minimal (although an important step) and at the time of research some informants had never heard of these programs – or just barely.[130]

Federal government officials and consultants stressed that there were two goals for the Mexican government regarding the provision of electricity – 1) electricity for all

[129] Interviews with eight SWH companies, two government agencies and one consultancy, November 2005 - January 2006

[130] Interviews, 13 SWH companies, seven government representatives, five university representatives and two consultancies, November 2005-January 2006; Informal discussions, November 2005- January 2006

Mexicans[131] for socio-economic improvement, and 2) electricity for productive applications, so as, they argued, to also increase economic development for these communities. The focus on RETs in Mexico is principally on rural areas, where some RETs, including photovoltaics (PV) and wind, are more viable. One official gave an example about a project in a remote community in Tamaulipas, a northeast state in Mexico, which in addition to providing electricity to 40 families, also used electricity to refrigerate shrimp.[132] Some experts also spoke about the potential for CDM projects in this area, arguing that to make solar water heating into a viable CDM project, a number of projects would need to be bundled together, increasing the transaction costs; thus not many considered the CDM as a viable option at present. The potential for CDM is discussed further in Chapter 7.

Many other studies examining RET uptake in developing countries (e.g. Philibert 2006; Renewables 2004) also purport that direct environmental policies play a positive role on increasing adoption. These results are interesting because while in principle although people all agreed that these types of policies help encourage RET use, there were mixed views regarding their actual effectiveness in the case of SWHs in Mexico. Attention must be placed on how a policy is designed, managed and executed. Furthermore, these results indicate that direct environmental policies are only one factor affecting RET use. Other aspects often neglected, including systemic policies such as trade and competitiveness approaches, as well as networks also play an important role.

The third theme that respondents underscored was the role that **networks, or a lack of networks**, can have on the uptake of SWHs in Mexico City. One challenge with respect to the concept of networks is that "there has yet to be a common lexicon for studying the construct, leaving those who study networks with multiple definitions and a tangle of meanings" (Provan et al 2007: 481). Having said this, a number of common traits shared by most definitions include attention to "social interaction (of individuals

[131] As of late 2005, about 5% of the population did not have electricity, or 5-6 million people. Interview, one government official, November 2005
[132] Interview, one government official, December 2005

acting on behalf of their organizations), relationships, connectedness, collaboration, collective action, trust, and cooperation" (Provan et al. 2007: 481).

Some scholars take a more narrow approach, focusing on relationships between organizations. However networks are broader. Others also highlight this broader view, examining the relationships between nodes – whether those nodes be individual people, organizations, communities, etc[133]. It is important to clarify that the definition of networks will differ between contexts and actors. As this study centres on the meso-level, the core networks under scrutiny are those between and within stakeholder groups, rather than between individuals. Subsets of this theme also highlighted by respondents include agreements with other institutions, whether informal or formal, and **communication**. There are variations regarding the concept of communication, which can be verbal and nonverbal, but generally involves at least two people, organizations, or groups who share ideas, insights, information, etc. When referring to communication, people mainly spoke about interpersonal networks, although some referred to mass media channels – including the potential to increase awareness through newspaper, television advertisements, etc.

A number of interviewees noted that, generally speaking, there was a disconnect between companies, universities, and government institutions. Furthermore, even in the instances when these three groups did come together, the public remains outside of the technology cooperation process. In addition, although universities collaborated with other universities on solar energy, there was little collaboration between government institutions and companies. That said, these relationships are changing – for instance, as noted earlier the NGO ANES, run by academics in the past, was incorporating more industry representatives in their management committee. Also, at the time of study (2005-06), the municipal government was very interested and active in this issue and was establishing links between themselves, academics and industry. Since that time, personnel including the Secretary of Environment of the Federal District and many of her staff have changed (e.g. she left the position in 2006 to work on Andres Manuel Lopez Obrador's presidential campaign), so it is not clear how active the municipal government is in this area at the time of writing (2009).

[133] For a more thorough discussion on the debates regarding the concept of networks please see Provan et al. 2007

There was also a lack of communication within industry. Although the market was dominated by "technically simple" versions of SWHs, companies shared little information – jealously guarding and protecting their niches, and cooperating little with other companies and / or organizations. For instance, also linked to the first theme, trade and competitiveness regimes, some experts indicated that "fighting" occurred between Mexican SWH companies and foreign or local subsidiaries / distributors of foreign SWH companies, terming it a "war" between these groups[134].

Interactions done by companies with universities (if there was any) often consisted of providing information to interested students, attending fairs, or talking informally to a few professors[135]. Representatives from firms, the government and consultancies asserted that the research community involved in solar energy (small but strong) was out of touch with the problems faced by the Mexican population (e.g. those people with no access to hot water or no access to electricity (or only with poor quality electricity) often possess little income)[136].

Many SWH companies engaged with the end user only at the point of sale and often, for many companies, little action is taken after the sale for follow up – as one interviewee remarked "no news is good news." [137] This was confirmed through a number of informal conversations with final users, who noted that after purchasing a SWH there was little follow-up or guidance to ensure the user knew how to maintain the product, confirm it was working, etc. (e.g. no manual, presentation).[138] Some end users went further to express their dissatisfaction with their lack of engagement with those developing, producing and selling the technology. For instance, one hospital in Mexico City bought a large number of SWH panels in 1994 and claimed that they never worked and so they have always been using diesel to heat water for hospital use[139]. Another informant, extremely dedicated to energy and environmental issues,

[134] Interviews, one government agency and one consultancy, November 2005 and January 2006
[135] Interviews with five SWH companies, November 2005 – January 2006
[136] Interviews with seven SWH companies, two consultancies and one government agency, November 2005 – January 2006
[137] Interview, one SWH company, November 2005
[138] Only two SWH companies indicated that they followed up with clients at least once a year (Interviews, two SWH companies, December 2005).
[139] Informal discussion, one organization representative, January 2006

also noted that once he had a SWH installed at his house he was "left on [his] own…there were no follow up phone calls, maintenance checks, etc."[140]

While many conventional studies on renewables do not pay enough attention to networks, alternative technology adoption and innovation studies (e.g. Douthwaite 2002, Walter 2000) stress the importance of relationships, arguing that linkages can create understanding and trust. This theme is explored further in Chapter 7.

The fourth prevalent theme affecting the use of SWHs in Mexico City was **awareness**, amongst potential users about this technology – that it exists and / or can be an alternative to gas in order to heat water in Mexico City. There is no single agreed-upon definition for awareness, but generally people view it as knowing something exists, that something will happen, or has happened based on experiences they have had themselves or from others. Awareness also relates to different things including situations, behaviours, etc. Regarding technology, as indicated in Chapter 2, similar to Rogers (2003a), I view awareness as knowing that a technology exists, and also recognize that previous events, current trends, and perceptions can influence awareness.

According to respondents, not many people amongst the general public in the city and nation were aware of this technology, which had a negative impact on its use. This claim is similar to other studies (e.g. Quintanilla et al. 2000). A broad range of stakeholders including university representatives, the private sector and the government, noted however, that this technology was known amongst those with a technical background (e.g. engineers, government or academic researchers in engineering and / or the environmental and energy sciences)[141]. Furthermore, while only mentioned by one interviewee, informal conversations indicated that wealthier segments of the Mexican population were aware of SWHs.[142]

[140] Interview, one consultancy representative, January 2006
[141] Interviews, five university representatives, three SWH companies and two government officials, November 2005-January 2006
[142] Interview, one SWH company, December 2005; Informal discussions, November 2005 – January 2006

For instance, one SWH company stated that "people do not trust this technology because they do not know it [versus] gas technology, which they do know"[143]. Another company pointed out that SWHs were unknown – it was not like "Coca Cola, where everyone knows the product and the company that makes it"[144]. In essence, key informants claimed that although "people with technical skills [e.g. engineers] realize the advantages [of the SWH]", the Mexican public in general remains uninformed[145].

An important facet that some spoke under this theme had to do with the negative impact on SWH use that has occurred as a result of previous negative experiences with SWHs in Mexico City and elsewhere in the country. The main types of problems were technical in nature, including improper installation, inferior equipment, technical glitches, or being installed in improper environments, therefore being unable to deliver hot water at the temperature and amount promised. Representatives from the government and the private sector avowed that these negative experiences by some in the past permeated into the present, despite the technical advances that had been made on this technology[146].

In contract to those RET studies that emphasize the importance of awareness of technology itself, previous experiences affect awareness, or how a technology is perceived. This is important in the adoption of RETs because as Frewer et al. (1998) argues, a negative experience with a technology often has a more pronounced negative affect on use, rather than a positive experience with a technology with help boost uptake.

The fifth theme interviewees spoke of was **government engagement.** Responses varied with regard to general trends within the government. Some claimed that, generally speaking, the Government of Mexico at the federal level especially is not really interested in Solar Water Heaters or renewables at the moment[147], although a number of people recognized that advocates for renewables within government existed and were trying to push for initiatives to promote their use.

[143] Interview, one SWH company, December 2005
[144] Interview, one SWH company, November 2005
[145] Interview, one SWH company, December 2005
[146] Interview, four SWH companies and two government agencies, November – December 2005
[147] Interviews, six SWH companies, November 2005 – January 2006

Others noted that the government at all levels was becoming more aware of the need for renewables due to environmental issues such as climate change and energy security issues. The municipal government is interested in this technology (so much so that they created a mandatory environmental norm regarding SWHs for new buildings – discussed in detail in Chapter 6). A third view regarding government was that it was antagonistic towards the penetration of RETs in Mexico. They stressed the corruption and vested interests that exist within the government, highlighting the fact that the Mexican government is heavily interdependent with the petroleum industry (Petroleos Mexicanos - PEMEX), which is state-run. When up against "the power of PEMEX"[148], as manifested in their advertising and ability to influence, (some indicate that about one third of federal government revenue is generated through the activities of PEMEX), the task of promoting solar energy is made that much more difficult.[149] This figure (PEMEX providing about one third of government revenues) is confirmed by other sources (USDOE 2007). I considered energy security issues here, where informants indicated that the government has not paid enough attention to this. Informants felt there was a missed opportunity here to promote renewables more – that the government was being too short-sighted by concentrating efforts on NGCC -- because about one third of natural gas is imported from the United States and purchased at market prices. Studies indicate that there are domestic sources for natural gas, but PEMEX does not have adequate technical capacity or resources to access this natural gas.

Unlike those studies which highlight a link between government efforts -- whether positive or antagonistic -- and the use of renewables, these differing views mean this link is not clear. Even within the same level of government, there is a hierarchy among different agencies. Relationships between and within these organizations, as well as with the ruling party and / or leader, are dynamic; changing, as people change and the institutions change.

The sixth most common theme identified by key informants as affecting the use of SWHs in Mexico City was **capacity building**; ranging from the need to create more

[148] Interview, one SWH company, December 2005
[149] Interview, one SWH company, December 2006 and Informal discussions, November 2005- January 2006

programs and certification requirements in universities and technical institutes, to informal seminars to the general public. As noted earlier in the chapter, many spoke of the efforts of the National Association of Solar Energy or Asociacion Nacion de Energia Solar (ANES) in Mexico, to increase awareness about SWHs.

After assessing these relevant themes, as noted in Chapter 3, Section 3.4, I undertook a second level of analysis to determine how often these codes manifested themselves in the four explanations proposed by the thesis 1) conventional explanations, 2) Diffusion of Innovations 3) Trade and competitiveness regimes, and 4) urban technology cooperation.

Table 4.3[150] Frequencies of Key Explanations for SWH Use in Mexico City

	Conventional Explanations	Rogers Diffusion of Innovations	Trade and competitiveness regimes	Urban Technology Cooperation
P 1	4	12	5	12
P 2	17	16	1	7
P 3	14	13	12	14
P 4	14	13	9	13
P 5	8	8	6	12
P 6	17	18	11	16
P 7	16	16	4	10
P 8	9	12	10	16
P12	10	9	5	2
P13	6	6	2	2
P14	8	10	8	11
P15	13	11	6	6
P16	5	8	4	8
P17	12	10	8	13
P18	10	10	9	9
P19	11	11	1	3
P20	17	15	7	13
P21	5	5	10	8
P23	10	9	6	3
P24	13	12	4	8
P25	20	20	10	16
P26	13	12	4	8
P27	5	4	5	10
P28	13	11	5	7
P29	13	11	4	6
TOTALS:	283	282	156	233

Source: Author based on Atlas ti analysis, August 2009

Table 4.3 above shows common themes grouped under these frameworks were among SWH informants in Mexico City. As the table indicates, conventional explanations for renewable energy adoption (emphasizing economic factors, technical issues and

[150] See **Annex 2** for details on respondents

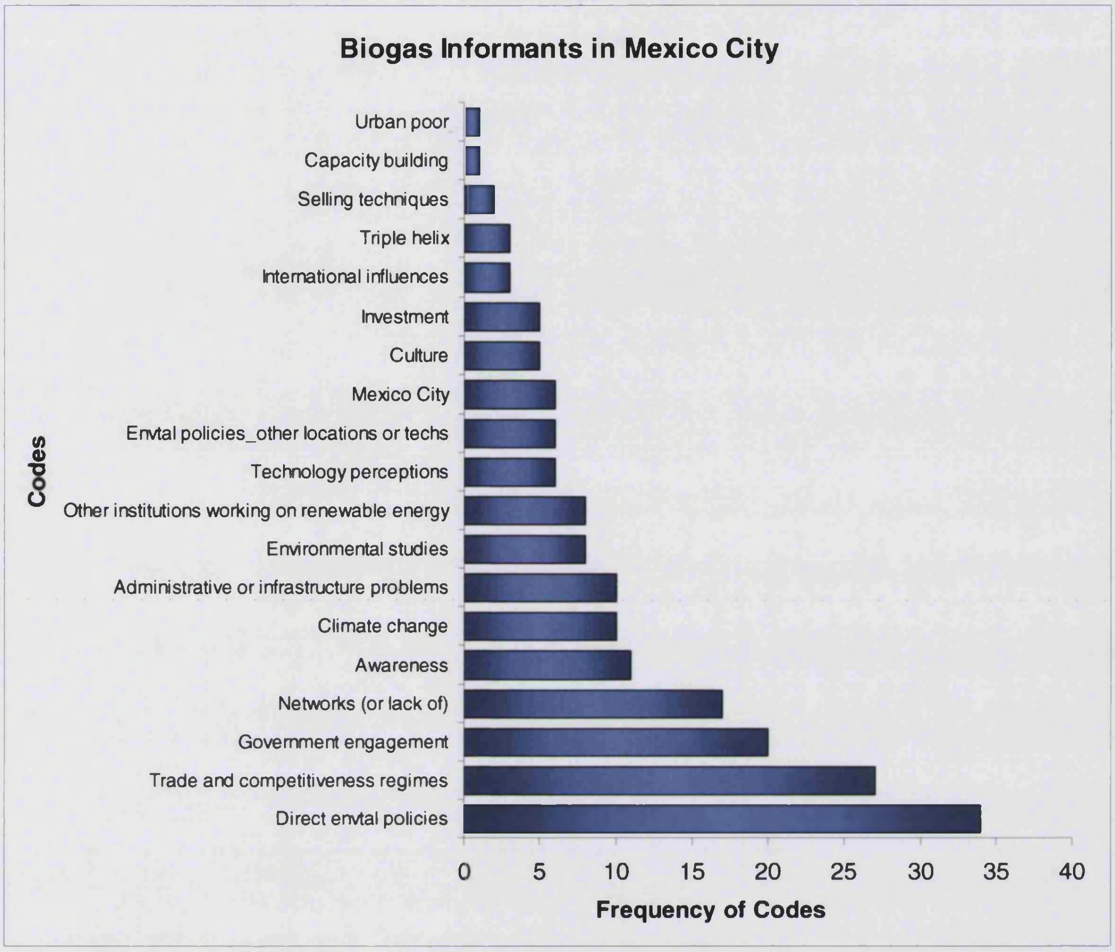
awareness for instance) are very important determinants. What is interesting however is that in contrast to conventional explanations for RET adoption, networks and trade and competitiveness approaches, grouped under the 'urban technology cooperation' and 'trade and competitiveness regimes' frameworks, also constituted a large portion of explanations (discussed further in Chapters 7 and 8). Rogers (2003a) diffusion of innovations also picks up on these conventional factors but takes them further, as shown in Chapter 6, through understanding how prior experiences and awareness of energy conservation can impact technology awareness and thus adoption.

The next step is to decipher the details within these code families regarding how these three alternative frameworks reveal the most important factors affecting RET use in developing countries. This analytical task is carried out in Chapter 6, 7 and 8. Before undertaking this task however, themes identified by respondents in the case of biogas to produce electricity in Mexico City will first be examined.

4.8 Factors Affecting the Use of Biogas to Produce Electricity in Mexico City

This section examines factors affecting the uptake of biogas to produce electricity in Mexico City as identified by informants. Codes were themes identified by respondents, with some based on predetermined topics to serve as guideposts, during the discussions.

Graph 4.2 Factors Affecting Biogas Technology Adoption in Mexico City



Source: Author, based on Atlas ti analysis, June 2008 and updated August 2009

Graph 4.2 above represents the frequency that processes were discussed by informants – namely those factors having an impact on the uptake of these RETs. The, the key factor in acquiring enough interest to get any biogas to electricity project off the ground was due to **direct environmental policies**, and especially **climate change** policies (e.g. CDM, methane to markets initiative[151], renewable energy sources). Although not all respondents mentioned that these **influences were international**, those people that explored this theme further noted that the main source of interest was from abroad (e.g. World Bank, US EPA and USAID, as well as foreign companies interested in generating carbon credits).

[151] Methane to markets is an international initiative, spearheaded by the United States' Environmental Protection Agency (EPA), to reduce methane emissions by capturing methane for use (e.g. flaring, using as an alternative fuel to coal or petroleum). See www.methanetomarkets.org for further information.

For instance, one biogas company saw the CDM as a:

> "...national opportunity that works well, as Mexico does not have targets [to reduce GHG emissions] under the Kyoto Protocol....there are no specific policies [to help biogas to produce electricity], but the government is open to the possibility of taking on targets in the second commitment period"[152]

Another biogas company stated, "with respect to environmental policies and sectors [to focus on], in each of the secretaries (ministries), they are looking at sustainable development [options] in the country, and are looking at the Kyoto Protocol". The representative further claimed that of those within the government who knew of these opportunities to generate carbon credits, about 50% were in favour of them, while the other half were not, for various reasons – including the fact that they did not understand the issue or would not stand to gain from carbon credits.[153] These views are similar to other studies emphasizing the benefits of biogas projects for developing countries either for climate change purposes or as a way to increase renewable energy sources, and local environmental quality, (such as Iniyan and Jagadeesan 1997; UNESCAP 2007).

An additional theme discussed and related to this is **environmental policies in other locations and / or other RETs**, where informants spoke about the Monterrey biogas to electricity project (discussed in Section 4.7), or those to help other RETs, such as the Federal Electricity Commission's goal to have 100 MW come from wind power[154], and those related to SWHs (discussed above).

While most did not see **trade and competitiveness policies** as being a key reason affecting use of this technology, nevertheless this was the second most common theme discussed by respondents. I was told that companies are focusing on foreign equipment, but using Mexican expertise. "They are not making this technology in Mexico"[155]; the hardware all comes from abroad, including places such as "France and Spain", but that "...normally [companies] use local technicians".[156] The majority of companies exploring this technology are foreign, although two Mexican companies – using foreign physical equipment – are also looking at biogas to generate electricity

[152] Interview, one biogas company, January 2006
[153] Interview, one biogas company, January 2006
[154] Interview, one government official, December 2005
[155] Interview, one biogas company, January 2006
[156] Interview, one government official, November 2005

opportunities. One foreign biogas company is currently focusing on "American technology for projects, but we are looking to develop this technology in Mexico...depending on the project, we are looking for technology that can be made in Mexico...equipment; more than components".[157] How exactly trade and competitiveness regimes affect the use of this RET will be examined further in Chapter 8, Trade and Competitiveness Policies.

The third topic is themes labelled **government engagement** regarding biogas to generate electricity in Mexico and Mexico City. Respondents, like those in the SWH section, noted that interest in renewables is increasing in Mexico, and was expected to continue. One government official indicated the Mexican government's interest in alternative energy sources "as oil and gas prices have been rising and are expected to keep rising"[158].

With respect to biogas technologies in particular, (and related to the **networks (or lack of)** theme), people noted, "the main parties involved are the private sector and [a few] municipalities, rather than [the state and federal] government[s]". People claimed this was the case because those within government, let alone the general public, were not aware of this option; or if they were aware, some were not as keen on this technology and the potential to generate carbon credits, "because it does not serve their interests."[159] While some didn't elaborate, others highlighted again the Mexican government's relationship with the oil and gas sector in that country. Private firms and / or municipalities are the principal owners of landfills in Mexico, rather than the federal and state governments.

The fourth factor identified by interviewees affecting the use of biogas to produce electricity is **awareness** of this technology. This technology is generally unknown amongst the populace in Mexico City and the rest of the country. – With respect to methane or biogas from landfills "the public knows nothing about this."[160] In other words, for many Mexicans, they were not aware of the possibility of generating electricity through their garbage through various technologies. People that I spoke with

[157] Interview, one biogas company, January 2006
[158] Interview, one government official, December 2005
[159] Interview, one biogas company, January 2006
[160] Interview, one government official, December 2005

in Mexico City were aware that their garbage (in areas of the city where it was collected) went to one large, central dump. Some indicated that a few people within the government knew of this technology, but not many knew about the potential for biogas projects to be CDM projects. Awareness was slowly increasing however.

Another theme highlighted by energy experts that influences the uptake of biogas to produce electricity in Mexico City is **networks, or the lack of them.** Many Mexicans noted that the nature of projects, and the various jurisdictions involved, warranted collaboration among domestic and foreign partners – including municipalities, federal government agencies (e.g. CONAE, SENER and CFE if electricity is being generated) and foreign and domestic businesses. In addition, foreign government agencies, such as the US EPA and USAID are also active. Having said this, as in the case of SWHs, these networks are not necessarily institutionalized; they are more *ad hoc* on a per project basis. At the same time, more permanent links are starting to form, such as when some government agencies work together, such as the federal environmental agency SEMARNAT and the federal energy agency SENER on questions of carbon emissions and credits.

Respondents further noted that a key obstacle to replicating this project in Mexico City and elsewhere in the country was not due to technical or cost restrictions, but due to **administrative or infrastructure problems**. One government official spoke in detail about the Monterrey biogas to electricity project, which "...had problems. The project needed the permission of the CFE [to get its electricity on the grid] and there were operation and interconnection problems...[but] with this experience, they are resolving these problems and hoping to replicate this project and technology in other parts of the country."[161]

Regarding Mexico City, the government of the Federal District has a law requiring the separation of organic and inorganic garbage in place since 2003, which was voluntary in 2005-06, although it is scheduled to become mandatory. However, informants noted this law would be difficult to implement due to a number of reasons including a lack of

[161] Interview, one government representative, December 2005

garbage trucks that would be needed to transport the separated garbage. Informants indicated that the city had to purchase special trucks with separate compartments (in early 2009 about 90 percent of them did not have these special compartments)[162] but were unwilling to speculate further (e.g. the dynamics involved between players involved in the current garbage contract, and those pushing for these changes). The municipal government was not thinking necessarily about separating the garbage to make biogas from the organic garbage to produce electricity[163], and so some informants argued, lacks the necessary infrastructure to make this into a viable project. In 2005/06, there was only one landfill which accepting waste for Mexico City, Bordo Poniente[164]. This dump handles about 700-900 truckloads of waste per day.[165]

However, the potential to reduce GHG emissions was estimated in Mexico City's Local Climate Action Strategy in 2004, with an estimate that this separation could lead to a reduction of 1.8 million tons of CO_2 equivalent between 2006-2012, mainly through burning methane rather than having it be passively released (Sheinbaum and Vasquez 2006). Since the time of research (2005/06), things have changed dramatically as the Clinton Foundation and Mexico City mayor in 2009, Marcello Ebrard, are working together to shut down Bordo Poniente, which is nearing capacity and to capture the methane this dump produces and create a biogas plant generating 10-20 MW of electricity, for 10 years, to be used on the city's subways and homes. They are also working together to open up some new waste management sites, using best practices on waste management from Los Angeles and Madrid for Mexico City. Also, the garbage collectors employed by the city have agreed to collect organics and inorganics on separate days in order to use existing garbage trucks. The project also aims to employ current formal and informal garbage workers – from those who live at the dump and scavenge daily, to city workers and others who collect garbage from other people for a fee, although details are sketchy regarding how this is to be achieved.[166] This strategy

[162] See http://www.msnbc.msn.com/id/28777897// for further details

[163] Interview, three government representatives, and two biogas companies, November 2005 – January 2006

[164] Interview, one government representative, December 2005

[165] http://www.msnbc.msn.com/id/28777897// and Foundation, C. (2009). "Waste Management in Mexico City." Retrieved August 21, 2009, from http://www.clintonfoundation.org/i/mexico-city-waste-management.

[166] http://www.msnbc.msn.com/id/28777897// and http://www.clintonfoundation.org/i/mexico-city-waste-management

is similar to other waste to energy projects, such as in the Philippines and Inda when companies aiming to produce biogas offered jobs to informal garbage collectors (Forsyth 2005).

As mentioned earlier, at the time of study, the key players involved were the private sector, and to a lesser extent, municipalities, but not Mexico City. Because of these infrastructure and administrative challenges – especially involved when generating electricity – I was told that the majority of investors in Mexico were more interested in reducing carbon emissions for credits, and saw generating electricity as a 'bonus' that may or may not be worthwhile to do depending on the amount of work (e.g. obtaining permits, networking with the 'right' people) required. This stands in contrast to other studies on this issue, such as Forsyth (1999; 2005)'s experience in Asia where communities and governments were very keen on generating energy. For instance, the government of Thailand "Small Producer Programme and Biomass Programme" which provided a subsidy for plants to use new technologies for waste to energy projects. That said, the joint project by the Clinton Foundation and Mexico City noted above, is likely to increase engagement by the state and federal government in this area, which would be favourable to waste to energy projects rather than just flaring methane to generate carbon credits.

After assessing these relevant themes, as noted in Chapter 3, I undertook a second level of analysis to determine how often these codes manifested themselves in the four explanations proposed by the thesis 1) conventional explanations, 2) Diffusion of Innovations 3) Trade and competitiveness regimes, and 4) urban technology cooperation.

Table 4.4 below shows how common themes grouped under these frameworks were among biogas informants in Mexico City. The discussion chapters – 6, 7 and 8 -- assess these findings using the frameworks indicated.

Table 4.4[167] Frequencies of Key Explanations for Biogas Technologies to Generate Electricity Use in Mexico City

	Conventional Explanations	Rogers Diffusion of Innovations	Trade and competitiveness regimes	Urban Technology Cooperation
P 2	17	16	1	7
P10	2	2	3	4
P11	9	10	4	6
P23	10	9	6	3
P24	13	12	4	8
P28	13	11	5	7
TOTALS:	64	60	23	35

Source: Author based on Atlas ti analysis, August 2009

Similar to Table 4.3, conventional explanations for RET uptake in developing countries is the most prevalent grouping, similar to Rogers' Diffusion of Innovations approach, but trade and competitiveness regimes and urban technology cooperation – ways through which to capture networks and trade and competitiveness approaches, two of the most common themes highlighted respondents – also featured prominently. Like Table 4.2, the next step is to assess the details within these code families regarding how these three alternative frameworks reveal the most important factors affecting RET use in developing countries. This analytical task is carried out in Chapter 6, 7 and 8.

4.9 Conclusion

To conclude, as sections 4.2 and 4.3 indicate, the uptake of SWHs in Mexico, at 0.8 m^2 / 100 inhabitants in 2006 is low when compared with other countries with similar populations and climates. In Mexico City, the adoption of this technology is higher, as shown above, at about 1.6 m^2 / 100 people (without pools), or 2.3 - 3 m^2 / 100 inhabitants (including pools), although still relatively low when compared with other countries, such as China with a rate of about 7.5m^2 / 100 inhabitants in 2006. However, as indicated in these earlier sections, these numbers are in no way meant to represent a definitive figure, rather they serve as a guideline for researchers. This is because I based these numbers on a number of assumptions, which would change, depending on the assumptions I use.

[167] See **Annex 2** for details on respondents

Furthermore, in Mexico City, cheaper versions of the technology are being used (i.e. those for swimming pools rather than to produce hot water for residential use) and are more common among commercial and industrial customers, or those who have more access to capital. Conventional models – that stress the high cost and access to capital – provide explanations for why this is the case. But these models cannot explain why Mexico and Mexico City have lower adoption rates in comparison to other cities and countries. In addition, as will be shown in Chapter 5 that looks at São Paulo, when broken down by market segment, these models cannot provide adequate explanations for the differences between the two cities.

Having said this, the SWH market is growing steadily. The industry has been in the country for a number of decades (since the 1950s). Furthermore, Mexico City and the surrounding environs possess an active group of engaged actors working to promote the use of SWHs. Major players that have been dominant in this area are continuing their efforts and other players are increasingly getting involved. However, there are still some major hurdles with respect to SWH adoption in Mexico City – these factors will be explored further and assessed in the analytical chapters (6, 7 and 8).

With respect to biogas to generate electricity, as noted in section 4.4 and 4.5, this technology is unknown in Mexico City, except among a small group of experts including biogas companies, mainly foreign, and some people working at the federal environment ministry, SEMARNAT and energy ministry (SENER and CONAE) and the public research institution IIE. Having said this, interest in this technology is increasing. At the time of study, I found that the main driver was the potential to generate carbon credits rather than to generate electricity. One reason why I suspect that to be the case is due to the prominence of the private sector in this area at the time 2005-06, although municipalities were also becoming more interested. The planned project to generate between 10-20 MW of electricity on Bordo Poniente between the city and the Clinton Foundation – generating electricity, carbon credits, and attempting to employ informal workers – will likely create more interest in generating energy rather than just carbon credits. Behind this trend lies the larger question regarding how electricity is generated and distributed in Mexico City. At present, although IPPs can be sub-contracted by CFE to generate electricity and sell it to them, many argue that the process (e.g. permits needs, negotiations, etc.) are complicated, terms are considered unfavourable by investors, etc. Privatizing the energy sector is a very politicized issue in Mexico and so a major reformation of the sector is not likely to occur in the near future. Nevertheless, there are opportunities to make the process easier for IPPs (e.g. perhaps they could sell directly to the distributer, Luz y Fuerza, for Mexico City rather than CFE, or 'red tape' issues could be reduced) which can also help Mexico meet its growing electricity needs through non fossil fuel means.

The last two sections turned to the question "why (or why not) are these technologies being used in Mexico City?" Similar themes came up in discussions with people speaking of both technologies. Trade and competitiveness and environmental policies featured the most prominently in discussions with informants. Regarding trade regimes, the origin of the technologies (hardware and software) and / or the companies was discussed. With respect to environmental policies and SWHs, the two programs discussed the most were CONAE's program to increase the use of SWHs in Mexican homes – with a number of informants questioning its effectiveness - and the Federal District Secretary of the Environment's mandatory requirement to use SWHs for 30% of hot water needs in larger new buildings. In the case of biogas to generate electricity, as noted earlier the key influence on this technology is through environmental policies (especially climate change), although the origins of these policies come from international initiatives, including the CDM, methane to markets, among others.

These findings are important for two reasons. First of all, the role of trade and competitiveness regimes and networks are areas generally neglected in conventional explanations of RET adoption (or a lack of use). Secondly, while many studies espouse the importance of direct environmental policies to increase uptake of RETs, more attention is need on how these policies are designed, managed, implemented and evaluated.

The above findings suggest that conventional approaches to technology adoption and transfer / cooperation, mainly focusing on economic and technical attributes are inadequate explanatory frameworks to explain the uptake of RETs in the urban developing world. This thesis therefore turns to systemic approaches, which have been proposed as an alternative approach as they try to include social and economic factors at various scales to explain RET adoption. But, as noted earlier, to date there is little evidence supporting their application in this area. Chapter 5 will compare these findings with those uncovered in São Paulo, while Chapters 6, 7 and 8 analyze the findings in the context of the three systemic approaches – Rogers' diffusion of innovations, urban technology cooperation and trade and competitiveness policies -- identified earlier, with the aim of answering the research question: ***What are the most important factors affecting RET adoption in the urban developing world?***

Using these same RETs in a different location, how does Mexico City compare with a similar urban centre in Latin America -- São Paulo, Brazil? Chapter 5 will answer this question.

CHAPTER 5: SOLAR WATER HEATERS AND BIOGAS TECHNOLOGIES IN SÃO PAULO

5.1. Introduction

The main purpose of this chapter focuses on the sub-research question "*what are the reasons SWHs and biogas to produce electricity technologies are being used or not in São Paulo?*" The focus of Chapter 5 is on the findings from São Paulo. Chapters 6, 7 and 8 analyze these findings using the three systemic frameworks as guidelines for their explanation. This chapter provides details about the situation for Solar Water Heaters (SWHs) and biogas to produce electricity in São Paulo. The chapter is divided in five sections. The first section provides more information about São Paulo. The following two sections focus on information on these two RETs in Brazil and São Paulo - including, which segments are using them, where they are being used, and most importantly, how much they are being used. The last part of this chapter consists of the other two sections and turns to the factors affecting their uptake in São Paulo, teasing out common patterns and themes, as identified by informants and other secondary sources.

As noted in Chapter 4, the study looked at trends regarding these two technologies from about the mid-1970s to the present (2009), with a focus on the 2000 – 2007 time frame. Mexico City and São Paulo provide fascinating backdrops for this research.

Chapter 4 spoke about some of the similarities between these two cities (large populations, a high-energy demand, major discrepancies between the urban wealthy and poor, etc.). Yet these cities are different in important and subtle ways.

One distinct difference between the two places is that they possess differing trade and competitiveness approaches. Mexico has a more open approach, favouring free trade, while Brazil also does, but there are more stipulations in place regarding trade and foreign investment. In addition, their electricity sector is distinct as Mexico City's electricity is generated and distributed by state-run organizations, whereas São Paulo's electricity is generated and distributed by companies that are owned by both the public and private sectors. Also, the electricity for Mexico City mainly comes from fossil fuels (thermal power plants run on oil and / or natural gas) whereas São Paulo relies mainly on hydropower.

This chapter shows that in comparison with other nations with similar attributes (e.g. insolation patterns, population), Brazil also has a lower than average rate of SWH use, although it is higher than Mexico (2 m^2 / 100 inhabitants versus Mexico's 0.8 m^2 / 100 inhabitants in 2006). In São Paulo, the rate of use is 2 m^2 / 100 people, which is higher than Mexico City's calculated rate of 1.6 m^2 / 100 people not including pools, or lower than Mexico City's rate of 2.3 – 3 m^2 / 100 inhabitants including pools. In addition, as explained in detail in the chapter, when broken down by market segment, the number of SWHs used in each city is quite different.

Regarding biogas technologies to generate electricity, there are two landfill gas to electricity projects up and running in São Paulo, with the generation of carbon credits serving as the key rationale to their development.

Similar to other studies examining the adoption of SWHs in developing nations noted in Chapters 1 and 2 this chapter shows that in the case of SWHs in São Paulo, respondents also noted direct environmental policies (2nd most prevalent theme noted) and awareness (4th most prevalent theme noted) as key factors affecting RET use. The ranking of these themes in terms of frequency is also the same in the case of SWHs in Mexico City. Similar to findings in Mexico City, two of the most prevalent themes identified by participants as having the potential to affect RET use in Mexico City are trade and competitiveness regimes (1st most common) and networks (or a lack of them) (3rd most common), which were also the same ranking in Mexico City. These themes are not as readily explained using conventional technology adoption and transfer models.

In the case of biogas technologies, like Mexico, a lot of the majority of studies on biogas technologies in Brazil assess the potential through various PDDs (e.g. PDD Bandeirantes and São Joao), rather than an assessment. I found that direct environmental policies were the most common theme. That said, other studies examining biomass in Brazil (e.g. Goldemberg 1998) indicate the importance of direct environmental policies. However, an interesting trend is that, similar to the SWH results but different than many RET studies in developing countries, trade and competitiveness regimes were also noted as being important (2nd most common theme) and networks (4th most common theme). These findings lie outside of the classical explanations of RET adoption, centering on costs, access to finance, technical problems, awareness and institutional issues.

5.2. São Paulo – Context

São Paulo, with a population of nearly 10 million, and 18 million when including the outskirts, is the largest city in Brazil. Brazil practices a more conditionally-open trade and competitiveness approach. Under this rubric, at the national level, there are more restrictions on foreign investment (e.g. more Joint Ventures, more 'buy-locally' policies). Beginning in the early 1990s, Brazil has undertaken a series of measures aimed at encouraging foreign investment, such as allowing foreign investment in the Brazilian stock market in 1991, and the privatization of some key state sectors such as energy and telecommunications in 1995 and the insurance industry in 1996) (Political Risk Services 2002).

The *Real Plan*, (consisting of privatization, exchange rate reform and structural economic reform) which former President Cardoso introduced in 1994, saw inflation decrease from over 2000 percent in 1994 to 3 percent in 1998 (Elass and Myers Jaffe 2004). Having said this, there are a number of stipulations in place, such as, in those firms that employ three or more people, Brazilians must constitute two thirds of the workforce and receive two thirds of the payroll (Political Risk Services 2002).

This push and pull toward liberalization and / or increasing domestic ownership has also manifested itself in the energy sector:

> Expensive but socially beneficial government intervention in the energy sector can serve as the basis for short-term economic stimulus as well as help redistribute income inside society. However, heavy government intervention in the energy sector can be expensive in the longer term, preventing a country from reaping the efficiency gains from the liberalization of energy markets and keeping it competitive internationally. Brazil has wavered between these two policy alternatives over the last decade. (Ellas and Myers Jaffe 2004: 4).

The beginnings of reform occurred with the democratic constitution of 1988 where the private sector was able to invest in infrastructure, but after anticipated investment did not materialize, Cardoso (1994-2002) began to aggressively target the electricity sector for privatization. The idea was to debundle generation, transmission and distribution of electricity. However, a number of problems occurred that affected this reform – including the devaluation of real, overall management problems with the sector as personnel and priorities changed, and the apagão of 2000/01. These problems slowed the Brazilians government's enthusiasm for privatization of the sector (Roman 2007).

But since then Lula developed a New Model for electricity generation, which stops further privatization and the government has control again. Generation and distribution are still unbundled but two markets have been created – one for smaller consumers that is regulated (contracts are for 8 years), and one for larger consumers who are able to negotiate sales prices and on a longer term (Roman 2007). But, potential investors have become skittish in this sector as the government "has had a tendency to change the rules at the last minute" (Roman 2007: 47).

Electricity generators, including government and private sector, are able to sell electricity to either smaller consumers through Agência Nacional de Energia Elétrica, ANEEL, or larger consumers, but the largely government-controlled power generators have a buy-local policy, therefore foreign companies must undertake joint ventures with Brazilian firms (Cunha 2004).

For example, the Brazilian government has developed the Alternative Sources of Electricity Incentive Programme (Programa de Incentivo às Fontes Alternativas de Energia Elétrica, PROINFA), where the government is actively seeking the generation of 3,300 MW of energy equally from biomass, micro hydro plants and wind.[168] In order to qualify, 60% of the project's components must be from Brazilian sources (ITA 2005). Wind energy projects require 70% of domestic sources.[169] Electricity generation for São Paulo mainly comes from Empresa Metropolitana de Aguas e Energia (EMAE), owned by the state of São Paulo. It is distributed by a somewhat

[168] For details on the program, including its problems (e.g. the targets for wind energy and micro hydro under PROINFA have not been met), please see Ruiz et al. 2007
[169] Interview, one electricity distributor, April 2007

privatized entity (Eletropaulo, owned jointly by AES of the U.S. since 1998 and the Brazilian National Bank for National Social and Economic Development (BNDES)). Eletropaulo distributes electricity to the city of São Paulo and parts of the surrounding area, equivalent to about 8.8% of the population of Brazil.[170]

Another interesting facet regarding the electricity sector in São Paulo is the apagão (or black outs) of 2000/01. Brazil, including São Paulo, is heavily reliant on large-scale hydropower for their electricity, over 80% (US DOE 2007). During the apagão, major parts of Brazil, including São Paulo, were subjected to black outs and energy rationing due to an electricity shortage as there were droughts at the time and Brazilian electricity is mainly hydroelectric. Basically, "this involved a five months energy cut of 20% for both private consumers and industry, as well as organized blackouts all over the country. Needless to say, the societal costs were immense as industry was forced to a virtual standstill" (Roman 2007: 33). As noted in Chapter 1, in the immediate aftermath of these black outs, there was more push for diversification of electricity sources, although representatives from universities and a NGO suggest that the Lula government continues to be too reliant on hydro power.[171] Roman (2007) also notes that despite 'all the talk' of the government wanting to diverge away from hydropower, the sector grew by 6.1% in 2005, higher than ethanol (5.9% - natural gas was the only energy sub-sector higher (7.4%) that year.

In São Paulo, and the rest of Brazil, transportation of natural gas, and domestic production of natural gas, is dominated by Petrobras, which owns most of the infrastructure. The company is partially privatized, in that it is still majority government-owned. Petrobras regulates the price of natural gas to distributors – setting it lower for certain uses (including for industry / commercial use) in order to encourage its uptake (Roman 2007). In Mexico City, natural gas is state-run but the price is often at market rates[172]. Table 5.1 provides a summary of these differences.

[170] Interview, one electricity distributor, April 2007
[171] Interviews, one university representative, two NGO representatives, March 2006
[172] Interviews, three SWH companies, Mexico, November 2005-January 2006 and one NGO and one government representative, Brazil, March 2006 and Ellsworth and Gibbs 2004

Table 5.1 Different Approaches Between the Case Studies

	Mexico City	São Paulo
Trade and competitiveness regime	Open (foreign investment with little stipulations encouraged, many free trade agreements)	Conditionally open (foreign investment also encouraged but stipulations – more buy local policies, more JVs versus subsidiaries, Brazilians majority of workforce and payroll for foreign firms in Brazil)
Environmental Policies	In the past, mainly focused on air pollution A few more recent examples targeting renewables (e.g. SWHs) at the federal and municipal levels	Long history of support for renewables (including large-scale hydro), especially at the federal level (e.g. ethanol program, PROALCOOL, PROINFA) More push for diversification after apagão, although some argue that the government continues to be too reliant on hydro power
Main electricity sources	Fossil fuels (oil, natural gas)	Large-scale hydro power
Electricity sector	Generation, transmission and distribution state-run	Generation state-run but transmission and distribution jointly run by state and private sector
Natural gas sector	State run but at market rates (although sometimes subsidized to Mexicans)	Dominated by Petrobras, partially privatized, but at regulated rates

Source: Author

As noted in Chapter 4, SWHs used in both cities are on a large-scale (e.g. institutions) and a smaller scale (e.g. household level). Biogas technologies to generate electricity being considered or in use in both cities are generally used at a larger-scale (e.g. landfills for large cities). It is important to examine the amount of disposable income and access to credit available for residents of these two cities and access to credit available to larger institutions.

Disposable income - It is difficult to know how many families would be able to make the necessary investment to purchase a SWH. This is because official figures for the average disposable income in São Paulo were unavailable. In addition, the prices of SWHs in São Paulo at the household level range from US$100 to US$900.

That said, an extensive study on monthly home budgets between 2002-2003 by IBGE was consulted to make some estimates. In the IBGE 2004 study, the average monthly income (from all sources including formal and informal employment and remittances) for a family in the Southeast (which includes São Paulo) was about R$2 205 or US$760[173] (IBGE 2007). For many Brazilian families, monthly expenses were the equivalent or even higher than monthly incomes – on average, in 2003, monthly expenses took over 93 percent of monthly income (IBGE 2007). In urban areas (which includes São Paulo) about 84 percent of respondents in the study stated they had difficulty meeting their monthly expenses. If one assumes that the same trend existed in São Paulo, only 16% of the population would not have difficulty in meeting their monthly expenses. This is interesting because even though a cheaper SWH option for a household exists in São Paulo versus Mexico City (US$100 versus US$800-900), using the above figures, **about 16%** of the population would be able to afford to purchase one at the household level. This number is similar to Mexico City, where it was estimated that about 17% of the population could purchase a SWH.

There are no credit schemes in place to help families or institutions purchase a SWH in São Paulo, although at the time of study (2006) the NGO Vitae Civilis was looking into potential Energy Service Company (ESCO) schemes to be used in Brazil, or schemes where a family could purchase the services of a SWH (similar to renting a house or leasing a car). Institutions have better access to credit versus individual families, which can help them come up with the capital needed to purchase a SWH. Some photos of São Paulo are included in **Figures 5.2** below. Similar to the figures of Mexico City included in Chapter 4, the purpose of these photos is to give the reader a flavour of the city of Sao Paulo. The first photo is Paulista Avenue, which is a main artery within the city, and a street where a number of companies are located – linking the city to other global cities, regions and countries. The second photo tries to capture how large the city is too – as can be seen, the buildings (mainly apartments and offices) stretch for many kilometres. Finally, the third photo shows that like Mexico City, Sao Paulo is a city of contrasts. On the one hand, it is a city with major wealth concentration (e.g. it is the city with the most privately-owned helicopters on a per capita basis), while at the same time the city possesses a number of shantytowns, termed favelas, where families live in rudimentary, self-made shacks.[174]

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[173] Using rates from December 31, 2003 www.oanda.com
[174] Informal discussions, various informants, January – March 2006

Figures 5.1 Views of São Paulo

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Source: www.istockphotos.com

Permission to use © AM29

Source: www.istockphotos.com

The municipal secretary of environment of São Paulo conducted a 2005 GHG inventory with the aid of a prominent national climate change research centre, the Centro Clima da Coordenação dos Programas de Pós-graduação de Engenharia (COPPE) da Universidade Federal do Rio de Janeiro (UFRJ). Using the guidelines established by the IPCC, the study estimated that greenhouse gas (GHG) emissions in São Paulo were approximately 15.7 million tonnes of CO_2 equivalent in 2003 (Secretaria Municipal do Verde e do Meio Ambiente (SVMA) de São Paulo 2005). This amount is significantly lower than the estimates given for Mexico City, which as noted in Chapter 4, range from 60 million CO_2 equivalent in 2000 to 62.6 million tonnes of CO_2 equivalent in 2004.

GHG emissions in São Paulo from solid waste[175] (a little more than 23% of emissions) are higher than in other cities (e.g. in Mexico City and the surrounding area, they are estimated to be 6.6%), while emissions from the transport and electricity sector are much lower as many vehicles run on ethanol or a mixture of ethanol and petrol, and the majority of electricity is from large hydro. Energy (including industry, agriculture, transport, commercial enterprises and households) makes up the bulk of GHG emissions at about 76% in 2003 versus Mexico City where they were estimated to be 94% of GHG emissions in 2004. Of this amount, electricity was about 11%, while almost 89% was due to fossil fuel combustion. Even though transport emissions are lower than other cities in comparison, they still constitute the largest source of energy use (about 78%). Other sectors, such as industry (about 7%) and residential use (about 9% are much lower) (Dodman 2009, Secretaria Municipal do Verde e do Meio Ambiente (SVMA) de São Paulo 2005; Sheinbaum and Vasquez 2006).

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[175] When assessing GHG emissions and removals, the IPCC is concerned with "methane produced from the anaerobic microbial decomposition of organic matter at solid waste disposal sites" (IPCC 2006, Chapter 8: 33) – CO_2 is accounted for separately. The IPCC also suggests that if solid waste is a key component of GHG emissions, then the "inventory compiler should determine whether subcategories are significant" (IPCC 2006, Chapter 4: 12). In Sao Paulo, the landfills mainly have municipal waste. Industrial waste is calculated separately (in 2003 they accounted for about 0.05% of GHG emissions) as they are treated separately at sewage treatment stations, although some waste (e.g. some informal enterprises), ends up dumped in water sources (Sao Paulo SVMA 2005).

5.3. Solar Water Heater (SWH) Use in Brazil and São Paulo – the hardware

As discussed in Chapter 4, when answering the research question *"what are the reasons that SWHs and biogas to produce electricity technologies are being used or not in São Paulo?"*, one must establish exactly **how much** of these RETs are being used. This is important, as a key goal of the dissertation is to determine if there are acute differences between the two locations in terms of how much these RETs are being used and potential factors that may affect RET adoption, in which more general deliberations can be established. As noted in Chapter 3 on Research Methods, the use of RETs is measured by examining technologies that are considered hardware (physical equipment) and / or software (knowledge and processes).

5.3.1. Brazilian SWH Industry

There is a solid national SWH industry, with many companies, and a large SWH market in Brazil.[176] According to informants, the SWH industry has been active in the country for over 30 years. The industry mainly began when one professor from the State University of São Paulo, or Universidade Estadual de São Paulo, (UNESP), went to Israel (one of the pioneering countries involved with this technology) and became familiar with the Solar Water Heater, and adapted it to the Brazilian climate. Later on, the Brazilian company Tecnosol was created in 1991, using this technology based on an Israeli design but adapted to Brazilian conditions, which produced and sold SWHs in Brazil.[177]

As of 2007, In Brazil, there were about 140 companies that produce and / or distribute SWHs (ABRAVA 2007). In São Paulo and the surrounding state, there are about 23 companies that produce, distribute and / or sell SWHs in São Paulo. Many of these companies are members of these companies are members of the trade association, the Brazilian Association of Refrigeration, Air Conditioning, Ventilation and Heating - National Department of Solar Heating, or Associação Brasileira de Refrigeração, Ar Condicionado, Ventilação e Aquecimento - Departamento Nacional de Aquecimento

[176] Interviews, two SWH companies, March 2006 and May 2006
[177] Interview, one SWH company, April 2006

Solar (ABRAVA – DASOL). In addition, a number of government officials at the federal, state and local levels are working in this area (SWHs in São Paulo). Also, there is one university working on this form of solar energy in and around São Paulo, as well as few NGOs and consultancy firms, such as Vitae Civilis and Sociedade do Sol. According to ABRAVA, about 26 SWH companies are members of the association, which represent about 70% of the SWH market in Brazil (ABRAVA 2007).

Many stakeholders indicated that SWH companies in Brazil are Brazilian and the majority use either 100% or almost 100% of Brazilian components for their equipment (copper is imported from Chile and all copper in the country is distributed through two companies located in São Paulo). However, there are a few companies working on SWHs for pools (using plastic for heating) that import equipment then produce SWHs in Brazil, while one company imports systems from abroad.[178] In addition, a number of government officials at the federal, state and local levels are working on SWHs in São Paulo. Also, there is one university working on this form of solar energy in and around São Paulo, as well as few NGOs and consultancy firms, such as Lumina, Vitae Civilis and Sociedade da Sol.

Like Mexico, Solar Water Heaters (SWHs) are only a small portion of the energy sources that are used to heat water in Brazil. For example according to a comprehensive 1988 study by Brazil's National Electricity Conservation Program, or Programa Nacional de Conservação de Energia Elétrica (PROCEL) on the residential use of electricity, looking at electrical appliances and consumption habits, about 83.5 % of homes used an electric showerhead to heat their water in the Southeast region of Brazil (the region most densely populated and the region where São Paulo is located) (Rodrigues and Matajs 2005: 13).

5.3.2. SWH equipment use in Brazil

According to ABRAVA-DASOL, the installed capacity of SWHs in Brazil was about 3 634 000 m^2 in 2006, or 4 134 000 m^2 in 2007 (ABRAVA 2007). This is the equivalent of almost 2 m^2 / 100 inhabitants, which is also low when compared to countries with

[178] Interviews, one NGO, 11 SWH companies, March-May 2006

similar climates and larger populations, such as China, [179] with a rate of 7.5 m^2 / 100 in 2006, mentioned in Chapter 4, although higher than Mexico's rate of 0.8 m^2 / 100 inhabitants in 2006.

5.3.3. Brazilian SWH Market

Interviewees from the government, a consultancy and the private sector indicated that the Brazilian SWH market is growing steadily.[180] One company noted that they had seen growth of 120% for SWHs from year to year in the state of São Paulo, or about 20% in monthly increases.[181] One interesting fact about the Brazilian energy sector mentioned by about one third of respondents was the apagão of 2000/01. All stakeholders viewed the apagão as a great opportunity for renewable energy – noting that interest in renewables in general was also growing.[182]

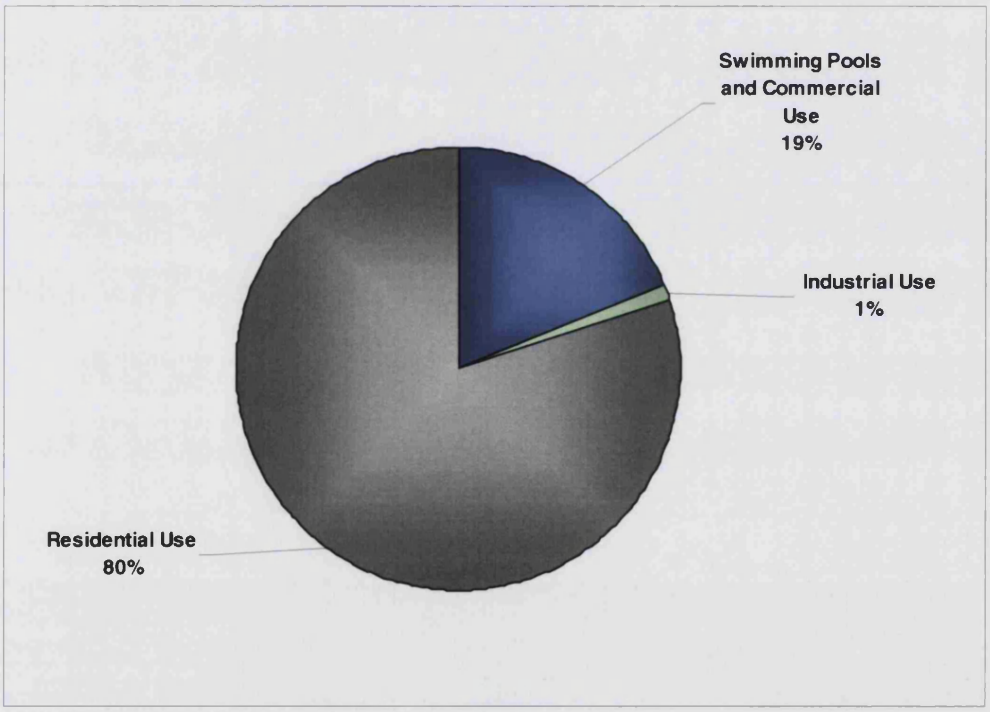
During this time period and shortly after, people working in the SWH sector saw major increases in interest, purchases and use of SWHs– especially SWHs for largest applications (e.g. hotels, motels and industry). [183] Even though these respondents noted that the rates of growth for the SWH industry between years after 2001 are not as striking as between the years 2000 and 2001, as noted above, the uptake of SWHs is steadily increasing. Moreover, some informants indicated that the potential market for SWHs in Brazil is large but has been explored little.[184]

Previous studies also confirm these trends. For example, the installed capacity of SWHs in Brazil was 2.2 million m^2 in 2002. This was equal to about 1.2m^2 / 100 inhabitants in 2002 (Milton and Kaufman 2005: 17). However, installed capacity increased to about 3.2 million m^2 in 2005. As Brazil's population was a little under 184 185 000 in 2005, this was equal to about 1.7 m^2 / 100 inhabitants in 2005. Annual production is generally about 350, 000 m^2 per year, and growth rates are about 10 percent per year, although production increased to almost 500, 000 m^2 in 2001 after the 2000/01 apagão in Brazil (Hoyt et al. 2006; Milton and Kaufman 2005).

[179] Interview, one NGO, March 2006
[180] Interviews, five SWH companies, one government agency, one consultancy, March 2006
[181] Interview, one SWH company, April 2006
[182] Interviews, two SWH companies, one union, two government representatives, one alternative energy company
[183] Interviews, two SWH companies, March 2006
[184] Interview, one NGO, one consultancy, March 2006 and May 2007

Representatives from the private sector and a NGO noted that SWHs in Brazil are used in residences to heat water in single-family houses – about 80% of the market (although one informant indicated this number was as high as 90%). Like Mexico, residential clients in Brazil are often wealthy, or from the highest earning top 10% of the population. Hotels, sports clubs, hospitals, and other businesses also use SWHs.[185] In addition, even though there are little SWHs being used for industrial purposes in Brazil, an increasing number of industries and hotels are looking for alternatives, such as SWHs, to heat their water.[186] SWHs for multifamily dwellings are about 8%. SWHs used for industry is very recent and represents about 1%. The rest are for pools as well as hospitals, hotels, etc.

Figure 5.2 Estimated Market Share of SWHs in Brazil (approx.)



Source: Author, Based on Estimates Provided by Informants, March 2009

5.3.4. Types of SWHs in Brazil

An average SWH system for a family in Brazil to be used for domestic hot water use would consist of a simple open-looped system where a storage tank would adjoin solar

[185] Interviews, one NGO four SWH companies, March-April 2006
[186] Interviewes, four SWH companies, March-April 2006

panels. According to a number of interviewees, the average price for a SWH for family use (equipment and installation) in Brazil (on average 4-5 people, requiring 2-3 m^2 for a 200 litre tank) is about $US900. One company however indicated that the price could be as low as $US500.[187] However, a larger tank may be required. The most popular form of SWH sold by Soletrol, the largest producer of SWHs in the country, is a 400 litre tank with 4 solar panels of 1 m^2 each. This version can be considered ideal for a Brazilian family (average 4 people), assuming each person on average uses 100 litres of water per day.[188] As noted earlier, please in São Paulo take two showers per day. In Mexico City less hot water is used. Estimates show that between 30-80 litres of water are used per person per day, depending on income and family habits (Castro Negrete 2005: 18).

Like Mexico, one can find many different types of SWHs at many different prices. For instance, some noted that aluminium and copper (which is the tubing that the water runs through) are the most common materials used for SWHs in Brazil.[189] A common size for SWHs for residences is about 6-10 m^2 per residence, although there are also systems available with 50 – 100 m^2.[190] A higher end version costs about US $1400 while a lower end version can cost as low as a little over $US100. In addition, one NGO noted that while a SWH costing a little under $US 500 does exist; it is rare because there is simply no market in Brazil to purchase it (i.e. little "middle class")[191]. Previous studies conducted on SWHs in Brazil confirm these figures (e.g. Milton and Kaufman 2005; Rodrigues and Matajs 2005).

Representatives from the private sector and a NGO stressed that looking at the global SWH industry, prices in Brazil for SWH systems are considered moderate to low.[192] Several interviewees indicated that this is mainly due to the climate in Brazil (a lot of sun on average annually and little frost), which means that simpler forms of SWHs can be used. However, SWHs even at lower prices remain unaffordable for much of the

[187] Interview, one SWH company, March 2006
[188] Interview, one SWH company, May 2006
[189] Interviews, two SWH companies, one consultancy, March – May 2006 and May 2007
[190] Interview, one consultancy, May 2007
[191] The exchange rate of $1US dollar = R2.13 Brazilian reais, March 2, 2006, was used as this was the date of the interview. See www.oanda.com, Interview, one NGO, March 2006
[192] Interviews one NGO, two SWH companies, March 2006

Brazilian population,[193] who, according to one interviewee indicated that, generally speaking, "…even though SWHs deemed "first class" in Brazil are about one third of the cost of those in Europe….salaries in Brazil are a tenth of what they are in Europe".[194] This statement is interesting because while in both places, but particularly in Brazil, I found that there was an affinity towards Europe as being an example to emulate, ranging from topics as diverse as environmental policies (considered innovative and effective), technologies (considered cutting-edge), to quality of life and other attributes (income distribution, socialized medicine, maternity leave, etc.), (considered advanced).

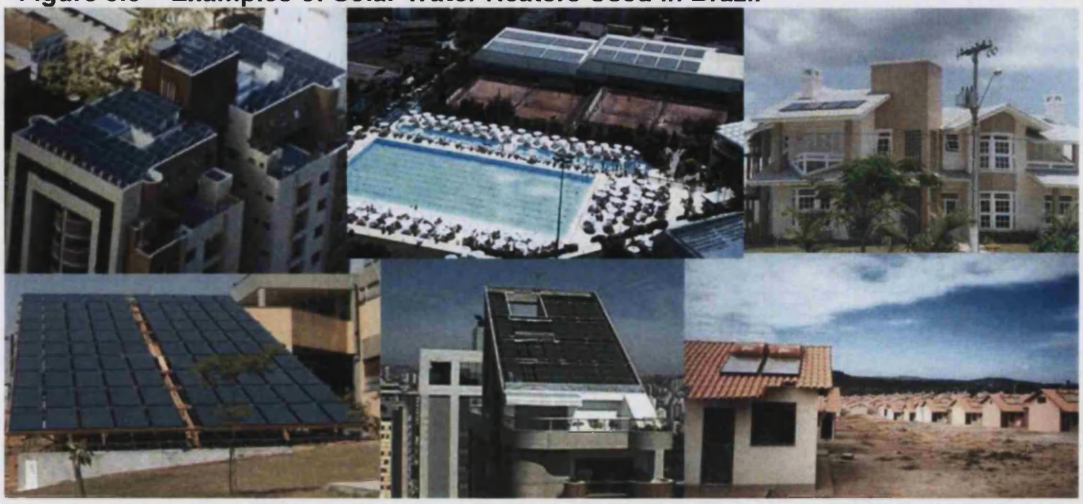
Table 5.1 Principal Types of SWHs Used in Brazil

SWH Type	Cost in US$ (equipment + installation)[195]	Details	Main Use
Plastic with no covering	100 400-500	2-3 m^2, no guarantees, lower water temperatures (e.g. 25 degrees Celsius) Varies, lower water temperatures (e.g. 25-30 degrees Celsius)	Residential Water Heating (single family) Residential swimming pools
Copper with glass covering	500-900. 900+	2-3 m^2 about 200 litres about 30 – 60 degrees Celsius depending on climate / conditions 4 m^2 about 400 litres about 30-60 degrees Celsius depending on climate / conditions	Residential water heating (single family)
Copper with glass covering	1400.	Varies	Larger sized swimming pools (e.g. hotels, sports clubs)
Copper with glass covering	1400+	Varies	Commercial, industrial water heating (e.g. hospitals, hotels)

Sources: Interviews with 1 NGO and 4 SWH companies-B, March – May 2006.
NOTE: 1 US dollar = 2.15 reais in March 20006, when the majority of this information was obtained. www.oanda.com

[193] Interviews, one SWH company, one organization, March 2006
[194] Interview, one NGO, March 2006
[195] This is the average number based on information provided by key informants when in Brazil.

Figure 5.3 – Examples of Solar Water Heaters Used in Brazil



Source: ABRAVA, 2007

5.3.5. SWH Equipment Use in São Paulo

A broad range of stakeholders noted that the pattern of the SWH market in Brazil is similar in São Paulo. For instance, SWHs for single-family residences represent about 80% of the SWH market in São Paulo. Also, like Brazil, a numerous respondents indicated a strong market growth potential in São Paulo whether the city itself or the greater metropolitan region (called Grande São Paulo).[196] For instance, one consultant indicated that SWHs could heat water in buildings of the middle class. He indicated that approximately 60% of apartments produced in São Paulo are for the middle class – which, in 2007, represented about 100 000 apartments.[197]

The main reasons of this view cited by informants were because of the high population density of the region (in 2006, the population of Grande São Paulo was about 18 million, or almost 10% of the country)[198], and the apagão, which affected São Paulo greatly and made this population more aware of energy issues and SWHs. One NGO

[196] Interviews, one government agency, three SWH companies, one NGO representative, one university representative, one consultancy, March 2006 and May 2007
[197] Interview, one consultancy, May 2007
[198] Interview, one NGO, March 2006

representative also mentioned that the Brazilian government and energy companies were becoming increasingly concerned about the electricity "peak" and looking at ways for demand management (discussed in more detail in Chapter 6) of which SWHs could play a role.[199]

Compared to Belo Horizonte, where SWHs are fairly common, they are not used very much in São Paulo.[200] ABRAVA is scheduled to release accurate data on the number of SWHs installed by state and / or city in Brazil at some point in 2009.[201] For this reason, calculations on number of m^2 in São Paulo were done using two approaches. Using a population of about 184 million for Brazil and 10 million for São Paulo in 2006, and 3 634 000 m^2 of SWHs, in Brazil, one could calculate the amount, based on population figures, or about 195 700 m^2 of SWHs in the city of São Paulo, or almost 2 m^2 / 100 people, similar to the country average of about 2 m^2 / 100 people.

According representatives from the private sector and government, similar to Mexico City, the climate in the city of São Paulo would make it useful for SWH users to have an alternative technology to heat water as a "back up". This is because the region is subject to periods of rain. In addition, the climate of São Paulo is cyclical and the region has colder winters about every four to five years.[202] This is confirmed by other studies such as one done by (Montoro Taborianski and Prado 2004) who conducted an in-depth comparison of the SWH to an electric showerhead, and a hybrid of the two in a suburb of São Paulo, and showed that "the auxiliary system [to the SWH] was used 23 percent of the time" (2004: 649).

Basically, what I was told was that people wanted the convenience of having a hot shower (either once or twice daily in Mexico City and São Paulo respectively) exactly when they wanted it.[203] A SWH with a back up alternative can fulfill this need. Other studies on SWHs versus their counterparts in São Paulo suggest that "the water flow obtained through a gas or solar heater is larger [versus an electric shower] and provides

199 Interview, one NGO, March 2006
200 Interview, one government official, November 2006
201 Personal communication, ABRAVA, February 2008
202 Interviews, two SWH companies, one government agency, March 2006
203 Interviews, one Mexican energy expert, September 2007 and Interviews, two university representatives, March 2006 and April 2007

a more comfortable bath for the user" (Taborianski and Prado 2004: 645), although informants in Brazil did not mention this advantage.

5.4. SWH Use in Brazil and São Paulo – the software

Another part of these technologies examined is the "software". Like the two technologies in Mexico City, the majority of information came from responses from key informants, including formal and informal capacity building activities, and the number of organizations working on SWHs in and around São Paulo. Indicators used in other studies, namely R&D expenditure, number of researchers and patents, were not easy to determine quantitatively. This was mainly because of a lack of availability of data while others did not wish to disclose this information. Like Mexico, many companies in Brazil did not have a specific amount of budgetary expenses allocated to R&D nor staff or staff time specifically for this purpose. This is because (like Mexico) the majority of SWH companies in Brazil are Small and Medium Enterprises (SMEs) and so do not have the budget, space, or time to conduct R&D activities. However, small adaptations of the technology were occurring over time. For instance, one SWH company noted that the cost of a solar panel in Brazil (aluminum with copper) had decreased from about US$500 to under US$100 in a 13-14 year period.[204] While some of this price has to do with the price of materials, reductions in price have also occurred as a result of learning, thus increasing the efficiency of production processes. The reduction in price of solar panels for SWHs in Brazil is particularly interesting because before the global downturn of Fall 2008, the price of copper had been – on and off -- steadily increasing since 2002 (where it was under US$1.00). Copper was trading at about US $4.08 per pound in July 2008, versus about US$1.35 in January 2009 (Gross 2009).

Other organizations, such as Sociedade de Sol, provided their monthly budget, which was 7 000 reais, or US$ 3 300 and mainly financed through monthly courses, but this included all activities of the NGO – a large portion being devoted to dissemination, and the operations involved in running an NGO (e.g. salaries, overhead) – not just R&D.[205]

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[204] Interview, one SWH company, April 2007
[205] Interview, one NGO representative, March 2006

Another proxy used to "measure" knowledge is through patents or types of patents. In general companies do not have a patent on their SWH (although some receive royalties when a distributor uses a SWH produced by another company).[206] One company indicated that no one had a patent as it was a common good – although another company did indicate that they had a patent on their SWH in Brazil.[207] One NGO noted that they "do not want a patent" – their goal was to spread this technology to as many people as possible – with a particular focus on grade school-age children through disseminating "kits" (or an example low cost SWH) to be used in classrooms.[208] Having said this, although there were some examples of companies working with universities on R&D activities, the SWH companies did note that they rarely worked with others due to IPR concerns.[209]

Also, as noted in Chapters 1 and 4, the problem with using these proxies as ways to measure knowledge is that they do not account for the differences between information (e.g. number of patents applied for and received, R&D dollars) and knowledge (how this information is processed and interpreted). While recognizing these limitations, one way to measure the software is to examine those organizations working on SWHs in São Paulo.

5.4.1. Organizations working on SWHs in São Paulo

All interview respondents working on SWHs spoke of capacity building initiatives underway regarding solar energy and SWHs in and around São Paulo. All respondents from a broad range of stakeholders indicated that there are two key players involved in capacity building efforts for SWHs in Brazil and especially in São Paulo. These organizations are the trade association ABRAVA through their DASOL section and the Brazilian environmental NGO Vitae Civilis. Activities undertaken include active participation in an International Construction Industry Trade Fair in São Paulo, or Feira da Indústria e Comércio (FEICOM), a yearly conference of the construction industry, workshops and presentations to various municipalities throughout Brazil, maintenance

[206] Interview, one SWH company, March 2006
[207] Interview, two SWH companies, March 2006
[208] Interview, two NGO representatives, March 2006
[209] Interviews, two SWH companies, one NGO, March 2006

of the ABRAVA and Cidades Solares website and fostering these networks, studies on solar water heating for Brazil and pursuing the climate angle for this technology, details on SWH companies and the SWH market, etc.[210] Other active organizations working on SWHs in and around São Paulo include the consultancy Lumina, the NGO Sociedade de Sol – mainly through their "Do It Yourself" model of a SWH which is disseminated through various courses run throughout the year on SWHs, information on the low cost SWH available on their website, and their project aimed at distributing kits to all grade schools within the Grande São Paulo region and the Grupo Solaris, running out of the Piracicaba campus of the USP (about 160 km from the city of São Paulo).[211]

Formal capacity building efforts in and around São Paulo include the Piracicaba campus of USP and, while located in Minas Gerais, the Pontifica Catholic University of Minas Gerais, in Belo Horizonte, is also very active on this front in Brazil. This university has a Green Solar lab where they simulate solar conditions – only one of six available worldwide - so as to test SWH equipment.

There are also other universities and groups in other parts of Brazil working on SWHs such as the Federal University of Santa Catarina or Universdade Federal de Santa Catarina (UFSC) in the south (their LABSOLAR) and National Reference Centre for Solar and Wind Energy, or Centro de Referencia para Energia Solar e Eólica Sergio de Salvo Brito (CRESESB) in Rio de Janeiro.

This is interesting because Belo Horizonte, the capital of Minas Gerais, is the nexus of SWH activity in the country, but it is not close to São Paulo (they are about 300 miles apart). By contrast, one key hub of SWHs in Mexico is in Cuernavaca which is less than an hour by vehicle south of Mexico City. At the same time, a number of those involved in the SWH industry in São Paulo were aware of this research and had contacts with these institutes – especially with the Green Solar Lab in Belo Horizonte where SWHs were tested. For instance, one SWH company representative from Belo Horizonte but now working outside of São Paulo had formerly studied and worked at

[210] Interviews, 11 SWH companies, three NGOs, one consultancy, one energy company, four government officials
[211] Interviews, one consultancy, one NGO, March 2006 and May 2007

LABSOLAR and was in communication with his former colleagues.[212] In Mexico City, although connections between academics and industry also existed (e.g. Cuernavaca researchers with Cuernavaca SWH companies, and the changing dynamics of ANES where academics and industry representatives were a part of the steering board), these networks were smaller and more recent.

Regarding government involvement, at the federal level, the Ministry of Science and Technology has at least one official examining SWHs under the renewable energy portfolio.[213] There are no people working specifically on SWHs at the state level government in São Paulo – only one person is devoted to renewable energy sources within the Secretary of the Environment of the State of São Paulo.[214] The municipal government however is becoming increasingly involved in SWHs especially their Secretary for Green and Environment but also the Secretary for Social Housing[215] as they approved a law at the municipal level on June 30, 2007, making it mandatory for various new buildings in São Paulo to have 40% of their water heating come from SWHs – residential buildings with 4 or more bathrooms, and commercial and industrial buildings (Vitae Civilis 2007).

In Mexico City, the municipal government was also very active on SWHs at the time of study 2005/06, with some key voices supportive of this industry in the federal government too. However, as one Mexican federal government official told me, there were still "many missed opportunities"[216]. In other words, as is demonstrated in Chapter 7, it is important to pay attention to the dynamics between and among stakeholder groups, as these connections can play a role on RET use.

In Brazil, certification of people working on SWHs – developers, producers, distributors and / or installers generally occurs through companies themselves. People are trained through their experience in the companies after receiving technical training at universities.[217] One company representative noted that initially he was a distributor for a SWH and then, as the technology was simple, and he had university-level,

[212] Interviews, eight SWH companies, March – May 2006
[213] Personal communication, one government official, November 2006
[214] Interview, one government representative, March 2006
[215] Interviews, two government officials, November-December 2006
[216] Interview, one government official, November 2005
[217] Interviews, three SWH companies, March - May 2006

technical training, he decided to make SWHs himself and open up his own company.[218] To summarize, there are about nine organizations (including three government agencies), apart from SWH companies, actively working on SWHs in and around the context of São Paulo.

In 2006, there were over 3.6 million SWHs installed in Brazil and, using the estimates above, almost 200 000 installed in the city of São Paulo. This would be a rate of almost 2 m^2 / 100 inhabitants for Brazil or 2 m^2 / 100 inhabitants for São Paulo in 2006. While low when compared with other countries with similar populations and climates, these are higher numbers than Mexico (0.7 m^2 / 100 inhabitants) and Mexico City 1.3 m^2 / 100 inhabitants, not including pools. That said, if pools were included, the number would be similar 2 m^2/ 100 people.

So in other words, SWH use on a per person basis is similar in both cities. But, when broken down by market segment the numbers are quite different – including about 28% for residential use in Mexico City versus 80% in São Paulo and commercial and industrial use[219] about 72% in Mexico City versus 20% for commercial, industrial *and* swimming pool use in São Paulo. What accounts for these differences? This question will be explored in Chapters 6, 7 and 8.

Like Mexico, the SWH market is growing steadily. In addition, the SWH industry has been in existence for over 30 years and an increasing amount of players are becoming actively involved in this technology. Before turning to the factors that affect SWH use in São Paulo identified by informants we will first examine another viable RET for urban environments in Brazil – biogas to produce electricity.

5.5. Using Biogas to Produce Electricity in Brazil and São Paulo – the hardware

5.5.1. Biogas to produce electricity equipment use in Brazil

[218] Interview, one SWH company, April 2006

[219] This number also includes SWH for multifamily dwellings (i.e. apartment buildings) but I was told by informants that there were very few examples of this in Mexico City, Informal discussions, key informants, November 2005 – January 2006.

Like Mexico, another potential renewable energy source for urban areas in Brazil is biogas – and specifically, the production of electricity through landfill gas. This technology was chosen based on previous research done in this area, arguing for its potential. The majority of waste from urban areas in Brazil is sent to *lixões*, which are, in essence, open dumps, lacking basic technologies required in order to minimize the environmental and health impacts of the waste.[220]

In addition, even though the waste per capita in Brazil is significantly less than many Organization for Economic Cooperation and Development (OECD) nations, the huge population of Brazil (186 million est.) means a large amount of waste is generated. As an example, in 2007 São Paulo generated nearly 15 000 tons of waste daily with half going to one landfill in the north (Bandeirantes) and the other half going to another landfill to the east of the city (São Joao).[221] This amount is also confirmed through other sources, such as the CDM Bandeirantes project proposal (2005: 2).

As noted in Chapter 1, the decomposition process of organic waste in a landfill in the absence of oxygen (anaerobic digestion) produces methane gas, which, rather than being passively released, is directed through tubing to an electricity generating plant. The gas is treated (cooled down and then heated again) to enable it to be used as a fuel for electricity generation. The gas is constantly monitored, measured and analyzed. Here, motors are adapted to work on a smaller scale and to use biogas as their fuel. Some methane gas may also be flared.[222] This information is also confirmed in the detailed project proposal prepared for the CDM Executive Board to generate Certified Emissions Reductions (CERs) for the Bandeirantes and São Joao Landfill Gas to Energy Project (Biogas 2005): 2-8 and São Joao 2005: 4-5).

Government and university officials noted that research in this area began after the first energy crisis in the 1970s, however when the prices for fossil fuels decreased in the 1980s, much research in this area was abandoned.[223] More recently however, experts indicated that there is increasing interest in the biogas market in Brazil by investors due to the climate change link – the potential to generate Certified Emissions Reductions

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[220] Interview, one consultant, one government official, March 2006
[221] Interview and Personal Communication, one government official, March 2006 and October 2007
[222] Personal communication, one biogas engineer, March 2006
[223] Interviews, one government representative, one university representative, March 2006

(CERs) under the Clean Development Mechanism (CDM). This is because 75% of the methane produced in Brazil is from landfills and the other 25% is from industrial effluents or treated domestic effluents.[224] This is confirmed in Wagner Silva Alves and Lucon's "Brazilian Country Profile – Methane to Markets Partnerships" (Wagner Silva Alves and Lucon 2005: 2).

Another reason for the interest in biogas to produce electricity (or through flaring biogas) is due to local air pollution problems. One respondent indicated that the burning or flaring of landfill gas was also a means through which to decrease the concentrations of a number of harmful gases (e.g. NOx and carbon monoxide) at lower levels of the atmosphere.[225] In addition, work on this area has been occurring for a number of years. For example, in 1998, the first meeting of good practices to reduce methane to address climate change occurred through an initiative of CETESB and the Intergovernmental Panel on Climate Change (IPCC).[226]

As of late 2007, there were five landfill gas to energy projects up and running in Brazil. Two projects are in São Paulo (Bandeirantes and São Joao – discussed below) and the others are in the states of Mauá and Espirito Santo and NovaGerar, just outside of Rio de Janeiro[227]. According to Osvaldo Stella Martins, National Reference Centre on Biomass (CENBIO), the majority of investment and interest in landfill projects as potential CDM projects is on flaring methane, rather than producing electricity, using biogas as a fuel to run a motor. This is because carbon emissions generated in both cases (whether the biogas is flared or burned to operate a motor) are about the same. In fact, emissions generated by using biogas to run a motor rather than through flaring are a little bit more, but "the difference is very small".[228] Similar to Mexico too, Brazil's electricity sector – characterized by stipulations for IPPs is not so conducive for investment in this area.

However, discussed further in Section 5.7 and Chapter 8, this situation may change as there have been some changes in Brazil's electricity legislation and there is increasing

[224] Interview, one government representative, March 2006
[225] Interview, one engineering consultant, March 2006
[226] Interview and Personal Communication, one government official, March 2006 and October 2007
[227] Personal Communication, one government official, October 2007
[228] Interview, one university representative, March 2006

interest to have CDM projects contribute to the development dividend, where electricity can benefit community members.

Interest in this RET is also occurring at the national level of government. According to one engineering consultant, the federal government – the ministries of Science and Technologies, Cities, Environment and Energy -- are working on a biogas program at the national level with assistance from UNDP. The World Bank is also interested in this initiative – they conducted a course regarding how to do these projects. The federal government put together a group of experts (about 20 experts throughout the various regions) in the country to examine the 200 largest municipalities in Brazil in order to identify 30 potential landfills throughout Brazil where biogas to generate electricity would be most feasible. The Japanese government is providing funds for these studies.[229]

5.5.2. Biogas to produce electricity equipment use in São Paulo

As noted above, there are two biogas to generate electricity projects up and running in the two landfills where waste from São Paulo was and / or is deposited (a third landfill, San Mateo, is no longer operational) at the time of the study (2006) and writing (2009).[230]

Bandeirantes - This landfill is located north of the city and has been operational since 1979. The active part of the landfill (which is two of five parts, or "cells AS-4 and AS-5") or the part still receiving waste in 2006, is about 400, 000 m^2. However, the landfill was closed in March 2007.[231] In March 2006, Bandeirantes had over 36 million tons of waste deposited.[232] In addition, unlike many of the other landfills in Brazil, Bandeirantes uses some of the most modern technology to decrease environmental degradation in Brazil.[233] Moreover, the waste located in Bandeirantes has a high organic content (about 70%). At present, inorganic and organic waste is not separated,

229 Interview and Personal Communication, one government official, one engineering consultant, March 2006 and October 2007
230 Interviews and Personal Communication, one government official, one engineering consultant, three university representatives, March 2006 and October 2007
231 Personal communication, one government official and one engineer, March 2009
232 Interview, one engineering consultant, March 2006
233 Interviews, one government official, one engineering consultant, March 2006

but there are plans to do so in the future.[234] In the past, the waste was buried in strips with clay separating the layers and there were pipes placed throughout the system, which served as vents to release the methane gas produced through the anaerobic process of the organic waste. Occasionally, the gas was flared but more often than not, methane was simply released into the atmosphere.[235]

This landfill was viewed as a potential for biogas since 1996 by CETESB, and reiterated in 2001 after an extensive study on the potential for biogas from landfills in and outside of São Paulo with the assistance of the United States Environmental Protection Agency (EPA). After this study there was a Brazil-wide seminar with World Bank aid on solid waste and carbon credits.[236] During this time, technicians interested in this project spoke with CETESB about the possibility of this project.

In this project, a consortium of companies – both Brazilian and international – decided to work together, creating the company Biogas, to generate electricity through biogas. In other words, rather than releasing the methane through the venting system, the gas would be used to run 24 motors from Caterpillar (an American company) to generate electricity, and a small amount would be flared to reduce methane emissions. These companies are two Dutch firms – Arcadis and Van der Wiel and a Brazilian construction company, Heleno & Fonseca. Caterpillar would guarantee the electricity produced and the companies operating in Brazil would handle the administrative and financial aspects of the project. While the installed capacity is for 20 MW of electricity to be produced, as of 2006, about 15-18 MW was produced. Unibanco, one of the largest banks in Brazil, owns the electricity generation equipment (leased out to another company biogeracao). The electricity produced through this plant is owned by Unibanco and provides electricity to their various branches throughout Brazil.[237]

One interesting point about the Bandeirantes project is that it was implemented in a very short time frame (September – December 2003) – including the construction of the powerhouse, as well as installation of the motors and flaring and monitoring

[234] Interview, one engineering consultant, March 2006
[235] Interview, one engineering consultant, March 2006
[236] Interview, one government representative, one engineering consultant, March 2006
[237] Interviews, one university representative, one government representative, one engineering consultant, March 2006

equipment. This is because there was a very short window in the Brazilian federal legislation regarding electricity, which allowed energy producers to transmit electricity free of charge and not necessarily sell it to Eletropaulo, which had been the requirement otherwise[238] - Unibanco was able to transmit the electricity generated from Bandeirantes to their bank branches throughout Brazil (about half of the electricity required by the branches comes from Bandeirantes).[239] Half of the generated CERs go to the municipality of São Paulo (who owns the landfill) and the rest is shared between biogas and Unibanco.[240]

Conventional technology adoption arguments emphasize how this legislation was a direct incentive for this RET by providing free access to the grid. But this does not tell the whole story. Rather, this legislation was also related to Brazil's trade and competitiveness approach, favouring neoliberal reforms but with stipulations, allowing more flexibility and reducing costs for IPPs thus encouraging private investment.

São Joao - This was other active landfill for the municipality of São Paulo in 2006, located to the east of the city, which was expected to close down in April 2009. (A new landfill, Ecourbs o Floresta, is being built in front of São Joao at the time of writing).[241] This landfill has the potential capacity to accept waste for the next 40 years. Moreover, the potential to generate biogas is the same as Bandeirantes.[242] The same consortium of companies created a landfill gas to energy project, which came into operation May 2007. Detailed information about this project was unavailable from key informants at the time the majority of information was obtained (Spring 2006) but according to the CDM project proposal it is expected to generate the same amount of electricity (20 MW), using the same types of technologies and possessing the same company to manage the project as the Bandeirantes project (São Joao PDD 2005: 2).

[238] Since June 2007, a new federal law was created allowing for free transmission of electricity from renewable energy sources (Personal Communication, one government representative, October 2007).
[239] Interview, one engineering consultant, one government representative, March 2006
[240] Personal communication, one government official, October 2007
[241] Interviews, one government official and one engineer, March 2009
[242] Interview, one government official, March 2006

5.6. Using Biogas to Produce Electricity in Brazil and São Paulo – the software

As noted earlier, some indicators used in other studies to measure technological knowledge, such as R&D expenditure, number of researchers, patents and types of patents, were difficult to use in this case study. This is because even though there are both national and international technology options available for biogas from landfills to produce electricity, the projects in São Paulo are using international technology – making these attributes harder to trace.

Capacity building efforts and interest in this technology are increasing in Brazil. Joao Wagner of CETESB provided an example to demonstrate this point. He noted that when he undertook his Masters at the University of São Paulo (USP) (1995-2000), he was the only one studying the issue of biogas. However, as of 2006, he noted that there were 20 studies underway on the issue – he has seen a major increase in interest in the last eight years (1998-2006).[243]

There are a number of companies, such as Biogas, Econergy and EcoSecurities, working on landfill gas to generate electricity in Brazil. Moreover CETESB, of the state government of São Paulo is working with the federal government MCT and the State Secretary of the Environment on a software program, which simulates methane emissions at a landfill (as well as another version dealing with wastewater and rural waste) and measures potential biogas recuperation rates. CETESB is also working on a guide regarding biogas, also produced with the municipality of São Paulo, and financed by the federal Ministry of Science and Technology.[244] The federal government is active on this issue, mainly through the nation-wide project being jointly run by the MCT, the Ministry of Cities, MME and MMA. One of the key areas where Brazilians saw a good potential for this technology was São Paulo due to the large amounts of waste concentrated in one area and the sophistication of the two landfills used by the municipality of São Paulo.

[243] interview, one government official, March 2006
[244] Interview, one government official, March 2006

5.6.1. Organizations working on biogas to generate electricity in São Paulo

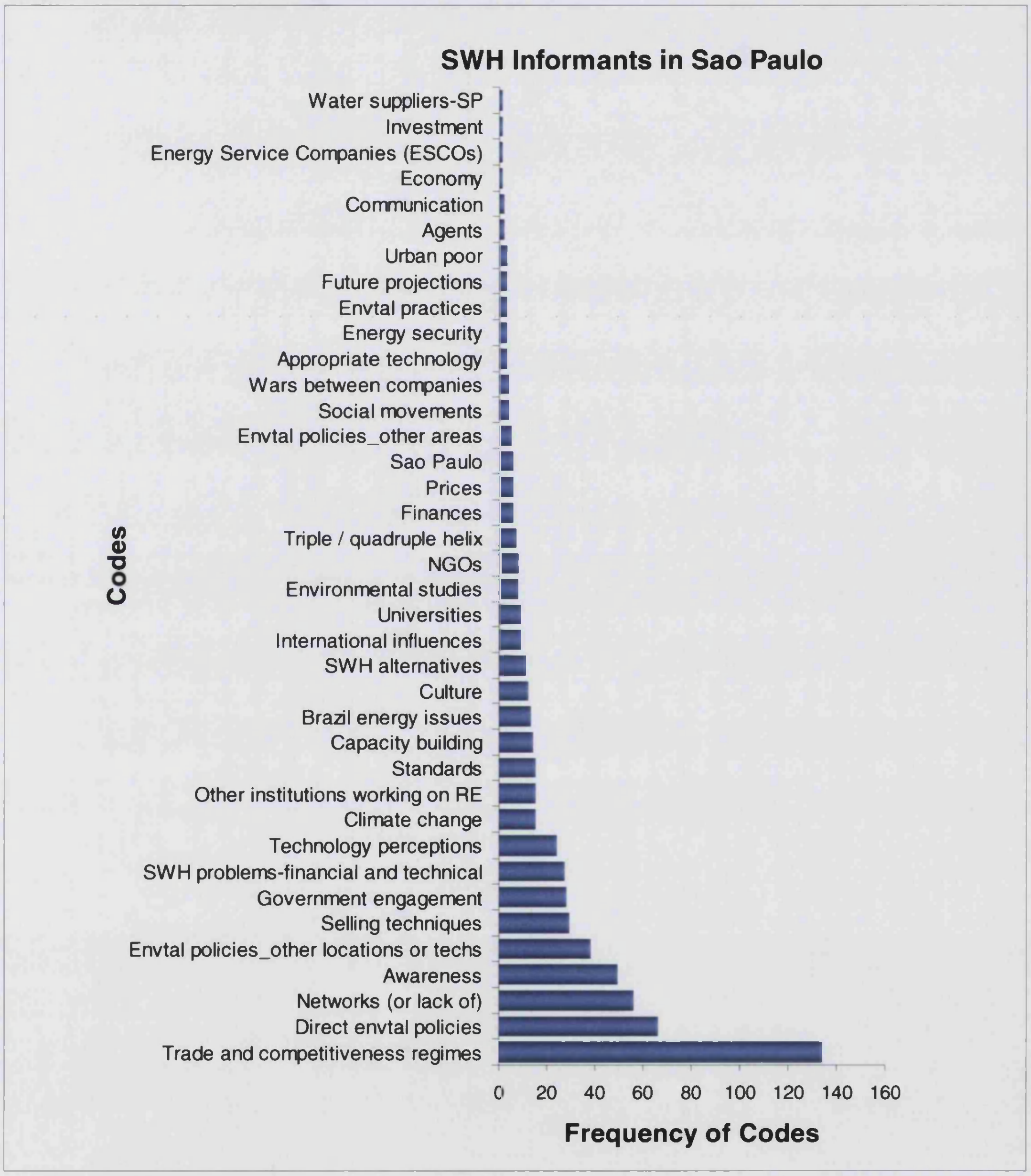
With respect to the amount of organizations working on biogas to produce electricity in São Paulo, as noted above, there is one company (actually a consortium of companies), one university, and two government agencies. The specific number of consultants working on this issue was difficult to determine (my research brought me into contact with one of the key engineering consultants), but informal discussions indicate there are a number of consultants working on this issue in São Paulo.

To summarize, in contrast to Mexico City where the key player working on the potential for biogas projects at the time of study (2005-06) was the private sector, with the majority of companies coming from abroad, Brazilians, including the government, especially at the state level and others who are consultants, engineers and other technicians, are more actively engaged in this technology. Networks between stakeholders have also been around for longer and are more established verses Mexico City. This is important for two reasons. First of all, one reason for Brazilian earlier engagement on biogas technology is due not only to direct government incentives (encouraging research on renewables including biogas after the oil price shocks of the 1970s), but also because of their trade and competitiveness approaches, which discouraged imports of foreign technologies up until the reforms that Cardoso put in place in 1994. Even after Brazil began allowing more imports, the country did so at a slower place and with more stipulations involved. For instance, as explained earlier in the chapter, foreign companies with more than 3 people employed in Brazil had to ensure that 2 / 3rd s of their workforce and payroll recipients were Brazilian. These represent more opportunities for Brazilians to develop their technological capacity, where they acquire knowledge, skills and expertise, as well as physical equipment. Secondly, as is explained further in Chapter 7, the nature of the relationships between and within stakeholder groups can also impact adoption. In this case, like SWHs, links between the groups had been established for longer and were more institutionalized.

5.7. Factors Affecting SWH Use in São Paulo

The graph below represents the frequency that processes were discussed by informants – namely those factors having an impact on the uptake of SWHs and biogas to produce electricity. Codes were themes identified by respondents, with some based on predetermined topics to serve as guideposts, during the discussions.

Graph 5.1 Factors Affecting SWH Use in São Paulo



Source: Author, based on Atlas ti analysis, July 2008, updated August 2009

As indicated in the graph above, themes identified by respondents ranged from trade and environmental policies to social movements and appropriate technology. This chapter on findings will explore the most prevalent themes affecting the uptake of these RETs, as identified by key informants. Initial explorations are made in this section, but these themes are expanded upon in the analytical chapters – 6, 7 and 8.

The most prevalent theme noted by respondents was **trade and competitiveness regimes**. Specific topics identified include origins of the technology and standards. In Brazil, as noted above, SWH companies are domestic and mainly rely on products found in Brazil (one major exception is copper, but all copper in Brazil is concentrated in two firms in São Paulo), which reduces the time between acquiring components and production.

Similar to Mexico, there was no general consensus among informants that Brazil's current regime (conditionally open trade) was helping or hindering the uptake of SWHs. One informant for instance indicated that the current make up of the SWH market in Brazil – consisting of Brazilian standards, Brazilian technology, and tax exemptions between Brazilian states was "helping to commercialize this technology."[245] Another echoed the same sentiment "you can purchase all of the components [needed to make a SWH] in a *loja da esquina*, or a corner store – everything is made using local material."[246]

On the other hand, all emphasized the fact that because the alternative to SWHs in houses was an electric shower (very inexpensive), and that the electricity sector was heavily regulated – contributing to cheaper prices for electricity[247], played a negative role on adoption. Brazil has some programs in some distribution and transmission networks that charge different prices for electricity consumed during peak, and outside of peak, hours, and for large consumers of electricity and residential users, but these were not in place in São Paulo at the time of research (2006).

The second most prominent theme identified was the role of **direct environmental policies**; or, those policies which sought to increase the adoption of renewables – either in general, or specifically Solar Water Heaters (SWHs). A number of informants spoke

[245] Interview, one SWH company, March 2006
[246] Interview, one NGO, March 2006
[247] One reason for these government subsidies was to help several industrial sectors in Brazil, such as aluminium

about the federal government's increasing interest in renewables through the Alternative Sources of Electricity Incentive Programme (Programa de Incentivo às Fontes Alternativas de Energia Elétrica, PROINFA), where the government is actively seeking the generation of 3,300 MW of energy from biomass, micro hydro plants and wind. In order to qualify, 60% of the project's components must be from Brazilian sources (ITA 2005).

People also spoke about Brazil's National Electricity Conservation Program, or Programa Nacional de Conservacao de Energia Elétrica (PROCEL), created in 1985, which focuses on various energy savings programs including demand side management (DSM) activities. In 1993, Presidential decree created the Energy Efficiency seal, or PROCEL seal, which recognizes energy equipment used by Brazilians that have the best energy efficiency levels and / or consumes the least amount of energy. Informants indicated that these programs were helpful in generating interest in renewables generally speaking, but not SWHs per se as they are not specifically targeted in either initiative.

One policy informants from NGOs and the private sector considered helpful is the joint PROCEL-INMETRO Performance seal (classification "A" under INMETRO standards) that SWHs can received – to be used by companies and organizations in their marketing, on their equipment, etc. But all did not share this view. Some interviewees however felt that these standards, albeit voluntary, penalized other forms of SWHs that may not be as reliable, but were significantly cheaper (and thus more affordable for many Brazilian families).[248]

[248] Interviews, six SWH companies, two NGOs, March 2006; Rodrigues and Matajs, 2005

Figure 5.4 PROCEL-INMETRO seal

Source: www.eletrobras.com.br

Another policy at the federal level noted by interviewees requires energy utilities to devote a small percentage of their annual revenue on research and development (R&D) for conservation measures, of which SWH programs would qualify. Eletropaulo, for instance, is required to spend 0.5% of its revenues on energy efficiency projects.[249] There were no SWH projects operating under this fund however at the time of study (although there was one project considered successful in Rio de Janeiro). I was told one reason for this was because at the time of study (2006), "Eletropaulo is not interested in this issue".[250] But things have likely changed at the time of writing (2009) because responses from Eletropaulo in 2007 indicated that they were starting to initiate projects regarding this technology (planning stages), through this mandatory requirement to allocate some revenues to energy efficiency projects.[251]

Some interviewees noted discussions, lead by the municipal government and Vitae Civilis and ABRAVA, to mandate the use of SWHs in various buildings including houses, apartments, as well as commercial, service and industrial buildings. These discussions occurred over two years, and were made into a law at the end of June 2007. This law 11.228/1982 was incorporated in municipal building codes.[252] A subset of this theme identified was **climate change,** where some respondents had worked on reports estimating the potential to generate carbon credits through SWH CDM projects as will be discussed further in Chapter 7.

Related to this area were environmental policies **in other locations or for other renewables**, where respondents noted success stories or failures with other RETs or in

[249] Interview, one electricity distributor, April 2007
[250] Interview, one NGO, March 2006
[251] Interview, one electricity distributor, April 2007
[252] Personal communication, two NGOs, June 2007

other settings. One example of SWH adoption considered successful in Brazil, mentioned by the majority of respondents from a range of stakeholders, is the case of Belo Horizonte, Minas Gerais. Here, the Energy Company of Minas Gerais, or Companhia Energética de Minas Gerais, (CEMIG), a state-run electricity company for the state of Minas Gerais was concerned about electricity being used, especially during peak hours. One major consumer of energy, which forms much of the electricity demand during this period (about 6-9pm in the evening), is the electric showerhead as it customary for Brazilians to take a second shower in the evening. For this reason, CEMIG put in place a number of incentives, such including rebates to encourage people – consumers, construction companies and architects, to adopt this technology. This was done as a result of the apagão of 2000 / 01. Over the past 10 years SWHs have become very common in this city; they can be seen on top of many apartment buildings. This technology is common among the middle and popular classes also.[253]

People highlighted this story however as a way of indicating their discouragement as to what was happening in São Paulo. That said, this situation might be changing with the introduction of the mandatory SWH law of April 2007 noted earlier and most recently São Paulo's comprehensive climate change policy law of June 5, 2009 (14.933). This law promotes the use of renewables and the gradual substitution of fossil fuels, and the research, development, dissemination and promotion of low carbon technologies. Incentives are to be put in place for decentralized energy options, focusing on renewables and to eliminate the subsidies on fossil fuels. The city will also implement energy efficiency and renewable energy programs in the construction, transport and industry sectors (Paulo 2009; Robinson 2009); Robinson 2009).

To summarize, one cannot say definitively whether or not these environmental policies have played a positive role on increasing SWH use in São Paulo. Brazil's policies favouring renewables were considered useful in instigating more interest in renewables, but it was not clear that they were helping the uptake of SWHs. Most felt that Brazil's voluntary standards program for SWHs was a positive influence on SWH use, as they guaranteed quality and reduced 'bad quality' products in the market, but some felt that

[253] Interviews, two NGOs, one government representative, one consultancy, three SWH companies, March 2006, April 2006, November 2006, May 2007

this program pushed out simpler, more affordable SWHs, even though there were not as reliable.

The third theme that respondents underscored was the role that **networks, or a lack of networks**, can have on the uptake of SWHs in São Paulo. Although many companies worked independently, at least some form of connections existed between companies, government agencies (mainly INMETRO) and some universities (those with solar labs). A number of SWH companies in and around São Paulo had some form of individual contact with universities as those companies wishing to have their product certified by INMETRO were required to send their technology to university test labs (either IPT in São Paulo or GreenSolar Lab in Belo Horizonte).[254]

> "INMETRO is a government organization that tests products. So a product must pass a series of minimum requirements...INMETRO analyzes whatever product...so that the product will reproduce what you have promised ...[INMETRO] has a classification system.".[255]

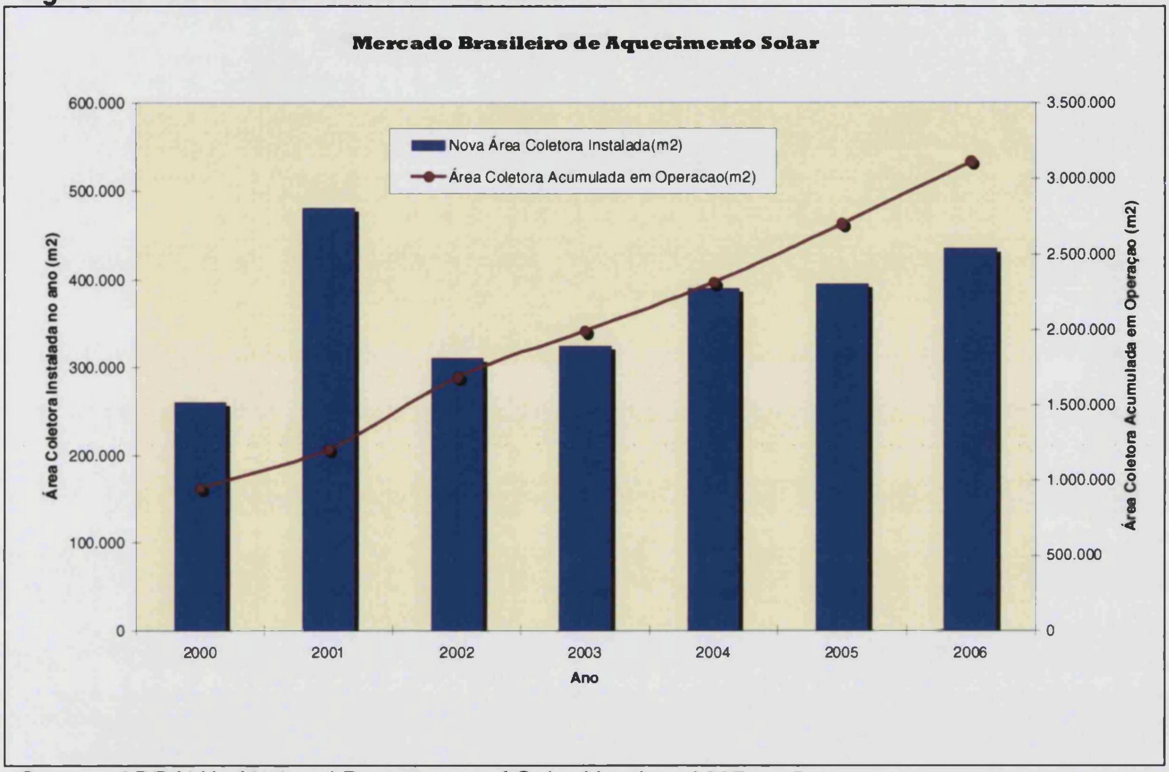
Another network occurred as a result of the work of the NGO Sociedade de Sol, which is physically located at the University of São Paulo's "incubator park" called the Incubator Centre for Technical Businesses, or Centro Incubador de Empresas Tecnologicas (CIETEC). Sociedade do Sol has been housed at the university since its beginning, in 1992, where it began as an engineering firm as a means to implement some of Agenda 21's goals – namely to find a simple, indigenous, non-fossil fuel energy technology for Brazil. It became an NGO in 1999, and after 10 years of research, they developed a cheap solar water heater, using local materials. The NGO continues to work with CIETEC but it also noted that some university professors – those interested in cutting edge and 'state-of-the-art' technologies – did not agree with the NGO's philosophy of pursuing social, economic and environmental goals simultaneously, at the expense of efficiency and quality.[256]

A further factor that respondents indicated as playing a role on technology adoption is **awareness**. Rather than awareness of the technology however, many spoke about the

[254] Interviews, six SWH companies, March – May 2006
[255] Interview, one SWH company, March 2006
[256] Interview, one NGO, March 2006

apagão of 2000/01, where they had witnessed a strong spike in sales of SWHs immediately after the event.[257]

Figure 5.5 - Solar Water Heater Market Growth in Brazil



Source: ABRAVA- National Department of Solar Heating, 2007, p. 5

Respondents indicated that some of the public in São Paulo is more aware of environmental issues, conserving energy, and renewable energy options because of the apagão. However a number felt that as time passed, memories of black outs and energy rationing were decreasing.

Responses varied with respect to **government engagement**. Some felt the government was active, while others felt the government was not doing enough. The majority of informants however indicated that the Brazilian government has been interested in renewables for a long time (focusing on hydro electricity, through the PROALCOOL program, etc.). That said, the interest of government on energy, environmental issues and climate change depends on the technology and the level of government. The government at the federal level is active in biogas to generate electricity, and (mainly through the work of INMETRO) on SWHs. The state government of São Paulo has

[257] Interview, eight SWH companies, March – May 2006

been an active player on biogas to generate electricity at the technical level for many years, and most recently in the mid-1990s, but was absent on SWHs at the time of study. The municipal government was an active player regarding both technologies.

Financial and technical problems with SWHs were also noted as playing a role on adoption. Whether using a PROCEL-certified SWH (about US$900.) or Sociedade de Sol's low cost SWH (about US$100.) for a family in São Paulo, the electric showerhead, costing roughly a little over $US10, is significantly cheaper than the SWH. Some also felt that efforts to produce a cheap SWH at the expense of quality and efficiency (i.e. technical problems), i.e. to popularize this technology, would lead to more people having a negative **perception of this technology** as a whole, not just the cheaper types; they were afraid that all SWHs would be perceived the same – as a technology that did not work.

As indicated in many conventional studies on RETs noted in Chapter 1, financial and technical difficulties with SWHs do play a role on their use. But this finding is also important for the following reasons. First of all, as is discussed further in Chapter 7, it reveals the divisions within stakeholder groups as some NGOs were advocates for popularizing this technology through promoting an affordable, if not as reliant, option, while another NGO, working with a trade organization, were keen on increasing this technology to lower income populations through the creation of financial credit schemes. At present, the SWH market is dominated by those used in residences but the majority of those customers come from the top 10% earners in Brazil. In order to effectively reach the other 90% of the Brazilian population some reconciliation is needed between these actors pursuing these two distinct philosophies.

Secondly, these divisions show that some in Brazil are afraid that popularizing the technology will lead to negative perceptions of the technology, as a whole, not just the cheaper, simpler versions. Comparing with the Mexican case study where many informants felt that these negative experiences with SWHs were hindering its adoption in that country, and as some other studies have pointed out (e.g. Philibert 2006), these concerns may be valid. But, the Mexican case study also showed that these negative experiences occurred as a result of not only technical issues such as shoddy installations and equipment but also due to a lack of communication among players involved in the technology cooperation process and due to trade and competitiveness policies, as many informants in Mexico City indicated that these poor quality products were generally a result of 1) a lack of nationally-certified standards – which the majority of informants felt were not in place due to divergences of opinion among foreign and domestic firms and 2) Mexico's free trade policies that allowed cheap, inferior products into the country easily.

Similar to Chapter 4, after assessing these relevant themes, I undertook a second level of analysis to determine how often these codes manifested themselves in the four explanations proposed by the thesis 1) conventional explanations, 2) Diffusion of Innovations 3) Trade and competitiveness regimes, and 4) urban technology cooperation.

Table 5.2[258] Frequencies of Key Explanations for SWH Use in São Paulo

	Conventional Explanations	Rogers Diffusion of Innovations	Trade and competitiveness regimes	Urban Technology Cooperation
P36	6	3	4	4
P37	2	1	6	1
P38	9	8	5	1
P40	10	10	4	10
P41	6	7	2	0
P42	16	9	4	2
P43	4	4	4	7
P45	7	7	5	0
P46	11	13	5	18
P47	10	8	8	7
P48	5	4	4	3
P49	2	2	6	5
P51	5	6	4	5
P52	3	5	9	14
P53	3	4	6	3
P54	13	11	9	5
P55	11	13	21	14
P60	2	5	6	6
P61	16	17	9	16
P62	11	17	3	9
P63	31	20	14	13
TOTALS:	183	174	138	143

Source: Author based on Atlas ti analysis, August 2009

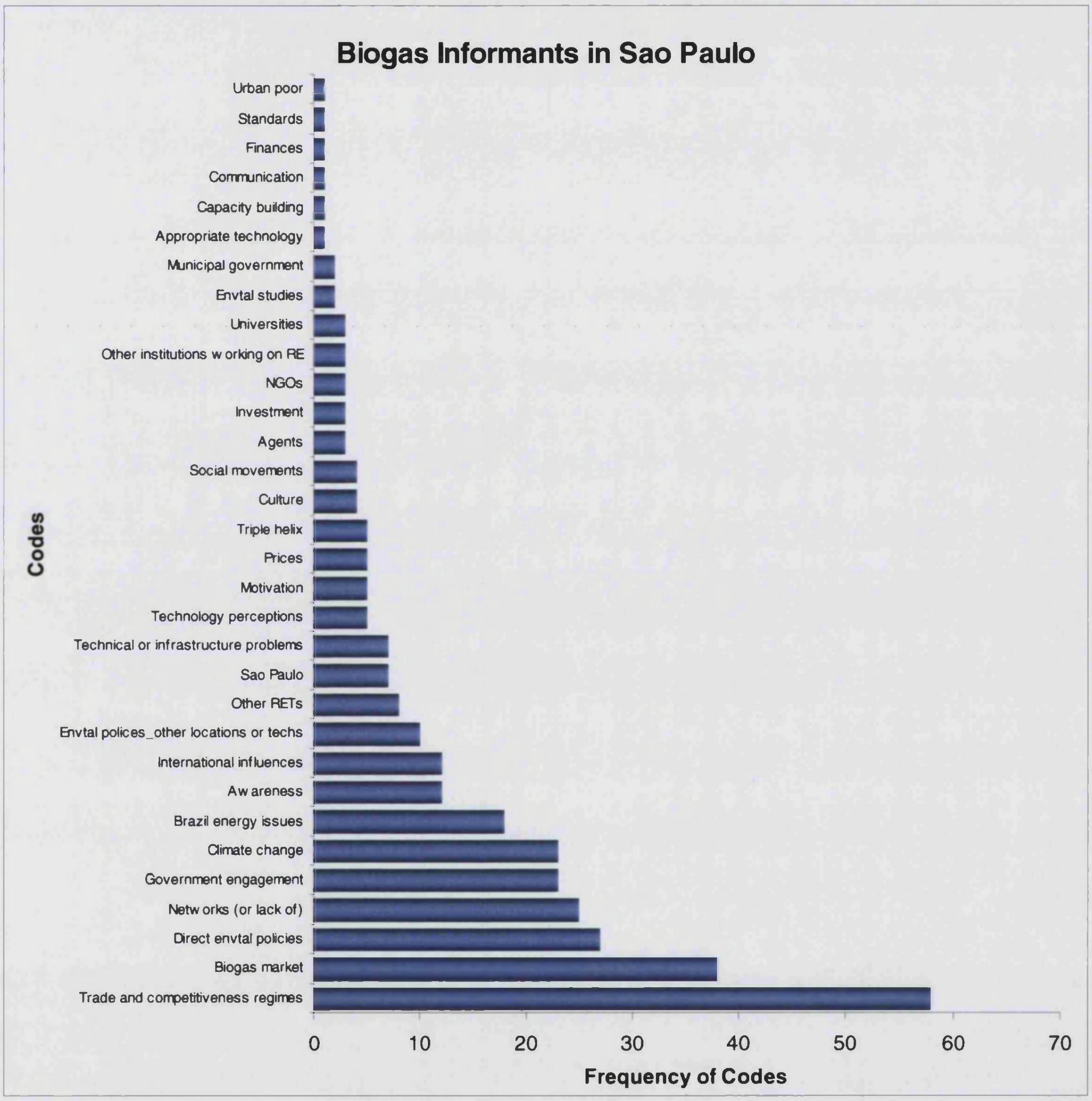
Table 5.2 above shows how common themes grouped under these frameworks were among SWH informants in São Paulo. As shown above, factors considered conventional explanations for RET uptake in developing countries, as well as those captured under Rogers' Diffusion of Innovations were prevalent. Yet in contrast to many conventional studies of RETs in developing countries themes grouped under the trade and competitiveness regimes and urban technology cooperation frameworks, were also significant. Similar to Sections 4.7 and 48 regarding responses in Mexico City, the next step is to examine the details within these code families regarding how these three alternative frameworks reveal the most important factors affecting RET use in developing countries. This analytical task is carried out in Chapter 6, 7 and 8

5.8. Factors Affecting the Use of Biogas to Produce Electricity in São Paulo

[258] See **Annex 2** for details on respondents

The graph below represents the frequency that processes were discussed by informants – namely those factors having an impact on the uptake of SWHs and biogas to produce electricity. Codes were themes identified by respondents, with some based on predetermined topics to serve as guideposts, during the discussions.

Graph 5.2 Factors Affecting Biogas to Produce Electricity Use in São Paulo



Source: Author based on Atlas ti analysis, July 2008, updated August 2009

The first factor most prevalent in discussions was the potential impact of **trade and competitiveness regimes** on this technology. Specifically, informants spoke about taxes, which constituted 50 percent of project start up costs, and the momentary "break" in the Brazilian legislation which allowed IPPs access to the electricity grid to sell to others, not just Eletropaulo, as noted above.

According to one government official, when determining which technology to use in the Bandeirantes project, there were three options available for this type of technology: Brazilian equipment costing 1000 reais per kW installed, more sophisticated Brazilian equipment costing 2000 reais per kW installed and foreign equipment costing 3000 reais per kW installed. Due to negative experiences with Brazilian technology and the better guarantees provided by the imported technology, the latter form was chosen for these projects.[259] In other words, despite these initiatives put in place by the Brazilian government to encourage the use of domestic technology, project developers were willing to pursue a foreign technology, despite these taxes. Similar to the SWH example in Mexico City, previous experiences or underlying conditions involved in a technology, rather than just awareness of a technology itself can affect adoption This is important because despite the theoretical and econometric studies that indicate otherwise, trade and competitiveness policies in and of themselves will not necessarily lead to the adoption of renewables but rather are context and technology-specific.

The second factor identified by participants affecting adoption rates of this technology was **direct environmental policies**, and especially **climate change** policies (e.g. CDM, methane to markets initiative, renewable energy sources). In the Bandeirantes project, for example, the municipal government of São Paulo owns half the money generated by the carbon credits from Bandeirantes. The city uses 50% of this money for a "green fund" for the city, to finance projects to work on the city's 'green spaces'.[260] Further discussions with study participants indicated that **international influences**, including the U.S. Environmental Protection Agency (EPA), and the U.S.-led methane to markets international initiative, have generated interest in this area.

Another factor participants identified is under the heading **government engagement**. . The Brazilian government is engaged on this issue at various levels, especially at the technical level. For specific projects however, government engagement – especially at

[259] Interview, one government official, March 2006
[260] Interview, one government official, one engineering consultant, March 2006

the political level – is mixed; one informant joked that the politicians showed up only when it was time to "take their picture".[261] I considered energy security issues under this heading. Biogas technology informants and some SWH informants indicated that Brazil still remained interested in energy security, as they were after the oil shocks of the 1970s, but that what was different now is that environmental considerations were also being taken into account. The general view among informants from all stakeholder groups however was that for all the government's rubric on the importance of diversity of energy sources, they still remained wedded to hydro power due to massive earlier investments and powerful interest groups. In addition, although the Lula administration indicates their interest in being more self-reliant, the South and Southeast of Brazil, and the state of São Paulo in particular is heavily dependent on natural gas from Bolivia, largely because of their 2004 agreement to 'use it or pay'.[262] As indicated in Section 5.1, this view is also similar to other studies (Roman 2007; Ruiz et al. 2007).

A further area identified by participants as affecting the use of this technology has to do with **Brazilian energy issues**. This is because Brazil, including São Paulo, is heavily reliant on hydro electricity. Some challenges with having a less diversified power portfolio include those identified earlier – the apagão, which caused power rationing and strains on peak electricity hours, where sources of electricity that can operate for 24 hours and not be dependent on seasonal fluctuations are attractive. On the other hand, as noted under trade and competitiveness regimes, usually IPPs were required to sell their electricity to Eletropaulo, but Unibanco was given access to the grid to transmit their electricity elsewhere (to their bank branches). Informants also spoke about the complications and complexities involved with generating electricity in Brazil – including various legislative and bureaucratic issues that deterred a number of potential investors away from these technologies.

Also, similar to discussions with informants involved in SWHs in both countries, and biogas to produce electricity in Mexico City, some interviewees spoke about increasing

[261] Interview, one engineering consultant, March 2006
[262] Interview, two university representatives, two NGO representatives, three SWH firms, two government officials, March 2006

awareness about renewable energy in São Paulo, in general – with increasing knowledge of climate change, and as a result of the apagão.

Table 5.3[263] **Frequencies of Key Explanations for Biogas Technologies to Generate Electricity Use in São Paulo**

	Conventional Explanations	Rogers Diffusion of Innovations	competitiveness regimes	Urban Technology Cooperation
P37	2	1	6	1
P39	11	4	16	19
P40	10	10	4	10
P41	6	7	2	0
P56	6	9	9	11
P57	3	2	5	4
P58	10	7	5	4
P59	8	8	7	8
P60	2	5	6	6
TOTALS:	58	53	60	63

Source: Author based on Atlas ti analysis, August 2009

Table 5.3 below shows how common themes grouped under these frameworks were among biogas informants in São Paulo. These results are particularly interesting because as indicated above, trade and competitiveness regimes and urban technology cooperation, as explanation groupings are higher than those factors grouped under conventional explanations and Rogers diffusion of innovations. The discussion chapters – 6, 7 and 8 -- assess these findings using the frameworks indicated.

5.9. Conclusion

In both countries, SWHs and biogas are marginal inputs into the energy matrix. Regarding SWHs, in both Mexico and Brazil, there are many different types of SWHs being used and this technology is steadily increasing in use within these countries but when compared to other developing countries with similar climates, the adoption rate is rather low. In terms of hardware, there are slightly more SWHs being used in São Paulo on a per person basis. But this difference is only slight. When broken down by market segment, differences between the cities are rather stark – with the majority of the SWH market in Mexico City devoted to commercial and industrial purposes or

263 See **Annex 1** for details on respondents

pools (depending on assumptions), and the majority of the SWH market in São Paulo allocated to residential use. This difference also has implications for energy savings because the majority of SWHs used for pools do not require as much energy as the water temperatures required are lower. So, in terms of energy savings, addressing climate change and energy security concerns, this is higher in São Paulo.

Secondly, the SWH hardware is more domestic in Brazil – SWH companies are Brazilian owned, and there are very little imports (copper from Chile and a few components by one company operating in another region of Brazil. In Mexico City however, there are domestic and foreign companies using foreign and domestic technology. As shown from the findings, issues related to trade and competitiveness regimes were the theme most highlighted by interviewees but opinions were mixed as to whether policies in this area were helping or hindering the use of SWHs in these countries. Under what conditions, if any, do trade and competitiveness policies impact the use of these technologies is the subject of Chapter 8.

With respect to biogas, in Mexico City, landfill gas to generate electricity is only at the exploratory stage – and as of 2008 there were no studies providing specific details about this possibility publicly available. Nevertheless, in both places there is a decades-old industry in place for SWHs and increasing interest by mainly the private sector in Mexico and both the private and public sectors in Brazil on biogas to generate electricity – the main impetus for the interest being the ability to generate CERs from the CDM under the Kyoto Protocol. In both places there is consensus that interest in these technologies is growing and that there is a real potential for the market to grow in these cities.

There is also a general sense that interest in renewables is also increasing in both places. Moreover, in both cities, there is a core set of active stakeholders – and these stakeholder groups are growing. In both places, a lot of people working on these technologies had either been involved with these technologies for a very long time (since the oil shocks of the 1970s), or relatively recently (since 2000).

Regarding the "software" for SWHs, there are slightly more organizations working on this technology in Mexico City, but this difference is very small (20 versus 18 SWH companies, and eleven versus nine organizations). With respect to biogas to produce electricity, there is more usage of this technology (looking at both hardware and software) in São Paulo. Chapter 6 which attempts to answer the question "why?" using Rogers' technology adoption model to explain RET adoption in these urban Latin American centres.

With respect to factors affecting the uptake of this technology, many of the key themes identified were similar in both places – including trade and competitiveness regimes, direct environmental policies, networks, and awareness. The impact of direct environmental policies and awareness has been well documented in other studies on renewables in developing countries (See Chapters 1 and 2 for details). That said, many RET studies from developing countries focus on awareness of a particular technology (e.g. Muntasser et al. 2000; Wilkins 2002). In this instance however, what appears to be more relevant are prior experiences which have shaped awareness and awareness of energy conservation issues more generally. In the case of São Paulo, positive awareness has become more pronounced due to the apagão. In Mexico City, there are negative connotations towards SWHs due to previous negative experiences with the technology.

What is also particularly interesting is that two of the prevalent themes – trade and competitiveness regimes and networks – are often neglected in conventional technology adoption and transfer models. Furthermore, although research regarding trade and competitiveness policies and the use of low carbon technologies is recent, the majority of evidence suggests that an open trade and competitiveness approach is more conducive to their uptake. Looking at evidence from Mexico and Brazil for both technologies however – SWHs and biogas technologies to generate electricity – it is not clear that an open or conditionally open approach leads to more use of RETs. Therefore, Chapter 8 assesses these findings in further detail by focusing on the question under what conditions, if at all, do trade and competitiveness regimes affect the uptake of low carbon energy technologies?

So what does this all mean? How are these factors, including similarities and – more importantly -- differences explained? The next step is to assess these findings using some alternative approaches. I have chosen to analyze these findings using three systemic approaches, accounting for economic and social factors, which have been proposed as different ways to explain RET uptake. These three lenses centre attention on the linkages between actors and stress the interdependent nature of technology adoption, which can in turn tease out the potential role of indirect / systemic policies on the adoption of RETs. For these reasons, as well as those noted in Chapters 1 and 2, the dissertation now examines Rogers' Diffusion of Innovations approach in Chapter 6.

CHAPTER 6: DISCUSSION – EXPLAINING RET UPTAKE IN MEXICO CITY AND SÃO PAULO THROUGH ROGERS' DIFFUSION OF INNOVATIONS MODEL

6.1. Introduction

Chapters 4 and 5 focused on the findings by looking at how much Solar Water Heaters (SWHs) and biogas to produce electricity technologies are being used, and factors affecting their use, in Mexico City and São Paulo. When broken down by market segment, these chapters concluded that more SWHs for homes and biogas to generate electricity technologies are being used in São Paulo versus Mexico City. But on the other hand SWHs for larger applications are being used more in Mexico City versus São Paulo. Discussions with informants indicated that some of the key factors affecting the use of these are direct environmental policies and awareness (similar to conventional approaches), but also RETs are trade and competitiveness approaches and networks between and within stakeholder groups, or technology cooperation participants, areas often neglected in classical explanations for RET use.

The following three chapters (Chapters 6, 7 and 8) analyze the findings using the research questions indicated earlier – namely what are the most important factors affecting RET adoption in the urban developing world?, And the sub-research questions - how can systemic approaches help to explain the uptake of RETs in the urban developing world? why are SWHs and biogas to produce electricity technologies being used or not in Mexico City and São Paulo? And under what conditions, if any, do trade and competitiveness approaches affect RET use?

Chapter 2 discussed three systemic approaches considered relevant for this study – Rogers' diffusion of innovations, urban technology cooperation and trade and competitiveness approaches. Another objective of these next three chapters is to assess these systemic approaches in explaining RET adoption in developing country cities.

The focus of Chapter 6 is on applying Rogers' Diffusion of Innovations model to the case of explaining SWH and biogas technologies use in Mexico City and São Paulo. I chose this model for a number of reasons. First of all, the model accounts for the classical explanations regarding RET use including economic and technical aspects. But this model is broader in that it also captures the potential affects of social factors and has a broader view of awareness, accounting for previous experiences and awareness of issues related to the technology, not necessarily the technology itself. Furthermore, the model examines a technology over time and recognizes the role of people who can influence technology uptake.

This chapter centres on three assertions. First of all, conventional explanations for RET adoption – stressing economic and technical facets, which are also captured in Rogers' model – are helpful in explaining why overall adoption rates are rather low. But when comparing these two cities, they cannot effectively account for certain differences between the two locations – why are more SWHs in homes and biogas technologies being used in São Paulo and why are more SWHs for commercial and industrial applications being used in Mexico City? This is because some results are actually the opposite of what would be expected from the diffusion of innovations model. As a specific example, the alternative for SWHs in homes in São Paulo is significantly cheaper there versus Mexico City (about US$10 versus US$300), and yet more are being used in São Paulo. Furthermore, results indicate that while incentives to encourage the use of these technologies are important steps, their ability to directly assist the uptake of SWHs and biogas technologies is not quite clear. Thus, there are limitations involved in applying systemic approaches to real world situations, as history and context can alter expected assumptions.

Secondly, Rogers' model helps to understand how prior experiences and awareness of energy conservation issues, rather than just awareness of technology, can impact adoption in these cities. He asserts that as awareness of a technology grows, so does the propensity for people to use it. But, he also indicates that negative experiences can have ramifications for adoption of the technology. Specifically, many informants claimed that Brazil's apagão of 2000/01 positively affected SWH adoption there, while in Mexico City past experiences with SWHs were deemed to have had a negative effect on the industry as a whole.

But, I suggest that it is not as clear-cut as this. Rather, history and context are important, which put some of his assumptions into question when applying the approach to Mexico City and São Paulo. For instance, Chapter 5 demonstrated that prior experiences led Brazilians to use a foreign technology to produce biogas despite the numerous taxes put in place by the government to encourage Brazilians to use domestic technology. In this case, one cannot say that prior experiences had a negative impact on the technology as a whole, just certain types of this technology, leading Brazilians to favour foreign versus domestic technology.

Thirdly, Rogers also recognizes the importance of change agents, which are people or organizations (agencies) aiming to promote the use of technologies. In São Paulo, the change agents for both technologies are readily identifiable, as in Mexico City for SWHs. However, in the case of biogas in Mexico City, there is no one (or two, etc.) identified "champions" for biogas technologies; only small pockets of research being done by various groups, which can play a role on their uptake.

That said, in São Paulo, there are two distinct groups of change agents promoting differing philosophies. Furthermore, in Mexico City, differing groups are seeking to influence the behaviour of change agents (e.g. to favour flexible or more stringent SWH standards). As noted in Chapters 4 and 5, time and time again informants spoke about divisions between and within stakeholder groups – including communication problems, promoting differing philosophies, company origins (domestic or foreign), etc. I propose an alternative lens, urban technology cooperation, centring focus on the dynamics of these relationships, to help better assess the uptake of RETs in these cities.

Details about Rogers' model can be found in Section 2.1.2. To remind readers, attributes of the model are also found in Table 6.1.

Table 6.1 – Rogers' Technology Adoption Model

Stage	Attributes	Relevant Factor and / or Some Examples
Knowledge		Awareness, How-to Use, Principles
Persuasion	Economic Relative Advantage	Cost in general Cost vis-à-vis alternatives
	Compatibility	Values, Beliefs

	Complexity	Ability to understand technology (how it works and the principles behind it)
	Triability	Whether or not a potential user has the ability to "try out" an innovation – either for a limited time period, or as a complement to conventional system
	Observability	Whether or not the technology can be observed
Decision	Type of Decision	Optional, collective, authority or conditional
All	Communication Channels	Can be mass media or interpersonal (cosmopolite or local) or internet
All	Nature of Social System	Norms, degree of interconnectedness can affect adoption
All	Change Agents	

Source: Adapted from Rogers 2003a, Diffusion of Innovations, p. 222

The bulk of information from these case studies discusses the attributes of technologies, as well as the efforts of change agents as these were found to be most relevant. From there, a re-examination of the factors affecting RET use provided by informants is undertaken, to determine the ability of this model to explain the use of these RETs in Mexico City and São Paulo and to determine how systemic approaches can help to explain RET adoption in the urban developing world.

6.2. Knowledge and Relative Advantage - Complexity and Compatibility of Solar Water Heaters and Biogas for electricity production

Rogers indicates that there are three types of knowledge that relate to: i) what the innovation is, ii) how it works, and iii) why does it work. These discussions are similar to those found in technology transfer studies such as Lall (2000) and Bell (1990), which distinguish between these three types of knowledge. Roger also indicates that knowledge is related to complexity, arguing that the more 'complex' a technology, the less likely it will be used.

However, there are a number of concerns with this approach. The first lies with how knowledge is treated. As noted in Chapter 2, Rogers does not provide a clear definition for knowledge. Based on the above definition, there is not enough recognition that knowledge is more than just information, as individuals will process information differently depending on their experiences, social setting, etc. Also, some scholars suggest that whether explicit or implicit, words like 'knowledge', 'technology' and 'complexity' tend to equate to the dominant technocentric view of these terms in Europe and North America, i.e. focusing on concepts of scientific principles and engineering, and negating alternative forms of knowledge and interpretation (Jasanoff et al. 1995, Mills 1998).

Secondly, although Rogers asserts that the more people know about a technology, they will be more likely to adopt it, he also recognizes the influence of prior experience. He argues that a technology must be compatible with an actor's values, beliefs and prior experiences. He argues that a negative past experience of an innovation can lead to innovation negativism, where a technology's failure conditions a potential adopter to reject other future technologies; viewing all with apprehension (Rogers 2003a: 245). While Rogers' assertions are helpful in explaining RET use, I argue in the following section that this is not always the case.

6.2.1. SWHs in Mexico City and São Paulo

As indicated in Chapter 4 and 5, one of the top themes identified by respondents affecting the use of SWHs in Mexico City was awareness. Informants indicated that most people in Mexico City are unaware about Solar Water Heaters and / or that they can be used as an alternative to gas to heat their water, although some people with technical skills[264] are aware of this technology. One government official stated that there was a lot of research into solar energy after the oil shocks, but that, even though there was some research now, "it was not like before".[265] The majority of respondents indicated however that as a general trend (as noted in the previous chapter) they were

[264] Although discussions on what interviewees meant by technical skills were not extensive, further conversation revealed that some had a broader view, i.e. those skills needed to undertake a certain task, to those that equated technical skills to mean abilities in engineering and the 'hard' sciences (physics, chemistry, biology)
[265] Interview, one government official, December 2006

noticing increasing awareness as reflected by increasing interest in SWHs in Mexico City and Mexico – especially since 2000.

In Mexico City, understanding about SWHs was wide-ranging including those that did not know about this technology, those who were aware of SWHs but did not understand the technology (awareness-knowledge), those understanding the basics (how-to knowledge), to experts understanding the technology and the principles behind it – which Rogers refers to as principles knowledge (2003a: 173), or Lall calls the "know why" aspect in his discussion of technological capacity (2000). One company had this to say "no one knows this technology nor the companies [that sell them]. It's not like Coca-cola, which everyone knows".[266]

Awareness was also one of the principal themes affecting SWH use in São Paulo noted by respondents in Chapter 5. Respondents indicated that those with technical knowledge knew of SWHs. Some noted that people who attended relevant trade fairs were aware of this technology, but that generally they were aware of only the basics and were generally not interested in knowing the technical details – just that it heated water.[267] Another company stated that of those who knew about SWHs, many were not aware of the details – "we receive phone calls for people looking for PV as they think it is the same technology."[268] Interviewees also asserted that awareness as reflected by interest in this technology was increasing in São Paulo and Brazil.[269]

But, as noted earlier, awareness was affected due to prior experiences. Some interviewees indicated that the general population in the city is more aware of SWHs as an alternative to the electric showerhead or gas to heat water (as well as energy conservation issues in general) due to the apagão of 2000/01. One SWH company noted that both the electricity and gas prices rose substantially in 2000. Another pointed out that large water heating consumers (e.g. hotels, hospitals, industry) have been particularly active after this time in seeking out alternative ways to heat water.[270]

[266] Interview, one SWH company, November 2005
[267] Interview, one SWH company, March 2006
[268] Interview, one SWH company, May 2006
[269] Interviews, five SWH companies, one government agency, one consultancy, March 2006
[270] Interviews, two SWH companies, March 2006 and April 2007

A further SWH company indicated that the energy crisis of 2000/01 "was good for the popularization of solar energy because at least people now know that a SWH exists".[271]

That said, all did not share this view. A number of informants viewed the apagão of 2000/01 as a major event that increased energy conservation issues in general and / or created opportunities for renewable energy, but that it did not necessarily translate to awareness or interest in SWHs.[272] In urban environments, people were often not aware that SWHs could be an option – "they only think of electric showerheads."[273] Awareness of the SWH as an alternative to heat water is confined to certain pockets in the population (e.g. the wealthy and / or the middle class). According to one NGO, the wealthy and middle classes together in Brazil represent about only 10 percent of the population.[274]

In the case of SWHs, others' previous experiences with the same technology did negatively affect SWH usage, especially in Mexico City. Informants – whether pointing the finger at specific SWH companies, their distributors, or just distributors and unqualified people (e.g. plumbers with no specific training) in general – told me that the fact that certain cheaper versions of SWHs in Mexico (whether locally-made or imported) are of poor quality has had a profound effect on the adoption of SWHs from bad experiences with the technology – due to bad installations, or a poorly working system. In Mexico, many argued that because there are no standards, those purchasing a SWH do not know if they are receiving a good one or a bad one – as many of these technologies are available and range enormously in terms of price and quality.[275] For this reason, some perceived this as a technology to be "written off"[276] as it simply did not work. Similar to Frewer et al's (1998) study noted earlier, they argued that these negative experiences did more to hurt adoption than any positive experience.

[271] Interview, one SWH company, March 2006
[272] Two SWH companies, one university representative, one government official, one union representative, one alternative energy company
[273] Interview, one NGO, April 2007
[274] Interview, one NGO, March 2006
[275] Interviews four SWH companies and one government official, November 2005 – January 2006
[276] Interviews one SWH companies, November – December 2005

This negative impact for SWH use was also not mentioned in São Paulo as much as it was in the Mexican case study – instead many spoke of the Brazilian standard system in place for SWHs by INMETRO, where products went through a series of tests, and if they passed these tests, they would be given the PROCEL seal. Not all Brazilians shared this view however. The Brazilian NGO Sociedade de Sol, argued that even though their low-cost SWH did not meet the technological nor efficiency standards of INMETRO's PROCEL, this technology would increase empowerment amongst the general population – creating pride, self-esteem and happiness that they were able to put this technology together by themselves – they can do what professionals do.[277]

6.2.2. Biogas to produce electricity in Mexico City and São Paulo

All key informants noted that the general population in Mexico City and Mexico for that matter really "had no clue"[278] about the technology of biogas from landfills to generate electricity. However, experts, such as engineers and government representatives with a technical background, were aware of this technology and the principles behind it (bacteria forming gas mainly composed of methane in the decomposition of organic matter in the absence of oxygen or anaerobic digestion, and using this biogas to run a motor or flaring it, rather than releasing it into the atmosphere 'as is').[279] According to all key informants working on biogas projects in São Paulo, the general population "has no idea"[280] about this technology, but, similar to Mexico City, experts were aware.[281]

None of the informants working on biogas technologies mentioned the apagão as having affected awareness of that technology. One important distinction between the landfills used in Mexico City and São Paulo is that in Mexico City there are populations that work and / or live informally in and around there, but in São Paulo there are none because access to the landfills is controlled.[282]

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[277] Interview, one NGO, March 2006
[278] Interview, one biogas company, December 2005
[279] Interviews, two biogas companies, five government agencies, November 2005 – January 2006
[280] Interview, one government official, March 2006
[281] Interviews, two government representatives, one engineering consultant, three university officials, March 2006
[282] As discussed in Chapter 4, in 2009, Mexico City is currently considering the possibility of biogas projects from the Bordo Poniente landfill when it closes. A number of informal residents who make their livelihoods through the landfill are concerned about these changes because Mexico City is planning to build some state of the art landfills, which would be more controlled. See

Although informants noted that this technology was relatively unknown, none felt that there would be any negative reaction to using these technologies in these cities.[283] At the time of study (mainly 2005/06) informants indicated there were no NGOs actively working on this issue in either city. This is different than Forsyth (1999, 2005) 's studies on biogas and biomethanation from India and Thailand where environmental NGOs were actively opposed to these strategies as they were viewed as legitimizing waste and foreign technologies, sometimes linked to corrupt politicians.

Past experiences were not as relevant when looking at biogas for electricity use in Mexico City, except to say that the Monterrey project was largely considered a success – it was viewed as a learning process with which to draw lessons from – making people more apt to regard it as a viable RET for Mexico City.[284] In São Paulo, interestingly, as shown in Chapter 5, past experiences with Brazilian technology in this area lead to the use of a foreign version in the two landfill gas to energy projects.[285]

To conclude, most people are not aware of these technologies in both cities. Certain segments of the population are aware of SWHs, but there are differences regarding how much they know (i.e. awareness, how-to and / or principles behind the technology). Through recognizing the role of previous experiences, Rogers model would conclude that the apagão makes SWHs and biogas technologies more compatible to people.

However, as noted above, it is not clear exactly what role the apagão may have played on the adoption of SWHs in São Paulo due to increasing awareness. As indicated in Chapter 5, the event had a positive impact on increasing awareness for renewables, and perhaps SWHs immediately following, where sales spiked. One interviewee wanted to ensure that I understood just how profound this event was – "everyone in the city of São Paulo (as well as many other parts of Brazil) had to ration their energy use".[286]

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http://www.msnbc.msn.com/id/28777897// and http://www.clintonfoundation.org/i/mexico-city-waste-management. While in Brazil, I was able to see one of the two landfills being used in Sao Paulo (Bandeirantes), which confirmed the assertions made by experts working in this area.

[283] Interviews, one government representative and two consultants, March 2006 and April 2007 and three consultants, three government officials, December 2005-January 2006

[284] Interview, two biogas companies, one government agency, December 2005 – January 2006

[285] Interviews, 1 government agency, 1 engineering consultant, March 2006

[286] Interview, one NGO, April 2007

Other researchers have also noted that this event seriously led the Brazilian government, companies and public to look for alternatives – after 2000/01, sales of CFLs in Brazil tripled.[287] At the same time, reactions were mixed as to whether the apagão was directly increasing adoption of SWHs through awareness at the time of writing – with some noting that over time, people forgot.

Building on this, it is not necessarily clear from the model how exactly previous events and current trends can shape compatibility, knowledge and perceptions. History and context matter and when integrated into a model, some assumptions are put into question. As Johnson points out in his article regarding common property relations, highlighting current trends in social science (especially in the U.S. political science discipline) favouring a positivist, methodological individualism approach, "peculiarities of historical events [are undermined by] the logic of deductive reasoning" (2004: 427).

As demonstrated above, the apagão had a positive impact on renewables but not all informants were convinced that this directly translated to increased SWH usage, while none of the biogas informants mentioned it playing a role. In addition, prior experiences in Mexico and Brazil had a different outcome – with bad experiences in Mexico with SWHs negatively affecting the industry, whereas in Brazil, only certain types of technologies were negatively affected (domestic rather than foreign).

History and current trends can have a positive or negative impact, and change over time. There are other historical events and current trends that shape knowledge and perceptions. Relevant factors include the oil shocks of the 1970s, climate change, and source of technology.

1970s Oil Shocks and Impacts on Knowledge and Perceptions in Mexico and Brazil

Interest in these two RETs occurred in Mexico and Brazil as a result of the oil shocks of the 1970s, which made governments and universities look for alternatives to fossil fuels mainly for energy security reasons.[288] Interest in renewables in Mexico was

[287] Personal Communication, David Ockwell, June 2008 on Richard Bradley, IEA, Presentation, Bali, Indonesia, COP13, December 11. 2007

[288] In 1973-1974, the price of oil quadrupled, which had a major impact worldwide. The price of oil also increased in 1979. Oil producing nations therefore had access to hard currencies with which to finance public spending projects and increase services (e.g. public health care). Oil importing nations –

especially apparent during the first oil shock, which was before Mexico discovered vast new oil reserves in the late 1970s (Du Pin Calmon et al. 1998). One respondent working on solar energy since 1974 informed me that at the time it was considered to be "the career of the future".[289] Although the discovery of oil in Mexico did increase foreign reserves and cash, and thus public spending and credit to the private sector, this prosperity was short lived and limited. Upon discovery of oil in the late 1970s, the government of Mexico at the time

> "vowed to avoid the 'mistakes' of other energy exporters, i.e., 'disastrous political results' in Iran, Venezuela's reliance on food imports, Nigeria's port congestion, and Saudi Arabia's enterprises overrun by foreign technicians. And yet, 'almost fatefully,' [that government] also became addicted to oil." (Amuzegar 1982: 833)

Economic imbalances occurred as a result of this oil, leading to "hyperinflation, a stagnation in tourism and non-oil exports, one of the largest external debts of a developing country, towering interest rates and a reduction of purchasing power for 'ordinary' Mexicans" (Amuzegar 1982: 820-821).

In Brazil, the government was particularly focused on alternatives to fossil fuels after the oil shocks of the 1970s, creating its world-renowned National Alcohol Program, or Programa Brasileiro de Alcool, (PROALCOOL) in 1974[290]. In the 1980s interest in renewables decreased as the price of oil decreased, but interest in RETs has slowly been increasing since the 1990s. One major difference between this renewed interest in renewables in both Mexico and Brazil is the fact that environmental considerations as well as energy security considerations are being taken into account.[291]

These oil shocks laid a solid foundation to establish a committed group of actors (albeit small) in both cities to the promotion of renewable energy.

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especially developing countries – were hit hard, due to dependency on this commodity. For further information, see Amuzegar 1982 for example.

289 Interview, one university representative, December 2005

290 The federal government provided tax breaks and subsidies which encouraged farmers to plant more sugar cane crops, investors built distilleries to convert the crop to ethanol, and automobile manufacturers built cars which could run solely on ethanol in Brazil. For further details please see WRI 2005 http://projects.wri.org/sd-pams-database/brazil/national-alcohol-program-proalcool

291 Interview, one university representative, March 2006

Climate Change

As noted in the prevalent themes in Chapters 4 and 5, in both Mexico City and São Paulo, climate change awareness and policies were increasing interest and uptake of renewables.

Mexico City established a "Local Climate Action Strategy of Mexico City" in 2004. The initiative provided:

- a GHG Emissions Inventory;
- Greenhouse Gas Emissions Trends to 2012;
- Mexico City's Vulnerability Analysis;
- Mexico City's Adaptability Analysis; and
- Emissions Mitigation: Programs and Projects – including reforestation, waste management, environmental education through a Child Summit on climate change in 2003, switching to more efficient florescent lighting in businesses, promotion of public transit through various measures such as the Bus Rapid Transit Corridors (based on Bogota's model) and taxi substitution, and as indicated in Chapter 4, the Solar Water Heating obligation.

Mexico City's Metrobus program was the city's first registered CDM project purchased by Spain, where it is estimated to save 37 000 tons per year of CO_2 equivalent (Sheinbaum and Vasquez 2006).

Mexico has an Inter Ministerial Climate Change Commission, developed in 2005, which consists of representatives from relevant government departments (e.g. energy, environment, agriculture). At the time of research (2005-06), the federal government was working on a coordinated approach to climate change. In May 2007, the government released their National Strategy on Climate Change, which provides a comprehensive overview of Mexico's sources of emissions, as well as identifying existing and proposed opportunities to reduce that nation's GHG emissions (Climatico 2007). Mexico has also identified reducing GHG emissions and promoting efforts to further that country's ability to adapt to climate change in their current National Development Plan (2007-2012). Following this strategy, the government established a Programa Especial por Cambio Climatico" (PECC) or Special Climate Change Program in 2009. The government has set a long term goal to reduce GHG emissions in 2050 by 50% of 2000 levels, and a short term goal to reduce GHG emissions by about 50 Mt of CO_2e by 2012. A range of measures – mainly in land use and land use change, energy generation and use, and solid waste and wastewater, are currently being promoted (Martinez 2009).

São Paulo developed a comprehensive GHG emissions inventory in 2005 and as noted in Chapter 5, recently established a comprehensive climate change law, Law 14.933 in June 2009. The goal of the law is to reduce São Paulo's GHG emissions by 30% in 2012 based on 2005 emissions levels through a series of policies and programs noted in Chapter 5. In addition, the city must complete a GHG inventory every five years (São Paulo Prefeitura 2009; Robinson 2009). São Paulo is also an active player in the 'International Council for Local Environmental Initiatives'- Local Governments for Sustainability (ICLEI)'s Cities for Climate Protection (CCP) Programme, where cities agree to reduce GHG emissions and receive software, information from case studies, technical assistance, etc. by taking part (Setzer 2009).

At the state level, the government has been particularly interested in climate change because of global attention to alternative non-fossil transportation fuels – including ethanol. The State of São Paulo is the country's principal area where ethanol from sugarcane is produced (over 60% of sugarcane is grown there), and Brazil is the largest producer of ethanol in the world. In 1995 the state established a Climate Change Prevention Program (PROCLIMA) – the group working in PROCLIMA's goal was to increase awareness of climate change through seminars, workshops, etc. and the group assisted the federal government in establishing Brazil's national emissions inventory. The state has also established an Integrated Transportation Plan to encourage the use of public transit and a program called Transporte Solidario, where free software indicating place of residence and habits (e.g. smoker, non-smoker) helps people in communities to establish car pools (Rei and Cunha 2007).

In 2005, the State of São Paulo and the State of California in the United States jointly developed a plan to work together to identify climate change mitigation opportunities climate change strategy jointly with the State of California in the United States. The plan, called "No reason to wait", was an effort to demonstrate that sub-national efforts could happen despite inaction on climate change at the federal level (Brazil currently has no mandatory GHG emissions reductions stipulation under Kyoto and the United States under Bush did not ratify the treaty). The state has three main areas of focus for policies 1) landfill emissions reductions – highlighting the Bandeirantes project in São Paulo (the São Joao project was not implemented at that time) and other potential landfill gas to energy projects in the state, 2) carbon sequestration programs, 3) electricity through biomass, mainly from sugarcane, 4) transportation programs such as those noted above (Goldemberg and Lloyd 2005). The state is also an active member of the Network of Regional Governments for Sustainable Development (nrg4SD), a group established at the World Summit on Sustainable Development in 2002, which shares information, and opportunities for capacity building and technology transfer (Setzer 2009).

At the federal level, similar to Mexico, the government established an Interministerial Commission on Climate Change (CIMGC in Portuguese) in 1999, with the Ministry of Science and Technology (MCT) serving as the lead, coordinating agency. The country also has a Brazilian Climate Change Forum, where other actors such as NGOs and industry can articulate their views to the federal government (Roman 2007).

There are three policies in particular that assist Brazil's GHG emissions reduction. The first program is Brazil's National Alcohol Program, or PROALCOOL, established in 1975 to reduce Brazil's reliance on foreign oil imports through encouraging the production of ethanol through sugarcane as an oil alternative. The government had a number of subsidies in place, which were eliminated in 1999. It has been estimated that from 1980 – 2003, there was 82 million tons of CO2 equivalent avoided in São Paulo state because of gasoline replacement with ethanol. Brazil's National Program for Motor Vehicle Pollution Control (PROCONVE), has also helped reduce carbon emissions although it was put it place to reduce air pollution since 1986 (Rei and Cunha 2007).

Two other federal programs that are reducing carbon emissions were highlighted earlier in Chapter 5 (Section 5.6), identified by informants as policies potentially helping the uptake of SWHs in São Paulo, as they were increasing interest in renewables and awareness of energy conservation. These programs are PROINFA and PROCEL. That said, as indicated earlier, it is not clear from my research that these programs had a direct impact on the use of SWHs in São Paulo.

Regarding the two technologies in particular, climate change is the principal reason prompting research, knowledge and understanding of biogas to generate electricity technologies.[292] The main reason for this interest is due to the international climate change market -- the potential amount of carbon credits under the Clean Development Mechanism (CDM) that can be generated[293]. As discussed in detail in Chapter 1, the CDM is a tool through which developing companies can generate carbon credits through projects that abate carbon emissions that would occur otherwise (e.g. through installing more renewable energy options versus original plans to develop thermal power plants).

In Mexico, although there is strong potential for biogas from landfills in that country, the market is considered limited; only about 40 cities or so – one expert considered those cities with a population of 200, 000 or more people only -- would be viable options for this RET[294].

Promoting SWHs as a way to address climate change was not as prevalent a rationale in Mexico City; although informants had clearly assessed the potential to generate carbon credits under the CDM through this RET. Moreover, all respondents viewed SWHs as a possible CDM option in the future. More recent efforts to include efforts to address climate change at a larger-scale, such as through programmatic CDM[295], may serve as an important way forward.

In Brazil, key players in São Paulo, such as Vitae Civilis, ABRAVA and various consultancies (e.g. Lumina), were actively promoting SWHs as a way to reduce carbon emissions. For instance, in addition to their Solar Cities campaign which includes information on climate change potential (see www.cidadessolares.org.br for more details), Vitae Civilis included an assessment of the CDM potential for SWHs in Brazil in their publication "Brazil Finds its Place in the Sun" (Rodrigues and Matajs 2005).

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292 Interviews, two biogas companies, five government agencies, November 2005 – January 2006 and Interviews, two government representatives, one engineering consultant, three university officials, March 2006

293 Interviews, two biogas companies, four government officials, November 2005 – January 2006

294 Interview, one biogas company, January 2006

295 The idea of programmatic CDM is to bundle individual projects together, or amalgamate projects under a programme of activities. Programmatic CDM is being considered and can occur in more than one sector, location and / or project type. See Ellis, J. (2006). Issues related to implementing "programmatic CDM". Annex I Expert Group on the UNFCCC. Paris, IEA.

At the time of the interview (April 2007), the consultancy Lumina was undergoing a study for a hospital to assess the potential for carbon credits should that hospital use SWHs to heat its water.

In other words, in both places, governments and other groups such as NGOs, consultants, and trade associations are paying attention to climate change, which has generated an increased interest in and commitment to renewables in these cities – especially biogas technologies to generate electricity, although it is not clear exactly how this interest at a more general level translate to the use of Solar Water Heaters.

Source of Technology

A further aspect of awareness that Rogers' model does not adequately account for has to do with where the technology comes from – whether indigenous or foreign or both. Respondents in Mexico City and São Paulo spoke about this topic for both RETs. For instance, with respect to SWHs in Mexico City, the hardware and ownership of the technology is either Mexican, foreign, or both (often designed abroad but using Mexican inputs to make the finished products). The "software" is also either foreign or domestic.[296] Regarding SWHs in and around São Paulo, the hardware is almost 100% Brazilian (copper, a primary product used for piping water in some SWH systems is imported from Chile), the ownership of the technology is Brazilian, and the "software" – after having been in the country for over 30 years – is mainly Brazilian too [297]

With respect to biogas technology in Mexico City, at present the principle feasible option would be to use foreign hardware (although some companies are looking for national production) – and likely joint efforts between Mexicans and foreign "software" – including personnel and process.[298] In São Paulo on the other hand, there is Brazilian hardware (motors adapted to use biogas), but in the case of the two biogas projects (Bandeirantes and São Joao), there is also a recognition that the foreign hardware options are more efficient even if more expensive. For this reason, foreign hardware and joint Brazilian and foreign "software" are being used. The origins of a technology

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[296] Interviews, eight SWH companies, three university representative, one university official, two government officials, two consultancies, one NGO, November 2005 – January 2006

[297] Interviews, eight SWH companies, one university official, two NGO representatives, one consultancy, March – May 2006

[298] Interviews, two biogas companies, two government agencies, November 2005 – January 2006

may have an impact on its adoption but using Rogers model it is not clear exactly how. In both places, indigenous technological capacity building is increasing but in São Paulo it is more pronounced. Studies which argue that successful technology cooperation is a result of being a broader process at acquiring skills and knowledge and not just technology (Ockwell et al. 2007; Bell 1990; Nelson and Pack 1999) may be a way in which to help explain the differences in uptake between these two cities. Chapters 7 and 8, examining urban technology cooperation and trade policies, will explore this above issue further.

In summary, the apagão in Brazil, as well as the oil shocks and climate change in both cities have definitely increased interest, awareness and uptake of renewables in these case studies, but not necessarily always the two technologies under scrutiny. The origins of technology may also play a role on adoption but at this point it is not clear exactly how. Chapters 7 and 8 explore this issue further. These findings suggest that history and context matter and their integration into a model puts assumption – such as the assumptions that awareness and compatibility are positively correlated to adoption found in Rogers model – into question.

One interesting question is involved with previous experiences. Using Rogers' technology adoption model, one could say that potential end users had gone through this decision-making process earlier (whether in the 1970s, 1980s or 1990s) and based on negative experiences (due to either bad quality equipment or good quality equipment but bad installations among other reasons) did not adopt this technology. However, since that time some technological advancements have been made improving the efficiency and making the technology less costly. Is there a way to incorporate those "revisiting" adapted versions of the same technologies again? Moreover, these past experiences can be traced to questions about foreign versus domestic technology and standards – areas examined when looking at trade and competitiveness policies, in Chapter 8.

6.3. Relative Advantage – Cost

Another stage in Rogers' decision-making model is termed persuasion. Several aspects that Rogers' identified in his persuasion stage were found to potentially impact the use of these RETs in Mexico City and São Paulo. The first is termed "relative advantage". In the case of SWHs and biogas in these two places, the relevant relative advantages deemed pertinent include the cost of the technologies in general, and the cost of the technologies relative to their alternatives. Economically speaking, if the cost of a technology is expensive in general, and / or more expensive than an alternative (with comparable functions and outputs), cost will impact technology adoption. This section will first discuss these relative advantages as they relate to the situation of SWHs in both locations, and then biogas in both places. Other relative advantages the framework notes, such as "a decrease in discomfort, social prestige and a saving of time and effort" (Rogers 2003a: 233) were not considered to be as relevant in these case studies.

6.3.1. Cost of SWHs in Mexico City and São Paulo

With respect to SWHs in Mexico City, the cost of equipment and installation in general, and vis-à-vis alternatives is key to understanding their use.[299] In Mexico City, water is mainly heated using Liquefied Petroleum Gas (LPG), which is more expensive than natural gas, the other main option for Mexican cities. About 80% of LPG in the home goes towards heating water and 20% is used for cooking.[300] This figure is higher than other studies such a one done on the potential for SWHs in Mexico City conducted by Quintanilla et al. (2000: 18), which showed that in 1999, a little over 50 percent of LPG was used to heat water and the rest was for cooking.

As highlighted in Chapter 4, the cost of a SWH in Mexico City (equipment and installation) ranged from about US$800 - 1100 for a single family, to more expensive models, costing about US$2200. These figures are confirmed by other studies such as Hoyt et al. (2006: 32). For many people in Mexico City, some versions of SWHs are simply too expensive or people cannot afford the up front cost of the equipment and installation of a SWH at one time. Other studies, also confirm that even though there are monthly gas payments involved with a gas water heater versus a SWH, many people find this easier to pay as these payments are over time, rather than paying for the

[299] Interviews with eight SWH companies, three government agencies, November 2005 – January 2006
[300] Interviews, one university, three SWH companies, December 2005 and January 2006

installation and equipment of SWHs all at once (Quintanilla and Mulas 1998; Quintanilla et al. 2000). That said, simple, cheap versions of SWHs also exist in Mexico City (although not as common). In Mexico, "there is a little bit of everything"[301] with respect to SWHs.

Cost was the main reason cited by some informants for market growth for SWHs in the commercial, industrial and government sectors versus the residential sector in and around Mexico City. These buyers have more capital available and so are not as worried about cost. Even though there are no credit schemes in place specifically for SWHs for institutions in either place, in general, institutions have better access to credit versus individual families, which can help them come up with the capital needed to purchase a SWH. [302] This point is reiterated in Castro Negrete's study on SWHs in Mexico (2005: 30).

The cost of a SWH in São Paulo for a family, representing about 80% of the SWH market in São Paulo and Brazil is about US$900 as noted in Chapter 5. The average cost per m2 is US$100. While the equipment is cheaper in Brazil when looking at m2, generally a larger tank is needed for families in Brazil, as people in São Paulo tend to take two showers per day – one in the morning and one in the evening. As noted in Chapters 4 and 5, one would likely purchase an alternative technology as a "back up" in both locations due to the climate. In Mexico City the "back up" would often already be in place (e.g. the LPG water heater), so no extra cost would be needed. This would be similar in São Paulo where the electric shower (already in place, thus requiring no further cost) would serve as the "back up" technology. Costs would be similar in both places in larger buildings (e.g. apartments, sport complexes) as these larger buildings rely on gas for water heating. Costs would be significantly higher in Mexico City versus São Paulo however in cases where a SWH and a back up system would be put in new houses -- Mexico City US$900 + US$300 = US$1200 versus São Paulo US$900 + US$10 = US$910 + labour time for modifications.

With respect to SWHs being used on a larger scale in São Paulo (whether for pools or other uses), they are cheaper than their counterparts in Mexico City (comparing specific

[301] Interview, one government official, November 2005
[302] Interview, one SWH company, one government official, November - December 2005

parts – panels, tanks of the same size, etc.) -- although this is only 20% of the SWH market in São Paulo. Only 1% of twenty percent is for industrial purposes. In Mexico City by contrast, as noted in Chapter 4, industrial and commercial applications of SWHs are about 15% of the Mexican market and 72% of this number is in Mexico City. It is interesting to see more SWHs for large-scale purposes being used in Mexico City versus São Paulo, as the hardware is cheaper in Brazil (when comparing specific components).

Rogers' also suggests that costs must be assessed in comparison with alternative technologies, with increasing rates of adoption happening when the alternative is more costly or comparable to the price of the innovation.

6.3.2. Cost of SWHs in Mexico City and São Paulo vis-à-vis Alternatives

The main alternative to SWHs to heat water in Mexico City (whether for bathing, pools or other uses) is a LPG water heater. The cost of a boiler for natural gas or LPG is about a third of the cost of a good quality SWH (equipment and installation). Key informants noted that the equipment for SWHs accounted for about 80% of the cost and the installation the rest.[303] This is similar to other studies, such as Quintanilla et al. (2000) and Castro Negrete (2005) who claim that the equipment is about 85% of cost and installation 15%. Although it is not clear how much of the population uses LPG in the city, respondents noted that hot water alternatives to natural gas (including SWHs, electricity and wood) are marginal.[304]

Informants avowed that studies demonstrate that in the long run, a SWH is more cost effective than the LPG system. Respondents indicated that the payback time for a SWH is about three years, but that because the price of natural gas was increasing, a payback time of two years was becoming more plausible.[305] Various factors changed this number including: price of natural gas or LPG (as noted above), assumptions on energy savings, the climate or weather which affected not only the amount of hot water

[303] Interviews, one government representative, one SWH company, November 2005
[304] Interviews, three SWH companies, two government representatives, November – December 2005
[305] Interview, one university representative, two SWH companies, November 2005 – January 2006

produced but also the "wear and tear" and lifespan on the equipment, the size and type of the system, among others. The increasing price of natural gas and LPG – especially noticeable since 2000 -- has been advantageous for SWH companies.[306] In Mexico, which generally allows market prices for LPG and natural gas (albeit with some major exceptions)[307], natural gas has been increasing at a higher rate than inflation, "with major price spikes occurring between 2000 and 2001".[308] Specifically, the price of natural gas in the central zone of Mexico (which includes Mexico City) fluctuated from about US$ 2.20/MBTu in January 2000, to a high of about US$9.50/MBtu in January 2001, to US$5.80/MBtu in February 2004 (Probst 2004: 5),

The main alternative to the SWH in São Paulo is without a doubt the electric shower (*chuveiro eletrico*). Whether using a PROCEL-certified SWH (about US$900.) or Sociedade de Sol's low cost SWH (about US$100.) for a family in São Paulo, the electric showerhead, costing roughly a little over $US10., is significantly cheaper than the SWH.

Some informants highlighted the fact that many studies demonstrate that over time, one would eventually recoup the costs of a SWH when taking the cost of electricity into account.[309] Other studies provide further insights into why this is the case. For example, PROCEL's extensive 1988 study on household energy consumption habits in Brazil noted that water heating represented about 33 percent of home electricity costs in the country (Rodrigues and Matajs 2005: 13). More recent statistics from the Brazilian government demonstrate that "...a quarter of all electrical energy of the country is used in residences. The electric shower is one of the major [culprits] responsible for the high price of the [electricity] bill at the end of the month" (Brasil 2007). Having said this, gas water heaters are being used increasingly in operations on a larger scale (e.g. apartments, hospitals) in São Paulo. Nevertheless, they represent only a small percentage of the water heating market in São Paulo.[310] In contrast to Mexico, where LPG and natural gas prices have been increasing, in São Paulo, the prices of natural gas

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[306] Interviews, 3 SWH companies, 3 university representatives, 2 government representatives, November 2005 – January 2006

[307] For example, the Fox administration authorized a six-month subsidy for natural gas for residents of Monterrey in 2005 (which some interviewees pointed out was 'coincidently' the home riding of the Energy Secretary at that time).

[308] Interview, one university representative, December 2006

[309] Interviews, three SWH companies, two NGOs, March 2006

[310] Informal discussions, February – March 2006

are more regulated. The cost of natural gas in Brazil varies depending on the source. For example, in 2003, the average price of national natural gas was US$2.60 / MBTu, whereas the price of natural gas from Bolivia was US$3.60 / MBTu. The majority of natural gas used in São Paulo is from Bolivia (Moraes 2003).

One other reason why the alternative is cheaper in both Mexico City and São Paulo is because the infrastructure is already in place – including personnel (e.g. LPG distributors, electric shower sellers), and those involved in the building industry such as architects and construction workers – they are "used to" LPG water heaters and electric showers and the necessary surrounding attributes. Moreover, interviewees in São Paulo noted that there is no separate piping for hot water, pointing out that this practice [separate piping for hot water] was not common in Brazil, "a hot country"[311]– there are only one set of pipes carrying water to buildings. As the majority of SWH systems used in Brazil heat water in the solar panel, this separate piping would be needed to make them a viable alternative.[312] This aspect can be traced to institutional barriers, which indicate the existing infrastructure favours the status quo, thus making it harder for RET penetration (Philibert 2006; Rodrigues and Matajs 2005).

6.3.3. Cost of Biogas for electricity generation in Mexico City and São Paulo

There was no biogas for electricity generation project in Mexico City implemented as of 2007, and so it was difficult to obtain information regarding the price of this technology. Although the IIE had conducted some studies regarding the viability of biogas projects for the Valley of Mexico, where Mexico City is situated inside, were mainly focused on rural options (e.g. biogas from agriculture and forests) rather than from landfills. [313] However, the Monterrey biogas project, starting in 2003, cost about US$11.5 million in total to produce about 7 MW of electricity[314].

[311] Interview, one consultancy, May 2007
[312] None of the respondents mentioned this factor in Mexico City.

[313] Personal communication, research institute representative, November 2007
[314] Having said this, one government official in Brazil estimated the Monterrey project cost closer to US$20 million to produce 7 MW versus Bandeirantes which cost about US$20 million to produce almost 20 MW – joking that the Mexicans were able to negotiate better salaries (Interview, one government representative-B, March 2006).

Figure 6.1 "Back of the Envelope" Cost Estimates for Potential Biogas to Energy Project in Mexico City Using Monterrey Project Details

Several assumptions can help to understand the " cost" of a hypothetical biogas plant in Mexico City:

- One could assume that this power plant is off line for various reasons (e.g. repairs, etc.) about 20% of the time throughout the year[315]. This would mean that every year about 0.8 * 365 days/year * 24 hours/day * 7MW = a little more than 49 000 MWh (mega-watt hours) of electricity is produced.
- Using a project life of 21 years and annual costs (including O&M and costs involved with having it as a CDM project) of US$1.5 million per year, this would mean costs would be about US$418 per MWh).
- This money included the construction of a powerhouse, 7 motors adapted to work on a smaller scale, flaring and monitoring equipment
- This figure is useful to know, as any biogas project for electricity production in Mexico City would likely require similar costs.

Source: Author based on information from Bartone et al. 2005, p. 20

The Bandeirantes landfill gas to energy project cost about US$20 million to build but the overall investment was calculated to be approximately US$80 million (where a project life of 10 years was used to make estimates) in the CDM project proposal. According to one government official involved with the project about 50% of the start up costs were taxes (something explored further in Chapter 8). About 18 MW of electricity was produced as of 2006[316]. There are 24 motors being used to generate this amount of electricity.

Figure 6.2 "Back of the Envelope" Cost Estimates for Biogas to Energy Project in São Paulo using Bandeirantes project information

Several assumptions can help to understand the cost of the biogas plant in Bandeirantes:
One could assume that this power plant is off line for various reasons (e.g. repairs, etc.) about 20% of the time throughout the year.
This would mean that every year about 0.8 * 365 days/year * 24 hours/day * 18MW = more than 126 000 MWh (mega-watt hours) of electricity is produced every year, which, using a project cost estimate of about US$80 million above, would represent a cost of about US$634 per MWh.
Source: Author, based on discussions with biogas informants in São Paulo, November 2007

In Brazil, as noted in Chapter 5, even though cheaper, domestic options of motors modified to use biogas versus other fuels to generate electricity exist, project

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[315] This estimation was confirmed with landfill gas experts, November 2007

[316] Although there is capacity to produce 20 MW, only 18 MW is produced as that is the maximum amount that the transmission lines can carry as if 2006 (Interview, one engineering consultant, March 2006).

developers decided to use more expensive forms of the technology from foreign sources in Bandeirantes as they can provide better guarantees.[317]

This is interesting because, using these back of the envelope calculations as guidelines, a biogas plant in Mexico City would be cheaper than São Paulo, and yet there are none operating at present (although this may change) there, while there are two in São Paulo.

6.3.4. Cost of Biogas for electricity generation in Mexico City and São Paulo vis-à-vis Alternatives

The main alternative to biogas to produce electricity in Mexico City would be from thermal power plants using natural gas which served as 42.5% of the sources of electricity for the city in April 2006 (the other two sources being thermal electric plants using steam from oil to generate electricity) and hydroelectricity) (Luz y Fuerza del Centro 2007). The Mexican government plans on meeting new energy demand mainly through combined cycle gas-fired turbines.[318] Combined cycle means that both a gas turbine and a steam turbine, using the gas released from the gas turbine to then turn the steam turbine, are used. Project developers for the CDM proposed landfill gas to generate electricity project in Ciudad Juarez, Mexico, provide some cost comparisons in Table 6.2.

[317] Interview, one government representative, March 2006
[318] Interview, two government representatives, November – December 2005

Table 6.2 Examples of Cost Comparisons by Technology per MW

Technology Cost Comparison						
	Natural Gas Combined Cycle	Simple Cycle Gas Turbine		Diesel Engine		Landfill Gas Engine (Reciprocating)
	(World Bank)	(Boyce)	(World Bank)	(Boyce)	(World Bank)	(United States Environmental Protection Agency)
Size Range (MW)	300	0.5-400	50	0.02-25	5	1-15
Turnkey Cost ($/MW)	510 000 to 690 000	300 000 to 650 000	380 000 to 520 000	200 000 to 500 000	470 000 to 650 000	1 200 000

Source: Adapted from Project Design Document (PDD) for Ciudad Juarez LFG to Energy, 2006 - See pp. 14-15 for original World Bank, Boyce and US EPA sources

While these comparisons can provide readers with an idea of costs, there are some major uncertainties in place, making cost projections for CCGT power plants difficult. For example, as noted above, the price of natural gas has fluctuated greatly in Mexico in the past decade. Another uncertainty involved with using natural gas for electricity generation in Mexico City is that because one third of natural gas is imported (mainly from the US), prices must be paid in US dollars.[319]

The point of these 'back of the envelope' cost comparisons is to provide readers with some guidelines to understand why they are being used in the first place. According to Rogers' model, and conventional technology adoption models, if costs of a RET are than there counterparts, they will not be used. But, as indicated in Table 6.2, the costs are significantly higher to use landfill gas versus natural gas or diesel to generate power. So, a glaring question becomes, why are they being used in the first place? But, Rogers' model also examines how climate change plays a role on increasing use – which in the case of biogas technologies was considered to be the single most important driver by informants.

With respect to alternative technologies to produce electricity in São Paulo, plans examining future sources of electricity generation for the State of São Paulo are from a

[319] Informal discussions, November 2005 – January 2006

number of sources including gas-fired power plants[320], more hydroelectricity, small hydro, solar, and biogas. However, the main alternative to hydroelectricity being considered in São Paulo state is biomass through bagasse from a sugar mill (e.g. combined heat and power plants from bagasse). These plants would mainly operate at peak times (6 – 9 pm) to help with the electricity burden.[321] As many sugar mills exist, the costs would not likely include building a new "power plant" but focus on putting in place equipment to burn the bagasse, which creates steam, and turbines, to produce electricity, thus being significantly less costly than biogas which involves building new (even if smaller) power plants.[322]

Another alternative with strong support in São Paulo, Brazil at the time of field research (January – March 2006), was CCGT plants, but these plans may have waned due to supply concerns of natural gas, which have increased with the nationalization of natural gas production and export in Bolivia – the main provider of São Paulo's natural gas - in May 2006[323]. On the other hand, there may be increasing support again for gas-fired plants in the region due to more recent major oil and gas reserves finds of Petrobras in November 2007[324].

Similar to Mexico, there are also uncertainties involved in projecting costs between biogas and alternative sources for electricity. Regarding natural gas, according to Ellsworth and Gibbs, gas prices for existing power plants are "based on a formula that links gas to a basket of international oil prices" (2004: 33) and gas prices for new power plants are fixed at about US$2.58 / MMBTu with adjustments for inflation incorporated (Ellsworth and Gibbs 2004: 33). Another problem with using natural gas in São Paulo (where it is imported from Bolivia) is that its price is in US dollars, whereas the price of electricity is in reais (Ellas and Myers Jaffe 2004; Moraes 2003). In other words, although natural gas in São Paulo is not subject to the same amount of

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[320] One reason for this is due to the large gas reserves found off shore near Santos, Sao Paulo in May 2003 (Personal communication, one government official, November 2007). Ellsworth and Gibbs also confirm this find, while pointing out that Petrobras indicated this gas would not be available for consumers until about 8 to 10 years (2004: 10-11).

[321] Personal communication, one government official, November 2007; Interviews, two government officials, one NGO, March 2006

[322] Interview, one government official, one university representative, March 2006

[323] Interestingly one government official informed me in March 2006 that they [the state of Sao Paulo] were not concerned about Bolivia "reneging" on their supply contracts as this was a provincial / state issue rather than federal issue in Bolivia (Interview, one government official, March 2006).

[324] See http://www.cnn.com/2007/WORLD/americas/11/08/brazil.oil.ap/index.html

price fluctuations in Mexico City, there are still some risks involved with its usage (e.g. supply concerns, foreign exchange concerns).

To summarize, Rogers' emphasis on economic relative advantage, similar to other RET studies in developing countries that use conventional approaches noted in Chapters 1, when looking at adoption rates overall, cost whether in general or vis a vis alternatives does have an impact on the adoption of SWHs and biogas to produce electricity, but costs cannot fully explain the major differences between the uptake of SWHs in these cities when broken down by market segment.

Costs of SWHs overall are similar in both cities, except in two instances. The first case is for SWHs for large-scale purposes where they are slightly more costly in Mexico City. Why are SWHs being used for larger-scale purposes more in Mexico City if costs are slightly higher there? The alternative to SWHs for large-scale applications is cheaper in São Paulo as the price of natural gas is more regulated. Less SWHs for commercial and industrial applications are used in São Paulo, concurrent with Rogers' model. But it is also important to understand exactly why there are cost differences of the alternative (natural gas) in both cities. As is explored in further detail in Chapter 8, these cost differences of natural gas and LPG can be traced back to trade and competitiveness policies at the macro level, which further sheds light on RET adoption.

The second instance is for SWHs and a back up system for new homes, which are more costly in Mexico City (US$800-900 (SWH) + US$300 (LPG furnace) in Mexico City versus US$800-900 + US$10 (electric showerhead) in São Paulo). Rogers model indicates that technologies with higher costs will be less likely adopted; a factor one would expect to be more pronounced in developing countries. The alternative to SWHs for houses is significantly cheaper in São Paulo versus Mexico City. Rogers' model would assume less SWHs being used in houses in São Paulo, but in fact the opposite is happening. I propose that although classical explanations for RET adoption, focusing on economic and technical attributes, are useful they are inadequate in and of themselves to explain RET use. Rogers' model also fails to explain this phenomenon. This is particularly interesting because, as noted in Chapter 3, disposable income is comparable in both cities.

With respect to biogas, the cost of this technology – including all aspects of the project – is somewhat higher in São Paulo versus Mexico. Also, about 50 % of the costs for the Bandeirantes project were devoted to taxes – does this make a difference on technology adoption? Chapter 8, examining trade and competitiveness policies can help answer this question. Moreover, biogas projects in both countries are significantly more costly versus potential CCGT projects and / or biomass projects, so why are they being used in São Paulo and explored for use in Mexico City in the first place?

As noted in Chapters 4 and 5, all informants stressed that the main reason that landfill gas to generate electricity activities were being pursued was due to climate change opportunities. Some informants working on SWHs also spoke of policies in place aimed at increasing the uptake of RET, whether to address climate change, energy security issues and / or other environmental challenges. As I argued in Section 6.2, regarding knowledge and compatibility, historical events and current trends shape knowledge and perceptions. This may have a positive impact on their uptake (climate change's role for biogas technologies in both places), whereas in other instances, the impact is not as discernible (climate change's role on SWHs in both places, the apagão on biogas projects in Brazil, previous experiences in São Paul), is debatable (the apagão on SWHs in São Paulo, source of technology for both in both places), or is negative (previous experiences in São Paulo).

6.3.5. Incentives for SWHs and biogas technologies in Mexico City and São Paulo

As noted in Chapter 1, numerous studies on RETs in the developing world (e.g. Rodrigues and Matajs 2005, Milton and Kaufman 2005, Renewables 2004, Wilkins 2002, Mor 2008) emphasize the key role that incentives – whether voluntary or mandatory - play on encouraging the uptake of renewables. Rogers (2003a) also recognizes that incentives can play an important role on adoption as they can increase the relative advantage of innovations. Incentives include government policies at international and national levels aimed at encouraging the use of renewables. Specific examples include subsidies for renewables, a long-term feed in tariff system (where a government and / or electricity utility guarantees a specific rate of electricity to potential producers over a long period of time), rebates and an obligatory renewables requirement.

With respect to the case studies in particular, at the international level there are a number of policies and programs to encourage the use of RETs in developing nations – especially through technology transfer. As noted in Chapter 1, in the UN climate change process, the main tool is through the Clean Development Mechanism (CDM). This instrument provides a monetary value on the amount of projected carbon dioxide, or carbon dioxide equivalent emissions avoided in developing countries. Other avenues also exist, such as Article 4.5 of the United Nations Framework Convention on Climate Change (UNFCCC), which obligates industrialized countries to diffuse lower carbon emitting technologies to developing countries. As indicated in Chapter 1, the effectiveness of these tools at achieving reduced carbon emissions and / or increasing technology cooperation has been the subjective of numerous studies.[325] Speaking about increasing technology cooperation for instance, Dechezleprêtre et al. (2009) claim that " there is no visible effect of the Kyoto protocol on technology transfer: international technology flows have been increasing in the recent period, but the growth rate is the same as the average" (2009: 3).

As indicated in Chapter 4 and Section 6.2, interviewees in Mexico familiar with the CDM saw it as a potential opportunity for SWHs in Mexico City, but argued that the only way this would be economically viable, would be through a program done on a large scale. This finding is echoed in Hoyt et al.'s study which showed that in order for CDM opportunities to make sense for SWHs, at least 10, 000 units (single family) would need to be implemented to make up a single CDM project – as well as noting the difficulty involved in monitoring and verification and making the project cohesive as the SWHs systems would be implemented in a number of places (2006: 61). Groups in Brazil however, such as Vitae Civilis and ABRAVA, are promoting this technology as a CDM opportunity – especially when considered on a large-scale, taking Brazil's electricity peak and the sources used to generate electricity at this time into account.

[325] For further information on these topics, including debates and assessments, please see Haites et al. (2006). Technology Transfer by CDM Projects. Toronto, Canada, Margaree Consultants Inc., Seres (2007 and 2008) for the CDM and Ockwell, D., Alexandra Mallett, Ruediger Haum and Jim Watson (in review). "Intellectual Property Rights and low carbon technology transfer: the two polarities of diffusion and development." Global Environmental Change for the Article 4.5 issues for example.

As noted in Chapters 4 and 5 and Section 6.2 however, the CDM was one of the key drivers encouraging the adoption of biogas to produce electricity technologies in both places.

Regarding domestic policies, in Mexico, with respect to SWHs, although the general consensus was that little was being done domestically, there were a few exceptions. For instance, many interviewees highlighted CONAE's program to encourage the use of SWHs in Mexican homes. However, as indicated in Chapter 4, the program had a number of problems. It was rather complicated, there was little awareness, and deemed onerous for potential participants required to calculate their current use and expenses, among others. A few people also noted that tax breaks existed for those firms operating in Mexico that sought to import RET components. But, many SWH firms did not know this – industry leaders claimed that programs and policies to help renewables were often complicated, convoluted, and / or unknown. In other words, it is not clear how effective these policies have been. A more recent law at the municipal level mandating the use of SWHs in new buildings of a certain size introduced in April 2006 may hold more promise.

In Brazil, there are few domestic policies to encourage SWH use in São Paulo, although one major exception is the municipal law of June 2007, mandating their use in certain buildings. Many noted broader renewable energy and energy conservation policies, including PROINFA, PROCEL, and the national level law requiring energy companies to spend 1% of their revenues on R&D for energy savings programs, which could play more of an indirect role on adoption of SWHs. On the other hand, many noted that these efforts, while important, were not enough and that the government needed to do more to encourage the adoption of this important technology. For instance, key informants underscored the absence of the state government and Eletropaulo Metropolitana Eletricidade de São Paulo (Eletropaulo), the key electricity distributor in São Paulo, which is owned jointly by AES of the U.S. and the (Brazilian) National Bank for National Social and Economic Development (BNDES) on this issue.

Regarding biogas technologies in Mexico, there are few domestic policies in place. Government agencies and other research institutes, such as the INE and IIE, are studying their potential in Mexico City. Other agencies, such as the Ministry of Social Development (SEDESOL), offer support for those interested in pursuing these types of projects, from the landfill design-phase to the generation of electricity (Torres and Gomez 2006: 65). In Brazil, governments at the federal, state and municipal levels have been or are becoming engaged in this area. For example, at the state level, CETESB has been working on this issue seriously since the mid 1990s and also offers support to potential project developers.

Related to incentives are environmental studies. In the case of SWHs a number of studies had been done in both cities. Numerous experts were aware of Quintanilla's work on SWHs in Mexico City. Quintanilla showed that the residential sector in Mexico City "generates, approximately 3 percent of NOx, 2 percent of methane, and 13 percent of CO2 emissions" (2000: 22-23) and that SWHs would be an excellent way to help reduce these emissions. West et al. (2003) also argued that SWHs could represent an important manner through which to reduce the emissions from these three pollutants). A more recent study (Hoyt et al. 2006: 8) also confirms the local environmental benefits of reduced NOx and CO emissions, and the global environment benefits of mitigating climate change through reduced CO2 emissions and potential ozone depleting pollutants when using SWHs versus LPG in Mexico City.

In Brazil, groups such as Vitae Civilis and Lumina, are undertaking studies to demonstrate the environmental benefits of SWHs. Interestingly, one study comparing SWHs to LPG systems and SWHs + electric back up systems in São Paulo using a Life Cycle Assessment (LCA)[326] approach demonstrated that there were more GHG emissions released from the SWH + electricity back up water heating system versus an LPG system (Taborianski and Prado 2004: 650). Despite these studies, many informants stressed that, generally speaking, environmental studies were few and that much more research was needed.

[326] Life Cycle Assessment, or Life Cycle Analysis (LCA) examines the environmental impact of a good or service throughout its entire lifespan (a cradle to grave approach). In the case of a product, this would include the energy, air and water pollution, and solid waste involved in the collection and transportation of raw materials, the process involved in making it a finished product (e.g. a water heating system), the distribution and use of the system, and finally its disposal Macauley, M. and M. Walls (2000). Solid Waste Policy. Public Policies for Environmental Protection. P. a. R. Portney and Stavins. Washington D.C., Resources For the Future: 286.

But one problem with these studies, and related to Rogers' compatibility argument, is that even if people were aware of scientific studies that exist demonstrating savings of stand-alone SWHs, or SWHs with a "back up" gas system versus their stand-alone natural gas or LPG counterparts, in Mexican culture, the concept of making such a large investment in which payback may be seen in about five years is incongruent with a culture in which many people tend to live day by day. Many people in Mexico would only make this kind of investment (with a payback of five to six years) on a house or a car.[327] This facet was not mentioned as much in the São Paulo case study for SWHs. However, informal discussions in São Paulo indicated that many people in that city also live day to day or month to month, and echoed by Brazil's 2003 INGE study on income levels discussed in Chapter 5, likely negatively affect the uptake of SWHs at the household level in that city.

Some conventional studies on renewables categorize this challenge as an economic trait, noting that those with less disposable income have higher discount rates (i.e. money they have today is worth significantly more than money they will have tomorrow) (Philibert 2006). But this facet is also intrinsically linked with socio-cultural aspects, which are often neglected when promoting these environmental advantages. Jorge Cela's (1997) Culture of Poverty, speaking about the urban poor in the Dominican Republic, highlights instability involved in all aspects of their lives, institutions, family and other relationships; not just finances – moving to various locations, living with various family members, perhaps, or perhaps not attending schools, and having numerous workplaces and / or forms to generate income.

Policies encouraging these RETs are important steps but the role they have played on the uptake of SWHs and biogas technologies in Mexico City and São Paulo is not clear. Incentives at the international level have played a role in encouraging the use of biogas to generate electricity technologies in Latin America, but considering the technology is more costly in São Paulo they cannot explain the differences between the two cities adequately. It is important to take a step back and ask what are the driving forces for these incentives? The main rationale behind encouraging the adoption of RETs is due

[327] Personal Communication, Mexican scholar, February 2006; Interviews, three SWH companies, two consultancy, November - December 2005 and January 2006

to phenomena occurring at a systemic level. These aspects include poverty alleviation, climate change, energy security, other environmental challenges, and increasing technological capacity; all of which merit responses at a systemic level.

As argued in Chapter 1 however, these incentives – offered as solutions to barriers -- are often too economic or technical focused, neglecting other aspects just as important. By the same token, policy incentives are often too narrow and do not account for the role that other, seemingly unrelated, indirect policies can have on RET adoption. Incentives put in place to address barriers are often interdependent and their existence can be traced back to policies formulated at the macro-level. Thus, addressing one, several, or all of the barriers does not necessarily equate with an increase in technology adoption.

6.4. Triability, Observability and Social System

The other two attributes that Rogers identifies as potential factors affecting adoption are triability and observability. In Mexico City and São Paulo at present no "trial periods" exist in which a family / hotel / hospital, or, in the case of a landfill, a municipality, can "try out" a SWH (even if a "back up" alternative to heat water was also used) or biogas technology to produce electricity for a period of time without undertaking a major investment in the equipment and installation – thus making some potential users more reluctant to take on this technology.[328]

In São Paulo, Vitae Civilis and ABRAVA were starting to work with others, including a government bank that focuses on lower income populations (Caixa Econômica Federal (also known as Caixa or CEF)), on an Energy Service Company (ESCO) option for SWH usage. Under this initiative an ESCO would sell hot water or lease the SWH equipment, making this technology or the services from this technology (hot water) more viable for end users.[329] However, at the time of writing (2009), this had still not been implemented.

[328] Interviews with two SWH companies, one government agency, November – December 2005; Interviews three SWH companies, one NGO, March 2006
[329] Interview, one NGO, March 2006

Observability of SWHs was similar in both places – some examples existed in various places throughout the cities (e.g. houses, hospitals, sports centres) but not enough that they were deemed commonplace. Biogas technology to produce electricity was also similar in both places amongst the general public because even though this RET existed in São Paulo, the majority of the general public had not been to their landfills nor did they desire to go there. In both cities, even though there was not a local example of the RET up and running in Mexico City, most experts were aware of the details involved in the Monterrey biogas to energy project. However, one interesting point noted in Brazil was that there were some journalists that had taken an interest in the São Paulo biogas projects.[330]

The core organizations focused on increasing awareness and understanding for SWHs in Mexico City are ANES and ABRAVA, Vitae Civilis and Sociedade de Sol in São Paulo (discussed further in Section 6.8). Their main method of communication – organizing conferences, courses, and seminars as well as conducting presentations and mobilizing other stakeholders -- is cosmopolite and to a lesser extent local interpersonal channels, as well as communication via the internet. The main communications channels used by organizations aimed at increasing awareness and understanding of this technology (discussed in detail in Section 4.10) is also cosmopolite and to a lesser extent local interpersonal channels and the internet. For both RETs in both Mexico City and São Paulo, mass media channels (e.g. television, radio) are not used much. As the communication forms are similar in both locations for both technologies, less attention was placed on this factor to explain the differences.

Two other features in the diffusion of innovation model – type of innovation system and communication channels were similar in both cities, so less attention was placed there. Rogers (2003a) also indicates that the nature of a social system, such as its norms and degree of interconnectedness can affect the adoption of technologies. He defines it as "a set of interrelated units that are engaged in joint problem solving to accomplish a common goal". (Rogers 2003a: 23). But as has been stressed throughout the dissertation, these interconnections are ever evolving. Furthermore, as noted in Chapters 4 and 5 and discussed further in Chapters 7 and 8, rather than the degree of

[330] Interview, one university representative, March 2006

interconnectedness, the nature of these relationships and the dynamics not only between but also within stakeholder groups can affect adoption.

Moreover, the social systems under scrutiny are extremely complex – with major differences between socioeconomic levels, various ethnicities, neighbourhoods, governments, policies, etc. Furthermore, these social systems are cities, with unique attributes and features including serving as nexus points for innovation, and providing opportunities for various sectors (e.g. public, private, academic) to have increased personal contacts. For these reasons, an alternative framework, termed urban technology cooperation and applied at the meso-level, was used to determine how the social system played a role on adoption.

6.5. Efforts of Change Agents

The final salient feature considered in Rogers' model is the effort of change agents, or intermediaries. Change agents are members of a social system who seek to influence a person or organization's decision to adopt (or not to adopt) a technology. The view is that a change agent is more successful in ensuring the adoption of innovations through a number of criteria including their effort to contact clients, orienting their efforts at clients versus the change agencies, the extent to which they work with opinion leaders, etc. (Rogers 2003a: 27 and 400). But, as explored below, the problem with this definition is that not enough attention is placed on the dynamics occurring between these change agents, or within stakeholder groups.

6.5.1. SWHs in Mexico City

As indicated in Chapter 4, the NGO ANES was considered the main change agency promoting this RET in Mexico City. ANES has shouldered most of the responsibility of creating awareness and understanding of SWHs through undertaking a multitude of activities in order to increase awareness of this technology – from the basics to its advantages -- amongst many different actors (e.g. students, engineers, potential developers, etc). ANES works with other active players, such as the academics and CIE and SWHs.

A number of SWH companies in Mexico City noted that, since the majority of their time is spent on keeping afloat, they have little time to devote to increasing awareness and promoting the technology among potential consumers. Many companies also claimed that the government was doing little to promote SWHs, although a number noted actions taken by the municipal government which facilitated discussion amongst key players during 2005/06[331]. At that time, the agency was lead by the Secretary of Environment of Mexico City, Dr. Claudia Sheinbaum, an engineer by training very familiar with solar energy. However, they are unable to promote SWHs amongst the general public due to a lack of time and financial resources[332]. Some individuals at the federal government or outside of government are also critical change agents (e.g. Odon de Buen, when he was Director of CONAE or working as an energy expert for a consultancy), but by far the most organized efforts are those of ANES.

6.5.2. SWHs in São Paulo

Many SWH companies in and around São Paulo are too busy to focus their efforts on promoting this technology amongst the general public. Many defer this task to ABRAVA. The municipal government is interested in this technology (like Mexico City, São Paulo has recently approved a mandatory SWH norm for new buildings) but many informed me that governments (especially at the federal and state levels) were simply "not interested in this technology".[333] The bulk of awareness raising of SWHs in São Paulo (the city, the greater city area, and the state) is being done by two initiatives supporting two distinct philosophies.

The first initiative is the joint activities of ABRAVA and Vitae Civilis. Change agents are individuals working at these two organizations. Through their efforts (e.g. workshops, presentations, advocacy efforts), information about SWHs is increasing amongst experts and also, through their Cidades Solares program, amongst municipalities – including São Paulo (both technical and non-technical personnel).

The second effort, albeit on a smaller scale, and more at the "grassroots" are the efforts of Sociedade de Sol – the individuals working there would be considered other change

331 Interviews, six SWH companies, November 2005 – January 200
332 Interviews, 2 government representatives, November – December 2005
333 Interview, one NGO, March 2006

agents. Through their monthly courses on a low-cost model of a SWH and their SWH kit in the classroom program, information on SWHs is also increasing in São Paulo. Another organization also focusing on easy to build / install and cheap SWHs, although more for rural applications – building on the intermediate technology movement of the 1970s -- is the Grupo Solaris, operating out of the Piracicaba campus of USP. Their philosophy, like that of Sociedade de Sol's, is to focus not only on technical attributes, but on how to ensure it is simple and cheap, and therefore more accessible to the general population[334].

In conclusion, efforts to increase awareness and understanding of SWHs amongst the general population and experts by consultants, companies and government officials are, generally speaking, sparse due to a lack of time and resources, and / or a lack of interest (in the case of some government agencies).

The NGO ANES, through their various activities, are actively disseminating information about this technology in Mexico City and in the country. In São Paulo, three organizations are undertaking efforts to increase awareness of this technology – ABRAVA, Vitae Civilis and Sociedade de Sol. What is interesting about these three groups is the fact that while their ultimate goal is the same – to increase awareness about SWHs in São Paulo and Brazil -- these are two distinct "branches" or forms of knowledge. One branch, lead by Vitae Civilis and ABRAVA, in addition to creating awareness about the technology in general, also focuses their efforts on making certified SWHs more accessible to the population – through proposing credit schemes, ESCOs, and legislation requiring their use.

The other knowledge branch, akin to the Schumacher, intermediate / appropriate technology school of thought. This philosophy stresses not only the technology, but also the social benefits that can accrue from its use (including pride, and an increase in self-esteem). In essence, the philosophy of Vitae Civilis and ABRAVA's efforts is to get the social situation to "fit" the technology, while Sociedade de Sol and Grupo

[334] The Grupo Solaris representative pointed out that there were a number of organizations across Brazil working along these lines (intermediate technology) including groups in Parana and others in the northeast of Brazil, Interview, April 2007

Solaris' is to get the technology to "fit" the situation. Rogers' model fails to account for these different types of knowledge being pursued concurrently.

Table 6.2 discusses these features as they relate to SWHs in Mexico City and São Paulo.

6.5.3. Biogas in Mexico City

As noted in Chapter 4, there is some work being done on biogas in and around Mexico City by various organizations, including the IIE, SEMARNAT, INE, SENER, and CONAE. They are not focusing their efforts on increasing knowledge of this technology amongst the general population. Several biogas companies are also active in this area – mainly Mexican subsidiaries of international companies, such as Ecoenergy and MGM International – but their efforts to increase knowledge are aimed at potential investors. However, some of these potential investors include municipalities (both technical and non-technical personnel). The majority of the work in this area is relatively new, stemming from the Monterrey biogas project, which began in 2003, to determine the feasibility of replicating this project elsewhere.[335] Mexican expertise is growing – amongst technical personnel in the government, biogas companies (whether Mexican or Mexicans working at foreign-owned companies) and municipalities, although this technology remains basically unknown amongst the general public in that city.

6.5.4. Biogas in São Paulo

Since the mid 1990s, there has been a lot of work done on this issue in São Paulo, especially by the state environmental agency CETESB. This agency has undoubtedly served as the nexus of information regarding this topic. Activities conducted include providing the technical and administrative knowledge at a Brazil-wide methane emissions reduction workshop in 1998, and fostering networks, drawing on national expertise from the USP (e.g. IEE, IPT and CENBIO), the federal government (e.g. MCT) and engineering consultants and international partners, such as the Japanese government, the World Bank and the US EPA. In addition CETESB has created software aimed at simulating a landfill so potential project developers can determine

[335] Informal discussions and Interviews, 2 biogas companies, 5 government representatives, November 2005 – January 2006

methane emissions reductions and electricity generation, a guidebook and a webpage to help disseminate information about this technology to experts, students, and, to a lesser extent, the general population. They are also a core partner in the country-wide effort by the federal government to determine the feasibility of this technology in 40 municipalities throughout Brazil. São Paulo-based experts are one of the driving forces behind increasing awareness of this technology in the city and state of São Paulo and beyond. Indigenous expertise has a solid basis in São Paulo – through CETESB and the USP, amongst others, and is growing within government agencies at the federal and state levels – as well as the municipal levels through the Bandeirantes and São Joao landfill gas to energy projects.

These aspects are important for the following reasons. First of all, the fact that there is no one clear change agent in Mexico City may partially explain why biogas technologies are not being used there, but they are being used in São Paulo. That said, as noted in Chapter 4, since the time of research things are changing in this area as the mayor of Mexico City is working with the Clinton Foundation on a biogas initiative. The second area to point out is the fact that regarding biogas technologies, in São Paulo these change agents were domestic, while in Mexico City, they were foreign and domestic. Although the main change agents in both cities for SWHs are domestic, there is more indigenous technological capacity in Brazil, which has also been in place for a longer period of time. This can have positive implications for adoption. Other studies also emphasize the importance of developing indigenous technological capacity through the sharing of knowledge and not just equipment and skills to ensure sustainable technology cooperation and use (e.g. Ockwell et al. 2007, Bell 1990; (Worrell et al. 2001). Developing indigenous capacity is also related to trade and competitiveness policies, as there is evidence to support the view that technology cooperation through joint ventures rather than through creating subsidiaries is more conducive to doing so (Ivarsson and Alvstam 2005); Ockwell et al. 2007).

Table 6.3 lays out the concepts identified above and how they were applied in the case of Biogas for electricity generation in Mexico City and São Paulo

Table 6.2: Aspects of Rogers' Technology Adoption Model to Explain the Adoption of SWHs in Mexico City and São Paulo

Stage	Attributes	Relevant Factor	Mexico City	São Paulo	Comparison	Explanation
Knowledge		Awareness	Little awareness of technology or as an alternative to a gas water heater by general public	Apagão – more awareness of energy conservation Some suggest awareness of SWHs due to apagão but view not shared by all	May partially explain more SWH adoption in houses in São Paulo.	Underlying conditions affect awareness, not just awareness of technology
		Prior experiences with technology	Negative perception of SWHs due to previous experiences (inferior equipment and / or bad installations)	Not really noted	May partially explain more SWH adoption in houses in São Paulo	Underlying conditions affect awareness, not just awareness of technology
		Other prior events – oil shocks and climate change	Oil shocks and climate change positive for RE but not necessarily these technologies	Oil shocks and climate change positive for RE but not necessarily these technologies	Not clear in both places if playing a direct role	unclear
		Source of technology	SWH technology foreign, joint, and domestic Biogas technology generally foreign	SWH technology domestic Biogas technology domestic, joint and foreign	May play a role on adoption but not clear from model how	More opportunities for technological capacity and absorption in Brazil? (Bell 1990, Lall 1995)
Persuasion	Economic Relative Advantage	Cost in general	Assessed SWHs for applicable users Unaffordable to majority of population in city (at least 17% of popn can afford)	Assessed SWHs for applicable users Unaffordable to majority of population in city (at least 16% of population can afford)	SWH for domestic use have similar costs – larger tank is used in Brazil. SWH for larger scale operations – SWHs are a little cheaper in Brazil, so one would expect more used there, but more are being used in Mexico City	Alternative to large-scale applications of SWHs is cheaper in São Paulo BUT alternative to household SWHs is cheaper in Brazil

Stage	Attributes	Relevant Factor	Mexico City	São Paulo	Comparison	Explanation
	Economic Relative Advantage	Cost vis-à-vis Alternatives	Versions of SWHs exist that are equivalent or cheaper than conventional counterparts (over time) LPG boiler is a little over 1/3rd cost of SWH, but 80% of LPG is used to heat water vs. cooking Need auxiliary system	No SWH is cheaper than alternative for single family homes at present (chuveiro eletrico), but, over time, 33% of electricity bill is used to heat water they will be the same cost Some multifamily dwellings and industry use gas – some SWHs are cheaper at present or in the long run Need auxiliary system	Chuveiro eletrico is so cheap, Alternative to SWHs for larger applications is cheaper in São Paulo.	One would think there would be less SWHs used in Brazilian homes, but opposite is happening. Can help to explain why more being used in Mexico City.
	Compatibility	Social aspects	Culture of more day to day	Many living month to month	Both countries – people who do find out about SWHs are interested but find them too expensive	
	Complexity		Mixed – some understood basic concept (using the sun to heat water through pipes) but not complexities (how does water stay hot at night / cloudy days?) Experts – yes – do not need to convince engineers of its advantages	Mixed – some understood basic concept (using the sun to heat water through pipes) but not complexities Experts – yes - – do not need to convince engineers of its advantages	Similar in both cities	
	Triability		At present, no option for a trial period for a SWH (whether on its own, or with a conventional "back up" system)	At present, no option for a trial period for a SWH (whether on its own, or with a conventional "back up" system)	Generally does not exist in either country ESCO model of VC – too early – not up and running in São Paulo	

Stage	Attributes	Relevant Factor	Mexico City	São Paulo	Comparison	Explanation
				Planning ESCO model but not operational		
	Observability		Can be viewed in a number of places throughout city, but not commonplace	Can be viewed in a number of places throughout city, but not commonplace	Similar in both cities.	
All	Change Agents		Individuals working at ANES are main change agents	Individuals at Vitae Civilis, ABRAVA and Sociedade de Sol are main change agents but promoting two distinct philosophies	Distinct change agents in both places	Not clear from model implications of promoting differing philosophies

Source: Author, August 2008, updated August 2009

Table 6.3: Aspects of Rogers' Technology Adoption Model to Explain Adoption of Biogas for Electricity Generation (Mexico City, São Paulo)

Stage	Attributes	Relevant Factor	Mexico City	São Paulo	Comparison	Explanation
Knowledge		Awareness	Generally speaking public had no or little idea about this technology but experts were aware.	General public had no or little idea about this technology but experts were aware.	Similar in both cities.	
		Prior experiences with technology	No implications noted	Lead actors to use a foreign versus domestic version of the technology	In Brazil, only a negative impact on some types of technology, not industry as a whole	Not clear from model
		Other prior events – oil shocks and climate change	Climate change key driver	Climate change key driver	Similar in both cities	
Persuasion	Economic Relative Advantage	Cost in general	Estimated at about US$417 per MWh	Estimated at about US$634 per MWh	Costs are a little higher in São Paulo (50% of costs are due to taxes)	Not clear from model
	Economic Relative Advantage	Cost vis-à-vis alternatives	Significantly more expensive then alternative	Significantly more expensive then alternative	Why are they being used? Projected revenues due to CDM	Prior conditions affect use
	Compatibility	Social aspects	Public generally thought little about landfills unless living nearby, working in industry or having no garbage collection	Similar	Similar in both cities.	
	Complexity		Only experts	Only experts	Similar in both cities.	
	Triability		This option is not available.	This option is not available.	Generally does not exist in either country.	
	Observability		As technology would be located at landfill which is outside of the city,	Technology is located at landfill which is outside of the city, therefore hard to	Similar in both cities.	

Stage	Attributes	Relevant Factor	Mexico City	São Paulo	Comparison	Explanation
			therefore hard to generate a lot of observability unless living / working near. Also, access to landfill would be restricted.	generate a lot of observability unless living / working near. Access to landfill is restricted.		
All	Change Agents		No one organizational (or individual) "champion" – numerous change agents	Individuals working at CETESB are the main change agents	May partially explain why more biogas technologies being used in São Paulo	Change agents can play a key role on adoption

Source: Author, August 2008, updated August 2009

6.6. - Conclusion

What can Rogers model tell us regarding the research question - what are the most important factors affecting RET adoption in the urban developing world? Through focusing on the first research question how can systemic approaches help to explain RET adoption in the urban developing world, I found that Rogers' model is useful to help explain RET adoption in these settings because it captures the classical explanations for RET adoption in developing countries, while also accounting for social aspects. In addition, the approach focuses on a system and places emphasis on technologies and actors. On the other hand using a model to determine causality is with limitations – history and context matter, which can put some of the model's assumptions into question.

Specifically, what can Rogers' model tell us about why or why not SWHs and biogas technologies are being used in Mexico City and São Paulo?

First of all, Rogers' model – akin to those approaches emphasizing economic and technical aspects -- is especially useful in explaining why adoption rates in both cities for both technologies are rather low (reflection of cost, lack of finances, lack of awareness of the technologies, a lack of and / or problems with implementing incentives and administrative hurdles). These themes are consistent with some of the findings noted in Chapters 4 and 5 including awareness and direct environmental policies.

However, when comparing the two case studies, there are a number of differences between the locations that the model cannot explain. For instance, the model can help to explain why more SWHs and a back up in new houses are being used in São Paulo versus Mexico City - because they are cheaper. However, SWHs in existing homes are significantly higher in Brazil versus Mexico, although the alternative to the SWH is much cheaper in São Paulo.

Rogers' Diffusion of Innovations model helps to explain why more large-scale applications are being used in Mexico City -- because the alternative to SWHs is cheaper in São Paulo versus Mexico City. This dissertation suggests however that analysis must take a step farther back and determine exactly why the alternative to SWH is cheaper – are there policies in place that affect this? I argue in Chapter 8 that policies at the systemic level put in place for different reasons can impact RET adoption nevertheless – such as trade and competitiveness policies.

In fact, trade and competitiveness regimes were one of the most prevalent themes identified by informants, as well as networks. These themes are not accounted for enough using Rogers' model. Therefore, two other frameworks – urban technology cooperation and trade and competitiveness regimes were also applied.

Secondly, the model helps to partially explain why there are more SWHs being used in São Paulo among residential consumers. Rogers' model asserts that knowledge of a technology does impact RET adoption and that the more people understand a technology, the more willing they are to adopt it. At the same time, Rogers' recognizes the importance of previous experiences. In the case of Mexico City, many indicated that these prior experiences negatively affected the use of SWHs, while in São Paulo, that city's experience with the apagão had a positive impact on SWH use through increased awareness of RETs and energy conservation leading some actors to seek out SWHs. However, a minority of informants felt that this awareness of energy issues did not necessarily led to increased use of SWHs. In this case, I assert that awareness of energy conservation issues in general in São Paulo *in combination* with previous experiences with SWHs in Mexico City also affect the uptake of RETs, rather than just awareness of these technologies themselves.

But, one thing interesting is that in Brazil, prior experience with biogas technologies led participants to choose a foreign rather than domestic technology, despite numerous taxes put in place to encourage the use of domestic technologies. Here, negative experiences only impacted the use of some types of the technology. In other words, a model's attempt at determining causality must also reflect the context and historical experiences of that particular setting.

Sources of technology, perceptions of technology ownership and the fact that indigenous knowledge of these RETs is increasing may also influence technology use but it is not clear from this approach exactly how. Frameworks emphasizing the role of developing technological capabilities through acquiring knowledge as well as skills and equipment, and absorptive capacity (e.g. Lall 1995, Bell 1990; Ivarsson and Alvstam 2005) provide a better explanation for how these attributes can impact adoption.

Related to knowledge are the efforts of change agents, which seek to increase knowledge of innovations. One assumption of Rogers' model is that they have similar goals (to encourage adoption of an innovation), but what if differing philosophies are being pursued concurrently, as in the Brazilian case study? This aspect will be discussed in Chapter 7.

Another concern with the approach is how knowledge is treated - it implicitly equates knowledge with information, but as stressed throughout, each individual processes and interprets information differently making them distinct.

The dissertation therefore turned to debates in technology transfer and innovation to better explain how key factors can influence renewable energy use in urban environments in developing countries. Technology transfer is an integral part of the technology adoption process, especially in developing countries. An alternative form of technology transfer, termed 'urban technology cooperation' was the second framework chosen for analysis of RET adoption in these two cities. This approach attempts to link actions at the local level with actions undertaken other levels, to capture the potential effects of indirect, systemic policies.

CHAPTER 7: URBAN TECHNOLOGY COOPERATION – AN ALTERNATIVE EXPLANATION FOR RET ADOPTION IN LATIN AMERICAN CITIES

7.1. Introduction

As indicated in Chapter 6, Rogers' diffusion of innovation model was useful in that it helped to explain:

- The fact that overall adoption rates are low in both cities;
- why more SWHs + a back up in new homes are being used in São Paulo and why large scale SWHs are being used in Mexico City (because they are cheaper than the alternative)
- how energy conservation issues through the apagão in combination with prior experiences played a role on the uptake rates of SWHs in São Paulo versus Mexico City;
- why biogas technologies are being used in the first place in Mexico and Brazil (climate change); and
- why more biogas technologies were not being used in Mexico City but are in São Paulo (presence of distinct change agents).

On the other hand, the approach was unable to explain:

- why more SWHs in homes are being used in São Paulo versus Mexico City (as the alternative is much cheaper in São Paulo);
- how trade and competitiveness regimes and networks – two pivotal themes noted by informants – impacted adoption;
- how source of technology and divisions between and within stakeholder groups can play a role on uptake.

Furthermore, the model treats knowledge as similar to information, but it is more than this. Information is processed, shaped and interpreted differently based on people's experiences and understanding.

Also, as noted in Chapter 2, some technology adoption and transfer approaches focus on interactions between stakeholder groups. But more attention is needed on the nature of these relationships.

When examining the interactions *between* stakeholder groups, there were a number of insights gleaned. Firstly, in the case of SWHs, these networks were considered to be stronger because their nexus point was in a city. Secondly, although Rogers' pointed out the importance of change agents, this approach helped to understand why these change agents were so effective. Thirdly, an assessment of networks, rather than mainly change agents and the person or organization making a decision whether or not to use a technology, showed some weaknesses within these links, which can play a role on adoption. Finally, this chapter shows that in São Paulo, networks that had been around longer were more institutionalised and the stakeholders groups more mobilized, affecting RET use for both technologies.

When examining the impact of international influences, I found that in addition to realizing the important role that climate change and the CDM has on adoption of these technologies (as noted in Chapter 6), examining the source of these drivers is also key. Here, international influences are key drivers prompting networks between technology cooperation participants at the level of the city, which helps to explain why these networks are fostering. But more importantly, Brazil has more indigenous expertise in this area due to the early engagement on climate change and the CDM by the government, academic communities, NGOs, and other stakeholders.

I also found that dynamics *within* stakeholder groups, affected by international influences, such as divisions uncovered at the meso-level, help explain RET use in these cities.

There were several implications involved with using this alternative paradigm. First of all, having more players does not necessarily equate to more successful technology cooperation. Secondly, although cities can serve as centres of innovation and nexus points to foster personal contacts between various sectors, unlike Porter (1990), who argues that rivalries among firms is good to trigger innovation and adoption, I found that these divisions played a negative role on technology adoption. In addition, although the urban technology cooperation approach recognizes the importance of engaging end users, in the realities of Mexico City and São Paulo regarding these two technologies, they were virtually absent – albeit the efforts of Sociedade do Sol and Grupo Solaris to popularize SWHs are important steps.

Finally, the model fails to tell us exactly the rationale behind some of these findings – why they were happening in the first place – for that answer, we must turn to an assessment of trade and competitiveness policies.

7.2. The Urban Technology Cooperation Approach

In Chapter 2, aspects of technology cooperation were discussed in detail. Technology cooperation is rooted various traditions including:

1) technology transfer and innovation literature, such as triple and quadruple helix (Etkowitz and Carvalho de Mello 2004; Saad and Zawdie 2005, Bunders et al. 1999), Douthwaite's (2002) innovation feedback model, technological capabilities (Lall 1995), technological systems (Hekkert and van den Hoed, citing Carlsson and Stankiewicz 1995), and technology cooperation (Heaton et al. 1994);
2) approaches marrying environmental and energy issues with local governance concerns, such as Glasbergen's cooperative environmental governance (1998), Mason's environmental democracy (1999) and Forsyth's work on climate change in the developing world and deliberative institutions and cross-sector partnerships (1999); Morsink, Hofman and Lovett's technology transfer work of environmentally sound technologies in Lesotho (in press);

3) system dynamics – recognizing that the process (or system) is as important a facet in determining how it acts as are the individual parts – a tool used as a way to address policies in a complex system (Forrester 1961).

To advance urban technology cooperation as a way to explain the adoption of renewable energy technologies, there are a number of assumptions and attributes to be examined. Discussed in further detail in Chapter 2, these include:

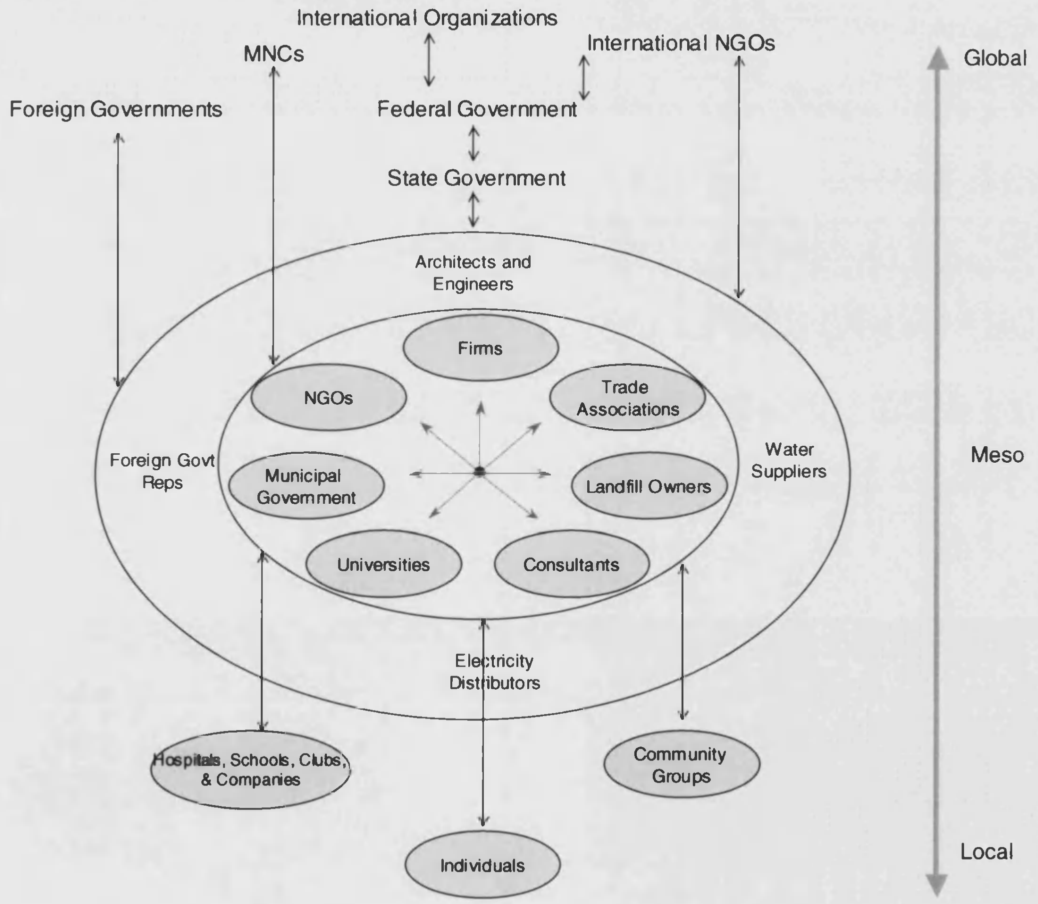
- the notion that sustainable technology cooperation includes technological capacity building;
- It is an iterative two- or more-way process where all participants are active players, inputting into the technology cooperation process;
- cohesive and continuous communication between technology cooperation participants – developers, producers, distributors, intermediaries, and ideally, end users;
- It operates at the meso-level – focusing on links existing between networks across levels – from the global to the local, better capturing the potential affects of policy and events at the macro-level that may affect the urban experience;
- It attempts to recognize the heterogeneity of stakeholders;
- It focuses on the importance of cities

Technology cooperation, like Rogers' technology adoption model, is an actor-centred approach, one that emphasizes the importance of actions and people. However, as noted in Chapter 2, defining actors is difficult as the category is an arbitrary one. Actors include the conventional parties noted in technology transfer models – developers, producers, distributors and users. But this concept also recognizes the role of intermediaries. Participants' roles can vary. For example, a developer can also be an intermediary and an end user; they are not mutually exclusive. In other words, technology developers can also be distributors and / or end users, etc. In contrast to Rogers that singles out the efforts of change agents, urban technology cooperation examines the networks that are taking place at the meso-level – incorporating the perspective of all partners involved in the technology cooperation process, and paying attention to their relationships. It is a broad view of technology cooperation, meaning in addition to formal agreements between companies, organizations, etc., it also includes conferences, informal information exchange between friends and colleagues, among other activities.

As discussed previously, many studies on energy and / or technology transfer in developing countries focus on the micro-level or the macro-level. However, technology cooperation was applied at the meso-level, or the level between individuals, firms and household, and the national level, as this level of analysis consists of two common aspects – interdependency dynamics and the heterogeneity of actors (Schenk et al. 2007), considered important when assessing RET adoption. The meso-level was also chosen as the focus of analysis to properly account for cities, which "tend to become both centrifugal and centripetal nodes in a national, and increasingly international, society linked by means of networks" (Capello et al. 1999: 5). In addition, in developing countries, cities – due to their infrastructure, services available, the presence of institutions, etc. – can serve as clusters, or areas where an industry, through the work of a group of firms and other institutions, has a competitive advantage (Porter 1990).

Rather than linear models of technology transfer or innovation, technology cooperation manifests itself as a series of interacting nodes, thus making the model an iterative process. **Figure 7.1** provides a graphic representation of the urban technology cooperation approach as it evolved after evidence from the case studies. Of course it is difficult to capture the ever-changing nature of these relationships, so it should be thought of as a simplified version, providing a 'snapshot' of the process during a particular time. As noted in Chapter 2, the urban technology cooperation approach attempts to understand the most important factors affecting the uptake of RETs in developing country cities through examining how public policy and technology cooperation can play a role. In addition, by focusing on various urban and innovation literature, the concept considers the potential affects that the unique aspects of cities may have (e.g. nexus of innovation, proximity and social networks of different stakeholders at the meso-level). The centre circles are at the meso-level, with the centre circle including players directly involved in the process, while those in the surrounding circle are more indirectly involved. At the same time, the concept also captures links between players operating mainly at other levels (marco and micro) with those at the meso level. After research, it was decided to concentrate the approach on actors as a way to capture more abstract notions such as 'public policy' and 'technology cooperation', as it is through these actors that specific aspects manifest themselves (e.g. the federal government of Brazil's policy to require foreign firms with three or more employees ensure Brazilians constitute two thirds of the workforce and receive two thirds of the payroll).

Figure 7.1 Urban Technology Cooperation – Post Field Research



7.3. Applying the Urban Technology Cooperation Approach to Explain RET Adoption in Mexico City and São Paulo

After undertaking field research in Mexico City, I did some initial analysis by applying this approach (which I was – and am still formulating) to the case of Solar Water Heaters in Mexico City (see Mallett 2007) for further information). As indicated above, the centre of focus for this approach is on the networks that exist between the various technology cooperation players, paying attention to their relationships. The first task is to assess the nature of these relationships to determine which players are active. Key questions include:

1) which sectors are engaged in the technology cooperation process? Several types of networks were explored including triple helix, or linkages between the academic, government and private sectors, and public-private partnerships, or linkages between government agencies and the private sector, and engaging with the public or non-experts.
2) Are these examples of clusters?
3) Where are the key influences on the networks (local? International? Regional?)
4) What about the relationships between and within these groups? Are they in constant communication? United or divisive?

The following themes emerged from the study, but which are not picked up or downplayed by Rogers' model. These factors include the nature of interactions between the technology cooperation participants, the role of international influences, and divisions occurring within stakeholders involved in technology cooperation.

7.3.1. Interactions between participants

The first factor that can affect RET adoption involves the interactions between the technology cooperation participants. This theme, coded as networks, was one of the most prevalent factors affecting the adoption of these Renewable Energy Technologies (RETs), as noted in Chapters 4 and 5. When examining this factor, several questions were considered including: are these networks institutionalized or *ad hoc*? Are they formal or informal? Are relationships long-term or short-term? Are there too many or too little players involved in the technology cooperation process? How do perceptions affect these networks?

A) Solar Water Heaters

For the majority of actors involved in the technology cooperation process for Solar Water Heaters (SWHs) in Mexico City and São Paulo, when looking at the micro level, interactions among the three sectors – academia, industry and government -- remain limited at best. For example, as noted in Chapters 4 and 5, SWH companies would answer occasional queries by students, and universities mainly link with other universities. Links between SWH companies were sparse as they often operated in isolation, focusing on their niches and the distinctiveness of their product(s) and / or processes. That said, as the technology cooperation process is examined a step higher, at the meso-level, some important networks between participants emerged in both cities.

Solar Water Heaters in Mexico City

Triple Helix – With respect to Mexico, like other countries in Latin America, the country supports the triple helix concept. There are small pockets of networks forming between these three sectors (academia, industry and government), but the majority of public funds are aimed at government agencies (e.g. management of funds and decisions on strategies) and public / academic institutions (e.g. university research on science and technology (S&T)) rather than the private sector.[336] Having said this, there are two major exceptions to this trend.

The first exception is the process instigated by the Secretary of the Environment of the Federal District of Mexico (i.e. Mexico City municipal government) to develop a

[336](OECD), O. o. E. C. a. D. (2004). OECD Science, Technology and Industry Outlook 2004 (Mexico). Country Responses to Policy Questionnaires. OECD. Paris, OECD: 1-14.

mandatory standard on the application of solar water heaters in the city. Through this standard, which was approved on April 7, 2006, in new buildings of medium (50 – 100 employees) or large size (more than 100 employees) a minimum of 30% of the energy needed to heat water must come from SWHs[337]. The second exception is the efforts of the National Association of Solar Energy of Mexico, or the Asociacion Nacional de Energia Solar (ANES) to promote, support and build capacity on SWHs / renewable energy in the city and country. In both of these processes, major stakeholders, including representatives from the private and public sectors, academic institutions and consultants, come together to discuss the technology cooperation process. The general view among all stakeholders was that these two initiatives were important in encouraging the adoption of SWHs in Mexico City and Mexico. Many stressed the efforts of ANES in particular.

These revelations are similar to those found in Rogers, where these change agents were identified. But, because this approach fixates on the networks and the dynamics within, the urban technology cooperation approach helps to explain why networks in cities can be stronger and why these change agents were so effective.

Networks in Cities - An advantage of these two initiatives cited by informants in the city, was the fact that many of the events took place in Mexico City. Larger companies and organizations located outside of the city were in Mexico City enough to be able to attend important events. Mexico City was considered to be an important "nexus". Although one representative from a smaller company located on the outskirts of Mexico City noted that he would "like to attend more meetings, conferences and workshops...but it is difficult for me to get there,"[338] the majority of informants found it advantageous to attend meetings in Mexico City, as they could undertake other activities (e.g. meet potential clients, suppliers, other researchers). In other words, networks were considered to be stronger as they were centred on Mexico City and the surrounding area.

[337] www.cidadessolares.org.br/cs/downloads/leis/mexico_norma_ambiental_obrigatorio_solar.zip
[338] Interview, one SWH company, December 2005

As noted in Chapters 4 and 5, more SWHs in homes and biogas to produce electricity are being used in São Paulo than Mexico City. However, in the case of SWHs, differences between the hardware being used at the national level (0.7 m2 / 100 inhabitants in Mexico versus 3 m2 / 100 inhabitants in Brazil), were not as stark between the cities (1.6 m2 / 100 inhabitants in Mexico City for SWHs not including those used for pools) versus 2 m2 / 100 inhabitants in São Paulo). One explanation for this could be because cities, as centres of innovation, and places in which various actors can more easily come together (through proximity and the infrastructure to take people from place to place), can increase technology adoption. Cities also play a role on RET adoption by having more 'traffic'. By virtue of high population densities, more people are exposed to certain RETs such as SWHs. As noted in Chapter 5, a number of informants in São Paulo highlighted the experience of Belo Horizonte and SWHs, indicating that they were commonplace on rooftops. Further exploring the role that cities can have on RET adoption, by comparing these settings with rural environments, is a further area warranting exploration.

Informants also argued that ANES was becoming increasingly effective, as the organization has more links with the private sector (traditionally the organization has been dominated by academics). For example, one respondent noted that one of the executive committee members working at a SWH company at ANES is also active in the National Chamber of Transformation Industry, La Cámara Nacional de la Industria de Transformación (CANACINTRA).[339]

Rogers also focuses on the efforts of change agents rather than all players in the process. An assessment of all players is important because although the efforts of change agents play an important role, an assessment of dynamics among other groups revealed weaker links, which can have a role on uptake.

Specifically, those technology cooperation players in Mexico City with stronger links to ANES tended to see an increase in the use of their 'hardware', or SWHs (as measured by

[339] Interviews with six university representatives, two consultancies and three SWH companies, November 2005 – January 2006

metres installed and maintained relative to the size of their operation, continued new sales, etc.[340]). These companies also tended to have links with other companies and / or government agencies and / or universities.[341]

These efforts are encouraging but further examination of these networks reveals instances when communication links and interactions are not as solid. For example, in discussions on the mandatory standard for SWHs in Mexico City, the National Agency to Save Energy in Mexico, CONAE – a key agency responsible for energy conservation policies, "participate in the meetings, but they do not make much impact."[342] In another example, at a high level meeting on renewable energy in Mexico, the sub Secretary of Energy told a SWH company that he wanted to install one in his house "but the company did not provide a proposal...they never got back to him...can you imagine [the potential opportunity for exposure]...the sub Secretary of Energy!"[343] Moreover, some academics indicated that relations between universities and the private sector had some challenges as those working in industry "found it difficult to accept advice from universities...[as academics] do not have any practical experience".[344]

Public-Private Partnerships - In Mexico City, there are government programs to try and help companies working in renewable energy. According to one informant "...any program or policy that is aiming to avoid the use of combustibles is helpful for renewable energy".[345] However, as the findings in Chapter 4 indicated, often these programs are difficult to find out about and complicated. Some interviewees also suggested that these programs were privy to only a small core group of companies (revealing yet another division between companies).[346] One SWH company had this to say.

[340] It is important to point out that some of the most successful SWH companies in Mexico (having close links with ANES) had suffered some setbacks including dissatisfied customers due to poorly installed / not working equipment, lawsuits, etc., but that they had managed to ensure new contracts and satisfaction by consumers (Interviews, three SWH companies, November 2005-January 2006).
[341] Interviews, three SWH companies, November 2005 – January 2006
[342] Interview, one government official, December 2005
[343] Interview, one government official, November 2005
[344] Interview, one university representative, November 2005
[345] Interview, university representative, December 2005
[346] Interviews, three SWH companies, December 2005

> Supposedly there is help, but it is little…it is not always feasible...there is help but we do not know of them [programs]. [These are] lost funds. The problem is that we need a person specifically devoting their time looking for this help. We have to pay this person - we just do not have the capital for this.[347]

Another factor compounding a lack of awareness of government programs is that many SWH companies operate in isolation. In the Mexican case, public-private partnerships did not necessarily equate to more use of SWHs, due to a lack of communication among partners.

This is not to say that other links within and between the sectors working on SWHs were completely absent in Mexico City. Links among SWH companies have occurred from time to time, but they are more *ad hoc* and sporadic. For example, a number of SWH companies got together in 2005 to jointly write a letter to CONAE protesting the federal government's natural gas subsidy of Mexican pesos $800 million to Nuevo Leon state for six months (which a number of respondents noted was, incidentally, the same state the Mexican Energy Secretary was from), arguing that these funds "could have been used to help those looking for alternative clean sources [of energy]".[348]

Engaging End Users / Quadruple Helix – In Mexico City, the end user in general cannot be said to be an active player in the technology cooperation process in the area of SWHs. They are only involved at the point of sale, and only briefly. SWHs are sometimes perceived negatively (as an expensive technology that does not work) by some, based upon past experiences where there was little follow up by those selling / providing the technology to those using the technology. Thus, in Mexico there are bad installations and / or bad quality technology, and so some original users have discarded their SWHs and 'written off' the technology.[349] In sum, little empirical evidence could be obtained regarding the end user perspective model in the technology cooperation process – and in the case of Mexico City and SWHs, where contact was made with the end users, their perception of technology or their experience in the technology cooperation process was,

[347] Interview, one SWH company-M, December 2005
[348] Interview, one SWH company, December 2005
[349] Interviews, six SWH companies, one government agency, and one NGO, November 2005 – January 2006

more often than not, a negative one. Indeed, perceptions are important factors affecting networks between these various sectors.

Solar Water Heaters in São Paulo

Triple Helix and Public-Private Partnerships – Brazil also espouses the importance of the triple helix. There are increasing networks forming between the three sectors (academia, industry and government). For instance, in the ethanol sector, where Brazil has become the world's leading producer of ethanol from sugar cane, these links are "long-standing and solid".[350] Other studies also attest to Brazil's interest in the triple helix. While in 1988 there were only two 'incubator parks' in the country, in 2005, there were 339 incubators (Sampaio 2006: 9). Unlike a number of other countries, such as the United States, Brazil's government is the main body spearheading science and technology. For example, even though it has the largest number of scientists in Latin America (with 50 000 scientists in 2006), 73% work in public research institutions – versus the U.S. where 72% of scientists work in companies (Sampaio Aranha 2006: 5).

Links between the sectors were more prevalent in São Paulo. For example, a number of SWH companies in and around São Paulo had some form of individual contact with universities as those companies wishing to have their product certified by INMETRO were required to send their technology to university test labs (either IPT in São Paulo or GreenSolar Lab in Belo Horizonte).[351]

> "INMETRO is a government organization that tests products. So a product must pass a series of minimum requirements...INMETRO analyzes whatever product...so that the product will reproduce what you have promised ...[INMETRO] has a classification system."[352]

Another example is the work of the NGO Sociedade de Sol, which is physically located at the University of São Paulo's "incubator park" called the Incubator Centre for Technical Businesses, or Centro Incubador de Empresas Tecnologicas (CIETEC).

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[350] Interview, one government representative, March 2006
[351] Interviews, six SWH companies, March – May 2006
[352] Interview, one SWH company, March 2006

Sociedade do Sol has been housed at the university since its beginning, in 1992, where it began as an engineering firm as a means to implement some of Agenda 21's goals – namely to find a simple, indigenous, non-fossil fuel energy technology for Brazil. It became an NGO in 1999 and continues to work with the Centre. The NGO is well respected in São Paulo and various parts of the USP, including the Piracicaba campus of USP, which works on SWHs, mainly for rural applications. However, the NGO noted that some university professors – those interested in cutting edge and 'state-of-the-art' technologies – did not agree with the NGO's philosophy of pursuing social, economic and environmental goals simultaneously, at the expense of efficiency and quality. This NGO also had links with companies which donated tubes for the Low Cost Solar Water Heater by an informal agreement.[353]

Another network among participants in São Paulo is being lead by the trade association ABRAVA and the NGO Vitae Civilis. They are important change agents in the city and Brazil. They have been very effectively working together in São Paulo with the municipal government. Representatives from USP are also involved in these discussions, although at the time of research they were not as active. On June 30th, 2007, the municipal government of São Paulo adopted a law making it mandatory for all new public buildings in the city to have SWHs in place to provide, as a minimum, 40% of the energy needed to heat water[354]. Their goal is to increase the uptake of "good quality" SWHs – adapting the context to fit the technology. It is generally known within the SWH community that those companies who have received INMETRO's "seal" and who are associated with ABRAVA are considered 'good', meaning their products and services meet a certain technical standard.[355]

Engaging End Users / Quadruple Helix – The NGO Sociedade do Sol is the main agent undertaking efforts to engage the public about SWHs. ABRAVA and Vitae Civilis are also working to make more people aware about SWHs, but they are targeting key

[353] Interview, one NGO, March 2006
[354] www.cidadessolares.org.br/cs/downloads/708103_propositura_projetodelei_SP.zip

[355] Interview, one SWH company, March 2006

decision leaders including government representatives rather than the public at large. The Sociedade do Sol are engaging the public in three ways: 1) running several one day workshops every month on how to build a SWH; 2) recruiting technicians from the surrounding favelas, or underprivileged neighbourhoods around USP, 3) establishing a network of volunteers throughout Grande São Paulo and the State of São Paulo and beyond who are promoting SWHs by distributing the technology as a demonstration kit to schools throughout the region – targeting students in grades 5 and 6. The view is that the children will learn about the technology and get their parents interested.

Networks in Cities - In the São Paulo case study, because the 'home bases' of these participants were more spread out (e.g. towns located in the state of São Paulo, outside of the city), the city of Belo Horizonte, etc., they tended to defer responsibility to the trade association ABRAVA, and to keep abreast of trends through the internet / ABRAVA's website. That said, the general view was also that São Paulo was considered as 'nexus' for these networks, and participants located outside of the city (as well as those inside the city) used events happening continuously (e.g. many cited the FEICOM meeting that happens yearly, usually in April), as opportunities to maintain contacts, meet counterparts, etc.

B) Biogas to Generate Electricity Technologies

Biogas to Generate Electricity Technologies in Mexico City

Triple Helix and Public-Private Partnerships - Government representatives, companies, and consultants alike all claimed that a key hurdle for this technology in Mexico was that it was too administratively heavy to do a project – there were too many jurisdictional issues, forms to fill out, permits to get and 'hoops' to get through; thus scaring off any potential investors, for the time being. Despite this recognition by all players, no projects have been under construction or in operation in Mexico City on this technology at the time of research 2005/06.

One reason for this is because activities on this technology in Mexico City are mainly being done in various "pockets" -- the private sector, the government (mainly federal level) and research institutions. Networks are starting to form between these groups, but, generally speaking, they are working in isolation. The private sector is the main player working on this issue in Mexico City – in terms of studies conducted and expertise. Specifically, there are a number of consulting firms active on climate change working on this area in Mexico City and Mexico. These companies, such as Ecosecurities (head office in Oxford, U.K.) and MGM International (head office in Miami, USA) are mainly foreign, or jointly Mexican and foreign. In terms of public sector activities, as of 2009, the federal government and a research institution have only conducted feasibility studies.

End User / Quadruple Helix – There were no efforts underway to engage the general public on this issue in Mexico City at the time of research.

Biogas to Generate Electricity Technologies in São Paulo

Triple Helix and Public-Private Partnerships - In São Paulo, the key drivers in the technology cooperation process for the Bandeirantes project were the consortium of foreign and Brazilian companies, which call themselves "Biogas" and consist of Hellica & Fonseca (Brazilian), Arcados Logos (70% Dutch) and Vandervilt (Dutch), and several consultants. Another project developer was Unibanco, one of the largest banking firms in Brazil, working with CETESB, who had technical expertise in this area. These players acted quickly when a window opened up in the Brazilian legislature in 2003 (September – December), allowing them access to the grid to transmit their electricity to other locations, to implement the project. Once the project was running, other players began to become more involved, including the University of São Paulo, the municipal government (who saw an opportunity) and other parts of the state government.

As noted in Chapter 5, the second biogas to electricity project in São Paulo, at São Joao landfill was not up and running at the time of field research, however, the same consortium of companies purchased the São Joao landfill from another company and are currently managing another biogas to electricity project there. Speaking about this technology more generally, the state government (CETESB) has been working with international organizations (World Bank, US EPA), and the private sector and the University of São Paulo on biogas to produce electricity in landfills just outside of the city.

Informants also noted that there were a number of challenges involved, including obtaining the adequate permits among others, in developing a project. One reason these projects are in operation is likely because links between the academic, public and private sectors have existed for quite some time on the Bandeirantes landfill. One informant indicated that there are masters and doctoral studies being conducted on the landfill site – where participants from these three sectors work together -- with respect to agriculture, environmental issues and seismology in that location.[356] In São Paulo, the state government and USP have been working with others on issue since the mid-1990s. For this reason these processes are more "institutionalized" and so can be managed better by interested technology cooperation participants.

End User / Quadruple Helix – There were few efforts underway to engage the general public on this issue in São Paulo at the time of research. One activity however, as noted in Chapter 5, is being done by CETESB. This organization has been working on developing a guide for this type of technology, available electronically, in Portuguese, although it is not clear how many Brazilians are aware of and access this resource.

So what does all this mean? Generally speaking, stakeholder groups and organizations within a stakeholder group (e.g. individual SWH companies, government agencies and divisions within agencies, biogas consultancies, etc.) often operate in isolation. However, links between these various groups are increasingly being formed. In both countries the importance of personal relationships cannot be overemphasized. Indeed, links between these actors were mainly informal – agreements between friends, versus formalized memorandums of understanding, joint ventures, etc. Intermediaries have been playing a pivotal role in both cities in terms of creating awareness, encouraging collaboration and

[356] Interview, engineering consultancy, March 2006

the use of these technologies. Examining these links can help to explain why there is more use of SWHs for homes and biogas technologies in São Paulo. In Mexico, most of these links are more recent (an exception being ANES' work, but even informants highlighted recent efforts by the ANES to diversity by integrating more industry representation in their structure as being positive steps), and more sporadic and *ad hoc*. In Brazil, networks have been around longer, are better established and more institutionalized, and there are more instances of triple helix, and attempts at quadruple helix.

Others working on renewables also recognize the importance of collaboration to further the uptake of clean energy technologies, although collaboration between different countries, with different histories and peculiarities is likely to be more difficult versus cooperation among players within these cities, as noted by (Al-Widyan and Al-Muhtaseb 2009), who examine collaboration on clean energy between Middle Eastern and North African (MENA) countries. They indicate that although regional cooperation is being discussed among academics, this has not transcended to the energy agendas of these countries. That said, although divisions occur among nations in all regions, the MENA region is faced with some serious regional and national risks to security, forming deep divisions within this region and beyond (including the Israeli-Palestinian conflict, the Sudanese civil war, the war in Afghanistan, etc.) (Shiyyab 2008). In other words, these examples from Mexico City and São Paulo can inform initiatives on renewables occurring in other parts of the world, but an analyst must thoroughly scrutinize the relevance of these examples to their particular situation, as each region, country, and community are unique.

Scrutinizing these networks revealed that major differences of opinion occurred not just between, but also *within* the various stakeholder groups – a facet often neglected by other studies looking at links between the various sectors. These divisions will be explored further in 7.3.3. Another revelation is that in the SWHs case study, key groups working on this technology are Mexican and Brazilian. In the biogas case study, the key group is foreign (international consulting firms) in Mexico, but domestic in Brazil. How these international influences may play a role on RET adoption in these settings is the next topic to be explored.

7.3.2. International Influences – climate change

The second factor explained by the urban technology cooperation approach is the role of international influences on adoption, which is a key driver prompting and / or strengthening networks between technology cooperation participants at the level of the city. As opposed to conventional studies that emphasize direct policies, this encompasses more than just incentives; also interest, attention and engagement. As noted in Chapters 4, 5 and 6, the main area of international influences discussed by participants is climate change.

Although the influence of climate change was also examined in Chapter 6, what the urban technology cooperation approach revealed were differences between the two cities – in that in Mexico City, the key players are foreign, whereas in Brazil, the key players are domestic and foreign.

These international influences manifested themselves in several ways, including direct environmental policies aimed at increasing RET adoption (e.g. mandatory requirements for buildings to have a certain percentage of their hot water come from SWHs in both cities, or the municipality of São Paulo's 50 percent stake in carbon credits being generated at one of the cities landfills through biogas to generate electricity) as discussed in Chapter 6, under incentives.

There are also other ways in which international influences can play a role on RET adoption. For instance, a more indirect way is through encouraging more public awareness about climate change and specific processes under the United Nations Framework Convention on Climate Change (UNFCCC) including the Clean Development Mechanism (CDM), or through conducting or supporting studies demonstrating the potential for avoided carbon emissions.

In Mexico City, many agents from all sectors also indicated that, although it was slow and at the margins of mainstream society, interest and awareness in climate change was growing in Mexico City. At the time of fieldwork (late 2005 / early 2006), Hurricanes Wilma and Stan had done some major damage in Mexico and people were starting to pay attention. Having said this, knowledge about climate change, and the potential benefits of the carbon market remains limited – some technology cooperation participants knew only a little about these topics.

The local government in Mexico City indicated that climate change was one of the reasons for pushing SWHs in the city. They recognized that the potential for carbon credits through SWHs would only make sense in terms of transaction costs, capital requirements, etc., in the short term, on a large scale. Because of this, they were promoting SWHs for large-scale applications (e.g. large businesses, large schools, hospitals, sports clubs, etc.). The federal government also noted the potential for SWHs to generate carbon credits, but also echoed the rationale that these projects would only be viable on a large scale. Others also share this point of view such as a study done by Econergy, a foreign consultancy firm on the carbon market, on the potential for SWHs in Mexico. The study indicated that a minimum of 50,000 SWH systems for residential use would need to be sold to create a potential CDM project (Hoyt et al. 2006: 7).

Here, many companies argued that more efforts were needed to promote the potential for reducing carbon emissions. They suggested that there were not enough studies being done espousing the environmental benefits that can accrue using SWHs – from local air quality problems to global climate change. Foreigners fund the bulk of studies that are being done. One interesting theme came out in the case of Mexico City and SWHs. According to some respondents "the Mexican government knows the potential [for addressing climate change through RETs] but the Mexican government is afraid of new things.... things will happen when there is international help."[357] They further noted that

[357] Interviews, two consultancy representatives, December 2005

there were some domestic government funds to support the use of electricity from renewables "but not for studies".[358]

This is interesting because it is in stark contrast to the Brazilian government experience with climate change and the CDM, which has been an active player on climate change for many years, as discussed further below.

In the case of SWHs in Brazil, studies on climate change are increasingly being viewed as powerful tools. The NGO Vitae Civilis has conducted numerous studies on the role that SWHs can play in addressing climate change, including Brazil's Place in the Sun financed by the Blue Moon Fund, a U.S. foundation that supports sustainable development and environmental projects, including climate change. Vitae Civilis' effort to advocate the use of SWHs in various cities in Brazil, through their CidadesSolares initiative[359] also includes information sessions on the CDM. Numerous SWH companies, in addition to brochures, also have "Fact Sheets" comparing SWHs to conventional technologies – gas, wood and electricity in terms of energy and carbon emissions savings.

Regarding biogas technologies, informants in both countries indicated that, without a doubt, a key driver generating interest in biogas technologies was climate change and the potential to generate carbon credits through biogas projects. Others also suggest that the CDM played a key role in increasing the uptake of landfill gas technologies in Brazil (Lederer 2009).

This is different from other studies examining biogas in other countries, such as India and the Philippines (e.g. Forsyth 1999, 2005), where the main rationale for investment was obtaining the energy; the carbon credits were viewed as being an additional benefit. The main reason for this was because, as noted in Chapters 4 and 5, regulations regarding electricity from Independent Power Producers (IPPs) were restrictive, unclear and involved a lot of paperwork. That said, more interest and investment was occurring with

[358] Interviews, two consultancy representatives, December 2005
[359] See www.cidadessolares.org.br for further information

respect to flaring methane (rather than allowing it to be passively released) versus generating electricity from biogas, as the carbon equivalent emissions reduced is about the same for methane flaring and using biogas to run motors to generate electricity.[360]

With respect to biogas technologies to generate electricity, in Mexico City, all studies examining their potential, whether foreign or domestic, include carbon emission reduction estimations as an element. This is similar in São Paulo.[361] Brazil has also been working with other countries for many years, including the U.S. EPA and Japan's International Cooperation Agency on biogas technologies. They are also active players in the U.S.-led Methane to Markets initiative.

To expand upon the above points, although Mexico has a well-versed committed community of domestic climate change experts and advocates, this community is rather small. A company in Mexico told me "they have learned more about climate change and the carbon market from foreigners"[362] than from Mexicans. Brazil on the other hand has developed a robust community of indigenous experts – including government officials, NGOs, consultants, and industry – active on this topic.

Brazilian experts have been at the forefront of the Clean Development Mechanism (CDM) market since its inception. In fact, the CDM was a compromise developed by Brazilian and U.S. negotiators. Brazil had proposed a Clean Development Fund (CDF) to fund climate change mitigation projects in developing countries in June 1997, which would be funded by industrialized nations out of compliance of their commitments. Industrialized nations, called Annex I countries in the UNFCCC, did not like proposed 'penalties' for non-compliance however, and were supporting a similar like mechanism to Activities Implemented Jointly (AIJ), but under the Kyoto Protocol. Under AIJ, Annex I countries could undertake projects that reduced GHG emissions in developing countries, thus offsetting GHG emissions in their own country. But many developing countries were not so keen on AIJ, as noted in Chapter 1, as they felt less attention was being

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[360] Interview, one university representative, March 2006
[361] See PDD Ciudad Juarez, Bandeirantes and Sao Joao for example
[362] Interview, one SWH company, December 2005

placed on technology transfer and more attention was being placed on sinks, and certain regions (Latin America) were being favoured. Many developing countries also felt that industrialized nations should reduce GHG emissions domestically.

The Clean Development Mechanism (CDM) was a proposal for projects to reduce GHG emissions in developing countries to help developed countries meet their commitments, but unlike the CDF, it was based on incentives, rather than penalties. In addition to reducing GHG emissions, the CDM would promote sustainable development, capacity building, technology transfer, renewable energy, and additional activities, or those activities that would not have occurred without the incentive of generating emission reduction credits.[363] As indicated in Chapter 1, there are a number of critiques of the CDM. On the one hand, some indicate that the CDM is not promoting enough of these other objectives, that certain regions and countries are favoured (e.g. China, India, Brazil and Mexico versus Less Developed Countries (e.g. in 2006, they were only 0.9% of CDM projects) and Asia and Latin America versus Africa), and that the CDM process is not transparent (Environmental Defence Fund 2007; CDM Watch 2009; Lederer 2009). Others suggest that the CDM is unable to instigate policy reforms in developing countries, that credits issued do not reflect real emissions reductions (de Sepibus 2009), or focuses mainly only finding the cheapest way to generate carbon emissions reductions per dollar spent, termed 'low hanging fruit' (Informal discussions, Carbon Expo 2005).[364]

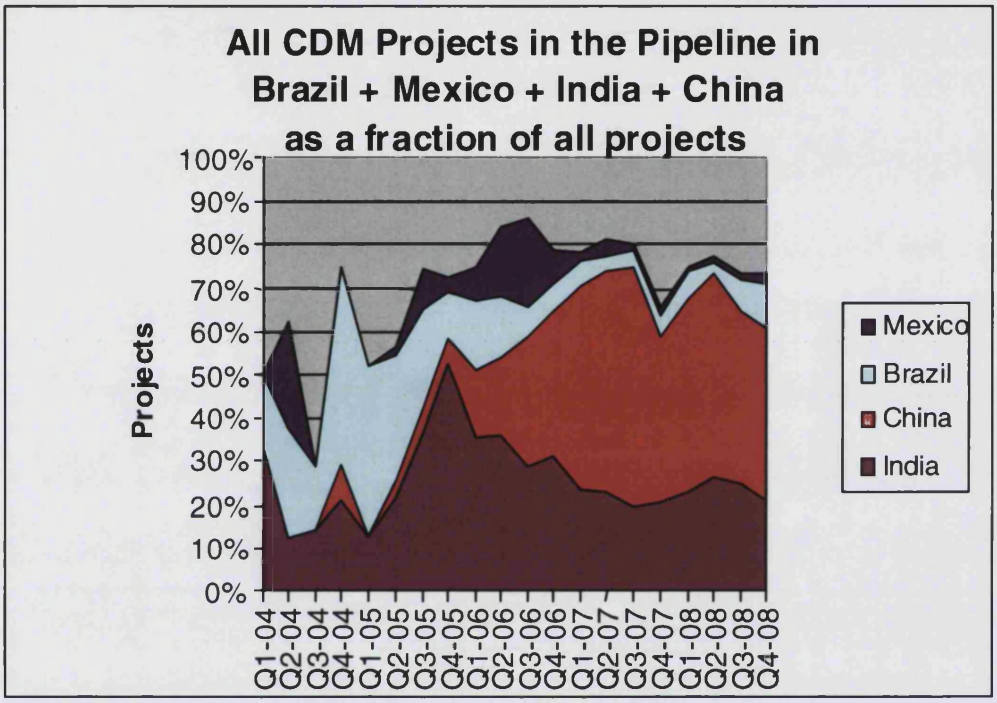
Some claim that this is because "despite the rhetorical trimmings, the CDM is a market, not a development fund nor a renewables promotion mechanism" (Pearson 2007: 249). On the other hand, some consider the CDM to too regulated -- plagued with transaction costs, and bureaucratic hurdles (Personal communication, CDM executive board meeting with stakeholders, Carbon Expo, May 2005). Nevertheless, Brazil is one of the principal

[363] Deliberations exist regarding how to determine additionality has occurred as a result of the proposed CDM projects, although the CDM Executive Board has developed a tool to help assess additionality. For further information please see Müller, B. (2009). Additionality in the Clean Development Mechanism Why and What? O. I. f. E. Studies. Oxford, Oxford University: 1-18.

[364] For a thorough examination of the CDM please see Holm Olsen, K. and J. Fenhann (2008). A Reformed CDM - including New Mechanisms for Sustainable Development. Roskilde, Denmark, UNEP Riso Centre.

countries that have CDM projects, especially dominant at the time of research in 2006. See Figure 7.2

Figure 7.2 - CDM projects in pipeline from Brazil, Mexico, India and China 2004-2008



Source: Adapted from Lederer 2009, p. 17

A study done on technology transfer in the CDM indicates that of those CDM projects with a technology transfer element assessed, Brazil, along with China, India and South Korea, account for 72% of the projects and 80% of the annual greenhouse gas (GHG) emissions reductions as of June 2008 (Seres 2008: 8). Informants indicated that Brazil has developed a well-established and credible expertise in this area, producing CDM project proposals and other studies, which forecast carbon emission reductions.[365] The CDM plays a key role in Brazil – according to Lederer (2009), carbon credits are the 20th largest export commodity in Brazil, Brazilians have strong local capabilities, and the CDM has helped turn government attention towards renewables, through PROINFA.

[365] Informal discussions, key informants, February – March 2006

But, Brazil's involvement in the CDM has not been without controversies. For instance, the Brazilian company Plantar S.A. submitted a proposal to the World Bank's Prototype Carbon Fund (PCF) to plant eucalyptus in 2003. The eucalyptus would be used for the production of charcoal for Plantar's pig iron plant, which would displace coal, used by many of the world's iron producers. This project proposal prompted a letter to the World Bank from more than 50 Brazilian NGOs, community groups, and other organizations asking for the Bank to not support this project.[366] Also, Brazil's dominant role in the CDM is changing as noted in Figure 7.2 above. In 2009, Brazil only constituted 7.8% of all CDM projects in the pipeline (Lederer 2009).

Furthermore, the Mexican government is also increasingly becoming an active non-Annex 1 player in the climate regime. For example, in addition to the government's Special Program on Climate Change, Mexico also has updated their GHG emissions inventory to 2006 and is currently completing their 4th National Communication, expected in November 2009 (Martinez 2009). That said, because Brazil has had an early start in the CDM market, this has lead to more indigenous expertise in this area. This is important for adoption because as noted earlier (e.g. Ockwell et al. 2007; Bell 1990; Worrell et al. 2001), the development of indigenous technological capabilities can also lead to an increase in the uptake of low carbon technologies.

In sum, the principal area where international players are engaged on these technologies in Mexico and Brazil is through climate change. In the case of biogas technologies, the potential for CDM projects is considered the principal driver increasing their adoption. Informants in Mexico and Brazil indicated that possible biogas to generate electricity projects had been looked at for a long time, but that the potential to generate carbon credits had really prompted interest. In Mexico, the Monterrey project of the PCF is considered an example, with the hope of replicating it elsewhere in the country. In Brazil, Bandeirantes and São Joao are two certified CDM projects.

[366] www.fern.org/pubs/ngostas/Planteng.htm

Unlike Rogers' model which also noted the importance of climate change through indicating the importance of 'prior or underlying conditions', the urban technology cooperation approach attempts to capture the origins of these prior conditions. In both places, interest in climate change at the onset mainly stemmed from the international community, but in Brazil, more stakeholders are aware, and have been aware longer, of climate change and the potential to generate carbon credits under the CDM. In the case of the CDM and climate change, Brazil has been engaged early on. This has led to more local expertise and knowledge of these technologies, which may partially explain an increase in the adoption of these technologies. The final factor considered using urban technology cooperation scrutinizes the relationships occurring within various stakeholder groups. Here, a number of divisions were found which are discussed below.

7.3.3. Divisions within Stakeholder Groups

Studies that focus on the interactions of sectors stress the links that are needed between these groups to ensure effective transfer and adoption of technologies (e.g. Bunders et al. 1999; Juma and Yee-Cheong 2005). As noted in Chapter 1, drawing from Reed (2008), stakeholders are those affected by or that affect the technology cooperation process. One assumption made by these studies is that points of view within those in a stakeholder group are similar. However, in Mexico City and São Paulo, there were differing opinions within these stakeholder groups, which have caused some major divisions. This is the final theme explored by urban technology cooperation.

Mexico City

In the case of SWHs, in Mexico City, there were several forms of divisiveness. The main two divisions were found among companies. These divisions included:

1) those companies selling imported SWHs and those producing and / or distributing nationally-made SWHs;

Some informants claimed that divisions were so pronounced between domestic and foreign SWH companies, this could be termed "a war".[367] One foreign company told me that in order to qualify for government contracts (e.g. SWHs for public hospitals, schools, etc.) one had to ensure that a certain percentage of products were Mexican in origin. If the government itself is the consumer, then 50% of the products must be Mexican.[368] On the other hand, some Mexican-owned companies and researchers however indicated that due to free trade, "the market is being flooded with cheap, often inferior products"[369] with many citing China as the country of origins for these 'bad quality' SWHs.[370]

and

2) those SWH companies that always received government support and contracts (termed by some SWH companies as being "in the club"[371]), and those that did not.

A number of SWH companies indicated that "it is always the same group of people"[372] that receive government support and contracts. Those outside of 'the club' remained on the margins. As an example, some firms spoke about CONAE's program to promote SWH use in Mexican homes. In this program six companies were chosen based on a series of criteria (years in business, SWHs sold, reputation). "We are a new company – how can we compete?"[373]

In addition, as noted earlier, there were many different perceptions towards the government in Mexico. These differing perceptions occurred within sub-groups too (e.g. domestic and foreign SWH companies; SWH companies in 'the club' and outside of 'the club'). Some companies felt that the federal government's interests were intertwined with the fossil fuel industry, while others felt the government was indifferent. Some indicated

[367] Interview, two government officials, two consultancy representatives, November-December 2005
[368] Interview, one SWH company, November 2005
[369] Interview, one SWH company, December 2005
[370] Interviews, four SWH companies and two university representatives, November – December 2005
[371] Interviews, four SWH companies, November 2005-January 2006
[372] Interview, one SWH company, December 2005
[373] Interview, one SWH company, December 2005

that the government favoured Mexican companies, while others claimed the government favoured foreign companies. These divisions were not as prevalent within stakeholder groups involved in biogas technologies to generate electricity in Mexico City.

For both technologies, divisions also existed within other stakeholder groups too. In Mexico City, divisions exist within the various levels of government, as each agency seeks to promote its interests. In Mexico, an obvious reason for these divisions is that the country is heavily dependent on fossil fuels, including the revenue generated; therefore any steps towards renewables would not be in its interest. However, even fossil fuel exporters are encouraging renewables as a way to free up domestic consumption, allowing them to sell more combustibles (Victor and Heller 2007). For instance, in 2006, the Middle East was the second fastest location (only behind China) for oil consumption, with a growth rate of 5.4% (Meisen and Hunter 2007: 4) – renewables, as well as nuclear, are thus being seriously considered by oil exporters in that region, as a way to increase conventional energy exports. Petroleos de Venezuela (PDVSA) has also been a keen supporter of renewables in that country in order to sell more fossil fuels abroad (Massabie 2008: 232).

São Paulo

In São Paulo regarding SWHs, the SWH companies and organizations operating in the city and state of São Paulo are Brazilian-owned using Brazilian technology. As of 2008, there existed only one company that sold imported Israeli SWHs, located outside of São Paulo state. As noted earlier, the main division is among those companies and other organizations (led by ABRAVA an d Vitae Civilis) advocating good quality products and services with guaranteed results (i.e. SWHs which meet the standards set by INMETRO), and those organizations (Sociedade do Sol, Grupo Solaris) who are advocating for intermediate technology, or technically-simple products and services (and thus inexpensive, making them affordable to the majority of Brazilians) with no guarantees.

The main goal of Sociedade do Sol is to popularize the SWH technology, which they term Aquecedor Solar de Baixo Custo (ASBC), or a Low-Cost Solar Heater, by making a

Do-It-Yourself model – adapting the technology to fit the context. The NGO indicated that their principal focus is on popularizing the technology by making it simple and affordable. I was told that "...between 1992 until 2002 we worked very hard and we did research, research and more research and finally, we came up with a cheap SWH".[374]

This approach is distinct from ABRAVA and Vitae Civilis', focusing on increasing 'good quality' SWHs in Brazil. In other words, these two networks are advocating two distinct philosophies, further supporting the view that actors within stakeholder groups are heterogeneous. Divisions within stakeholder groups in São Paulo working on biogas technologies to generate electricity were not as prevalent.

Divisions also existed within other stakeholder groups in São Paulo. One reason for divisions among government agencies may not be so obvious. In São Paulo, the term "Belindia" was used to describe Brazil – or in other words, 'Belgium in the middle of India'.[375] This is basically the notion that on the one hand, Brazil acts like a developed country, where the government and universities are focused on innovation and high technology policies and activities, while on the other hand, the Brazilian government focuses attention on addressing basic needs of its population – including access to food, clean water and basic education. Sampaio and others refer to this as the "two Brazils" (Sampaio 2006: 8).

As an example, several informants noted the federal government program "Light for All" or Luz Para Todos. This program suggests that renewables can provide electricity in certain areas (e.g. rural, isolated settings), but the bulk of attention has been placed on grid extension. Informants indicated that efforts to promote renewables through PROINFA, a key renewable energy promotion policy discussed in Chapter 6, and Luz

[374] Interview, NGO, March 2006
[375] Interview, one state government representative, March 2006

Para Todos are largely separate.[376] Informal discussions in Mexico indicate a similar phenomenon in that country.[377]

Clusters? I view both technologies in both cities as clusters, in the sense that both cities have a number of companies and institutions in an industry. Although no Mexican company is producing biogas technologies to date, in both places, the cities serve as a nexus point for consulting firms, and government research and activities.

In the case of SWHs in Mexico City, actors located within or around Mexico City were able to establish links, attend meetings and draw from the plentiful expertise found within this metropolitan area. Those with closer links to ANES also had higher rates of success with their technologies in terms of sales, reputation, etc.

However, in sharp contrast to Porter (1990), I argue that these divisions played a negative role on the use of these technologies in Mexico City, as it was difficult to reach consensus on a number of areas including a nationally-based certification program, as explained further below. Porter (1990) on the other hand purports that this rivalry is "desirable...the benefits are even stronger if concentrated within a region, or a city" (1990: 120). In other words, his claim is that this competition breeds innovation, which can also encourage adoption as these clusters stand out above their counterparts through various means (better quality products and services, unique features, low cost but good quality, etc.).

Although divisions within stakeholder groups in Brazil also negatively affect uptake of these technologies, I argue that there are two reasons why the effects are not as pronounced in São Paulo rather than Mexico City. The first reason draws from the example of SWHs in São Paulo. In Brazil, the two different groupings working on SWHs come together at various times to support the ultimate objective, which is increasing the adoption of this technology in the city and Brazil (e.g. Sociedade do Sol

[376] Interviews, one renewable energy company, two government officials, one NGO, two SWH companies, March 2006
[377] Informal discussions, informants, November 2005 – January 2006, April 2006, September 2007

was supportive of Vitae Civilis and ABRAVA's efforts to have the São Paulo city council develop a law mandating their use in certain buildings)[378]. Secondly, speaking about both technologies, as noted earlier, networks in Brazil are stronger, more institutionalized and have been around longer, versus in Mexico City where they are more recent and more ad hoc.

To summarize, although numerous literature exists highlighting the importance of links between various sectors for innovation, diffusion and / or adoption of technologies (e.g. Etkowitz and Carvalho de Mello 2004, Douthwaite 2002, Bunders et al. 1999), the dynamics within these stakeholder groups also warrant examination. Different individuals and / or institutions have different opinions. Some of these differences are so stark as to create major divisions within these stakeholder groups. In Mexico City, two key divisions were between foreign and domestic SWH companies, and between SWH companies considered 'in the club' and those outside of 'the club'. These divisions made collaboration difficult in Mexico City. Discussions with government officials indicated that one reason why Mexico had yet to develop government-led national standards, was due to these divisions – some SWH companies involved in discussions that imported were advocating flexibility, and some Mexican companies wanted strong certification. A voluntary standard has been in place since 1994, but it was only in 2004 that a number of SWH companies approached the privately run organization Normas Mexicanas (NORMEX), to create a more comprehensive, broadly-sanctioned standard, which materialized in 2005 NORMEX, and another in 2006. Brazil on the other hand, has had a voluntary but well-known standard on SWHs in place since 1998. These divisions can help to explain why networks in Brazil are better established, more institutionalized and organized. Divisions exist in Mexico City and São Paulo, but in Brazil these divisions are not as pronounced. This unity of purpose has afforded Brazilian groups opportunities to mobilize and advocate this technology, helping to explain why more SWHs in homes and biogas technologies are being used in that country. Tables 7.1 and 7.2 present the information discussed above in table format.

[378] Personal communication, NGOs, June 2007

Key Assumptions					
• Technology cooperation includes technological capacity building • Iterative two- or more-way process where all participants are active players • Cohesive and continuous communication • Operates the meso-level • Heterogeneity of stakeholders • Importance of cities					
	Attributes	**Mexico City**	**São Paulo**	**Comparison**	**Explanation**
Nature of Networks	▪ Triple Helix	Not very prevalent but two exceptions ANES and DF Secretary of Envt (more recent) ANES increasingly effective due internal structure - more links between sectors	Not very prevalent but more examples of links including companies with universities, Vitae Cilivis and ABRAVA, Sociedade de sol	More links between sectors in São Paulo	Links more established, institutionalized and organized in São Paulo, vs. Mexico City where links between sectors are more recent, more ad hoc Links considered stronger on both places as nexus is city
	▪ PP Partnerships	Are programs but complicated, convoluted, or unknown	No specific PP partnerships for SWHs	More in Mexico City but not considered so effective	Communication between technology players is lacking
	▪ Engaging Public	Efforts mainly aimed at experts	Efforts mainly aimed at experts but Sociedade do Sol engaging general public	In Mexico City, players are promoting a market-driven, technocentric philosophy, vs. São Paulo where different players are promoting both the market-driven, technocentric and social philosophies	More efforts to engage public linked to efforts to popularize technology in São Paulo
International Influences – Climate Change	▪ Incentives	Potential for CDM	Potential for CDM	Foreigners most active player in Mexico, while in Brazil, both domestic and foreign players are very active	More opportunities for technological capacity and absorption in Brazil
	▪ Public Awareness	Vitae Civilis, ABRAVA conducting workshops	General workshops on climate change, CDM		
	▪ Studies	Vitae Civilis doing studies financed from foreigners	Some international consultancy firms conducting studies		
Divisions within Stakeholder groups		Foreign and domestic companies Companies in and outside of the club	Market-driven, technocentric vs. social / contextualizing approaches	More in-fighting and more difficult to mobilize groups in Mexico City	Macro-level policies exacerbate divisions

Table 7.1 Urban Technology Cooperation and the Adoption of SWHs in Mexico City and São Paulo

Table 7.2: Urban Technology Cooperation and the Adoption of Biogas Technologies to Generate Electricity in Mexico City and São Paulo

Key Assumptions					
• technology cooperation includes technological capacity building • iterative two- or more-way process where all participants are active players • cohesive and continuous communication • operates the meso-level • heterogeneity of stakeholders • importance of cities					
	Attributes	**Mexico City**	**São Paulo**	**Comparison**	**Explanation**
Nature of Networks	▪ Triple Helix ▪ PP Partnerships ▪ Engaging Public	Pockets of research occurring in all sectors, but no effective links between sectors in Mexico City. Key driver is foreign private sector.	All sectors active in Brazil and work together at various times; links are strengthening. Key drivers are domestic and foreign, even if originally foreign	Links have been around longer and expertise is more indigenous	More opportunities for technological capacity and absorption in Brazil
International Influences – Climate Change	▪ Incentives ▪ Public Awareness ▪ Studies	Potential for CDM key driver Workshops geared towards experts	Potential for CDM key driver Workshops geared towards experts, although CETESB developing guidelines in Portuguese but not clear how many 'lay' Brazilians are aware of this resource	Foreigners most active player in Mexico, while in Brazil, both domestic and foreign players are very active	More opportunities for technological capacity and absorption in Brazil
Divisions within Stakeholder groups		Not as prevalent	Not as prevalent	Similar in both cities	

Source: Author, March 2009, updated August 2009

Now that we have explained various facets using this approach, an important question remains – what are the implications of applying the urban technology cooperation model to urban Latin America?

7.3. The Implications of applying the urban technology cooperation approach to urban Latin America

As indicated in Chapter 2, there are several critiques involved in using this approach. Some suggest that the term 'technology cooperation' may not appropriately reflect the power dynamics involved in these networks and processes (Stirling 2008). The SWH experience of a number of end users in Mexico City (unsatisfied, no follow up, etc.) could be characterized in this way. But, I argue that reverting back to transfer, immediately leads researchers back to the discourse implying a relationship between a donor and recipient, and a one-way flow of ideas.

Secondly, the approach emphasizes the advantages of developing country cities – as sources of innovation, and a rich network of various sectors, establishing and maintaining contact through personal relationships – as nexus points for adoption efforts. These links serve as opportunities to develop technological capacity, considered a key component in ensuring technology development and sustainable technology use. This is similar to Porter (1990)'s view that these are clusters, but unlike his claim that rivalries spur more innovation and competitive advantage, I argue that these divisions – especially pronounced among SWH companies in Mexico City – hinder the use of the technologies there.

Thirdly, the benefits that can accrue as a result of participatory approaches have been espoused by much literature, yet many problems remain when putting them into practice.[379] For example, in Mason (1999)'s study on environmental democracy, none of the case studies he selected, despite "all selected initially as promising forms of collective communication favouring environmental democracy norms, have so far triggered a meaningful governmental commitment to the one common political goal

[379] For more details on these challenges, please see Ockwell 2008: 264.

they all share" (Mason 1999: 212), which in that case was decentralizing environmental decision making. After applying the urban technology approach, relevant questions include claim can the active participation by all actors involved in the technology cooperation process would best ensure technology adoption realistically occur? And what are the implications of including all relevant stakeholders?

The above evidence suggests that links between the various technology cooperation actors can help the adoption of RETs. Having said this, it is important to point out that having more players does not necessarily equate to more adoption. As shown in the case of Mexico City and biogas, even though a number of agents are conducting work in this area, of the group, there is no single "champion", and so efforts continue to be separated. The origins of these technology cooperation actors also play a role. In Mexico City and SWHs, public – private programs were not as affective in eliciting RET adoption as those efforts engaging people from the three sectors of academia, government and industry. In São Paulo and biogas while there was one party largely responsible for getting the biogas to electricity project implemented (the consortium of businesses and the bank), other actors also played important roles (e.g. CETESB and an engineering consultant). In São Paulo and SWHs, efforts involving the government, industry and NGOs were occurring, however there was only one example of public engagement. In addition, this study has shown that intermediaries can serve as key bridge between experts and non-experts – NGOs, consultants, and government representatives. This finding is similar to other regions, where in China a local public-private agency, providing technical expertise and loans, is considered a key reason for the successful dissemination of renewables in rural areas (Sawin 2004). Also, Forsyth (1999) examining renewables in Southeast Asia notes that "specialist energy agencies...can act as links between international investors and local end users…such as Preferred Energy Investments in the Philippines" (1999: xxi).

Another revelation this study suggests is that while it is important to inform, engage, and make the public aware, in Mexico City and São Paulo, it is difficult to have non-experts be active participants in the technology cooperation process. Reasons for this could include – as Pietrobelli (2000) suggests, there may be too many people "under the tent", leading to logistical and coordination problems. What is more likely however is the fact that, although both places have a very active civil society, engaging the public has not been institutionalized enough by governments, among others. These aspects warrant further study.

On the other hand, while some may argue (an argument often made by some experts) that involving the public on technology issues is a gargantuan task, it is not impossible. Efforts by Sociedade do Sol and Grupo Solaris are important initiatives that demonstrate that the end user – from all parts of the socioeconomic spectrum -- can be an engaged and active participant in the technology cooperation process as other studies also suggest (Douthwaite 2002, Bunders et al. 1999).

7.4. Conclusion

Conventional approaches focus on interactions between stakeholder groups. But more attention is needed on the nature of these relationships. In São Paulo, networks that had been around longer were more institutionalised and the stakeholders groups more mobilized, affecting RET use.

Specifically, interactions between the technology cooperation actors play an important role on the adoption of RETs. In Mexico City and São Paulo, when referring to SWHs at the micro level, generally speaking, there is a lack of communication between technology developers, producers, distributors and end users, and between the public, academic and private sectors.

In Mexico, in the case of SWHs, this lack of cohesive and continuous communication in some cases has lead to divisions between and also within various stakeholder groups. There are also other instances when players work together – such as through the joint protest by a number of SWH companies to CONAE regarding the natural gas subsidy to Nuevo Leon state as noted in Chapter 4, but these efforts are more sporadic and *ad hoc*.

Many SWH companies in Brazil had some form of contact with universities as those companies wishing to have their product certified by INMETRO were required to send their technology to university test labs. In only one example, the Brazilian NGO Sociedade de Sol's efforts to create awareness about SWHs, were the end users engaged in the technology cooperation process – otherwise, the public remains outside of these actions. In São Paulo, links between the various players are more institutionalized – they have been around longer and are more organized. Also in Brazil, the NGO Sociedade do Sol has made a concerted effort to try and popularize this technology through public awareness and engagement. In São Paulo, Vitae Civilis and ABRAVA have worked with the Prefeitura of São Paulo to do the same. The NGO Sociedade do Sol is also encouraging the adoption of SWHs, although the philosophies of these two networks remain distinct.

Intermediaries in both countries for both technologies have played an important role encouraging their adoption. Links between most stakeholder groups are more recent, and more sporadic and *ad hoc* in Mexico City. In Brazil, networks have been around longer, are better established and more institutionalized. In and around São Paulo, both movements – one promoting a more techno-centric approach, and the other a more intermediate, Schumacher-influenced approach -- are more mobilized than in Mexico and become unified from time to time in the overarching goal to increase the use of these technologies in the city, state and beyond.

As noted in Chapter 6, incentives do exist to encourage the adoption of these RETs in both countries. However, in Mexico City, they are complicated (e.g. CONAE's program to increase SWHs in Mexican homes consisted of a number of detailed forms, and the onus was on the user to calculate their current usage and expenses), convoluted and not promoted. There is no single champion within government, so very few companies access these programs. In terms of engaging the end users, there were little efforts being done in both countries. The Brazilian NGO Sociedade de Sol was the main agency attempting to engage end users that are not experts into the technology cooperation process.

Furthermore, in addition to just noting the importance of climate change as a driver, the source of this driver can also play a role. In Mexico, the main source promoting climate change at the time of research (2005/06) was from foreign sources (e.g. foreign biogas companies and other consultancies, international organizations, etc.)

whereas in Brazil the main sources promoting climate change were indigenous (e.g. Brazilian NGOs, governments, academics) and foreign (e.g. US EPA, US foundations financing studies done by Brazilians). In essence, Brazil has more indigenous capacity in this area, which I argue has helped to positively affect the uptake of biogas technologies and SWHs in homes there.

I also found that dynamics *within* stakeholder groups, such as divisions uncovered at the meso-level, help explain RET use. One reason behind these divisions can be traced to trade and competitiveness policies, where in Mexico there is a major divide between foreign and domestically-owned firms.

Divisions also occurred among government agencies. People spoke about the two Brazils, concurrently undertaking policies similar to industrialized and developing countries alike. Informal discussions in Mexico indicate a similar phenomenon in that country.[380] While there have been claims that Mexico and Brazil are looking to RETs in order to diversify their energy portfolio; reducing over-reliance on one energy source (fossil fuels in Mexico and large-scale hydro in Brazil), many informants indicated that in reality, in both countries, attention remained on activities surrounding these conventional sources – from increasing exploration and production, developing new large-scale hydro projects, to making the refining process and transmission lines more efficient. Pursuing these divergent agendas has led to some conflicting policies and actions; a theme to be explored further in Chapter 8, when the potential role that trade and competitiveness regimes can have on RET adoption is examined.

[380] Informal discussions, informants, November 2005 – January 2006, April 2006, September 2007

CHAPTER 8: TRADE AND COMPETITIVENESS REGIMES AND RET ADOPTION IN URBAN LATIN AMERICA

8. 1. Introduction

The study was informed by results from Mexico City and São Paulo and Solar Water Heaters (SWHs) and biogas to produce electricity. As noted in the previous chapters, both biogas technologies and SWHs in homes and SWHs in general (not including pools) are used more in São Paulo versus Mexico City, but a little more SWHs (including pools) and more SWHs for commercial and industrial use, are being used in Mexico City – despite similar population sizes, income levels, supporting institutions, large state-owned oil and energy sectors, etc.

Some of the identified factors affecting RET use were explained in Chapter 6, using Rogers' diffusion of innovations model, as other events effected awareness, rather than just awareness of the technology itself, which in turn played a role on adoption. I argue that because more of the general population were aware of SWHs in São Paulo, due to the apagão of 2000/01 in combination with the negative prior experiences with SWHs in Mexico City, helps to explain the different rates of adoption between these cities for SWHs in homes, and overall (SWHs not including for pools). However, at times, other aspects of technology adoption predicted by Rogers' model – such as that a higher cost in general or vis-à-vis alternatives should lead to less adoption of RETs --did not occur.

Moreover, referring back to Chapters 4 and 5, other findings regarding factors affecting the uptake of RETs – including trade and competitiveness regimes and networks, were not explained through Rogers' model. Chapter 7 applied a new concept – urban technology cooperation – to better explain RET adoption in the urban developing world.

Using the urban technology cooperation approach at the meso-level revealed important insights. These insights include the fact that these networks were considered stronger as their nexus point was a city. In addition, in São Paulo, networks that had been around longer were more institutionalised and the stakeholders groups more mobilized, affecting RET use for both technologies. Also, international influences such as climate change have been encouraging these networks, but over time, in Brazil, these key drivers supporting climate change are both Brazilian and foreign, versus in Mexico, where they are mainly foreign. There is more indigenous capacity in this area in São Paulo. Finally, divisions were found within stakeholder groups at the meso-level, such as between Mexican SWHs that were foreign and those that were domestically-owned. But more information is needed – including the reasons behind why these dynamics are happening. For that reason, I turn to trade and competitiveness approaches in Chapter 8.

This chapter asserts that under certain conditions trade and competitiveness regimes can affect the adoption of Renewable Energy Technologies (RETs) in the urban developing world. As indicated in Chapter 2, the nexus between trade and the uptake of low carbon technologies is a relative new area of scrutiny. Research generally focuses on the potential role of IPRs. However, the common view of researchers in this area that espouse the neoliberal approach, such as the World Bank (2008a), Cosbey (2007) and Stern (2006), is that trade liberalization can lead to more RET use in developing countries. The UNFCCC also suggests that one way to foster an enabling environment for the transfer of low carbon energy technologies is through reducing taxes for imports of RETs (UNFCCC 2006).

While this may be true in some cases, this chapter argues that a conditionally open versus open trade and competitiveness regime can also lead to the use of more RETs under certain conditions. In other words, one cannot say definitely that more trade liberalization will equate to more use of RETs in the urban developing world. This is because technology transfer is also linked to local technology cooperation, as in these cases more successful technology cooperation occurs in environments where there are more opportunities to develop local technological capacity.

Chapter 8 focuses on the third sub-research question – *under what conditions, if at all, do trade and competitiveness regimes affect the use of RETs in the urban developing world*, comparing Mexico City, Mexico, an open trade regime, with São Paulo, Brazil, a conditionally open regime. It answers this question by taking a step back, at the systemic level, examining the trade and competitiveness regimes underway in each setting. As argued previously, the dissertation avows that efforts to address climate change and energy security are often focused on incentives, or "end of tailpipe" solutions. These are important but insufficient in and of themselves to effectively increase RETs.

A more comprehensive understanding for those interested in understanding why RETs are or are not being used is to turn to more indirect policies and influences that operate at the systemic level. Trade and competitiveness policies were focused on in this dissertation, due to their strong presence globally, where "over the past five decades, world trade has quietly grown at rates that dwarf the growth in world income" (Cosbey 2007: 137). Some argue that trade in goods plays a role in international technology diffusion (Saggi 2004: 75), providing further rationale to examine how these systemic policies can play a role on RET adoption in the developing world.

To recap from Chapter 2, which explored the themes of the dissertation, trade and competitiveness policies can be viewed as a series of instruments, which governments undertake to regulate the actions of others operating (or wishing to operate) in their jurisdiction.

Specifically, I found that in contrast to those studies stressing that elimination of tariffs is necessary to encourage adoption of RETs, in the case of SWHs and biogas technologies, high tariffs were not enough of a deterrent to stop project developers from using foreign technologies, considered better quality.

Secondly, I found that more state regulation on the prices of natural gas in São Paulo has had a negative impact on the use of large-scale SWHs in that city. By contrast, higher natural gas prices, dictated more by the market versus the Mexican government, have played a positive role on their use in that country, especially for large-scale applications. At the same time, privatization of the electricity industry in São Paulo – separating generation from transmission from distribution - is argued by some to discourage efforts aimed at conserving energy, as currently, profits are linked to increased generation, transmission and distribution.

Thirdly, I found that Brazil's foreign investment strategy (emphasizing more local engagement) has afforded that country more opportunities to develop indigenous capacity in these two RETs and climate change more generally. Fourthly, I found that the role of IPRs on the uptake of low carbon technologies is context and technology-dependent (in this case patents were less relevant a determinate on uptake), unlike those studies that purport that strong IPRs either help or hinder the use of low carbon technologies. In other words, through using the trade and competitiveness regime lens I was able to expand upon how some findings found in Chapters 6 and 7 can impact RET use.

8.2. Trade and Competitiveness Policies and RET Adoption

This section will place attention on how trade and competitiveness policies can affect RET use in urban Latin America. Four specific trade and competitiveness policies stood out as having a potential role on the adoption of RETs in Mexico City and São Paulo. These policies include the approach to 1) taxes, 2) privatization, 3) foreign investment, and 4) patents and intellectual property rights. It is important to note that the specific trade and competitiveness policies examined are only a small part of these regimes. Activities were occurring in other areas as well. For instance, in Mexico, the national agency for science and technology, a key government department promoting innovation in that country, CONACYT has a program which supports R&D efforts of Mexican firms in general (renewables or energy are not targeted in particular).[381] But, as indicated in the interview responses in Chapter 4, not many companies in Mexican involved in either technology mentioned them. For SWHs, CONACYT also has laboratories which SWH companies can use to ensure their equipment meets the voluntary standard established through NORMEX.[382] In Brazil, federal law mandates that Eletropaulo and other electricity utilities must devote 1% of their annual gross income into energy efficiency projects and 50% of this must be for R&D. However, at the time of field research, Eletropaulo was not involved in either technology in São Paulo. But, as noted in Chapter 5, they were looking at the

[381] Interview, one government official, December 2005
[382] Interview, one consultancy, January 2006

potential for SWH projects when discussed with them in 2007.[383] That said, those four policies considered above were ascertained to be the most relevant.

8.2.1.Taxes

Under the World Trade Organization (WTO) Non-Agricultural Market Access (NAMA) negotiations, debates continue regarding non-tariff barriers and tariff barriers as discussed in Chapter 2 and in Section 8.1. With respect to tariffs, the most prevalent view is that tariffs to environmental technologies must be reduced in developing countries to encourage adoption.

Regarding SWHs in Mexico City, there are no taxes in place for companies to purchase many foreign finished products or components, or tariffs are fairly low – for instance, the average tariffs for industrial goods is about 8.53% in 2008 (International Trade Centre 2008). This is due to the nature of the country, which practices trade liberalization. For example, in 1985 it joined the General Agreement on Tariff and Trade (GATT), joined the North American Free Trade Agreement (NAFTA) in 1994, established a free trade agreement with the European Union in 1997, and became a World Trade Organization (WTO) member in 1995. Moreover, since 2004, any goods subject to tariffs that are for environmentally-friendly technologies are exempted for companies. However, consumers in Mexico City must pay a value added tax (impuesto al valor agregado, IVA – about 15% should they wish to purchase this RET).[384] This tax is also confirmed by other studies such as (Hoyt et al. 2006: 29). In addition, informants noted that there were no municipal taxes applicable. The general view among experts in Mexico was that a lack of taxes – or anything to reduce the price of SWHs - was beneficial for increasing their use. But many companies complained more about the customs system in general – plagued with delays and bureaucracy, an issue examined later on in the chapter.

In São Paulo, regarding SWHs, as noted earlier, Brazilians owned all the companies in São Paulo and the surrounding area, and nearly all materials and expertise were

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[383] Interview, one electricity utility, April 2007; Interviews, one NGO, two government representatives, March 2006

[384] Interviews, five SWH companies, two government representatives, November 2005-January 2006

Brazilian. Companies are exempted from two taxes: 1) the Industrialized Product Tax, or Imposto sobre Produtos Industrializados (IPI), which is a federal level tax on many domestic and foreign manufactured products and applied to manufacturers or importers of finished goods, and 2) the Merchandise and Service Circulation Tax, or Imposto sobre Circulação de Mercadorias e Serviços (ICMS) (18% in the State of São Paulo), which is a state-level tax applicable to manufacturers as well as traders on both domestic and foreign products. However, SWH companies must pay a Contribution for the Financing of Social Security tax, COFINS for components (a federal tax – about 12%). Companies indicated that the extra cost from COFINS was passed on to consumers (as the IPI and ICMS would be too if they were not exempt). There were no municipal level taxes applicable.[385]

Brazilian SWH companies also noted that the only component that they acquired from abroad was copper (from Chile), and that only two companies based out of São Paulo imported copper into the country[386]. No informant indicated that they paid a higher amount for copper versus other countries – likely because Chile is part of the Southern Common Market or Mercado Comum do Sul (MERCOSUL) where tariffs on merchandise from within these countries is zero. However, a number of respondents indicated that as the price of copper has been steadily increasing in recent years (which they argued was mainly due to demand from China), the overall price of SWHs was expected to increase versus decrease[387]. That said, this has likely changed due to the reduced demand from China across the board since the global recession of fall 2008.

Comparing the two cities, organizations and people interested in purchasing SWHs are subject to similar taxes. The main difference however is that in Mexico, components and / or finished products are mainly imported, while in Brazil, virtually all aspects of SWHs are domestic.

Regarding biogas to produce electricity, in Mexico, informants did not identify taxes as a key factor affecting the adoption of this technology. Examining several Project

[385] Interviews, six SWH companies, March – May 2006
[386] Interviews eleven SWH companies, one NGO, one consultancy, March 2006, April – May 2007
[387] Interviews, three SWH companies, March 2006, April-May 2007

Design Documents (PDD) of registered CDM landfill gas to energy projects in Mexico, taxes were on the electricity generated versus the imported products or services. These were estimated to be about 7-8 cents per kWh of electricity produced (Ecosecurities 2006a; Ecosecurities 2006b).

Figure 8.1 "Back of the Envelope" Cost Estimates for Taxes of a Potential Biogas to Energy Project in Mexico City Using Monterrey Project Details

- One could assume that this power plant is off line for various reasons (e.g. repairs, etc.) about 20% of the time throughout the year[388]. This would mean that every year about 0.8 * 365 days/year * 24 hours/day * 7MW = a little more than 49 000 MWh (mega-watt hours) of electricity is produced.
- This would mean taxes of about US$3430 or US$3920 per year
- The Monterrey biogas project has been running since 2002 – as of 2009, taxes are about US$28 000.
- In the case of Monterrey, income taxes were also deemed applicable in the project, but specific details were not provided.

Source: Author, based on Bartone et al. 2005 and discussions with Brazilian biogas experts

In Brazil, I was informed that taxes made up almost 50% of project costs for the Bandeirantes project, almost $US 10 million. For instance, the taxes noted above in the SWH case study also applied here. In the case of ICMS, this tax is applied not only to the technology but also electricity distribution. In addition, a Common External Tariff, or Tarif External Comum (TEC), must be applied to products and services with origins outside of MERCOSUL countries, as well as the Import Duty, or Imposto de Importação (II). Moreover, project developers need to ensure that a specific amount of local content is contained in the goods and services (DFAIT 2007). This amount is even higher than numbers suggested by previous studies, including the United States' Trade Representative (USTR)'s report on "Progress in Reducing Trade-Related Barriers to the Export of Greenhouse Gas Intensity Reducing Technologies", where the average applied tariffs is 14% and the maximum tariff is 35% on these types of technologies with origins from the United States (USTR 2006: 36). See Table 8.1 below.

[388] This estimation was confirmed with landfill gas experts, November 2007

Table 8.1 Approximate Average Tariffs Applied at Border and Maximum Average Bound (Ceiling) Tariff Rates for Renewable Energy and Air Pollution Control Products - 2006

Country	Approximate Average Applied Tariffs (%)	Maximum Average Bound (Ceiling) Tariffs (%)
China	9	35
India	15	40
South Africa	3	25
Mexico	0	0
Brazil	14	35
Indonesia	6	40
Thailand	7	30
Malaysia	7	30
Egypt	7	60
Argentina	6	35
Venezuela	12	37
Pakistan	14	75
Nigeria	17	40
Philippines	4	50
Colombia	12	35
Chile	0	0
Bangladesh	9	25

Source: Adapted from United States Trade Representative, Report, October 2006, p. 36

Although Brazilians chose foreign equipment, Brazilians played a leading role on the rest of the project– construction of the plant was done by a Brazilian / Dutch company, and engineers, consultants, technicians, etc. were all Brazilian. Moreover, the fact that two of the three types of equipment considered as options for the project were Brazilian is also telling, in that there was enough indigenous expertise in the area of biogas technologies to develop domestic options in the first place. In other words, there was more Brazilian 'ownership' of the technology cooperation process.

To summarize, in the case of SWHs, taxes are similar in both places. In the case of biogas to generate electricity, despite the fact that taxes constituted a significantly higher amount of project costs in Brazil versus Mexico, there are currently two landfill gas to energy projects operating around São Paulo, versus none in Mexico City. This is interesting because a number of studies consider reducing taxes on the imports of RETs to be an important part of creating an enabling environment for technology cooperation (World Bank 2008a; Cosbey 2007). I argue that technology use is also related to local technology cooperation dynamics, where in Brazil there was more indigenous capacity in this area, more established networks, rather than just trade and competitiveness policies.

Seres' (2008) study examining technology transfer from foreign sources in the CDM noted a downward trend for technology transfer in two of three types of CDM projects prominent in Brazil –landfill and biomass projects. One reason for this is likely due to the Brazilian government's stipulation that the CDM project must contribute to technological development and capacity building (Seres 2008), which is in line with their approach to trade and investment overall. He argues that as Brazilians become more familiar with a technology – through implementing more and more CDM projects using a particular technology - they rely increasingly on local sources of knowledge and expertise. Although in my research the developers of the particular landfill gas project (Bandeirantes) chose an imported technology, high taxes on imported equipment are also likely contributing to this downward trend on technology transfer from foreign sources. This phenomenon has implications for developing technological capacity, further encouraging adoption in Brazil.

One may wonder why tariffs on environmental goods and services exist, as Doha promises to eliminate them. However, debates continue regarding what constitutes an 'environmental' good or service – its use, its production or its characteristics (Cosbey 2007). Debates also continue regarding whether or not proposals by developed countries on Non-Agricultural Market Access (NAMA), where most low carbon technologies would be classified, emphasizing tariff reductions to imports would be beneficial for developing countries (although some OECD nations support 'special and differential treatment' (S&DT) for least developed countries). Shafaeddin (2009) asserts that these proposals, if agreed upon, would 'lock' Africa into paths based on the production of primary products, and those requiring low- skills labour. He stresses that trade policies put in place to encourage developing countries' industrial sector, including tariffs, help these countries to diversify and develop expertise in other areas. For Africa and other low-income developing countries, "the use of tariffs is almost their only remaining trade policy instrument" (2009: 16).

Furthermore, as the evidence on two RETs in Mexico City and São Paulo shows, the existence of tariffs on foreign RETs does not necessarily equate to less uptake of the technologies in general, or even the exclusion of foreign versions of the technologies in these markets (although the market share for domestic technologies is likely to be greater than foreign ones). Others, such as Paul Waide (2007), looking at higher tariffs on environmentally friendly technologies more generally in Brazil and China[389], have also questioned whether tariffs are one of the important factors affecting RET uptake in various countries.

In this instance, taxes do not explain the differences between uptake of SWHs in these two cities; or, in the case of biogas to produce electricity, cannot be said to be a key factor hindering their use. In fact, these taxes may actually be encouraging their use through developing technological capacity, thus creating more of a sense of 'ownership' of the technology, in Brazil. Using evidence from the solar energy industry in India, Harriss-White et al. (2009) also suggest that imports can lead to disincentives for domestic research being conducted in that country's public science institutes.

8.2.2. Privatization

The second trade and competitiveness policy that was highlighted to have a potential role on the adoption of RETs is privatization. Generally speaking, as indicated in Chapter 2, those countries opting for trade liberalization are also increasing privatization, or increasing private ownership of previously publicly owned firms. In Mexico, following the path of trade liberalization, the 1990s saw the private sector enter the airline, highway construction, banking and telecommunications industries in that country. In 1995, over 1000 previously state-run firms were privatized (WSTB) 1995: 74).

Having said this, in the area of electricity management, the energy sector is more privatized in Brazil versus Mexico. In São Paulo, electricity is distributed through Eletropaulo, which is jointly owned by a Brazilian and American company (AES). Electricity in Mexico City on the other hand is distributed by Luz y Fuerza del Centro

[389] Personal communication with David Ockwell, July 2008, on Waide's presentation regarding the potential role of higher tariffs on environmentally friendly technologies at the 13th Conference of the Parties meeting, Bali, Indonesia, December 2007

(LyFC) and is generated by the Federal Energy Commission, or Comision Federal de Energia, CFE, both state-owned agencies.

Private firms are able to distribute LPG in Mexico City (de Buen Rodriguez and Bustillos 2006), and the price of LPG fluctuates, as it is based on the market price, although there have been times when the federal government has stepped in to provide a subsidy for residents.[390] In the case of water distribution – relevant when examining SWHs – the opposite situation exists, in that this is privatized in Mexico City[391], although a municipal level water commission exists, created in 1992, which regulates these companies, and in São Paulo, it is managed by a state agency Basic Sanitation Company of São Paulo State, or Companhia de Saneamento Basico do Estado de São Paulo (SABESP).

As noted in Chapter 4, in speaking with SWH experts in and around Mexico City, the majority felt that the main way in which privatization had played a role on their use was through rising natural gas prices. No one mentioned water distribution. These rapidly increasing prices had a positive impact on SWH sales – with experts linking higher prices to higher SWH use[392]. For instance, as indicated in Chapter 6, I was told that one third of Mexico's natural gas consumption comes from imports – mainly from the United States which is purchased at international market prices (although sometimes subsidized to the Mexican populace)[393]. Even though natural gas deposits have been located in Mexico, the country has largely been unable to extract these resources for various reasons (insufficient technical capacity), thus making Mexico more vulnerable from an energy security perspective. This correlation between higher natural gas prices and increased adoption of SWHs in Mexico is confirmed by other studies such as Castro Negrete (2005) and Hoyt et al. (2006).

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[390] As they did for natural gas for Monterrey residents for six months in 2005 – prompting some SWH companies to collective write to CONAE to express their displeasure at this government policy, Interviews and informal discussions, four SWH companies, November 2005 – January 2006.

[391] Four private firms currently distribute water for Mexico City; one firm for each one of the four zones the city was divided into. These firms consist of a consortium of Mexican, French, American and British firms (WSTB 1995: 74).

[392] Interviews, three SWH companies, two consultancies, one government representative, November 2005-January 2006

[393] Interviews, three SWH companies, December 2005

Informants in SWHs in São Paulo indicated that there was one way in which privatization – specifically I am referring to the instances in which the government has sold off some public firms to the private sector either fully or partially - has impacted the use of SWHs and it was a negative impact. This was through the restructuring of the electricity sector – separating the electricity generators from the transmitters from the distributors, making it not financially attractive for distributors to encourage electricity use reduction[394]. Other studies from Brazil indicate the same (Rodrigues and Matajs 2005).

On the other hand, a few informants felt that numerous RETs were not being adopted in São Paulo as natural gas was affordable, regulated by the government and readily available[395]. The price of natural gas in Brazil is lower than the market price. Brazilian gas prices are highly regulated and Independent Power Producers (IPPs) are required to cap the price of natural gas to distributors (and thus consumers) at a certain maximum amount (Ellsworth and Gibbs 2004: 5 and 33)[396]. This is important because the main alternative to SWHs in São Paulo for commercial and industrial use is natural gas, where SWHs only make up a small percentage of the market 1% for industrial and 11% for commercial applications – significantly less than Mexico City where commercial and industrial applications are about 20% of the SWH market there. There are more SWHs being used in Mexico City (20% of the SWH market, or 121 000 m^2 in 2006) versus São Paulo (1% for industrial use and 11% for commercial use of the market, or 23 484 m^2). This suggests that more state control on natural gas prices played a negative role on the use of SWHs for larger applications in São Paulo.

In the case of biogas to produce electricity in Mexico City, some experts noted that the price of electricity being offered to Independent Power Producers (IPPs) to the state-run CFE was lower than one desired by potential biogas investors. But, none viewed this as a key reason why these projects were not occurring in Mexico City.[397]

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[394] Interviews, two organizations and one consultancy, March 2006 and May 2007

[395] Informal discussions, industry experts, March 2006; Interview, one government official, March 2006. However, Sao Paulo is supplied by gas from Bolivia, where the price is higher due to the contract agreed and transportation costs, versus other parts of Brazil, like Rio de Janeiro which receives its natural gas from national sources, which had a 38.5% higher price in 2003 Moraes, S. E. G. d. (2003). O mercado de gas natural no Estado de Sao Paulo: historico, cenario, perspectivas e identificacao de barreiras. Economy and Administration. Sao Paulo, Universidade de Sao Paulo: 91).

[396] For a thorough look at Brazil's natural gas industry, please see Ellsworth and Gibbs 2004

[397] Interviews, two biogas companies, two consultancies, November 2005-January 2006

The Brazilian electricity sector is also viewed by some IPPs as being unfavourable to RET applications, as IPPs had to sell their electricity to Eletropaulo at an unattractive price. However, in 2003, the Brazilian legislature agreed to a three month (September – December) window in which IPPs could supply electricity directly to places, versus selling it to Eletropaulo – a move that allowed Unibanco (one of the owners of the biogas project) to supply electricity directly to all of their bank branches throughout Brazil. The conglomerate of Brazilian and foreign companies were able to get the project implemented within that short time frame. Interestingly, in November 2007, the Brazilian federal government changed the laws, allowing IPPs more flexibility on who they can supply electricity to, versus the previous stipulation requiring them to sell to the closest distributor / user.[398]

As the above examples illustrate, privatization can have a role on RET use in developing country cities. Privatization has had a positive impact on RET use in the case of SWHs in Mexico City, especially noticeable when comparing SWHs for large scale applications in both cities. Allowing more flexibility on destinations for electricity generators is also encouraging adoption of biogas technologies in São Paulo. That being said, privatization has not always lead to increased uptake of RETs, as attested to by informants. In other words, although much of the literature examining climate technologies, espouses the link between privatization and increased RET adoption (through increasing competition and access of IPPs to the grid for instance) this is not always the case. This is similar to other studies, which purport that "the impacts of privatization [on renewables] have depended on the specific policies and regulations in place." (Sawin 2004: 4). In essence, privatization has resulted in a number of implications, some having an overall positive affect on RET use, while others have a negative affect.

8.2.3. Foreign Investment

As indicated throughout the thesis, Mexico has a more open trade and competitiveness approach. Little stipulations are in place regarding foreign investment. One result of this approach is the fact that the sources of products,

[398] Personal communication, one government official, one biogas company, November 2007

processes and / or knowledge – or technology – were foreign for the majority of SWH companies. Some SWH companies – whether Mexican or foreign – have embraced the idea to receive technology from all sources. Some felt that this was a useful approach, recognizing that there was limited capacity in Mexico. These companies "have the advantage [because] whatever they need, they can import".[399] Other companies, either because they did not have the capacity to import, or the desire to import, centred their efforts domestically. However, foreign investment restrictions were not completely absent in Mexico. As noted in Chapter 5, for example, government projects for SWHs required that a certain percentage of equipment be from Mexico.

Thus, as explained in Chapter 7, the origins of companies and / or their technologies created "a political space in the group where there are clashes between importers and others".[400] In the case of biogas technologies in Mexico, the key actors active on this technology are foreigners or Mexicans working for international biogas firms, although some domestic institutions are also playing a role. For both technologies, Mexican companies were more oriented towards international partnerships.

Brazil has a more conditionally open trade and competitiveness regime, placing more requirements on foreign investment. These requirements include having a certain amount of local products, personnel and knowledge be used by foreign companies, foreign companies having to form joint ventures with Brazilian firms, etc. For instance, as noted in Chapter 5, in order to quality for PROINFA, 60% of the project's components must be from Brazilian sources (ITA 2005), or 70% for wind projects. Brazil imposes limitations on foreign capital participation in procurement bids[401].

In and around São Paulo, all SWH companies are Brazilian owned. The majority of SWH companies in and around São Paulo and Brazil use either 100% or almost 100% of Brazilian components for their equipment (copper is imported from Chile and all copper in the country is distributed through two companies located in São Paulo).

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[399] Interview, one consultancy, January 2006
[400] Interview, one consultancy, January 2006
[401] Interview, one consultancy, April 2007

These policies have had an impact on the networks formed between and within various stakeholder groups, affecting RET adoption, as shown in Chapter 7.

This is important for two reasons, expanding upon arguments made in Chapter 7. First of all, I argue that it is these policies regarding foreign investment that have lead to more established, institutionalized and mobilized networks between the various technology cooperation participants in São Paulo versus Mexico City. In the case of SWHs, the majority of firms were willing to defer responsibility of various actions (e.g. mobilizing cities to mandate SWHs in Brazil) to ABRAVA, the trade association, as well as Vitae Civilis, the Brazilian environmental NGO. In Mexico, SWH companies also deferred to ANES, but not to the same extent. This is because the interests of firms in Mexico were more difficult to group together as the origins of these companies and the technologies they produced or distributed where different. This finding is particularly interesting because it is supportive of Pietrobelli (2000)'s view that too many players involved in the technology cooperation process, with competing interests, may hinder its success.

Secondly, Brazil's more conditional trade and competitiveness approach has afforded that country more opportunities to develop absorptive and technological capacity in the areas of these particular RETs, and climate change and the CDM more generally, which has in turn had a positive effect on the adoption of both these technologies.

Forsyth (1999) also acknowledges these contextual-dependent assertions, as he indicates that foreign investment can lead to technology transfer. In his research from Southeast Asia, he notes that although increased indigenous capacity may not be an immediate goal, this foreign investment can help to achieve other goals, such as rural electrification. But, on the other hand, it could lead to increasing the market share of industrialized firms' technologies in the South, rather than increasing adoption overall.

Others indicate that emphasis on developing absorptive capacity is also important when assessing foreign investment. According to Saggi,

> "Several studies indicate that absorptive capacity in the host country is crucial for obtaining significant benefits from FDI. Without adequate human capital

> or investments in R&D, spillovers from FDI many simply be infeasible. Thus, liberalization of trade and FDI policies needs to be complemented by appropriate policy measures with respect to education, R&D and human capital accumulation if developing countries are to take full advantage of increased trade and FDI. Domestic policies that improve absorptive capacity might be of higher order importance than openness to trade and investment." (Saggi 2002: 229).

8.2.4. Patents and Intellectual Property Rights (IPRs)

The fourth types of trade and competitiveness policies assumed to have an affect on RET adoptions were Intellectual Property Rights (IPRs), and more specifically patents on RETs. As indicated in Chapter 2 and earlier in this chapter, with respect to linking IPRs and uptake of low carbon technologies in developing countries, the evidence has been mixed. On the one hand, Srinivas' (2009) review of analysis of certain technologies relevant for climate change, such as clean coal technologies and climate resistant crops, show that strong IPRs have been a barrier to the dissemination of these technologies. On the other hand, the United States' Trade Representative (USTR) report (2006) examining barriers to GHG emission reduction technologies, cites weak IPR protection in a number of developing countries including Mexico and Brazil as "further barriers to the widespread use of such important environmental technologies" (2006: 10). Mexico and Brazil are placed on the USTR's Special 301 Watch List and Priority Watch List respectively (USTR 2006).

But, others assert that Brazil and Mexico have been taking strides for stronger IPR regimes since their accession to the World Trade Organization (WTO) on January 1, 1995, whose stipulation was also to join TRIPs. Studies suggest different implications for these two countries upon joining.

In the case of Mexico, Forero-Pineda (2006) argues that, more often than not, the trade benefits afforded to developing countries that join the WTO / TRIPs come at the cost of technological development, as the goods and services provided by developing countries are often of low "technological content". He cites the case of Mexico where there was a distinct reduction in patent activities from domestic sources after patent reforms in that country in 1994, emphasizing robust patent protection. He examines a study on the Mexican pharmaceutical sector, which indicates that although foreign investment increased after these reforms, Mexican companies have yielded very few new technologies.

In Brazil by contrast, the OECD conducted a macro econometric analysis examining IPRs (through patent rights and applications) and technology transfer (through merchandise and service imports and inward Foreign Direct Investment (FDI)) to a many developing countries, as well as the emerging economies of Brazil, Russia, India and China, the BRICs. They indicated that Brazil significantly strengthened its IPR regime after TRIPs. "While the average developing country experienced a 37.5% change in the patent rights index [which was used as a proxy to measure strength of IPR regime in the study] over the period 1995-2005…., Brazil, China, and India experienced more than a doubling of their scores." (Park and Lippoldt 2008: 26).

They found that in these countries stronger IPRs lead to an increase in inflows of high-technology products (e.g. computer and information technology, chemicals, aerospace). They further assert that stronger IPRs can also stimulate local innovation, which they measured through developing country applications for patents (by both residents and non-residents). Applications for patents by developing country firms as well as expenditure on R&D in these countries increased, as the strength of patent rights increased. Looking at evidence from Chapters 6, 7 and 8, the fact that Brazil's trade and competitiveness regime has provided the country with more opportunities to develop technological capabilities may help to explain these differences.

That said, patents and Intellectual Property Rights (IPRs) did not play as much a role on the adoption of the two RETs under scrutiny in Mexico City and São Paulo. Regarding SWHs, in both places, the general view was that informants did not have a patent for their SWHs, while some companies claimed that yes, they did have a patent or trademark. Rather, many experts noted that the hardware – the general concept – was in the public domain and companies worked on strengthening their niches within the details.

When informants talked about the history of the SWH industry in both places – mainly originating from Americans living in Guadalajara in 1950s bringing insights about SWH technology with them in Mexico, and from a Brazilian professor going to

Israel and learning details about SWH technology in Brazil -- none indicated that IPRs or patent infringement was an issue. At the same time, companies in both countries were very guarded about the 'nitty gritty' details (trade secrets). SWH companies were reluctant to get into too much detail about their products, process and technical knowledge; although they knew I was a social scientist versus engineer. Trademarks also exist for some SWHs in both countries.

In a study done regarding the transfer of low carbon energy technologies in India, researchers from The Energy Resources Institute (TERI) suggested that the money spent on research and development, represented as a cost of IP in terms of overall price, gets passed on to the consumer, which can hinder adoption in some cases. In other cases, the cost of IP represented only a small amount of the price differential between a low carbon technology and its alternative (Mallett et al. 2009). In this dissertation research in Brazil and Mexico no one wanted to mention specifics, including what percentage of overall cost IP would constitute, but the main costs for SWHs are materials and installation. For instance, in Brazil the majority of companies were using copper and the price was steadily increasing at the time (2006) due to demand from China (although this has likely changed after the global recession of Fall 2008). Other interviewees also noted that installations could be rather expensive depending on the retrofitting needed.

In the case of biogas to produce electricity, both Mexicans and Brazilians realized that the most cost effective hardware was from foreign sources and are willing to use it, while encouraging Mexican and Brazilian expertise in the software at the same time. Brazil has domestic technology available, but decided to use foreign technology because, while more costly, it could be better guaranteed to achieve the desired performance. In Bandeirantes, the conglomerate of Brazilian and foreign companies bought the equipment from Caterpillar, of the United States. Mexicans also indicated that companies from Germany, Switzerland (hardware) and Canada (software), were active in this area. No informant from either country mentioned that there were or would be problems accessing the technology (i.e. that firms possessing the technology would be unwilling to sell it to them due to fear of IP infringement). The foreign technology was adapted, but Brazilians were not concerned about infringing on IPRs through their small tweaking.[402]

Some university representatives working on another RET in Brazil indicated a similar experience. Brazilians working at CENBIO, the National Reference Centre for Biomass in Brazil at the USP were using an Indian technology which was a motor, combusting vegetable oil. The Indian technology was not as 'finished' and so adaptations were made in Brazil. The Brazilian researchers repeatedly attempted to contact the Indians to ensure they were not infringing on any patent issues, but they did not hear anything back.[403]

So in other words, whether or not IP helps or hinders the adoption of low carbon technology in developing countries is context and technology-dependent – in some cases, IP is not as relevant an explanatory factor. This is a similar finding to other studies examining this issue (Mallett et al. 2009, Ockwell et al. 2007). As Harriss-White, Rohra and Singh indicate in their study regarding the solar energy industry in India, "while the international politics of state participation supports the transfer of ownership of IPRs, national politics supports licensing and import" (2009: 35-36). The above finding – that IP is context and technology-dependent - may help to explain the dichotomy found between what some developing country governments' are espousing at the international level, and what they are supporting at the domestic level.

8.3. Outcomes of Trade and Competitiveness Policies and RET Adoption

Four aspects occurring as a result of trade and competitiveness regimes affected RET adoption were revealed. These aspects include: 1) quicker access to SWHs for producers; 2) more perceived 'ownership' of technologies in Brazil versus Mexico; 3)

[402] Informants spoke about this topic generally, rather than providing details. It can be assumed that the companies involved had a Technology Transfer Agreement (TTA), where the terms of how the technology would be used, how any changes made would be dealt with, etc. would have been laid out.
[403] Interviews, three university representatives, March 2006

more effective mobilization in São Paulo; and 4) well established standards in Brazil. Each of these themes is explored in turn below.

8.3.1. Quicker Access to Technologies – SWHs but not biogas

Both Mexico City and São Paulo are considered administratively heavy. However, in the case of SWHs, Mexico's import of finished products or components meet with delays at customs, etc. – making it difficult for companies to deal with any rapid changes in the market. In São Paulo, there are exemptions on taxes between states, to encourage trade between them. In addition, as noted earlier, companies in and around São Paulo do not import any material apart from copper, which is centralized in Brazil as only two companies in São Paulo do so, and SWH companies purchase the copper from these suppliers or their distributors. In the case of biogas, Brazilian companies involved in this technology have opted for foreign versions of the "hardware" and so face the same potential delays as those in Mexico.

Delays with customs, proper paperwork, among other administrative requirements involved with using all RETs, but more pronounced when using foreign RETs or components or services, may have a negative impact on the use of SWHs in Mexico City and biogas technologies in both places, in that they affect the production process of companies and their ability to deliver a product on time, and / or to get a project up and running.

But these aspects may also be a question of the origins of technologies in the market (whether they are more domestic or more foreign), rather than whether or not this 'red tape' hinders the uptake of RETs in general. As an example, although Mexico and Brazil's cumbersome trade documentation system was identified as a trade barrier for US environmental technologies (USTR 2006: 12), a number of U.S. companies have managed to navigate the Mexican bureaucracy, as U.S. exports of these technologies to Mexico "have more than doubled since the implementation of NAFTA, from US$987 million in 1994 to more than $2 billion in 2005" (USTR 2006: 11).

8.3.2. More perceived technology "ownership" in Brazil

This proliferation of American products into Mexico has created an interesting dynamic explored in the second factor revealed by the study, which is the effect of 'ownership' of technology on RET adoption. In Mexico, I was reminded that "trade relationships are dictated more by proximity"[404], and for that reason, Mexico's largest trading partner is the United States. Between 1993-2007, Mexico's Gross National Product (GNP) from exports increased from 15% to 32%, and four-fifth's of their exports go to the United States (U.S.). This interdependence has some profound effects in Mexico; as some commentators have said, "when the U.S. gets a cold, Mexico gets pneumonia" (Perez-Rocha and Anderson 2008). During my stay in Mexico, many reminded me that they have a "love-hate" relationship with the U.S – enjoying the benefits of being close to such as powerful country, and yet feeling resentment whenever "the gringos" exercised their muscle, meddling into Mexican affairs.

Regarding SWHs in Mexico, they are considered foreign and domestic. Biogas technologies are considered foreign in Mexico. By contrast, in Brazil, both the hardware and software of SWHs are considered Brazilian. Generally speaking, only one component (copper) is imported from Chile, another MERCOSUR country.

In the case of biogas to produce electricity, in Brazil, even though the "hardware" is foreign, Brazilians perceive themselves to be an integral player in the process. Brazil has long standing expertise in the area. Distinct champions exist; especially CETESB, and a number of Brazilians working on this issue have been actively involved in the international climate change process.

This is important because, as explained earlier, these dynamics are linked to trade and competitiveness policies as well as local technology cooperation dynamics. In Brazil, there have been more opportunities to develop technological capabilities for both technologies, which have positively affected adoption, as there is more indigenous capacity there.

[404] Interview, one university representative, December 2005

8.3.3. More effective mobilization in São Paulo

Comparing the two types of trade and competitiveness regimes elicited another finding. This result was found in the SWH case study, expanding upon the findings shown in Chapter 7 that there were more institutionalized networks in São Paulo versus Mexico City. Here, in countries practicing more conditionally-open trade regimes (e.g. those that encouraged foreign trade but had more stipulations in place, such as using local suppliers, etc.), the renewable energy companies were more united, and so, working with NGOs and other stakeholders, they spent more time on mobilizing governments and other groups (e.g. construction associations) to increase RET adoption. Brazilian SWH companies were not interested in joint ventures with foreign companies unless it was to export their Brazilian SWH technology abroad. On the other hand, in more open trade regimes (e.g. more free trade), companies spent more time fighting amongst themselves – there was a sharp division between national and foreign-owned companies, making efforts to accomplish objectives (e.g. national-level standards) more difficult. Many Mexican companies were interested in collaborating with international companies, rather than domestic ones. This is not to say that there were no divisions within stakeholder groups in Brazil. Rather, as explained in Chapter 5 and 7, in and around São Paulo, the two movements pushing for SWHs were using distinct philosophies (one based more on a technocentric, market-based approach, and another based more on appropriate technologies). But these movements are more mobilized than in Mexico, and come together to support the objective of increasing SWH use in Brazil, although they differ regarding the way in which to do so (providing incentives to make the technology more affordable or popularizing the technology, through making it cheaper and less complicated).

8.3.4. Well-established Standards in Brazil

The third outcome that a comparison of trade and competitiveness regimes has shown is that there are well-established standards for SWHs in Brazil versus Mexico.

In Mexico, there are no mandatory standards regarding SWHs at the national level. Due to the variations in products including prices and technology origins, which are "enormous"[405], it is difficult to create a standard regarding SWH systems. However, SWH companies came together in 2004 to create the first voluntary norm on solar energy at the national level from the National Organism (Organization) of Normalization and Certification of Mexico, or NORMEX. NORMEX is a private company in Mexico that provides services that can develop norms and verify and certify products and / or systems through laboratory testing to ensure they comply with these norms[406]. The first norm on solar energy, at the national level, NMX-ES-001-NORMEX 2005 is entitled "Energía Solar – Rendimiento Térmico y Funcionalidad de Colectores Solares para Calentamiento de Agua – Métodos de Prueba y Etiquetado, or Solar Energy – Thermal efficiency and functionality of solar panels to heat water – methods of testing and labelling". This norm, not mandatory, provides technical guidelines for companies and consumers regarding solar panels[407]. However, the information is quite technical and so many potential SWH users do not really know what exactly they mean[408].

In addition, discussions were underway at the time of research 2005/2006 to create a national level norm regarding solar water heating systems[409]. Since that time, another norm regarding definitions and terminology in solar energy was created in 2007 NMX-ES-002-NORMEX 2007. In 2007, there were also two more norms regarding solar water under development – one regarding minimum installation requirements NMX-ES-003-NORMEX 2007, and another regarding a method to test the heating requirements of SWH systems NMX-ES-004-NORMEX 2007 (NORMEX 2007). While progress is being made, it is slow. One respondent spoke about some of the difficulties involved:

> One requirement for a Global Environment Fund (GEF) project [to put some SWHs in Ciudad Juarez] required that a certain percentage of SWHs used meet with NORMEX 2005 standards, but then a laboratory is needed to confirm that this equipment does meet these certifications"[410], requiring more time, personnel and money.

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[405] Interview, one government representative, November 2005
[406] Interview, one government representative, December 2005
[407] One government representative, one NGO and one SWH company, November - December 2005
[408] Interview, one university representative, November 2005
[409] Interview, one government representative, November 2005
[410] Interview, one consultancy, January 2006

In Mexico in 2005 and 2006, I was told that companies continue to argue over details, as well as the general approach (e.g. should these standards be stringent or flexible?). Those that import products (already subjected to international standards) are generally more receptive to nationally-certified mandatory standards, while some domestic firms are not. A number of Mexican informants felt this lack of national standards was hindering the adoption of these technologies. "Customers want to ensure they have purchased a good quality product – that it will work."[411] But, ultimately, any government standard at the national level would be administered through Secretaria de Economia (Secretary of the Economy), where the General Bureau of Standards is held (GEF 2008).

In Brazil on the other hand, since 1998, certification of SWH equipment is done through INMETRO, which has worked with universities, who test equipment at the Green Solar lab, Pontifica Catholic University of Minas Gerais, in Belo Horizonte and the IPT USP, and ABRAVA. This is a comprehensive national-level standard and certification program, which, if the equipment meets certain technical specifications (e.g. temperature reached, ability for materials to withstand heat, etc.) will receive the PROCEL "seal" indicating that the equipment has met these conditions. As indicated in Chapter 5, for those companies wishing to be a part of ABRAVA, their SWH equipment must have the PROCEL "seal". Although this Brazilian standard is unique to that country, it is largely based on European Union standards.[412] In other words, as noted earlier, key technology cooperation participants are more unified and organized in Brazil, and so more collaboration among the various sectors occurs, leading to increased RET adoption.

In contrast to my assertion, some would argue that standards could reduce innovation and uptake of technologies because their introduction may "(inadvertently or by design) reduce options for the use of existing and future technologies – in the form of technical production methods or product-specific features." (Lee 2008). This can prompt a 'lock in' to certain technologies, as alternative paths shrink, pushing

[411] Interview, one government representative, November 2005
[412] Interview, five SWH companies, March 2006

innovation in one direction[413]. Secondly, another study on SWHs in Mexico suggests that standards can increase the costs of products – borne by manufacturers and installers and thus passed on to consumers (Castro-Negrete 2005).

But, I argue the following points. Firstly, the nationally-sanctioned voluntary standards in place since 1998 in Brazil has not diminished alternative innovation paths for SWHs as the NGO Sociedade do Sol and Grupo Solaris, in their efforts to produce low-cost SWHs, continue to conduct research and disseminate their respectively different technologies.

Secondly, as indicated in Chapter 6, the previous experience of SWHs in Mexico has lead to some repercussions for the entire industry in that country. These negative experiences can have deeper negative effects on adoption, versus the impact that a good experience with a technology can have on increasing adoption (Frewer et al. 1998). Interestingly, Castro Negrete (2005)'s study on SWHs in Mexico noted above also advocates a strategy for high quality standards, because it "improves customers' service and in the long run increases the reliability of the SWH industry leading to an increment of SWH market volume". (Castro Negrete 2005: 55). Another study by the IEA shows that when developing countries have introduced standards and labelling with regard to energy-efficient induced products, considerable demand has been generated for these technologies.[414] In Lovett et al. (2009)'s assessment of technology transfer discussions at Poznan, and what is occurring in the private sector, they also assert that there are a number of examples where environmental standards have spurred rather than hindered innovation. That being said, care must be taken that these countries practice some flexibility regarding standards – my research shows where they can work effectively at the national level (even if based on more internationally recognized standards), rather than international harmonization of standards.

[413] See Unruh, G. C. (2000). "Understanding carbon lock-in." Energy Policy **28**(12): 817-830. for an examination of this concept at a more macro level
[414] Personal communication, David Ockwell, June 2008, on IEA presentation from Paul Waide, 13th Conference of the Parties, Bali, Indonesia, December 2007

8.4. Conclusion

This chapter shed light on findings established in Chapters 6 and 7 – including:

- why the alternative to large-scale SWHs is cheaper in São Paulo versus Mexico City (because there is more state regulation on the price of natural gas);
- why there have been more opportunities to develop technological capabilities in Brazil (due to its trade and competitiveness regime favouring more external versions (e.g. JVs, Brazilian involvement) versus internal versions (e.g. more subsidiaries) of technology cooperation);
- why there are more divisions and in-fighting among Mexican SWHs firms (partially because of company origins); and
- why networks are more institutionalized and mobilized in Brazil (more indigenous capacity with respect to these technologies).

As demonstrated above, trade and competitiveness policies do play a role on RET adoption, but this research suggests that one cannot say definitely that they will have an overall positive or negative effect. This recognition warrants the use of a nuanced approach, one that better reflects these complex realities. This is result is different than studies conducted at the macro level which make 'broad brush' statements such as trade liberalization will lead to more use of low carbon energy technologies, putting these results into question. Research regarding the role of trade and competitiveness policies and the uptake of low carbon energy technologies is a new but growing area. The majority of this research has focused particularly on the potential role of intellectual property rights (IPRs) on technology cooperation in developing countries, and evidence is mixed. Research that is broader indicates that lower barriers to trade in these RETs will increase their adoption in developing countries (UNFCCC 2006; World Bank 2008a; Cosbey 2007).

However this research shows that that under certain conditions, a conditionally-open trade and competitiveness regime can also increase RET adoption. Specifically, taxes were relatively similar in both cities for SWHs. However, they were significantly higher in for biogas technologies in São Paulo, and yet two biogas projects are currently underway, while in Mexico City there are none. This finding is particularly interesting, as the majority of research advocates a reduction of taxes to encourage the adoption for environmental technologies. This would be an interesting area for further study because at a macro-level, these high taxes may be discouraging use of foreign technologies for other biogas to electricity projects in other parts of Brazil, which may negatively affect overall uptake in the long run.

On the other hand, one case in which more interventionist trade and competitiveness policies have played a negative role on adoption is in the industrial / commercial SWH sector in Brazil as the price of natural gas (which is the main alternative) is regulated versus Mexico's price of natural gas, which is generally dictated by the market, although the federal government does provide a subsidy periodically. That said, some informants in Brazil argued that the privatization of the electricity sector reduced motivations for these separate companies to try and curb electricity demand, especially during peak hours, which is when the majority of Brazilians use the electric showers.

Approach to foreign investment played a role through creating divisions between and among stakeholder groups and through creating more opportunities for developing indigenous capacity. With respect to IPR and the uptake of these technologies, patents did not appear to play much of a role. Trade secrets may be affecting cooperation among and within stakeholder groups involved in SWHs however, thus exacerbating the divisions noted above.

Trade and competitiveness regimes also had other implications. For instance, in Brazil, as SWH technologies were generally not imported and taxes between states were exempted, Brazilian producers had quicker access to SWH components versus Mexico, despite its free trade policies. For both technologies, there was more perceived 'ownership' of technologies in Brazil versus Mexico and more effective mobilization in São Paulo. In addition, there are well-established standards in Brazil. Each of these examples supports the view that a conditionally open trade and competitiveness regime can encourage adoption of RETs.

CHAPTER 9: CONCLUSION

9.1. Introduction

Energy is a critical component of societies. At the same time, contemporary challenges dictate that we re-examine the way in which we produce, use and consume energy. Citing reasons including climate change, energy security, poverty alleviation, opportunities to develop technological capabilities, among others, researchers, practitioners and policy makers agree on the need to increase the share of renewable energy in developing countries' energy portfolio. Yet they continue to debate on the most effective ways to do so.

At the abstract level, there is a broad recognition that RET adoption requires considerations of the human dimensions involved in any transition – including sustainable development, quality of life, and access to meaningful employment. But this recognition has not translated down into concrete actions addressing complexities and peculiarities on the ground. Conventional strategies aimed at increasing RET uptake in developing nations often stress economic and technical factors, which, while important tend to neglect sociocultural aspects. Frameworks examining a systems perspective have been offered as an alternative approach, but there is little application of them in this area to date. In addition, studies examining the adoption and transfer of renewable energy technologies tend to rely on evidence from rural environments. Yet, the world is becoming increasingly urban – and a large portion of this urban growth is happening in large, developing country cities.

This thesis adds to these debates through answering the research question what are the most important factors explaining RET use in developing country cities? Here it was revealed that in addition to conventional explanations, prior experiences in combination with awareness of energy conservation versus just awareness of the technologies, the networks involved in the technology cooperation process and trade and competitiveness policies also play pivotal roles in explaining RET adoption. This was done through determining how systemic approaches can help to explain renewable energy technology adoption in developing country cities – a neglected but critical area of study warranting examination.

My findings indicate that systemic approaches are useful tools, better able to capture multiple facets at multiple levels, influencing the adoption of renewable energy technologies. However, in addition to their strengths, these approaches have limitations, including the fact that history and context are often not taken into account enough, leading to variations between what is occurring in the real world versus what one would assume from the model. Furthermore, any one approach provides only a partial view, but examining a phenomenon through various approaches yields a more comprehensive, in-depth examination, and often some unique insights.

Specifically, I have added to these debates in the following ways. First of all, in this dissertation I have tested three systemic approaches. Secondly, I have also applied a new methodological approach in the area of RETs and developing country cities by focusing my research at the meso-level. Thirdly, I have applied a new concept: urban technology cooperation to this area of study. These insights are discussed in detail in the sections below.

Also, it is important to be aware that there are many differences among nations, regions and communities within the developing world. Strategies followed by emerging economies such as Mexico and Brazil will undoubtedly be distinct from those strategies employed by Least Developed Countries (LDCs) and / or Small Island Developing States (SIDS). Nevertheless, one overarching objective can be to develop low carbon technological capacities within all developing countries; an integral part of ensuring long term, low carbon transitions. Emerging economies in particular can play a role as leaders and advocates for other developing nations. Brazil, which opened its doors to foreign trade and investment in the 1990s, but attempted to ensure that opening these doors would be beneficial for Brazilians, is a particular case in point. In some instances, the lure of the Brazilian market was enough of a draw for foreign firms to agree to some rather stringent stipulations (e.g. in companies with three or more people, the requirement that two thirds of the workforce be Brazilian, drawing two thirds of the salaries). Although the majority of advice indicates that this type of approach may slow down the uptake and diffusion process of RETs, there are instances where by providing more opportunities to develop indigenous capacity, ultimately has witnessed positive effects on the use of low carbon energy technologies.

9.2. Systemic approaches provide a more complete explanation for RET Use in the urban developing world

The dissertation argues that the most common paradigm used to explain RET adoption often places too much emphasis on technical and economic attributes. While there are differences between these models, the main thrust is on advice, providing ways to overcome these barriers. Although these aspects are important, there are other sociocultural factors often neglected that also shape technology adoption. Systemic approaches have been proposed as an alternative lens as they try to include social and economic factors at various scales to explain RET adoption, but to date there is little evidence supporting their application.

I began this dissertation by asking what are the most important factors affecting RET adoption in the urban developing world? I answered this question through answering a series of sub-research questions. The first was how can systemic approaches help to explain RET uptake in developing country cities?

I found that classical explanations for RET use (such as those emphasizing cost, awareness and incentives) can help to explain adoption rates in each location, but were unable to adequately account for differences between the two settings. By comparing the case studies, I conclude that applying alternative frameworks provide a more complete picture as they account for other facets, including how networks and trade and competitiveness regimes and take a step further back, tracing conventional explanations to their causes. This research indicates that systemic approaches can be effective tools to explain RET adoption because in addition to accounting for factors affecting adoption noted in conventional approaches (e.g. cost, direct incentives), they highlight larger social and policy trends. Yet, while systemic approaches are useful, they are not without their limitations when applied to real world examples, including the practicality of participatory approaches. Rather, history and context are important, which put some assumptions into question when applying these approaches to Mexico City and São Paulo.

9.3. Awareness of energy conservation and prior experiences play a role in the uptake of RETs

The first section turns to the sub-research question, what are the reasons SWHs and biogas technologies to generate electricity are being used or not in Mexico City and São Paulo.

Rogers' Diffusion of Innovations technology adoption was the first model applied to the case studies. This model was considered useful because it highlights social factors in addition to economic and technical attributes highlighted by conventional approaches. For instance, Rogers' suggests that prior experiences and underlying conditions can affect awareness, which in turn can play a role on adoption. By using this approach I found that one factor influencing RET adoption highlighted using this model is due to the apagão of 2000/01 in São Paulo. A number of informants felt that this event had a profound effect on encouraging awareness of renewables and energy conservation, which helps explain why more SWHs in homes and biogas technologies are being used in Brazil. However, it is not clear how much of a role this played on adoption because not all informants were convinced that awareness of environmental and energy issues and the specific RETs had significantly increased among Brazilians due to this event. In contrast, in Mexico City, the model showed how previous negative experiences with SWHs hindered their adoption in that setting. I argue that awareness of energy conservation due to the apagão, *in combination with* negative experiences in Mexico City affects uptake, rather than just awareness of a technology itself, as highlighted by other studies on RETs in developing countries.

There were a number of factors that could not be explained using this approach. First of all, on the surface, discrepancies exist between what Rogers' model would predict and what is occurring in these cities regarding biogas to produce electricity. For example, the cost of biogas to produce electricity is higher in São Paulo versus

Mexico City (as noted in Chapter 6, estimated to be about US$417 per MWh vs. US$634 per MWh), and yet there are projects up and running in the Brazilian city while there are none so far in the Mexican capital. Rogers' approach also tells us that the role of change agents is key as in São Paulo there is a distinct change agent (CETESB) encouraging this technology, while in Mexico City there was not one at the time of research (2005/06). But what is distinct about the change agents in these two countries is the fact that in Mexico, they are mainly foreign, with some domestic players, while in Brazil they are mainly domestic.

Secondly, by using this approach I found that climate change, and the potential to generate carbon credits is the key driver instigating biogas to generate electricity projects in both countries. What is different between these two countries however is that the main advocates pushing the climate change angle in Mexico are foreign whereas in Brazil they are domestic and foreign. The model cannot explain how source of advocacy can play a role on adoption.

Thirdly, Rogers argues that adoption of technologies is related to cost, a similar claim to many classical explanations. While true when examining adoption rates in each city, when examining uptake of SWHs in homes between the two cities, more are being used in São Paulo versus Mexico City, although the alternative technology is significantly cheaper in São Paulo. As noted previously, the cost for SWHs in Mexico and Brazil are similar. However, the cost of the alternative to SWHs for domestic use (an electric shower at about US$10) in São Paulo is significantly cheaper than the alternative to SWHs for domestic use in Mexico City (a gas water heater at about US$300), and yet there are many more SWHs for domestic use being utilized in São Paulo (80% of SWH market in the city, or 156 650 m^2) versus Mexico City (using an estimate of 5% of the SWH market in the city for single family homes, or 11 760 m^2 in 2006).

Fourthly, Rogers' (2003a) model helped identify one reason that SWHs for larger applications are being used more in Mexico City versus São Paulo; because the alternative to SWHs in both cities, natural gas, is cheaper in Brazil. An important question is why? Analysis must take a step farther back, determining those policies that make the alternative to SWHs cheaper. Policies at the systemic level put in place for different reasons can impact RET adoption nevertheless. Ultimately, Rogers' model, while useful, is insufficient on its own in explaining RET adoption in the urban developing world.

9.4. More opportunities to develop indigenous capacity, creating more 'ownership' in the technology cooperation process, plays a positive role on RET adoption

Other factors affecting RET adoption in these cities were identified using the urban technology cooperation approach. The first assertion is that the interactions between the various players can affect technology adoption. General speaking, players operate in isolation, but links are forming. However, these links are more institutionalized, established in Brazil and more sporadic, *ad hoc* in Mexico

More of SWH in homes are being used in São Paulo, which can be partially attributed to the fact that the networks between actors are more institutionalized, more communication occurs between the three sectors (public, private and academic) and efforts (albeit limited) are being undertaken to engage the public about SWHs. In the case of biogas, players are active in both locations, but in São Paulo, more links exist and most interactions have been occurring for longer periods of time.

In addition, international influences, especially climate change, have also played a positive role on the adoption of these RETs. A key driver prompting technology cooperation processes between various participants at the level of the city can be traced to international influences – with the main one being climate change. Agents in both countries -- especially the private sector, and some NGOs and government agencies -- are increasingly becoming aware of the potential role that carbon credits and environmental / climate change studies can have to increase adoption. But as noted earlier, one distinct feature between the two cities is the fact that the main agents promoting biogas technologies are domestic in Brazil, while in Mexico they are foreign. In the case of SWHs, the key agents are domestic in São Paulo, while in Mexico City they are domestic and foreign.

A further factor, not captured as much at the firm, national, or global levels, was the divisions that occurred within the stakeholder groups. A lot of studies focus on divisions *between* stakeholder groups (e.g. academics, public and private sectors, civil society), but divisions *within* stakeholders groups are just as important. In the case of SWHs, there are two key divisions in Mexico City 1) between foreign and domestic firms, 2) between firms 'in the club' and 'outside of the club'. This divisiveness between these players has had a negative impact on adoption, as it is more difficult to unify efforts and mobilize actors under one common objective (increasing the adoption of this technology in Mexico City). In Brazil, there was one major division between players involved with these technologies but they came together from time to time to support the overall objective of increasing SWHs in São Paulo.

I argue that the above three phenomena 1) more institutionalized links and more links between different sectors in Brazil, 2) more domestic engagement on climate change, biogas technologies and SWHs, in Brazil over time, and 3) more divisions among firms in Mexico, are linked to the trade and competitiveness approaches used in these countries. In Brazil, there have been more opportunities for developing technological capabilities, therefore establishing more indigenous capacity and more 'ownership' of the technology cooperation process, which in this case has helped with RET uptake. However, things are changing, as Mexicans are becoming increasingly engaged on climate change, spreading awareness and developing domestic 'home-grown' solutions to climate change. Indigenous capacity – which studies link to successful technology cooperation -- can also happen under an open free trade regime, but this suggests that it may take longer to become established in developing nations.

9.5. Under certain conditions conditionally open trade regimes can also encourage RET adoption in urban developing country cities

The next sub-research question examined under what conditions trade and competitiveness regimes explain RET adoption in developing country cities.

Evidence indicates that they do play a role, but how they do so depends on the circumstances. This suggests that any approach used to examine these facets be contextual, rather than purport generalizations based on meta-analysis. Although research in this area is recent, the general consensus is that trade liberalization can lead to more RET use in developing countries. However, my findings show that under certain conditions a provisionally open trade and competitiveness regime can also increase RET use.

This finding is in contrast to those studies that indicate the opposite. Specifically, regarding taxes, in Brazil, despite the fact that 50% of project start up costs were taxes, the consortium of companies were willing to undertake endeavour – due to the appeal of generating carbon credits and "getting in the game early". In other words, in the case of biogas technologies to generate electricity, taxes did not appear to have hindered the adoption of a foreign technology (hardware).

Secondly, I found that privatization has had different effects on the same technology. In Mexico City, it has helped with commercial and industrial SWH applications, and regulated natural gas prices have hindered their adoption in São Paulo. However, also in São Paulo, a number of informants suggested that the segregation of electricity utilities into separate companies (one for generation, one for transmission and / or another for distribution), has reduced the impetus on these utilities to create energy conservation programs. Foreign investment requirements can help to explain some divisions found within stakeholders groups, namely in-fighting occurring between foreign and domestic SWH companies in Mexico City.

Thirdly, I found that the role of IPRs on the use of low carbon energy technologies is context and technology-dependent. In this case, patents did not appear to play much role on adoption with respect to either technology, although trade secrets may have exacerbated divisions among producers of the technologies (most relevant for SWHs).

Other implications of trade and competitiveness policies were that Brazilian SWH producers had easier access to hardware versus their Mexican counterparts, as they were not really engaged in importing products (and all the bureaucratic processes involved). In addition, there is more 'ownership' of both SWHs and biogas technologies in Brazil rather than Mexico. In both instances, Brazilians appear to be more "in the drivers seat" of the technology cooperation processes. In the case of biogas technologies, they chose to use a foreign versus national technology and use more national versus. foreign experts. However, they came to this decision after assessing all of the technologies available, both domestic and foreign; ultimately deciding on the foreign option due to better guaranteed results, despite the added costs and the administrative burdens involved with importing products outside of MERCOSUR.

There are also better-established standards in Brazil in the case of SWHs. In Mexico, a voluntary standard does exist, but only after a number of SWH companies paid an organization outside of government to have a standard established. In Brazil by contrast, there is a government-sanctioned standard by INMETRO, which, although voluntary, has been in place since 1998.

In Brazil, the system is designed to encourage the use of more domestic components, products and expertise regarding both RETs. Those involved in the Bandeirantes and São Joao projects highlighted the fact that numerous and complicated processes were involved with respect to importing technology from abroad. Perhaps if foreign SWHs were in Brazil, it would spur innovation through competition, but it is difficult to say. One informant told me that in previous years, an Israeli company tried to enter the Brazilian market, but decided to leave after a number of unsuccessful years.[415] A study from the point of view of RET companies wanting to enter the Brazilian market may also shed some light on this topic.

9.6. Systemic Approaches and RET Adoption in Mexico City and São Paulo – Conceptual and Methodological Implications

This dissertation has expanded on the debates regarding technology transfer through taking the concept of technology cooperation several steps further. This was done in the following ways. First of all, I provided some clarification on what was meant by urban technology cooperation. It is viewed as a way in which to recognize that all

[415] Interview, one SWH company, May 2006

actors involved in the process are participants, exchanging views and engaging in relationships. The concept also attempts to recognize the heterogeneity of actors, and that these relationships and networks change over time. Secondly, by adding the notion of 'urban' the concept has attempted to account for unique attributes of cities – including serving as nexus points for innovation and creativity, and understanding the importance of proximity in engaging various pivotal sources of technological change – academics, the private sector, government and communities / civil society.

One interesting finding was that actors engaged in networks in these cities felt that these relationships were stronger by virtue of their location (being centred in and around Mexico City and Sao Paulo). At the same time however, in contrast to Porter's (1990) argument that rivalries found within these clusters will instigate more innovation and adoption through fostering competition, I found that these rivalries had negative repercussions for RET adoption in the case of SWHs in Mexico City.

Taking a step back and examining the effectiveness of using the meso-level approach in Mexico City and Sao Paulo has also yielded some considerations. It proved advantageous in that by taking this 'bird's eye view' of a city, rather than a specific community or neighbourhood, political dynamics playing out between various groups operating at the city-level became pronounced. For instance, as noted in Chapter 7, in Sao Paulo, I saw two distinct movements – one advocating a more market-driven, technocentric approach (I view it as 'here is the technology, let's adapt the society to match'), and another advocating a more socially-driven contextual approach (I view it as 'here is the society, let's adapt the technology to match') to SWH adoption. In Mexico City, the 'war' between foreign and domestic SWH companies also featured prominently. It is not clear that these dynamics would have been revealed had I decided to pursue this study at a more macro or micro level.

Secondly, one critique of this approach is that it is rather abstract, and difficult to determine exactly what 'space' it constitutes. I chose to define the meso-level as a city and its surrounding areas, all the while recognizing that there is no distinct boundary, and there are continual ebbs and flows. Third, similar to other studies recognizing the importance of public engagement, I was particularly interested in understanding how the public was involved in the technology cooperation process. I felt that by using frameworks based on understanding networks and motivations would be an effective tool to achieve this goal. Yet apart from the efforts of Sociedade do Sol and Grupo Solaris, the public in general is not really an active player.

Some disadvantages with this approach were the fact that by providing a city-level analysis, it may not have captured the differences within these cities enough. For instance, at present, the majority of SWHs being used in homes are within the wealthier and middle class segments – and so policy makers and communities interested in increasing the use of these technologies in lower-income communities will need to tailor these results to their circumstances. Nevertheless, they will likely find some results from this study of relevance to them.

9.7. A Cleaner World – Implications for renewable energy and climate change policies

Renewable energy technology remains a pivotal part of any strategy aimed at addressing climate change – in both industrialized and developing nations. This need is particularly acute in developing countries, which are now experiencing, and expected to experience, more pronounced effects of climate change, and whose energy demand – especially in emerging economies like Mexico and Brazil -- is increasing exponentially. As indicated in Section 9.1, it is also important to understand that developing countries represent an extremely diverse group of nations – ranging from large, emerging economies with robust industrial sectors, to small island states largely based on agriculture for exports and tourism, to nations suffering from the conflicts of war and major environmental degradation (e.g. droughts, etc.).

One commonality these countries have is the challenge of addressing climate change, which is particularly pronounced in many developing nations. This could be because some countries are particularly vulnerable to climate change effects and / or due to due to rapid urbanization, where the construction and use of buildings often involves energy-intensive processes (e.g. steel, cement) and because a number of economies are heavily based on manufacturing and industry – often highly carbon intensive activities. For instance, glaciers are becoming smaller in the Himalayas. This is particularly concerning, as it has been estimated that more than 1 billion people rely on the Himalayas to meet their various needs (Kuroda 2009).

Against this backdrop, a number of larger developing economies, such as Mexico and Brazil, are seeing the emergence a more significant middle class, and, similar to paths followed by many industrialized nations, the concurrent increase in private vehicle ownership, household energy use (with the purchase of home electronics and appliances for instance), high 'carbon footprint' lifestyles, and subsequent increases in carbon emissions.

Industrialized nations must take on a leadership role in addressing climate change. But, the gravity of the climate change threat requires actions from both industrialized and developing nations in order to be effectively addressed. Developing nations can capitalize on opportunities from the carbon market and technology transfer and there are many co-benefits involved (e.g. energy security, improved environmental quality) when pursuing low carbon efforts. At the same time, these benefits are not necessarily guaranteed, as some developing countries are concerned that introducing these technologies can have negative repercussions for domestic industry and / or reinforce continued dependence on the industrialized world for 'frontier' technologies, curbing innovation. Other studies also purport the importance of focusing on technological capabilities in developing countries, while some suggest that the key focus should be on introducing low carbon technologies rapidly in order to help reduce GHG emissions sooner rather than later. Yet what this dissertation shows is that an approach focusing on indigenous capacity includes both foreign and domestic technologies, where domestic actors have a solid foundation through which to assess which of these technology are most applicable to their situation and that, in certain instances, in the long run, is beneficial to the overall objective of increasing the use of renewables.

As indicated in Chapter 1, conventional channels of technology cooperation between the North and the South – ranging from joint ventures, subsidiaries, to technology licensing and partnerships have had mixed success. Yet, tools designed to foster collaboration between various countries within the UNFCCC context, while important steps, are falling short of their purported goals. For example, the Expert Group on Technology Transfer (EGTT), a body designed at ensuring implementation of UNFCCC country commitments on technology transfer recognizes the need for cooperation on all aspects of low carbon energy technologies (from the experimental to the more commercial stage), and the importance of finance. However, while the group talks about the need to harness the private sector and is starting to engage with various representatives, the majority of their efforts focus on public sector avenues.

Based on evidence from this dissertation the following policy suggestions are offered. To reiterate, there are a number of caveats concerning the generalizability of these findings to other contexts – including countries and technologies. For example, these findings may be considered less relevant for – say – an agrarian-based African nation with little domestic industry. However, opportunities to develop technological capacity also exist in the agrarian sector, and in a number of African nations – due to influence from the International Financial Institutions (IFIs) such as the World Bank and International Monetary Fund (IMF), for a number of countries, a significant portion of agriculture is for exports (e.g. Senegal and cotton). Here, often the technologies used are foreign and a lot of refining of products is done elsewhere. African nations – working in groups – could assert the stipulation for the need to encourage more opportunities for indigenous training and innovation as a means to access their markets. This notion is particularly interesting as the Chinese have been major foreign investors in African infrastructure in their quest to obtain more natural resources from the African continent in exchange – as the Chinese at present require Chinese workers to develop and build this infrastructure.

Ultimately however, the purpose of these suggestions is not to be prescriptive, but rather to serve as guidelines for policy makers. This is because one key assertion of the dissertation is that there is no ‘one size fits all’ approach, rather the ‘right’ policy approach for renewables adoption in developing country cities will be context and technology-dependent.

i) **Support multi-disciplined, systemic analysis** – Policy makers often base their decisions on economic and technical analyses. Having worked for the Canadian government and the Organization of American States (OAS) for a number of years before returning to academia, I know – "numbers talk". While these factors are important, my evidence shows that larger social and policy aspects are just as important. For instance, I found that networks were more established and institutionalized in Brazil, and links were more prevalent among various sectors when examined at the meso-level. There are also more divisions within stakeholder groups in Mexico. I argue that these facets can be traced to trade and competitiveness policies, as in Brazil there have been more opportunities for developing technological capabilities, therefore establishing more indigenous capacity and more 'ownership' of the technology cooperation process, which in this case plays a positive role on uptake. Using systemic approaches revealed that, as demonstrated in Mexico City, historical experiences had a negative effect on the whole SWH industry. And yet, negative prior experiences with a technology do not necessarily equate to ramifications affecting all types of the technology, as demonstrated in Sao Paulo, where Brazilians opted not to use certain versions of technology, rather than discard the technology altogether.

ii) **Use events to harness support** – My findings suggest that the apagão played a role on increasing energy conservation in São Paulo, prompting people – from the government to the general public -- to seek out alternatives to electricity from hydro power, but that over time this interest was waning. I am not suggesting that developing country players deliberately create a major event like the apagão in Brazil, or undertake smaller actions, including blowing up natural gas and oil pipes as in Western Canada, to garner support for renewables in developing countries, but rather to capitalize on events already happening worldwide (e.g. increases in oil and food prices) that provide a more conducive environment for renewables support.

iii) Provide more opportunities for developing technological capabilities – As the challenge of climate change and renewable energy technology uptake in developing countries has animated the global community, there are increasing instances of new commitment, investment and development of low carbon energy technology. Even as the world reels from this global recession many countries have indicated that pursuing a 'green economy' will be part and parcel in their economic recovery efforts. In addition, a number of developing countries – whether advocating a more government-controlled or private sector run approach - continue to reform their energy sectors. These represent important opportunities through which developing countries can enhance indigenous technology use and development. Examples from other developing countries such as India and China, now with companies considered global players in the solar photovoltaic (PV) and wind industries, can also be examined. These are two other countries which have historically taken a more conditionally versus fully open approach to trade and investment. That said, although these examples are important, these industries have mainly focused efforts on exports, rather than domestically, although with new mandates that it starting to change. But, evidence from this dissertation suggests that building indigenous capacity in certain RETs can also increase domestic use, as well as innovation. Developing country cities can serve as pivotal nexus points, acting as hubs to engage various sectors.

iv) **Foster local champions for these technologies** – In both settings, champions for these technologies really served to galvanize the community and networks towards encouraging their use. Generally speaking, worldwide, and Brazil and Mexico are no exception, actors involved in new renewable energy technologies (excluding large scale hydro) operate on the margins of conventional, often fossil fuel-based vested interests – deeply entrenched interests through which systems are built upon. Yet in both locations, I found a small but extremely committed community. The majority of these champions, or change agents, developed indigenously in both Mexico City and Sao Paulo and were found through various sectors (e.g. NGOs, trade associations, individuals within the government). In the case of Mexico City, although there were domestic change agents working on biogas technologies (e.g. IIE, CONAE), the loudest voice was the private sector, and these were mainly foreign firms.

That said, this situation is likely changing as the new mayor of Mexico City is promoting their use.

v) **Understand local technology cooperation politics and dynamics** – This thesis shows that effective technology cooperation requires understanding of local dynamics at play. The SWH market segments are completely different for these countries and cities. Advocates for free trade can point to the example of Mexico City and the use of SWHs in the commercial and industrial sectors, versus Sao Paulo, where in Mexico City the price of natural gas, based on market rates, is argued to be a direct contributor to their growth. (However, it would be interesting to compare more recent rates of SWH growth in these sectors, as the market prices of natural gas have been dropping in 2009.) Yet there are more SWHs being used in homes and biogas technologies in Sao Paulo, despite the fact that the alternative technology is significantly cheaper there in the case of SWHs (about US 10 dollars versus US 300 dollars), and that biogas technologies are slightly more expensive in Sao Paulo (where taxes made up 50% of the project costs). Having the opportunity to interact with players involved in this sector in both countries revealed a number of political issues and dynamics, including the 'war' between domestic and foreign SWH firms in Mexico City, , which ultimately have an effect on RET uptake.

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Annex 1 – Example of Interview Questions – Firms in Mexico City (English and *Spanish in italics*)

First of all, I would like to say that **if you prefer**, when I write information in my thesis, I will not put names together with quotes / information – this will be anonymous.

*Primero, quiero decirle que **si usted prefiere**, cuando escriba la informacion en mi tesis, no voy a poner nombres juntos con la informacion -- eso va a ser como anónimo.*

Also, I would like to say that although I have written questions with respect to my research, if you have any suggestions, additions, wish to change some questions, please feel free to input.

También, me gustaría decirle que aunque he escrito preguntas con respecto de mis investigaciones, si usted tiene algunas sugerencias / adiciones / piensa que es mejor si cambiar las preguntas, etc. por favor digame.

1) Tell me about your company – for example, how many people work here, you in this position, since when has the company been working in renewable energy

Quiero saber información sobre la compañía – ej. ¿cuantos personas trabajan en la compañía? ¿hasta cuando ha estado la companía trabajando en ese area? ¿Usted en esta posición?

Is your company national or intenational (where is your HQ)?

¿Ese su compañia nacional? ¿internacional? Donde esta su "HQ"

2) I wish to know more about Solar Water Heaters (SWHs) in Mexico (or Brazil) in cities – which type is the most popular?

Me gustaría saber mas sobre las calentadores solares del agua. ¿Que típo es mas popular?

(ej- (if they want more prompts) those more simple and cheap, with a black tank and water, or those more sophisticated where the tank is insulated – closed looped or open looped? Where do people use SWH (or biogas technologies)? On the grid or outside of the grid (for biogas technologies) or pools? Houses (for SWHs)?

lo mas sencillo y barato -- como un tanque negro con agua, o algo mas sofisticado donde el tanque esta aislado – closed looped o open looped) ¿Donde se usan esta technologías? ¿En el "grid"? ¿Fuera del "grid"? ¿las picinas? ¿Casas?

3) Who are your consumers?

¿Cuales son sus consumidores?

(more prompts if needed) schools, governments, hotels, the public (e.g. direct purchases for houses) since when? Do you have an idea why this is the case?

¿escuelas, gobiernos, Hotels? ¿El publico (ej. personas directamente para sus casas)? ¿Desde cuando? ¿Tiene una idea porque eso es asi?

4) I also wish to know about your selling process.

Tambien, me gustaría saber sobre su proceso de la comercialización.

(if more prompts are needed) – do people look for you? Do you look for people? Is there an organization (e.g. one for renewables) – to help? After a sale, what follow up do you do?

¿La gente se busca para ustedes? ¿O ustedes se buscan la gente? ¿Hay una organización, ej. una organización para energías renovables - energías solares, que les ayuda? Después de una venta, qué "follow up" / continuación hacen ustedes?

Energy / Electricity / Environmental / Climate Change Policies

Políticas sobre energia / electricidad / medio ambiente / cambio climático

9) Do you know if there are government policies or programs (national, regional or local level) to promote the development, production and use of energy technologies, including renewables and SWHs or biogas technologies in particular?

Sabe usted si hay políticas o programas del gobierno (al nivel nacional, regional or local) para promover el desarrollo, la producción y el uso de las tecnologías energías incluyendo technologías para energías renovables? Y esta tecnologia en particular?

(more prompts) to reduce greenhouse gas (GHG) emissions, to increase electricity access to the porr

(Para reducir las emisiones de los gasos del invernaderos? Para ampliar el aceso de la electricidad a los pobres?)

If there are some, what are they? Explain. What opinion do you have about carbon credits?

¿Si eso es así, cuales son? Explicame. Que opina tiene sobre los creditos del carbono?

.

Trade, competitiveness and technology policies

Políticas del comercio y de la competitividad y tecnologías

5) Do you know if there are restrictions on the import or export of technologies including components in the country, state or city? Specific technologies such as energy / renewable energy? Including training and processes and implementation? Other areas?

¿Sabe usted si hay restriciones de importaciones o exportaciones con respecto de tecnologías incluyendo partes en el país, estado o ciudad? ¿O tecnologías especificas? ¿Como energías / energías renovables? ¿El entrenamiento y / o procesos? ¿La ejecutación? ¿Otras cosas?

6) Where was this technologyo developed? Originally and now? Who was involved? For example, was this an internal process or were there different partners (e.g. a university, another company). Describe the process.

¿Donde estaba esta tecnología desarrollada? ¿Originalemente y ahora? ¿Quienes hizo eso? ¿Por ejemplo eso fue internal o había diferentes socios? (ej. una universidad, otra compañía). Describame el proceso

(ej. If prompts are needed) If there were partners was it a formal or an informal agreement? Has the process changed over time?

si había socios, había un acuerdo formal o informal) ¿Ha desarrollado / cambiado el proceso en un cierto plazo?

7) Where was this technology produced? (same questions as above if prompts are needed)?

¿Donde estaba esta tecnología producida? Quienes hizo eso? (ej. ustedes, otra compañía) ¿Eso fue originalemente también o ha visto cambios en un cierto plazo? Descríbame el proceso (ej. internal, socios)

8) What are some alternative technologies to SWHs and biogas technologies? What are the costs of these alternatives?

¿Cuales tecnologías son alternativas de este tipo de tecnología? ¿Cuales son los gastos de estas alternativas?

Opinions

Opiniones

10) In your opinion, what are the most important problems that affect the use of these technologies

En su opinion, que son los problemas mayores que se afectan el uso de estas tecnologias?

11) Who are not using these technologies? Why?

¿Quienes no están utilizando estos calentadores solares del agua? ¿Porque?

12) I am also interested in your opinion about the perceptions of these technologies in general – the public, your work colleagues and employees, the government, etc.? Have you noticed a difference when the origins of the technology are different?

Me gustaria saber su opinion sobre las percepciones de esta tecnologia en general -- el publico, sus empleos / colegas del trabajo, el gobierno? ¿Ha notado una diferencia cuando las origines son diferentes?

13) Is there anything you wish to add?

Hay algo que quiere añadir?

Annex 2 – List of Interviewees

Annex 2: List of interviewees

Informants – Mexico City
P1 Jorge Davila, Sunway
P2 Ubaldo Inclan, SENER
P3 Rodolfo Strevel Martinez, Bufete de Tecnologia Solar (BUTESCA)
P4 Areli Gomez and Guadaloupe, Ecomania
P5 David Meklar, Heliocol
P6 Saul Breton, Genersys
P7 José Castelan, Grupo PIM
P8 Daniel Garcia, Modulo Solar
P9 Adriana Oropeza, SEMARNAT
P10 Gabriel de la Torre, Ecosecurities
P11 Lourdes Fernandez, MGM International
P12 Juan Garcia, Reisol
P13 2 representatives, Servicios Especial Falcon
P14 Eduardo Lopez, Solartec
P15 Alberto Valdes, Universidad Autonoma Metropolitana (UAM) and small renewable energy company
P16 Eric Tripp, UMERYC
P17 Federico Sierra, USOL
P18 David Morillon, Asociacion Nacional de Energia Solar (ANES) and Universidad Nacional Autnoma de Mexico (UNAM)
P19 Aaron Sanchez, CIE, UNAM
P20 Isaac Pilatowsky, CIE, UNAM
P21 Octavio Garcia, CIE, UNAM
P22 1 representative, CONACYT
P23 1 representative, CONAE
P24 2 consultants, and Consultoría y Servicios en Tecnologías Eficientes (CYSTE)
P25 Odon de Buen, Energia, Tecnologia y Educacion (ENTE)
P26 Alberto Sanchez, IPN
P27 Rosa Isela Sánchez, Novae
P28 Claudia Sheinbaum, Federal District Secretary of Environment
P29 Oscar Vasquez, Federal District Secretary of Environment

Informants - Sao Paulo
P36 Celio Bermann and Janet Belleza, IEE, USP
P37 Gustavo, Sociedade do Sol
P38 Sergio Ennes, Lumina
P39 Ademar Ushima, IPT, USP
P40 Oswaldo Lucon, State of Sao Paulo, Secretary of Environment
P41 1 representative, City of Sao Paulo, Secretary of Green (issues) and Environment
P42 Maria Tereza Diniz, SEHAB
P43 Paulo Ruggeri, Alpina Termoplasticos
P44 Paula Caldwell, Canadian embassy in Sao Paulo, informal discussion
P45 Carlos Longue, Eletropaulo
P46 1 representative, Hidrosolar
P47 Breno Augustino, Ouro Fino
P48 Nelson, Solarpress
P49 Nelson Agustinho, Solartec
P50 Marcio Dias, Solarterra
P51 Rafael, Soletrol
P52 2 representatives, Tecnosol
P53 1 representative, Unipac
P54 José Lourenço Cassuci ,A Atual
P55 Euclides José Mininel, Unisol
P56 Luis Sergio, engineering consultant

P57 Orlando, CENBIO
P58 Osvaldo Stella Martens, CENBIO
P59 Joao Wagner, CETESB
P60 Temistocles, CUT
P61 Augustin Woelz, Sociedade do Sol
P62 Maria Lidia Romero, Grupo Solaris, USP
P63 Delcio Rodrigues, Vitae Civilis
P64 Carlos Felipe Faria, ABRAVA-DASOL