An Institutional Approach to Understanding Energy Transitions

by

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ABSTRACT

Energy is a central concern of sustainability because how we produce and consume energy affects society, economy, and the environment. Sustainability scientists are interested in energy transitions away from fossil fuels because they are nonrenewable, increasingly expensive, have adverse health effects, and may be the main driver of climate change. They see an opportunity for developing countries to avoid the negative consequences fossil-fuel-based energy systems, and also to increase resilience, by leap-frogging-over the centralized energy grid systems that dominate the developed world.

Energy transitions pose both challenges and opportunities. Obstacles to transitions include 1) an existing, centralized, complex energy-grid system, whose function is invisible to most users, 2) coordination and collective-action problems that are path dependent, and 3) difficulty in scaling up RE technologies. Because energy transitions rely on technological and social innovations, I am interested in how institutional factors can be leveraged to surmount these obstacles. The overarching question that underlies my research is: What constellation of institutional, biophysical, and social factors are essential for an energy transition? My objective is to derive a set of "design principles," that I term institutional drivers, for energy transitions analogous to Ostrom's institutional design principles. My dissertation research will analyze energy transitions using two approaches: applying the Institutional Analysis and Development Framework and a comparative case study analysis comprised of both primary and secondary sources.

This dissertation includes: 1) an analysis of the world's energy portfolio; 2) a case study analysis of five countries; 3) a description of the institutional factors likely to promote a transition to renewable-energy use; and 4) an in-depth case study of Thailand's progress in replacing nonrenewable energy sources with renewable energy sources. My research will contribute to our understanding of how energy transitions at different scales can be accomplished in developing countries and what it takes for innovation to spread in a society.

To the women in my family who humble me: Mom, Mémé, Nana, and Lu. I have made it to where I am today because of you. Merci pour tout! (Mom, Can I be a singer and dancer now?)

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I alone am responsible for any errors of fact and for the interpretation and emphasis found in this document.

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INTRODUCTION

1.1 ENERGY TRANSITIONS

When using science for decision making, "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz, 1991). The same issues arise when decision makers are confronted with energy issues. The way we, as a globe, choose to progress with our energy systems is going to greatly impact our future. Will we choose to remain with the status quo? Will we transition? And if we deem a transition necessary, will we transition quickly enough? Changing our energy system allows us to have an impact on the well-being of our planet and on each other. Will we make the world a better place for our children? What is going to happen with our gas prices? And do we even care what is going to happen to them? Will it be "old school" to have a car that runs on gasoline? It is impossible to know the answers to all of these questions. The future is too uncertain. What we can do, and what I hope to do in this document, is to start thinking about what the answers to these questions may be. Or at least, what are the drivers and motivating factors that help us better answer and understand the characteristics that go into answering these questions.

Transitions can take a variety of forms. "These [forms] include rampant innovations that slice through expected and desired pathways of change; trajectories of fossilization and decay (as established sociotechnical systems are abandoned); and fundamental transformations in the ordinary routines of daily life" (Shove and Walker, 2007, p. 768). To better understand which transition will occur, and how it will occur (most likely with the implementation of new and the revision of old, policies), we must first understand where the system is starting from.

Energy is a basic human need. It is also a central concern of sustainability because how we produce and consume energy affects society, economy, and the environment. Sustainability scientists are interested in energy transitions away from fossil fuels because fossil fuels are nonrenewable, increasingly expensive, have adverse health effects and, perhaps most importantly, may be the main driver of climate change. Sustainability scientists see an opportunity for developing countries to avoid the negative consequences of fossil-fuel-based energy systems, and also to increase resilience, by leap-frogging over the centralized energy grid systems that dominate the developed world. Also, many developing economies are faced with growing populations and deteriorating natural resources. Renewable-energy (RE) technologies can provide electricity needs to these growing populations and are much less detrimental to the environment than nonrenewable-energy technologies.

What is an "energy transition?" Energy transitions involve social, institutional, and technological changes. Most countries have emphasized technological changes by increasing their use of RE technologies. For example, instead of installing a coal power plant, a wind farm gets erected. However, technological changes will not make a long-term impact unless social and institutional changes are taken into effect as well. If policies and financial mechanisms are not implemented, then there is no long-term commitment nor emphasis for implementing RE projects.

Truffner et al. (2010) note that transitions can be measured in terms of relative dominance of particular socio-technical patterns, leading to a so-called socio-technical transition. In terms of performance indicators, a "sustainability transition" occurs when there is a marked change in sustainability indicators. Are we beginning to see such a transition globally? In 2010, fossil fuels provided about 80% of the total global energy consumed, nuclear provided 3%, and renewable sources provide the remaining 17% (Sawin, 2012). This represents a marked change from the late 1990s. In 1997, hydropower represented 3% and other renewables represented only 2% (Birol, 2000).

We look at energy transitions not as ends, but as means for attaining development goals. Developing countries may become the world's hotspots of energy innovation because they contain large areas without existing, fossil-fuel-based energy infrastructure. About 40% of the population of developing countries (1.6 billion people) have no access to electricity (Vaccaro, 2011). In the developed world, the status quo, centralized, nonrenewable-based energy system is deeply embedded in the social, economic, and technological aspects of people's lives. Developing countries can avoid the undesirable by-products of this status quo system by implementing renewables-based systems from the get go. As van der Leeuw notes (2008), the willingness to diverge from the status quo is highest in places where there are no physical constraints against change and social rules are not stringent.

The developing world faces both potentials and constraints for RE adoption. Limiting factors include the high upfront cost of RE technologies, high poverty levels with more pressing needs, high discount rates, and low state capacity. However, with little energy infrastructure and less restrictive energy policies that do not limit RE implementation, the developing world could become a world leader in RE implementation.

Developed countries must reduce their reliance on nonrenewable technologies while increasing their use of renewable technologies at a relatively quick pace (Jacobsson and Lauber, 2006). However, an energy transitions is extremely complicated, especially in the developed world, and may "require a long period (one to two generations), and take time, patience, money, confidence, but also courage, daring and perseverance to gain the upper hand over various types of resistance" (Rotmans, 2005). An energy transition is also difficult since the current electric grid infrastructure is not set up in a way to accommodate high RE use: renewable resources are usually located far from population centers and renewable generation can vary greatly (Crabtree and Misewich, 2010). "Although small penetrations of renewable generation on the grid can be smoothly integrated, accommodating more than approximately 30 percent electricity generation from these renewable sources will require new approaches to extending and operating the grid" (Crabtree and Misewich, 2010, p. 2).

Energy transitions pose both challenges and opportunities. Obstacles to transitions include 1) an existing, centralized, complex energy-grid system whose function is largely invisible to most end users, 2) coordination and collective-action problems that are path dependent, and 3) the difficulty in scaling up RE technologies. Because energy transitions rely on technological and social innovations, I am interested in how institutional factors can be leveraged to surmount these obstacles. The overarching question that underlies my research is: What constellation of institutional, biophysical, and social factors are essential for an energy transition? My objective is to derive a set of principles analogous to Ostrom's institutional design principles, that I term institutional drivers, for energy transitions. My dissertation research will analyze energy transitions using two approaches: applying the Institutional Analysis and Development Framework and a comparative case study analysis comprised of both primary and secondary data sources. The remaining chapters are organized as follows:

- CHAPTER 2: An Analysis of Global Energy

  This chapter will analyze the world's current energy system. To understand what makes a transition happen, it is necessary to understand the status quo system from which the transition departs. This chapter will show how innovation led to the current global energy system, and how innovation can help countries transition out of this unsustainable energy system and into a more sustainable one.

- CHAPTER 3: Institutional Factors for Successful Energy Transitions: A Comparative Case Study Approach

  This chapter will use the Institutional Analysis and Development Framework (IADF) to qualitatively analyze the relative influence of different institutional factors on energy transitions. I will begin by describing the strategies and implementation of RE technologies in some of the most progressive countries: Germany, Spain, Brazil, China, and the United States. An analysis of these cases will formulate similarities among them that are leading to successful energy transitions. A list of institutional drivers that lead to transitions will be created.

- CHAPTER 4: Thailand's Energy Transition

  Next, I will conduct an in-depth case study of Thailand's transition to RE sources to gather detailed empirical data. I will compare the institutional factors found in the previous chapter to Thailand to see if the analysis is congruent with, and therefore relevant to, energy transitions occurring in the developing world. Also, my work in Thailand will allow me to analyze energy transitions at smaller scales. My field work will allow me to get a personal perspective on the energy transition happening within the country.

- CHAPTER 5: Innovation within Tradition

  This chapter will conclude the dissertation. First, I will determine the success of the institutional drivers outlined in Chapter 3 in the case study countries. I will then apply the cases to Ostrom's Social-Ecological Systems Framework. I will briefly touch on two important lessons about transitions and then explain what is necessary to make RE implementation successful. I will explain the steps needed so that other countries can successfully implement RE. Next, the institutional drivers list developed in Chapter 3 will be compared to the findings in Cavanagh's "Ten principles for sustainable societies." Lastly, future research will be discussed.

This dissertation includes: 1) an analysis of the world's energy portfolio; 2) a case study analysis of five countries; 3) a description of the institutional factors likely to promote a transition to renewable-energy use; and 4) an in-depth case study of Thailand's progress in replacing nonrenewable energy sources with renewable energy sources. My research will contribute to our understanding of how energy transitions at different scales can be accomplished in developing countries and what it takes for innovation to spread in a society.

1.2 RESEARCH CONTEXT

Background

National energy systems today are either centralized, decentralized, or a combination of both. A centralized, or large scale, energy system is one in which large power plants produce hundreds of megawatts of power that are distributed as far as hundreds of miles away. A decentralized, or localized/concentrated/small scale, energy system is one in which power is produced at or near the point of consumption. (The institutional differences between these two systems will become obvious further in the document.) Which type of system an area chooses depends on the trade-offs that must be made among the kinds of energy resources available and what it costs to use the different resources. Some regions may use a centralized system because they lack access to RE sources. Such a choice is commonly made at the country level. However, individual communities may be able to have a decentralized system because, for example, they are close to a river where they could use a micro-hydropower system.

Infrastructure choice results not only from decisions about trade-offs, but from choices made in the past; we call this path dependency. "Path dependency in energy systems arises from differences in initial conditions (e.g., resource availability and other geographic, climatic, economic, social, and institutional factors) that in turn are perpetuated by differences in policy and tax structures, leading to differences in spatial structures, infrastructures, and consumption patterns" (Grubler, 2011, para. 2).

Energy systems in developing countries are subject to path dependency just as they are in developed countries. But unlike their developed neighbors, developing countries need to extend energy services to areas and populations that have never been served. Therefore, developing countries have the potential to leap-frog over the centralized energy-grid system used in developed countries, and use decentralized RE to serve new areas and populations. Thus, they can innovate to create their own new paths; they need not follow the paths already taken by developed countries. Developing countries have more options, so by innovating, they may be able to transition to RE sources faster than developed countries.

But developing countries can also take advantage of innovations made in the developed world (Verdolini and Galeotti, 2010).[1] It seems that developing countries are in a great place to experience an energy transition. They are less laden by past decisions, and they have the luxury to learn from the successes and failures of more developed countries. Thus, institutional drivers should focus on amplifying these factors.

Innovation, a defining characteristic of the Enlightenment and subsequent Industrial Revolution (1750-1850) (van der Leeuw, 2008), always has both intended and unintended consequences. The innovations of the Industrial Revolution potentially produced a major unintended consequence: global climate change. I would argue that we are now entering a new phase of innovation, thanks in part to climate change. Climate change may be the catalyst for the developing world to enter its own Enlightenment period, if it responds innovatively to its need for energy infrastructure. The developing world is not entirely trapped in a status quo energy infrastructure, and it is aware of the need to be resilient to global change. "The focus on system resilience...attache[s] great importance to the capacity of a system to survive by changing 'in tune' with its environment" and "in doing so, it not only draws attention to the importance of innovative behaviour, but also to the fact that from this perspective, it is change which is assumed and stability which is questioned, rather than vice versa" (van der Leeuw, 2008, p. 227). Developing countries that choose to strengthen their

[1] It is important to note here that a transition can occur at the individual, community, and/or national level. Although most of my research focuses on the national level, individual and community-level transitions are important because they can potentially lead to a national energy transition.

resilience through energy innovation may be in a better position to achieve energy transitions then developed countries, despite their less powerful economies.

Concerns about climate change and resilience are not the only motivations for transitioning to RE sources. Energy consumption affects a very important common pool resource: the atmosphere. The atmosphere functions as a waste sink. It is subtractable and it is difficult to exclude other users. The atmosphere can assimilate a certain amount of pollutants before it becomes unbreathable; this is called its waste assimilation capacity. But since the Industrial Revolution, "air and water resources have been overexploited as waste repositories" are "extremely sensitive to perturbations...and complex global patterns with new properties may emerge from local interactions" (Tietenberg, 2003, p. 342; Lansing, 2003, p. 189, 192). The use of nonrenewable energy sources increases the atmosphere's pollutant load, and therefore the likelihood that it will exceed its waste assimilation capacity. There are three technological solutions to dealing with pollutants: 1) reduce the amount of pollutants generated per unit of X produced; 2) find ways to recycle the stock pollutant instead of injecting it into the environment; or 3) develop ways of rendering the pollutant less harmful (Tietenberg, 2003). An energy transition is a solution of the first kind because it reduces the amount of pollutants generated per unit of energy produced.

While people may be highly motivated to transition to RE, they can be hindered from doing so by coordination and collective-action problems. To remove these barriers, we need to understand how institutions can facilitate cooperation at all levels of organization. Institutional analysis can answer questions such as "Who is positioned to make a take-it-or-leave-it offer, what other actions are available to the relevant parties, what information asymmetries or lack of verifiability bear on the problem (and, as a result, what agreements are enforceable by the parties), and what norms may affect the outcome of the conflict?" (Bowles, 2006, p. 31).

Whether and what kind of RE technology will be used depends not only on the decisions of actors at different levels, but on the scale at which the technology can be implemented. The optimal decision-making level (as defined by Ostrom, 2005) usually has to do with the implementation scale. For example, in Thailand, the decision to institute an energy transition was made at the constitutional level. This will be further discussed in Chapter 4.

Energy is essential to the provision of basic human needs, including food, water, shelter, transportation, healthcare, education, and trade. Individuals and nations are becoming aware that RE sources will have to make up an increasing share of global energy sources for the reasons noted above. Many countries have aggressively pursued RE development during the past decade, and some of them are developing countries. My study will describe, analyze, and model the human factors and organizational interactions that have combined to advance RE use. Chapter 4 will focus on Thailand as a case-study of how a mid-developed county can use an energy transition to drive social and economic development, protect the natural environment, and honor its cultural traditions and values. To best understand innovations that lead to energy transitions "we need to investigate the complete network involved, as well as the nature of the dynamic relationships between things and objects and between human and non-human agents" (van der Leeuw, 2008, p. 230). My research will analyze the networks involved along with the dynamic relationships that are leading to transitions. I hope my research will help other countries, both developing and developed, to create their own paths to increasing their RE share, thus enhancing their social, economic, and environmental welfare, and helping them move closer to sustainability.

My research uses ideas from political science and institutional analysis, based on the work of Elinor Ostrom, to better understand energy transitions - the where, when, how, why, and who. By using the Institutional Analysis and Development Framework, along with an understanding of Ostrom's institutional design principles, a set of institutional drivers to energy transitions can be created. This list will be further discussed in Chapter 3.

A Solutions Oriented Approach

This dissertation is an example of an emerging solutions-oriented research paradigm. This is a reflection of the mission of the School of Sustainability (SOS) and, more broadly, Arizona State University, to produce socially relevant, actionable research. Sustainability represents a young, transdisciplinary science and SOS has embarked on an innovative program to educate its students in this new type of solutions-oriented scholarship and make it a part of the formal curriculum. Researchers in the School are focusing their research and teaching on solving a variety of sustainability challenges in transportation, education, water, and energy.

Because this dissertation is solution-oriented, its structure departs somewhat from traditional scholarly expectations. For example, this dissertation is neither a traditional, detailed ethnographic study of a particular energy system, nor a comparison of many cases, where cases are chosen across some specified set of gradients with controls. Rather, this research focuses on selecting success stories in terms of RE implementation and analyzing the differences in implementation strategies to see which *solutions* are most effective. This restricted the number of cases included in this study to six. There are two practical reasons for the selection of case studies as well. First, because of the complexity of energy systems and energy policy, the analytical depth and data necessary to understand even single cases of implementation strategies make it practically impossible to compare a large number of cases.

Second, although from a traditional science perspective we would expect a study focused on understanding energy transitions to include both successful and unsuccessful cases, this does not make sense in the context of my dissertation. It is difficult to find data about "unsuccessful" cases, by the very nature of how I define success. These "unsuccessful" cases would represent countries that have implemented the set of institutional drivers outlined below, but still did not experience an energy transition. In fact, I was unable to find any data about cases at the national scale, documenting, what I term, failed RE transitions. Even if cases of failure could be found, it is not clear what value they would add to this solution-oriented dissertation.

The motivation, methodology, and case study choices reflect a solutions-oriented research paradigm that is not a dispassionate assessment of the evolution of energy systems but, rather, a qualitative evaluation of *successful* energy transitions. The research paradigm reflects a strong normative orientation and is purposively driven towards focusing on successful cases, rather than being representative of the population. Many features of a successful energy transition to RE are obvious. My research focuses more on the subtle differences and the additional institutional characteristics necessary for energy transitions to occur. The six cases chosen, in fact, do exhibit significant differences and represent a reasonable range of variation for the purposes of this study. Why these cases where chosen is discussed in further detail in Chapter 3.

The Institutional Analysis and Development Framework

Introduction

The Institutional Analysis and Development Framework (IADF) is a tool developed in the 1980s, led by Elinor Ostrom with the help of many others, to facilitate institutional analysis. The IADF is used to understand decision-making processes by focusing "the analyst's attention on individuals who make decisions over some course of action" (Koontz, 2003, p. 3). My research uses the IADF (Figure 1.1) to examine RE development. (I have added arrows to the diagram to make the connections among the exogenous variables and decision-making environment and between the exogenous variables, decision-making environment, and outcomes clearer.)

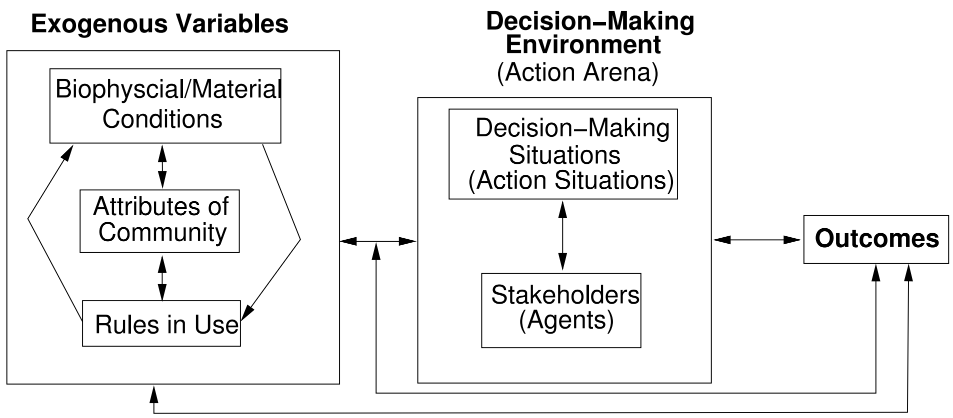

Figure 1.1: Slightly modified Institutional Analysis and Development Framework (IADF). Original labels for the IAD appear in parenthesis where appropriate. Adapted from: Ostrom, 2005.

Many researchers have used the IADF to analyze decision making about common-pool resources, such as water and forest systems since they "are among the core social dilemmas facing all people" (Ostrom, 2005, p. 219). Although Ostrom obviously understood the importance of all three exogenous variables, she focused on understanding how the rules in use affect collective action in the management of small-scale systems such as fisheries and forests. By analyzing hundreds of cases she developed eight institutional design principles. These principles will be further discussed in Chapter 3.

The Framework has been used to develop major databases with hundreds of cases related to studying common-pool resources. One such database is that of the International Forestry Resources and Institutions research program. The program aims to help fill knowledge and information gaps about how institutions affect the incentives of forest users, resulting in substantial deforestation in some locations and improved conditions in others (Polski and Ostrom, 1999). Another such database is the social-ecological systems (SES) Library at the Center for the Study of Institutional Diversity at Arizona State University, which contains analyses of SES from around the world based on the original Common-Pool Resource databased developed by Ostrom and her colleagues.

Although it has been used to study some commodities, the IADF rarely, if ever, has been used to study energy systems (at the time of writing, the only article publicly available is a book chapter by Wang and Liang, who studied "how provincial governments implement energy conservation targets assigned by the central government" in China.) My research will provide much-needed knowledge about how the IADF can be used to analyze strengths and weaknesses in the institutional arrangements involved in supplying an essential commodity, energy, from common-pool resources (most renewable sources). The Framework is a useful tool to understand the energy-implementation decision-making process of governments because the energy sources a country or individual uses depend on how energy is managed. My research focuses on understanding the interactions between the three exogenous variables. While Ostrom relied primarily on the rules in use to develop her institutional design principles, my research relies on the relationship and interaction among the biophysical/material conditions, attributes of the community, and rules in use to develop eight institutional drivers of energy transitions. These will be developed in Chapter 3.

Energy management occurs at many different scales, from the national to the individual. Countries have the choice to invest directly in large-scale RE projects and/or to implement RE policies that encourage investment in, and aid in the implementation of, such projects. The individual also has the opportunity to invest in RE projects, but at a much smaller scale. For example, in Thailand, the government initiated the Very Small Power Producer (VSPP) program in 2006 to incentivize small-scale RE development. Projects are limited to 10MW, and contracts usually last from seven to ten years. The power produced can be sold to the Provincial Electricity Authority (PEA), one of two government-owned distribution companies. Since the initiation of the VSPP program, contracts amounting to 4,300 MW worth of energy have been signed (Gipe, 2010). Thailand's energy system will be further discussed in Chapter 4.

Within governments, energy decision making can either be centralized or decentralized. Decision making can either be the sole responsibility of one ministry or department within the government, or it can be decentralized and spread throughout ministries and departments. To refer back to the above example, although Thailand is a constitutional monarchy, energy implementation has been highly decentralized through the creation of numerous ministries and departments responsible for various energy programs. Entrepreneurship exists inside these ministries and departments. The National Science and Technology Development Board (a sub-department of the Ministry of Science and Technology) has a sub-sector working on a solar-cell program and a biomass and bio-energy program. Even the Office of the Prime Minister, which initiated the Government Sustainability Challenge, participates in energy implementation: as part of the Challenge, the government installed 203,000 solar-home systems in rural Thailand.

The IADF can be applied to organize key issues and themes of energy management and dynamics by identifying the key decision-making factors. The following section will discuss some of these factors. I will begin by showing how the IADF can be used to characterize different energy systems by comparing a traditional fossil-fuel-based grid system with a decentralized RE-based system. I will then discuss how the Framework can be used to delineate the role of different actors and actor networks in different positions within energy systems. Next, I will explain how the Framework aids in the understanding of the governance structure of these systems. I will end with additional insights that the IADF can contribute to the discourse on energy management and dynamics.

The IADF will be used to compare the energy systems, and the nature of the energy transitions, occurring within six case study countries. The cases have been selected on the basis of three criteria while keeping in mind the solutions-oriented focus of this dissertation. While the sample size may seem understandably small, there is a strong rational for why these cases were chosen in Chapter 3. In addition, in Chapter 4 I will apply the IADF to understand Thailand's energy system in more detail. Why Thailand was chosen as a case study is further discussed at this point as well.

Characterizing Energy Systems

The IADF can be used to characterize energy systems by looking at the exogenous variables that define the system. I will briefly explain how these exogenous variables can be used, and then use them to characterize two different types of energy systems: a fossil-fuel-based and a renewables-based system. The first exogenous variable is the 'biophysical/material conditions.' For an energy system, these conditions include: size of the resource, amount of the resource available, where the resources are available, and potential storage of the resources. The second variable is 'attributes of the community.' Examples of energy attributes are: culture, values of behavior that lead to different energy-resource choices, level of common understanding of the energy-resource options, extent of homogeneity in the preferences for resources, size and composition of the community using the different resources, and the extent of inequitable access to different energy resources.

The third and last variable is 'rules.' Rules can be split up into four groups: regulations (i.e., energy policy), instructions (i.e., strategies for an energy transition), precepts (i.e., moral behavior associated with using the "right" energy source where "right" is location specific and based on local values and norms), and principles (i.e., renewable resources are location specific). Among these four groups, there are seven types of rules. Table 1.1 shows how these rules can be applied to understand energy transitions.

Although all of the rules are important when analyzing energy transitions, I argue that scope and payoff rules have the greatest impact. Countries that have set a Renewable Portfolio Standard, an example of a scope rule, and have financial incentives such as subsidies and taxes, examples of payoff rules, are more likely to experience an energy transition. Payoff rules are usually implemented to support the scope rule, otherwise the scope rule would not be attainable. This idea will be further elaborated on in Chapter 3.

Tables 1.2 and 1.3 show how the above three variables can be used to characterize the two different types of energy systems: 1. a tradition fossil-fuel based gird system and 2. a decentralized renewable-energy based system.

Type of Rule	Relation to Energy Transitions
Information	What is the effect of energy sources? Where are the energy resources? How energy is being used? How much energy is being used? How is energy information and decisions controlled? (i.e., Is voting on energy policies done privately?)
Aggregation	Do people need to decide which energy sources can be used? Necessary in a decentralized and/or polycentric society?
Scope	Affect outcomes depending on the actions taken - Which energy sources are used? How much of the source remains easily accessible? Implementation of a Renewable Portfolio Standard? Is a renewable energy law set?
Payoff	What are the subsidies and taxes in place? Is there domestic production? Are there energy security issues? Who are the property owners?
Choice/Authority	What the stakeholder must, must not, or may do depending on requirements that have or have not been met? Can energy users generate their own energy by installing solar panels? Does the government allow for net-metering? Can stakeholders choose to follow or not follow a renewable energy policy?
Position	Stakeholders - Who are the decision makers? Is decision making regarding energy resource use done only at the national level and/or do stakeholders have input? Who are the energy users?
Boundary	How people become stakeholders? How do stakeholders become knowledgable about energy resources and use of the resources? Is there transparency in the decision-making process regarding energy policies and projects?

Table 1.1: Types of Rules and their Applicability to Energy Transitions.

Biophysical/Material Conditions	Attributes of the Community	Rules
• Located in pockets around the world - Proven oil reserves concentrated in Canada and Saudi Arabia • Resources are depleting • Relatively easy storage of energy and distribution of power though centralized electrical-grid network • Cheap and easy to consume - The cost of solar PV is currently about \$0.20/kWh, while coal cost about \$0.02/kWh	• Developed world is the main user - OECD uses 43.8 percent of global fossil-fuel resources (International Energy Agency, 2012) • World is highly dependent on one type of resource - Oil represents 48.7 percent of the fuel share (International Energy Agency, 2012) • Electricity-delivery system set up in a way that emphasizes nonrenewable energy consumption	• Most policies emphasize use of nonrenewable energy sources - Highly subsidized • Developed world has become highly dependent and no longer puts thought into use, while developing world is more concerned about how much and when to use - All based on who has what resource and how much of it they have • "If the individuals who are crafting and modifying rules don't understand how particular combinations of rules affect actions and outcomes in a particular ecological and cultural environment, rule changes may produce unexpected and, at times, disastrous outcomes" (Ostrom, 2005, p. 3)

Table 1.2: Analysis of the Exogenous Variables for a Traditional Fossil-Fuel Based Grid System.

Decision Makers and their Environments

The IADF can be used to delineate the role of different actors and actor networks in different positions within an energy system. Information about the actors, including the positions they are

Biophysical/Material Conditions	Attributes of the Community	Rules
• Highly dependent on the type of energy - Much more variability than fossil fuels (i.e., May find a lot of sun in a place with little wind) • Storage can be complicated - Requires batteries • Can affect, and be a result of, the need to protect common-pool resources and public goods. Renewable-energy technologies are implemented both to protect the environment (i.e., from global climate change) and increase national security and national resilience (i.e., by avoiding the consequences of fossil fuels becoming depleted and/or too expensive) • Use may be inequitable since there is a high up-front cost to renewable energy implementation	• Starting to see a shift in values away from nonrenewables - People becoming more aware of their use (e.g., Germany targets switch to 100 percent renewables for its electricity by 2050 (Bundesverband Erneuerbare Energie e.V., 2012)) • Can be used on the large scale to power countries all the way down to individual scale so the definition of "community" depends on scale of use • People who use may or may not value the environment and some people just want to save money in the long-run	• What fossil-fuel options do they have and would it make sense to offset with renewables • Does policy incentivize use - Are there subsidies available • Which renewable resources are available in a certain country or community

Table 1.3: Analysis of the Exogenous Variables for a Decentralized Renewable-Energy Based System.

assigned to, who and what they control, the net costs and benefits associated with each action, and the interactions among the actors, can help in understanding why the energy implementation strategies were chosen. The Framework helps to identify who the key stakeholders are. Identification of key stakeholders will be especially relevant to the research that will be discussed in Chapter 3.

Decisions about how much and what kind of energy to use are made by different actors at different levels, from the country level all the way down to the individual level. As mentioned earlier, a country can decide to invest in large-scale RE projects, or it can continue to rely on fossil-fuel resources. In the developed world, the individual actor usually has four options for energy use. They can: 1) rely solely on the energy provided to them by their utility company through the grid (this will most likely be 100 percent fossil-fuel energy); 2) pay extra money on their monthly utility bill to help the utility company invest in RE; 3) offset some of their energy use from the grid by investing in RE technology for their home (i.e., install solar panels on their roof); or 4) remove themselves entirely from the grid and power their home completely with RE sources. The more individuals who choose options 2-4, the more likely an energy transition will be achieved.

The IADF can be used to track if and when a country or individual decides to change the amount of energy and/or the types of energy sources they have been using. If the goal is to change use, whether amount or type, the Framework can be used to characterize who the decision makers are, and, after further review, what they are basing their decisions on. In the case of RE implementation, government officials and voters are important actors. Actor networks are also important because not only are government officials and voters involved in decision making, but also: 1) energy providers (whether a utility or an independent RE company), 2) the people who will actually install any new energy technologies (e.g., wind-turbine installers), 3) any partnerships between countries or people who will share in the use of a source (e.g., neighbors who decide to invest in a shared wind turbine), and 4) the end users. Actors associated with nonrenewable and RE use in the case study countries will be described in Chapters 3 and 4.

Governance Structure

To understand a governance structure, we must understand the institutions that have shaped it.

> *"Institutions provide the basic structure by which human beings throughout history have created order and attempted to reduce uncertainty in exchange. Together with the technology employed, they determine transaction and transformation costs and hence the profitability and feasibility of engaging in economic activity. They connect the past with the present and the future so that history is a largely incremental story of institutional evolution in which the historical performance of economies can only be understood as part of a sequential story. And they are the key to understanding the interrelationship for economic growth (or stagnation and decline)"* (North, 2009, p. 118).

The IADF can be used to characterize the institutions associated with energy systems, as well as the systems themselves. The Framework can be used to help analyze what historical factors have led a country to use certain energy systems, the energy technologies employed, the potential transaction and transformation costs to using (or not using) certain energy resources, the profitability and feasibility of using (or not using) different energy resources, and finally, the relationship among the factors listed above.

By analyzing the components organized in the Framework, a number of other governance and institutional questions can be answered to attain a deeper understanding of past energy transitions, as will be discussed in Chapter 2. What are the formal rules (i.e., policies) associated with different energy-source implementation strategies, and are there any informal rules (driven by values and norms) that govern which energy sources have been used? What has been the main energy resource used in the past? Is there a national energy transition happening, or is there potential for one? What kind of incentive structure is needed, based on the attributes of the community, for a country to achieve an energy transition? Are the incentives currently, or should they be, driven by financial, social, and/or environmental factors? Is there potential to change individual norms by changing goals or implementing policy at the government level? How much are people willing to spend, if anything, to change how much and which energy sources are used? How much are people currently spending on nonrenewable versus RE sources, and is there a price mechanism in place that determines how much is spent on one versus another energy source? These and other questions will be answer in Chapters 2-4.

Additional Insights

There are a number of additional insights that the IADF can provide when using it to characterize energy management and dynamics. The Framework can be used to organize the institutional factors that have led to a country's energy policy by separating out and analyzing the various actors, community attributes, and rules in use. This also allows for greater transparency about the management of the system. "In the contemporary world there is a considerable emphasis on the need for improved standards of governance and of transparency in public policy (and in private sector) management as a means of achieving policy objectives more effectively and of reducing the extent of corruption" (Sumner and Tribe, 2010, p.140). Also, does the country have policies that allow for individual freedom in determining which energy sources someone wants to use for their home? And can individuals affect which energy sources their neighbors use? And could this limit the individual's freedom to choose? Ostrom found that, "subjects in a controlled setting would actually pay funds from their own earnings in order to sanction the less cooperative behavior of other participants" (2005, p. 91). Is this true in terms of energy decisions?

The IADF will provide a way to categorize: 1) whether certain actors prefer nonrenewable or RE sources (by analyzing the decision-making process) and 2) the institutional factors affecting the decision-making process. Are the decisions guided by values, norms, laws, historical use of certain energy sources, or some other factor(s)? Categorizing the exogenous variables should help answer these questions.

Renewable energy sources can be implemented all the way from the national to the individual scale. This scale difference justifies studying energy management from the country all the way to the individual level. A country might depend solely on nonrenewable energy sources due to a lack of policies and incentives for RE use at the country scale, but individuals in the country might be using RE sources. Again, is it because of norms, values, incentives/disincentives, or some other factor(s)?

The IADF not only categorizes the energy system, but after further analysis of the system, the Framework can be used to determine how to make changes to the energy system. By looking at the biophysical/material conditions, attributes of the community, and rules, a country or individual can determine the ideal resource to use.

Overall, the Framework allows for a comprehensive analysis of the system, because the analyst can assign different factors to the different categories established by the Framework. It also provides a systematic way of looking at and understanding systems. Systems that initially seem complex can become easier to manage by using an existing framework to analyze them.

1.3 ORGANIZATION OF THE DISSERTATION

This dissertation will take us on a journey through multiple energy transitions now underway. Chapter 2 will analyze the current global energy system and how it came to be. Chapter 3 will analyze five case studies of countries that are successfully transitioning to RE use. This chapter will summarize the findings by providing a list of institutional similarities among the countries that have lead to their energy transition success. This list will be used in Chapter 4 to analyze Thailand's current energy transition. Finally, Chapter 5 will conclude with a summary of my research findings and with a number of comparisons across cases. First, I will discuss to what extent the success of RE transitions can be predicted by the presence of the institutional drivers outlined in Chapter 3 in the case study countries. I will then apply Ostrom's Social-Ecological Systems Framework to the cases. I will briefly touch on two important lessons about transitions and then explain what is necessary for successful RE implementation. Next, the institutional drivers list developed in Chapter 3 will be compared to the findings in Cavanagh's "Ten principles for sustainable societies" to orient my research within the field of sustainability science. Lastly, I will discuss possible avenues for future research.

Chapter 2

AN ANALYSIS OF THE GLOBAL ENERGY SYSTEM

2.1 AN UNSUSTAINABLE SYSTEM

Energy is one of the most important and urgent global sustainability challenges. Most developed nations are stuck in a carbon lock-in (Unruh, 2000). Unruh (2000) notes that industrial economies have become locked into fossil-fuel based technological systems through a path-dependent process driven by technological and institutional increasing returns to scale. Once a country is "locked-in," it will face persistent market and policy failures that will reduce the chances of alternative technologies to join the market. To understand what makes a transition happen, it is necessary to understand the status quo system from which the transition departs. This chapter will show how innovation led to the current global energy system, and how innovation can help countries transition out of this unsustainable energy system and into a more sustainable one.

Chapter 3 will provide a comparative case study analysis of five of the top renewable energy (RE) users. To better understand the context of these cases, this chapter will provide a general understanding of the history and use of energy in a global context. I begin by providing an overview of fossil fuel use. Then the historical patterns of energy use for renewable energy, nonrenewable energy, and nuclear energy are discussed. A description of the dominance of fossil fuels and the fossil-fuel infrastructure is provided. The discussion then switches to the beginning of a global transition and notes the potential causes of change and the need for new innovations.

Fossil Fuel Use

Oil is the primary nonrenewable energy resource consumed globally (Energy Information Administration, 2012). Oil has made its way into almost every aspect of human's lives, especially as gasoline, heating oil, and plastics. It is also an ingredient in 6000 products, including ink, tires, clothes, balloons, crayons, aspirin, and toothpaste (Ranken Energy Corporation, 2012).

Oil use varies greatly by region (Figure 2.1). For example, the U.S. uses two trillion times as much oil as Niue. Of course, population size affects oil consumption. However, the U.S. uses more oil than China, and more than all of Europe combined. Both regions have populations larger than the U.S.

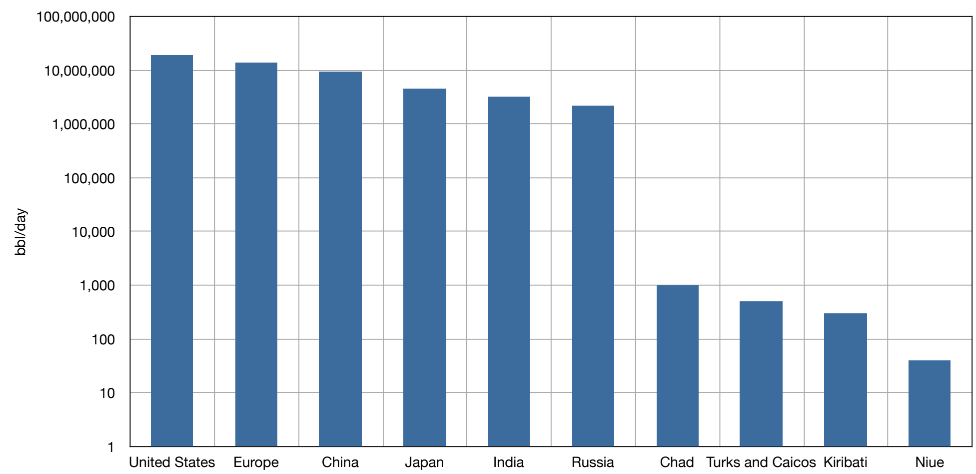

Figure 2.1: Largest and smallest oil users. The United States uses two trillion times as much oil as Niue. Data Source: Central Intelligence Agency, 2012

Most of the world's oil reserves can be found in the Middle East and Canada (Figure 2.2). The Middle East has 55.6% of global reserves, with Saudi Arabia holding 35.8% of Middle Eastern reserves. Canada holds 84.8% of North American reserves and 13.3% of global reserves. The United States, which consumes 20% of the world's energy, holds only 1.6% of total global reserves. Hence, the U.S. is reliant on international oil reserves. This is made possible because one of the largest benefits of nonrenewable energy is that it can be used far from its source.

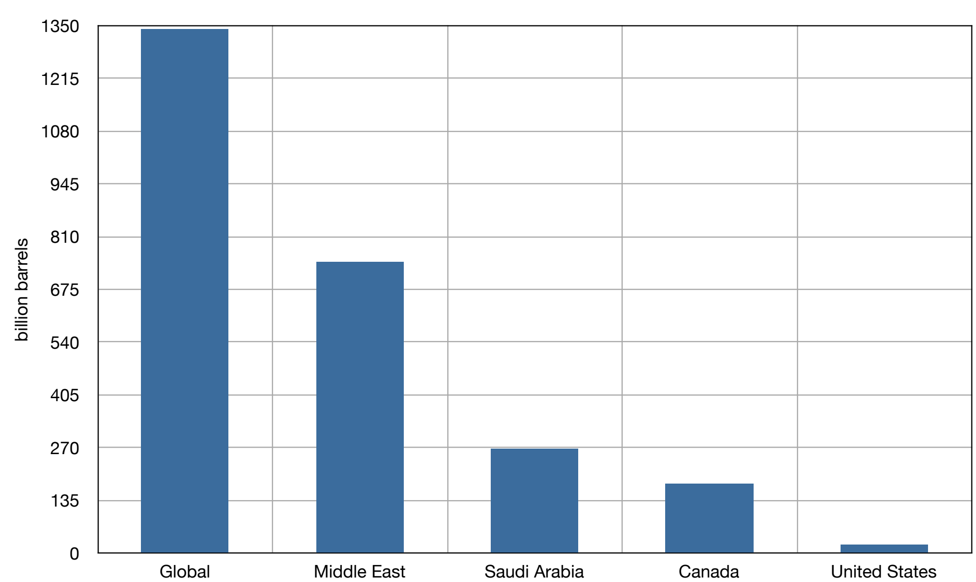

Figure 2.2: Oil reserves. The Middle East and Canada are home to the largest percentage of oil reserves globally. Data Source: Central Intelligence Agency, 2012

Recently, there have been a number of oil reserve discoveries. In 2010, there were 88 million barrels of new field discoveries, primarily in North Dakota and Texas. There was also 161 million barrels of new reservoir discoveries in oil fields, mostly off of Louisiana in the Gulf of Mexico (Energy Information Administration, 2012). However, oil is primarily used as motor fuel, and not for electricity generation. Most of the electricity in the world is generated from coal and natural gas. Natural gas has fewer emissions than both coal and oil, and with new shale gas reserves being discovered, is quickly becoming the main resource used for electricity generation. At the time of writing, the most recent natural gas discovery is shale gas in Canada. Apache Corporation, one of the world's top independent oil and gas exploration and production companies, says it has discovered an estimated 48 trillion cubic feet of shale gas, the equivalent of 8 billion barrels of oil, in the Liard Basin of British Columbia (Apache Corporation, 2012). North America, Argentina, and China also have major shale gas reserves. New discoveries of natural gas and oil reserves may be a disincentive to efforts to increase RE use.

Embeddedness

Sarah is a 17 year old girl who lives in Phoenix, Arizona. Every weekday she wakes up at 6:00 a.m. to get ready for school. Her morning routine includes waking up, turning off her alarm clock, making her bed, going to the bathroom and flushing the toilet, brushing her teeth, brushing her hair, putting on clothes, going down stairs, eating breakfast (cereal and milk) in front of the television, making her lunch, calling her best friend Jen to tell her she is on her way to pick her up, saying good-bye to her parents, getting into her car, picking up Jen, and driving to school.

Mwanawa is a 17 year old girl who lives in Tanzania, Africa. Every weekday she wakes up at 4:00 a.m. to get ready for school. Her morning routine includes getting dressed, waking up her five other siblings, eating breakfast (spiced milk tea and bread), walking an hour each way with her siblings to collect water and firewood, washing her face and saving the water to use it to brush her teeth, milking three goats, feeding one cow, and at 8:00 a.m. walking one hour to get to school.

Energy is used very differently in the morning routine of each girl. Sarah, the American, is completely embedded in a fossil-fuel based system. Every part of her morning involves some form of nonrenewable energy. Mwanawa, the Tanzanian girl, relies on renewable and human energy. She rarely uses fossil fuels in any form, with the exception of the plastic bucket she uses to carry water.

Neither of these young ladies has a choice about what energy sources she uses. Neither created the system, but both are completely embedded in it. How did these two very different energy systems arise?

2.2 DEVELOPMENT OF RENEWABLE AND NONRENEWABLE ENERGY SYSTEMS

Humans have used both RE and fossil fuels since at least 3000 BC. In addition, the development pattern of each source is quite similar: there is continual innovation to exploit the resource, and there is a fairly high degree of technical innovation prior to the twentieth century.

Historical Patterns of Energy Use

Renewable Energy

Biomass Biomass refers to organic matter that has stored energy through the process of photosynthesis. Plants themselves are biomass and their energy is transferred through the food chain to animals and their wastes. Most biomass fuel comes in the form of wood products, dried vegetation, crop residues, and aquatic plants. Biomass is currently the most widely used RE resource, comprising about 50% of RE sources and about 15% of the world's total energy supply. In developing countries, it accounts for as much as 35% of the energy supply because agricultural byproducts provide plenty of fuel (Centre for Energy, 2012). Historically, biomass has been used for heating and cooking purposes, as is still the case in many developing countries. In the developed world biomass is being converted into biofuels, bioproducts, and biopower. [1]

Biomass was first used commercially for pyrolysis by the London Gas, Light and Coke Company in 1812 (Higman and van der Burgt, 2008).[2] Solid biomass was first commercially gasified for use as biopower for steam generation for electricity in France in 1840 (Ahmad et al., 2011). By the 1890s however, coal began to replace biomass for steam generation, and by the 1910s it had also replaced biomass for home heating in the U.S. (Nye, 1999).

[1] A biofuel is a type of fuel whose energy is derived from biological carbon fixation. Bioproducts are materials, chemicals and energy derived from renewable biological resources. Biopower is the use of biomass to generate electricity. There are six major types of biopower systems: direct-fired, co-firing, gasification, anaerobic digestion, pyrolysis, and small, modular.

[2] Pyrolysis is the process of heating biomass in an oxygen-free environment to produce a liquid oil.

The Otto Cycle, invented in Germany by Nicolaus August Otto in 1876, was the first combustion engine to use gasoline blended with ethanol, a biofuel (Gunston, 1999). In the 1880s, Henry Ford used ethanol to fuel one of his first automobiles, the quadricycle (Miller et al., 2010). In 1900, Rudolf Diesel used peanut oil to show that a diesel engine could run on pure vegetable oil, another biofuel (Demirbas, 2002). By 1908, Henry Ford assumed that ethanol would be the motor fuel of choice and built an ethanol fermentation plant in Kansas. The end of World War II (WWII) coincided with the end of the U.S. ethanol fuel industry. The U.S. began to import cheap and abundant petroleum fuels from other countries (Solomon et al., 2007).

Biomass did not make a resurgence until the 1970s when the world experienced an oil crisis. Large oil companies, such as Chevron and Texaco, began marketing ethanol-blended fuels in the U.S. By the 1980s, biomass power plants were being built in the U.S. The Clean Air Act of 1990 encouraged further development of biofuels because they produce fewer emissions than petroleum-based fuels. Ethanol production in the U.S. grew from 175 million gallons in 1980 to 2.8 billion gallons in 2003 (Solomon, 2007). By 2011, production had jumped to nearly 14 billion gallons (Energy Information Administration, 2013).

Biofuel (both ethanol and biodiesel) use has increased dramatically over the past decade, especially in the U.S. and Brazil (Figure 2.3).[3] These two countries lead global biofuel production with their ethanol industries. The two countries are the two largest users of biofuel in the world. However, each country has created a different kind of ethanol: U.S. ethanol is corn based while Brazilian ethanol is made from sugar cane.

Biomass will continue to play an important role in energy transitions, especially in agricultural-based economies, mainly found in the developing world. Most countries have access to biomass, and the resource is usually the first RE resource used due to its availability.

Wind The first recorded use of wind power was in 3200 BC in Egypt, when the Egyptians used the sail (Herbst, 2006). Around 200 BC, the Chinese invented the first windmill. Wind power continued to gain momentum (e.g., for smelting in Sri Lanka, and corn grinding in Persia), and was widely

[3] Eurasia, Africa, and the Middle East are not represented in this figure since their 2010 biofuel use is minuscule compared to the other countries and regions at 2.6, 0.2, and 0.1 thousand barrels per day, respectively.

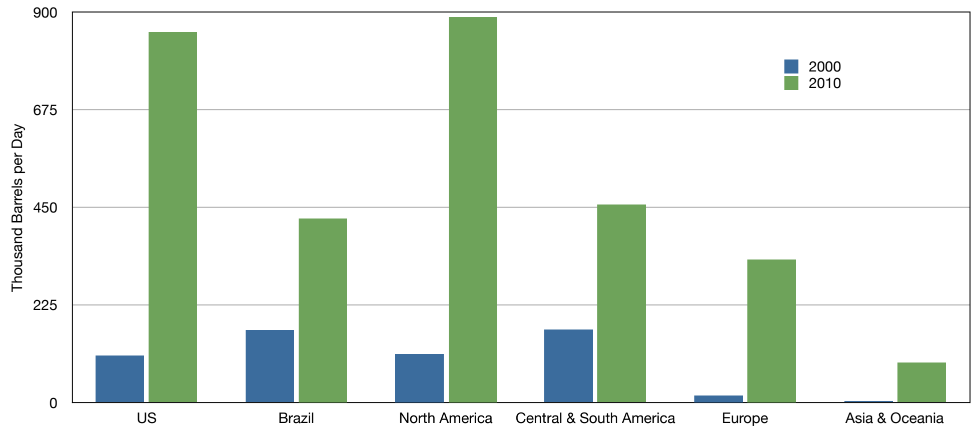

Figure 2.3: Global biofuel production, 2000-2010. The United States and Brazil are the two highest biofuel producers globally. Data Source: Energy Information Administration, 2012

used by 1000 AD in the Middle East. In the 1500s, Spain invented the triangle-shaped sail to make wind power more effective, and in the 1600s the Netherlands started using its iconic windmills. By 1700, England and the Netherlands had about 20,000 windmills. The Halladay and Eclipse windmills of the American west came onto the market in the 1850s, and by the 1880s, windmills were being used by many homesteaders for anything that required power, including pumping water, milling grain, and shelling corn (Pasqualetti et al., 2009).

In 1892, the Danes were the first to use wind turbines to generate electricity. The Smith-Putnam wind turbine was developed in 1941 and provided New England with 1.25 MW of electricity. But its operation was suspended when the U.S. entered WWII. Most windmill companies went out of business in the 1950s because they could not compete with cheap nonrenewable-energy sources. However, in the 1980s, wind farms began to be constructed in the U.S. and Europe in response to the global energy crisis of the 1970s (Pasqualetti et al., 2009). In 2005, the Global Wind Energy Council was launched in Brussels as the international trade association for the wind power industry (Global Wind Energy Council, 2013).

Wind turbines are perhaps the most iconic energy technologies, especially those in Holland and the American west. Wind power will play an ever-increasing role in energy transitions due to its relatively high efficiency. Also, any country with access to off-shore wind resources (which are usually significantly higher than on-shore resources), will be certain to take advantage of the resource, especially since it partially addresses the NIMBY (Not In My Back Yard) effect.

Solar The use of passive solar was first advocated in 400 BC by Socrates when he argued for orienting homes in ways to utilize the sun's heat in the winter and to minimize its impact in the summer. Not much later, in 300-200 BC, parabola-shaped reflective surfaces were first used to concentrate solar energy. The first solar collector, called a solar hot box, was invented in 1767 by a Swiss, Horace de Saussure (Perlin, 2009). Edmond Becquerel discovered the photovoltaic effect in 1839 (Shaheen et al., 2005). Augustin Mouchot, a French scientist, patented the solar engine in 1861 (Perlin, 2009). John Ericsson initiated the solar industry in the U.S. in the 1880s. He developed solar-driven engines to power steam generators on ships (De Laquil III et al., 1993). In 1891, the solar water heater was invented by Clarence Kemp (Perlin, 2009). Solar homes, using both passive and active solar, became popular in the U.S. in the 1940s after real estate tycoon, Howard Sloan, built the Sloan Solar House, designed by George Fred Keck (Claridge and Mowris, 1985). One hundred years after the discovery of the photovoltaic effect, Russell Ohl invented the solar cell (De Laquil III et al., 1993). By 1941 there were over 60,000 solar water heaters in the U.S., mainly in Florida, but in the 1950s, the entire market was nearly wiped out by cheap natural gas and oil (Perlin, 2009).

Nevertheless, Bell Telephone continued to develop solar technologies, mainly solar photovoltaic, in 1954 (Perlin, 2009). In 1979, President Carter installed 32 solar panels on the White House. The first solar-cell power plant came online in 1980 at Natural Bridges National Monument, Utah. This renewed interest in solar development in the 1970s, like that in biomass and wind, was a response to unstable oil prices and limited oil supply (National Park Service, 2013). In the early 1980s, the Reagan administration suspended U.S. government incentives for solar energy and removed the solar panels from the White House. (In 2010, President Obama reinstalled the solar panels.)

Solar is one of the most widely used RE resources, and most countries experiencing an energy transition have innovation institutions in place to update this fairly old technology. Solar panel efficiencies are continuing to increase, and financial mechanisms are making it easier for individuals to implement solar panels on their own homes.

Hydro Hydropower was first used by the Greeks and Romans around the 3rd century BC when they began using water wheels to grind wheat into flour. It has been used continuously since then in areas with sufficient water flow to turn a wheel including ancient China and Medieval Europe (Gulliver, 2009). A notable example is the hydropower system developed in the ancient city of Hama in Syria in the late 12th to early 13th centuries. Tourists today still marvel at the system that was used to raise water from the Orontes River and then drop it in aqueducts and canals that would bring the water to fields (Haven, 2008).

Hydropower was first used to generate electricity in 1882 when Wisconsin's Vulcan Street Power Plant came online (Gulliver, 2009). The first, largest, and last masonry dam, the Theodore Roosevelt Dam, was completed in 1911 about 75 miles northeast of Phoenix, Arizona on the Salt River. The Theodore Roosevelt Dam supplied Phoenix with electricity and irrigation water. The dam's original capacity was 4,500 kW; its current capacity is over 36,000 kW (U.S. Department of the Interior, Bureau of Reclamation, 2013). Franklin D. Roosevelt's New Deal included establishment of the Tennessee Valley Authority (TVA) in 1933. TVA currently provides electricity to nine million people in seven states (Tennessee Valley Authority, 2013). The largest hydropower plant in the world, the Itaipu power plant on the border of Brazil and Paraguay, was completed in 1983 with an installed capacity of 12,600 MW (Itaipu, 2013).

In the 1960s-70s environmental regulations led to the decommissioning of hydropower plants and reduced the number of sites under consideration for hydropower development. Such regulations include the Wild and Scenic Rivers Act (1968), the National Environmental Policy Act (1969), and the Fish and Wildlife Coordination Act (1974) (Climatepedia, 2011; U.S. Department of the Interior, Bureau of Reclamation, 2009).

Although historically important, large-scale hydropower is diminishing as an import RE source since many people are protesting the implementation of new plants due to their negative impact on the environment and farmland. However, many developing countries are implementing micro-hydro projects that have limited effect on the environment, and yet can power a substantial amount of the village's energy needs.

Geothermal Since the time of early cave dwellers, people have taken advantage of geothermal energy. For thousands of years, hot spring provided a welcome reprieve from the cold. In the 19th century, hot spring began to be actively exploited to heat homes and bathhouses in the U.S. The first geothermal power plant was developed in 1904 in Italy by Piero Ginori Conti (Lund, 2004). The first ground-sourced geothermal heat pump was installed at the Commonwealth Building in Portland, Oregon in 1946 (Hatten and Morrison, 1995). In 1960, the first large-scale geothermal power plant was developed by Pacific Gas and Electric in San Francisco with an installed capacity of 11 MW. In the 1970s, geothermal heat pumps became popular as a way of reducing heating and cooling costs, especially in commercial and university buildings. Today, the U.S. has 69 geothermal power plants (Centre for Energy, 2012).

Geothermal energy use will continue to increase as new sites are found. However, use will be slow compared to the other RE sources due to its high cost of implementation. Also, most geothermal sites are relatively far from where energy use is highest.

In Summary Renewable energy sources will continue to play an important role in most countries' energy mix. Many developed countries have policies and incentives in place to increase their RE share. Eventually, these countries may have RE as the dominant energy source.

Nonrenewable Energy

Although the world's current nonrenewable energy use is at an all-time high, nonrenewable energy has been used for thousands of years. Records of coal use date back to Palaeolithic settlements in France during the last glacial period when it is assumed that wood resources became scarce (Thery et al., 1996). In the Middle Ages, coal was used for forges, smithies, lime-burners, breweries and, with the invention of fire bricks, began being used for home heating. By the 1570s, coal was used as a major heating source for buildings in Europe (Daemen, 2009). It was especially useful in cities, where access to biomass was limited.

Natural gas began to be used extensively in Europe and the U.S. in the 1800s for lighting, until Edison's light bulb became widespread (Busby, 1999). There were very few natural gas pipelines until the end of World War II, when improvements in pipe-making made pipeline construction economically feasible (Chambers, 1999).

Records of oil use date back to around 3000 BC in Mesopotamia, where it was used in architecture, ships, medicine, and roads (Partington, 1950). The Chinese started drilling for oil around 500 BC (Kopey, 2007). But it was not until the 1900s, with the widespread use of electricity and the combustion engine, that oil first began to play the primary role in energy generation that it does today.

Although much research has been done on the negative consequences of nonrenewable energy use, it does have some benefits, such as providing political stability and capacity for economic and social development. For example, Smith (2004) notes, "Oil wealth is robustly associated with more durable regimes and significantly related to lower levels of protest and civil war" (p. 232). Hence, it is necessary to study fossil-fuel wealth as a driver of energy transitions.

Nuclear Energy

Nuclear energy's history is much shorter than that of RE and fossil fuels'. Uranium was discovered in 1789 by German chemist Martin Klaproth (Ferguson, 1940). Atomic fission was discovered in the late 1930s, and during World War II many countries were trying to harness this energy to make an atomic bomb (Halperin, 2006). After the War, nuclear power research focused on using the energy for naval propulsion and for making electricity (Allen, 1977). The U.S. began to develop nuclear energy to generate electricity with Eisenhower's "Atoms for Peace" program in 1953. The first commercial Pressurized Water Reactor in the U.S., Yankee Rowe, operated from 1960-1992. Argonne National Laboratory developed the Boiling Water Reactor, commercialized by General Electric at the Dresden-1 power plant, which operated from 1960 to 1978 (World Nuclear Association, 2010). While France is currently the largest nuclear energy user in terms of its electricity share, East Asia, especially China, has lead recent nuclear developments prior to the Fukushima Daiichi nuclear disaster (International Atomic Energy Agency, 2013; Zhou et al., 2011).

The Dominance of Fossil Fuels

Human innovation creates specialization, which in-turn gives rise to more innovation. This pattern applies to energy development, as it does to the development of every resource. Fire was perhaps the first human energy innovation. It allowed humans to warm themselves and cook their food. Humans began exploiting RE sources when they started using the sail in 3200 BC. For nearly 5,000 years humans were innovative in exploiting all kinds of energy sources, but after World War II, technological innovations in the developed world focused on the development of a centralized nonrenewables-fueled grid.

The end of WWII brought about strong economic growth for the U.S. because of the resurgence of the car industry, as well as the boom of new industries, such as aviation and electronics. There was also a housing boom since returning military personnel were given easily affordable mortgages. The "baby boom" increased the number of consumers of these products. The Employment Act of 1946 promoted "maximum employment, production, and purchasing power." During the war, women had gone to work in the industries historically occupied by men. Once men came back from war, women continued to stay in the workforce, and during the 1950s, the number of workers providing services surpassed the number who produced goods. The boom in these industries (i.e., car, housing, aviation, and electronics), required quick access to cheap energy sources. These booms rapidly increased nonrenewable-energy use.

The end of World War II saw the rise in the middle class and the growth of suburbia. Americans demanded single-family homes, and each home had at least one vehicle. Thus, Americans moved from the cities to the suburbs. With the invention of air conditioning, people started migrating to the "Sun Belt," and cities such as Houston, Atlanta, Miami, and Phoenix experienced major development. These large cities, in warm climates, needed access to a great deal of energy. Fossil fuel resources were the easiest and cheapest to use.

World War II changed the way the globe used energy resources. It created a focus on nuclear energy innovation with the development of atomic bombs. WWII also lead to globalization. Prior to WWII, countries traded spices, slaves, textiles, and agricultural products. After WWII, they began trading nonrenewable-energy resources. North America and Europe began acquiring cheap, abundant resources from other parts of the world. Predominant among them was oil.

Fossil fuels also became embedded within the processing, production, and distribution of goods. They became the dominant way to move vehicles, heat homes, and provide electricity. All prior investment and innovation in renewables stopped at this point until the energy crisis of the 1970s. Obviously, this deep embedding of oil in our psyches and industrial organization will affect energy transitions. One important example is the "sunk cost" effect: the huge past investment in infrastructure makes transitioning from oil very difficult.

Fossil Fuel Infrastructure

Infrastructure and technology are the engines of economic growth (Ridley et al., 2006). To understand current energy infrastructure and technology, let's follow a drop of crude oil from its origin to its use in the United States. All oil starts underground, either under land or under the ocean floor, and must be pumped to the surface. Let's say that our drop is pumped out in Saudi Arabia. (The process to pump oil out of the ocean is much more intensive than pumping it from land since the oil must come to the surface and then be transported via boats to land.)

Once crude oil is removed from the ground it must be tested for two characteristics that will determine its quality and price: specific gravity or density, and sulfur content. (Oil must undergo extra refining processes to make it useful if it has a high density and/or a high sulfur content, thus affecting the price.) Oil tankers, or oil pipelines, bring oil to refineries. Companies are constantly trying to maximize the value of a barrel of oil, and the barrels on a specific ship can be traded multiple times (G. Dirks, personal communication, August 28, 2012). This will change the ships direction depending on to whom the barrel is traded to.

Our oil drop was transported from Saudi Arabia to a port in the Gulf of Mexico to be refined. Once the barrel gets to a refinery, the oil will be converted into a number of different products. It can be refined into fuels, plastics, asphalt, fertilizers, paving materials, etc., with gasoline representing about half of total production volume and fuel oil about 15.3%. Ethane and methane will be used at the co-generating power plant to help power and heat the refinery plant (G. Dirks, personal communication, August 28, 2012).

Oil is abundant, easy to extract, and easy to transform into usable products. It still provides relatively cheap fuel because the initial infrastructure investment has already been made. In addition, in the U.S., prices remain low because consumers do not pay the true cost of oil. Neither the transportation cost nor the environmental damages are reflected in the price of use. These costs are hidden by government subsidies.

2.3 THE BEGINNING OF A GLOBAL TRANSITION

Causes of Change

WWII marked the initial end of major investment and innovation in the RE sector. Not until the energy crisis of 1973 was there a renewed interest in RE development. However, it was not until the beginning of the 21st century that RE development became both a policy and investment priority in the developed world. Currently, Germany, Sweden, Canada, the United Kingdom, and the United States lead the world in government-sponsored RE research programs (Centre for Energy, 2012). Industry and the market have also played large roles in the large-scale implementation of RE technologies. The current push for alternative energy development is driven by: rising oil prices, growing interest in nuclear energy, and the negative consequences of fossil fuel use.

Price of Oil

In 2003, Mamdouh G. Salameh posed the question, "How high will [oil] prices rise?" (p. 1090). He was unsure of the exact answer, but he believed it was unlikely that they would rise above $50/b, and prices would most likely range between $25/b to $32/b, unless the war in Afghanistan spread to Iraq. Salameh predicted incorrectly. The war did spread to Iraq and only ended in December 2011. As of this writing, prices are above $90/b. Countries neither expected nor planned for the worst. As Salameh's false predictions demonstrate, the direction the energy market takes is unforeseeable, even over a period as brief as ten years. In fact, oil markets are highly volatile, perhaps more so than markets for other goods, since the oil market is not truly competitive, thanks to the Organization of the Petroleum Exporting Countries (OPEC) (Johnson, 2011).

Although oil is an international good, only a few countries control its price. These countries comprise OPEC. OPEC was founded in 1960 by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela. The founding members were later joined by other countries (Table 2.1). OPEC was originally headquartered in Switzerland, but has since moved to Vienna, Austria.

Country	**Years Part of OPEC**
Iran	1960 -
Iraq	1960 -
Kuwait	1960 -
Saudi Arabia	1960 -
Venezuela	1960 -
Qatar	1961 -
Indonesia	1962-2009 (quit since no longer an oil exporter)
Libya	1962 -
United Arab Emirates	1967 -
Algeria	1969 -
Nigeria	1971 -
Ecuador	1973-1992, reinstated in 2007 (temporarily quite due to its need to increase oil output)
Gabon	1975 -
Angola	2007 -

Table 2.1: OPEC Countries and Years Belonging to OPEC. Data Source: Organization of the Petroleum Exporting Countries, 2012

OPEC largely controls the price of oil, but what if the market set the price of oil? “Letting the market set prices...would encourage the development of additional domestic supplies of oil as well as the development of alternative energy sources” (Bamberger, 2003, p. 2). Historically, high prices have led to reduced consumption. Is this still the case? In 2002, the price of gas per gallon was +/- $1.50. In May 2012, a gallon was +/- $3.70 - an increase of nearly 250%. By July 2012, the price had dropped 11% to $3.30. While in 2002, $3.30 would have been considered exorbitant, it is now considered a new low.

There is an interdependence and delicate political balance between producing and consuming nations (Bamberger, 2003; Salameh, 2003). In 2002, the world had just experienced a plummet in oil prices of 35% due to the bad performance of the global economy and the terrorist attacks of 9/11. The globe then experienced a severe oil shortage during 2007-2008. In January 2008, the average cost of gasoline in the U.S. was $3.05; by May it had risen to $3.50; and by July 2008 it was over $4.00 a gallon. Oil prices then increased as a result of the 2008 financial crisis. In 2011, riots in the Middle East, North Africa, and Libya (all major oil exporters) led to a decrease in global oil resources, and thus, an increase in price. Do countries want to be stuck on this see-saw? One way to get off is to move towards local solutions and RE technologies.

The Push for Nuclear

Nuclear energy offers a way to step off of the see-saw. Currently, there are more than 430 commercial nuclear power stations in 31 countries, with a total capacity of 372,000 MW. These reactors provide the world with about 13.5% of its electricity needs. In addition, 56 countries operate around 240 research reactors, and 180 nuclear reactors power 150 ships and submarines (World Nuclear Association, 2012). France is the most nuclear-dependent country in the world; almost 80% of its electricity comes from nuclear (World Nuclear Association, 2012). However, the largest user of nuclear is the U.S., which accounts for 31% of global nuclear use (Figure 2.4). The largest nuclear power plant in the U.S. is the Palo Verde plant located 50 miles west of Phoenix, Arizona.

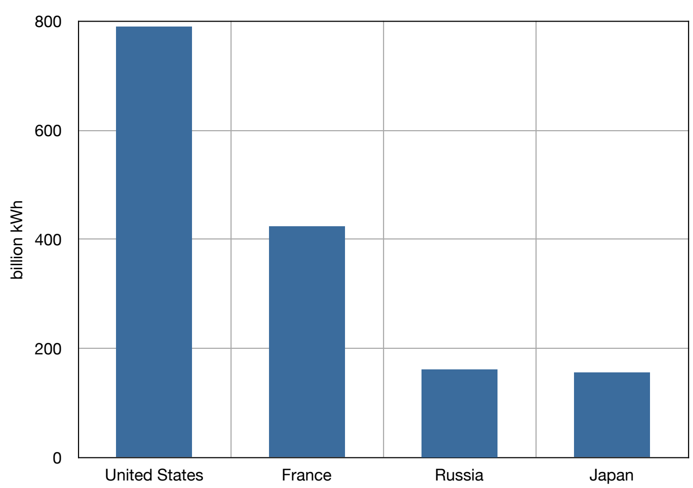

Figure 2.4: Nuclear power use. The United States and France are two of the highest nuclear power users globally. Data Source: World Nuclear Association, 2012

As is the case with oil, the true cost of nuclear energy is not reflected in the consumer price. Nuclear energy is heavily regulated and subsidized by the government. For example, in the U.S., the Price-Anderson Nuclear Industries Indemnity Act, originally passed in 1957, protects the nuclear industry from liability claims while allowing compensation coverage for the public through a no-fault insurance-type system (U.S. Nuclear Regulatory Commission, 2012). The Act keeps the market cost of nuclear energy down, while forcing tax payers to pay for the industry's liability insurance coverage.

Although nuclear energy production in the U.S. is driven by private sector participation, the government is still heavily involved through research and development funding, safety and environmental regulations, and setting national energy goals. In fact, the government remains more involved in commercial nuclear power than in any other industry (World Nuclear Association, 2012).

In 2002, the U.S. Department of Energy launched the Nuclear Power 2010 program, a government-industry, cost-share partnership that would lead to new construction of advanced current-generational plants. However, President Obama greatly reduced the amount of funding allocated to the program. Between fiscal years 2009 and 2010, he cut allocations by $72.5 million and by fiscal year 2011 the budget request for the program was zero (World Nuclear Association, 2012). The increase or decrease of nuclear energy development in the U.S. is highly dependent on which political party is in power. A Democratic government tends to reduce the use of nuclear energy while Republican governments tend to increase them. Hence, there is much uncertainty about the path nuclear energy development will follow in the U.S..

International Atomic Energy Agency The world leader in nuclear research and information provision is the International Atomic Energy Agency, headquartered in Vienna, Austria. The Agency works with its 154 member countries to promote safe and "peaceful" nuclear technologies (International Atomic Energy Agency, 2012) and was set up in 1957 as the "Atoms for Peace" organization within the United Nations. The Agency serves as a liaison among the nuclear industry, member countries, and the public, and works to help accomplish the United National Millennium Goals. "The IAEA works to maximize the safe operation of nuclear facilities that generate power, support industry, deliver health care and serve research. The IAEA promotes the responsible management and disposal of waste, while verifying that nuclear technology is used only for peaceful purposes" (International Atomic Energy Agency, 2011, p. 1).

Negative Consequences of Fossil Fuel Use

The negative consequences of burning fossil fuels are manifold, especially for agriculture and human health. Power plants continue to be the number one source of air pollutants in the United States, despite the passage of the Clean Air Act in 1970. Their pollutants include sulfur dioxide, carbon dioxide, nitrogen oxides, particulate matter, and toxic heavy metals (Figure 2.5) (American Wind Association, 2002). Pollutants released into the atmosphere pose serious health risks to people with respiratory ailments and have caused asthma to become one of the fastest growing childhood illnesses in the world. In addition, urban smog has increased the risk of low birth weight, premature births, stillbirths, and infant deaths (American Wind Association, 2002).

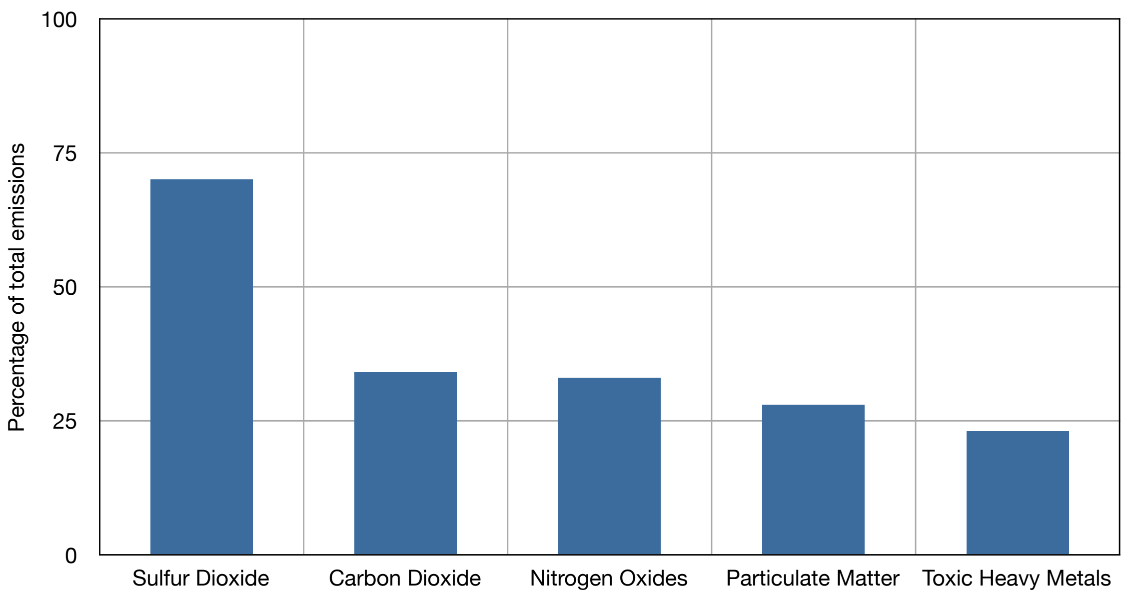

Figure 2.5: Power plant emissions. Sulfur dioxide is the number one power plant emission, but other emissions, such as carbon dioxide, are having a number of negative effects on the environment. Data Source: American Wind Association, 2002

Another result of burning fossil fuels, global climate change, also has human health impacts. Climate change may increase the transmission of mosquito vector-borne diseases such as lymphatic filariasis, dengue fever, and malaria. Malaria alone kills 3,000 people a day, mostly children (Godrej, 2001). Predictions of increased disease transmission "are based on the effects of changing temperature, rainfall, and humidity on mosquito breeding and survival, the more rapid development of ingested pathogens in mosquitoes and the more frequent blood feeds at moderately higher ambient temperatures" (Ramasamy and Surendran, 2012). The problem of increased disease transmission is compounded by growing drug resistance and a decline in public health efforts. Developing countries, which are most effected by these problems, have the fewest resources to cope with them.

Climate change negatively impacts food production, as well as health, especially in developing countries. Climate change may increase "cereal prices, and thus the population at risk of hunger...despite adaptation" (Rosenzweig and Parry, 1994, p. 138). While the developing world is most at risk for food shortages rooted in climate change, the food system of the developed world is a primary cause of those risks. The developed world's food industry is extremely energy intensive. In the U.S. it accounts for 10% of fossil fuel use (Horrigan et al., 2002).

Negative Consequences of Nuclear and Renewable Energy Use

Reducing or eliminating dependence on fossil fuels would solve the problems associated with price instability and negative consequences of burning fossil fuels. These changes would include increased use of nuclear and RE. However, these two sources have their own negative consequences.

Nuclear is not considered a renewable resource because it depends on mined uranium and generates radioactive waste that not only posses health problems but also national security issues. The use of nuclear grew steadily between 1970 and 1995 especially in Europe, Asia, and North America. But since 1995, nuclear energy generation has remained relatively stable, and in Europe it has declined since 2005 (Energy Information Administration, 2012). The 2011 Fukushima Daiichi disaster in Japan has further damped enthusiasm for nuclear energy development.

While the drawbacks of nuclear energy are more obvious than those of RE, the latter, nevertheless, does have some objectionable features. To increase RE use a country must

> *"overcome technical, institutional, social and economic barriers as [renewable energy] exhibits localized environmental impact-extensive land and water use requirements, landscape alteration, change of rural lifestyle, noise, etc...Even though renewable energy alleviates adverse environmental impacts from the global-regional scale (climate change, acid rain), it increases pressures to the local scale (landscape degradation, noise, conflicts with other land uses-recreational, touristic, etc.)"* (Polatidis and Haralambopoulos, 2004, p. 1253-1256).

While most people agree that increased use of renewables is desirable at the global scale, at the local scale people may not be willing to tolerate the disadvantages created by RE production (Gamboa et al., 2005). Local objection to RE is known as a NIMBY problem - NIMBY is short for Not In My Back Yard.

Renewable energy storage is a major challenge of large-scale implementation. Renewable energy sources are intermittent (e.g., sometimes the wind is not blowing or the sun is not shining) and localized (e.g., most wind resources in the U.S. are located far from population concentrations). Therefore, the energy must be stored. Currently, RE is sent to the grid for immediate use. Only small-scale systems permit energy to be stored in batteries. Therefore, a new electric grid system would be needed to accommodate large-scale RE use.

Each RE resource has some undesirable characteristics of its own. Solar panels use mined silicon to convert the sun's energy into electricity. Wind turbines placed in migratory paths can kill birds. Hydropower dams can destroy riparian habitats. Geothermal power requires putting large tubes in the ground, which can damage local habitats. However, biomass may have the worst negative consequences.

The burning of biomass, like the burning of fossil fuels, releases harmful emissions. In South Asia, the combustion of fossil fuels and biomass have created a layer of air pollution known as the Asian brown cloud (Gustafsson et al., 2009). In developing countries, where women spend a large portion of their day huddled over a burning pile of biomass, respiratory ailments are directly related to biomass burning. These ailments include asthma, lung cancer, chronic bronchitis, lower respiratory infection, and cardiovascular diseases. These ailments also affect children, because in many developing nations, babies are constantly strapped to their mothers' backs. Whatever the mother inhales the child also inhales. The World Health Organization estimates that more than 1.6 million deaths, and over 38.5 million disability-adjusted life-years, can be attributed to indoor smoke from burning biomass (Torres-Duque et al., 2008). While stove and household-ventilation improvements and behavior change could mitigate some of these problems, such changes involve personal and local beliefs and economic and sociocultural norms (Torres-Duque et al., 2008).

Need for New Innovations

So how does a country begin moving away from fossil fuel use? "During all of these [oil shock] episodes, importance was placed on conservation, more efficient use of energy, and development of alternative energy sources" (Bamberger, 2003, p. 3). These sustainable solutions were championed as lower-cost and environmentally appealing ways to achieve greater energy security (Bamberger, 2003). Bamberger (2003) suggests mid- to long-term policies, affecting both supply and demand, that could be enacted to support transitions. These policies can be modified to specifically increase the use of RE resources (Figure 2.6).

2.4 CONCLUSION

This chapter provided an overview of the current global energy situation. It illustrated why and how the world has become locked in to fossil fuel use and the current push towards RE use. This chapter summarized the exogenous variables. The biophysical context includes what are the resources and their respective technologies (i.e., fossil fuels and the current electric grid infrastructure to disperse the energy versus biomass, wind, solar, hydro, and geothermal as energy sources). The existing rules in use include both formal rules (i.e., subsidies for oil and nuclear insurance) and informal rules (i.e., the rules that structure OPEC). The community in this chapter is the globe as a whole. However, some countries, most notably the United States and those in Western Europe, have had a major impact on historical fossil fuel use and the current push towards RE use.

Clearly, transitioning will be difficult. Revising old policies and creating new ones is a daunting task. "There are limited prospects for significantly reducing [dependence on oil] without

	Affecting Supply	Affecting Demand
Mid- to Long-term Energy Policies	Tax incentives to promote production Open new areas to leasing and exploration of renewable resources Research and development of renewable energy sources Market pricing of nonrenewable and renewable energy	Update Corporate Average Fuel Economy Standards yearly Tax incentives to encourage less and more efficient consumption of nonrenewable energy, and more consumption of renewable energy Efficiency standards Efficiency labeling Research and development in renewable energy technologies

Figure 2.6: Mid- to long-term energy policies affecting supply and demand. Countries can apply these policies to increase renewable-energy use. Adapted from: Bamberger, 2003

incurring economic hardship and lifestyle compromises" (Bamberger, 2003, p. 8). However, in spite of these problems, a number of countries are successfully transitioning away from nonrenewable energy use.

The historical context described in this chapter is suggestive of a broad set of hypotheses that will be rigorously tested through a comparative analysis in Chapter 3 and 4:

1. Because energy use decisions are primarily made at the national scale, energy transitions are only possible if the government makes a strong commitment to their use by implementing policies and financial mechanisms;
2. Because citizen-led RE initiatives can either hinder (e.g., large-scale hydropower dams) or promote (e.g., micro-hydro projects) implementation, energy transitions are most successful in countries where citizen involvement in policy and project implementation is high;

3. Since there was a surge in RE policies and projects after the oil and financial crisis of the 1970s, it can be considered the original driver of RE implementation in most developed countries;
4. With most countries signing and ratifying the Kyoto protocol, and many countries beginning to see the negative consequences of burning fossil fuels, RE sources will be used as one of the key climate change mitigation techniques;
5. Since both nonrenewable and renewable-energy sources are subsidized, with the price of nonrenewable energy sources remaining much lower than those of RE sources, RE sources will only be seriously considered once they are cost competitive with nonrenewable energy sources; and
6. Because nonrenewable-energy infrastructure is outdated, and RE technologies are still difficult to connect to the grid and quite inefficient compared to their cost, innovation in the energy sector will be necessary to drive RE implementation.

By using a comparative case analysis and the IADF to answer these hypotheses, I hope to develop a set of institutional drivers, similar to the design principles Ostrom developed to better understand collective action. Chapter 3 analyzes the success of five countries that exemplify how innovation can overcome impediments to accomplish an energy transition. An analysis of these cases will provide a list of institutional similarities that can be applied to other countries. These drivers will be used to analyze Thailand's energy system in Chapter 4.

Chapter 3

INSTITUTIONAL FACTORS FOR SUCCESSFUL ENERGY TRANSITIONS: A COMPARATIVE CASE STUDY APPROACH

3.1 INTRODUCTION

Institutions are critical for the functioning of complex social systems. They facilitate exchange, reduce transaction costs, and structure repeated interactions between people. They also play a critical role in promoting investment and innovation. This is especially true in the case of common-pool resources and shared infrastructure. Energy systems are intimately related to common-pool resources - e.g., the climate system - and are comprised mainly of shared infrastructure - i.e., large power utilities. Promoting change in this enormous, complex infrastructure system will require careful consideration of institutional change. Comparative case-study analysis is an essential tool for attempting to extract basic design principles from complex coupled human-environmental systems (Ostrom, 1990). This chapter takes a comparative case study approach across energy systems to begin to uncover some structure of how they are governed. The goal is to exploit this structure to help facilitate transitions to renewable energy (RE) systems when appropriate.

RE technologies can be very difficult to implement. This is especially true in the developed world, where most energy investments and decisions were made many years in the past, and new investments must adapt in path-dependent ways (del Rio and Unruh, 2007). However, investment in RE is higher than it ever has been (Figure 3.1A). In 2011, $257 billion was invested in RE.[1] The top RE users in the world, other than Germany, have increased their RE investments between 2010 and 2011 (Figure 3.1B). However modest the recent increases may seem, these increases occurred during the worst financial crisis since the Great Depression.

For the first time in history, in 2011, solar investments surpassed those of wind (Figure 3.1C). This jump in investments was largely due to rooftop solar PV installations in Germany and Italy, small-scale solar projects in China and the UK, and an increase in large-scale solar-thermal electricity generation projects in Spain and the U.S. The drop in wind investments was due to lower turbine prices, European policy uncertainties, and a slowdown in the original fast-paced growth

[1] Investors include corporate R&D, government R&D, VC/PE, public markets, small distributed capacity, and asset finance. Small distributed capacity and asset finance have always been the RE investment leaders, far surpassing the other four categories.

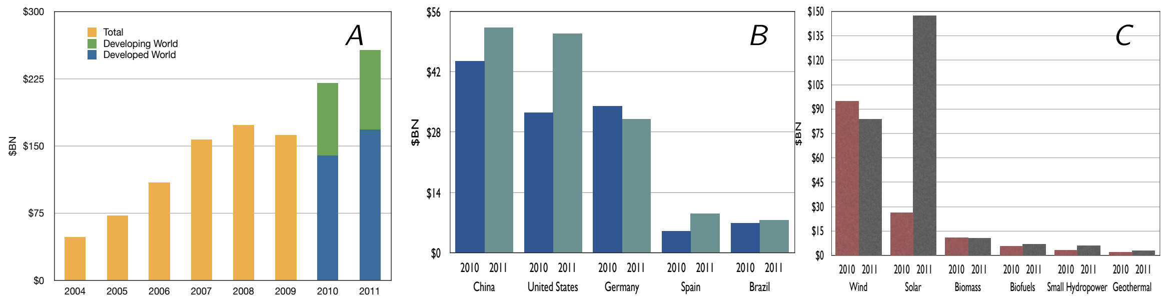

Figure 3.1: (A) Global renewable energy investment. Investments have been steadily increasing. Data Source: McCrone, 2010; McCrone, 2012. (B) Renewable energy investment by country. China and the United States lead renewable-energy investments. Data Source: McCrone, 2011; McCrone, 2012. (C) Global renewable energy investment by type. Solar investments surpassed those of wind for the first time in 2011. Data Source: McCrone, 2011; McCrone, 2012

of wind installations in China (McCrone, 2012; Musolino, 2012). While government support and industry investments continues to rise, the price of RE continues to drop. The per megawatt (MW) price of solar PV has dropped by 76% and the price of wind power by 18% since 2008 (McCrone, 2012; NC Sustainable Energy Association, 2012). These drops reflect not only fierce competition in the supply chain, but fierce competition with fossil-fuel based energy sources. In 2011, RE investments (excluding large hydro) surpassed net fossil-fuel investments (McCrone, 2012)

These developments are hopeful, but what progress has been made with energy transitions around the world? And are energy transitions even feasible? “In a manifestly complex world dominated by hegemonic ideologies of neoliberal capitalism, global finance, and commodity flows is it really possible to intervene and deliberately shift technologies, practices, and social arrange-not to mention their systemic interaction and interdependencies-onto an altogether different, altogether more sustainable track?” (Shove and Walker, 2007, p. 763).

The goal of a transition is to dislodge currently dominant socio-technical regimes and replace them with new configurations (Shove and Walker, 2007). Shove and Walker argue that in order to successfully transition, “most recommend the deployment of multiple methods and tools for intervention, also arguing for processes of governance (rather than government), for the involvement of diverse actors and knowledges, and for explicit recognition of the uncertainties and limitations of science-based expertise” (Shove and Walker, 2007, p. 764). The goal of this chapter is to determine what these methods and tools are for specific countries.

Of known reserves, and with current consumption rates, there are only 70 years of oil, 72 years of natural gas, and 230 years of coal left (Murphy, 2012; General Electric, 2013). There must be a shift away from our dependence on these finite resources. Wang et al. (2010) argue that there are three primary ways to reduce carbon emissions: slow economic growth, reduce energy intensity, and develop renewable energy. This chapter will describe strategies and implementation of the third way (i.e., develop RE) in the most progressive countries. The countries chosen represent five of the top RE users: Brazil (3.8% share of total), Spain (6.5% share of total), China (9.1% share of total), Germany (11.9% share of total), and the United States (23.2% share of total)) (British Petroleum, 2012) (Figure 3.2).

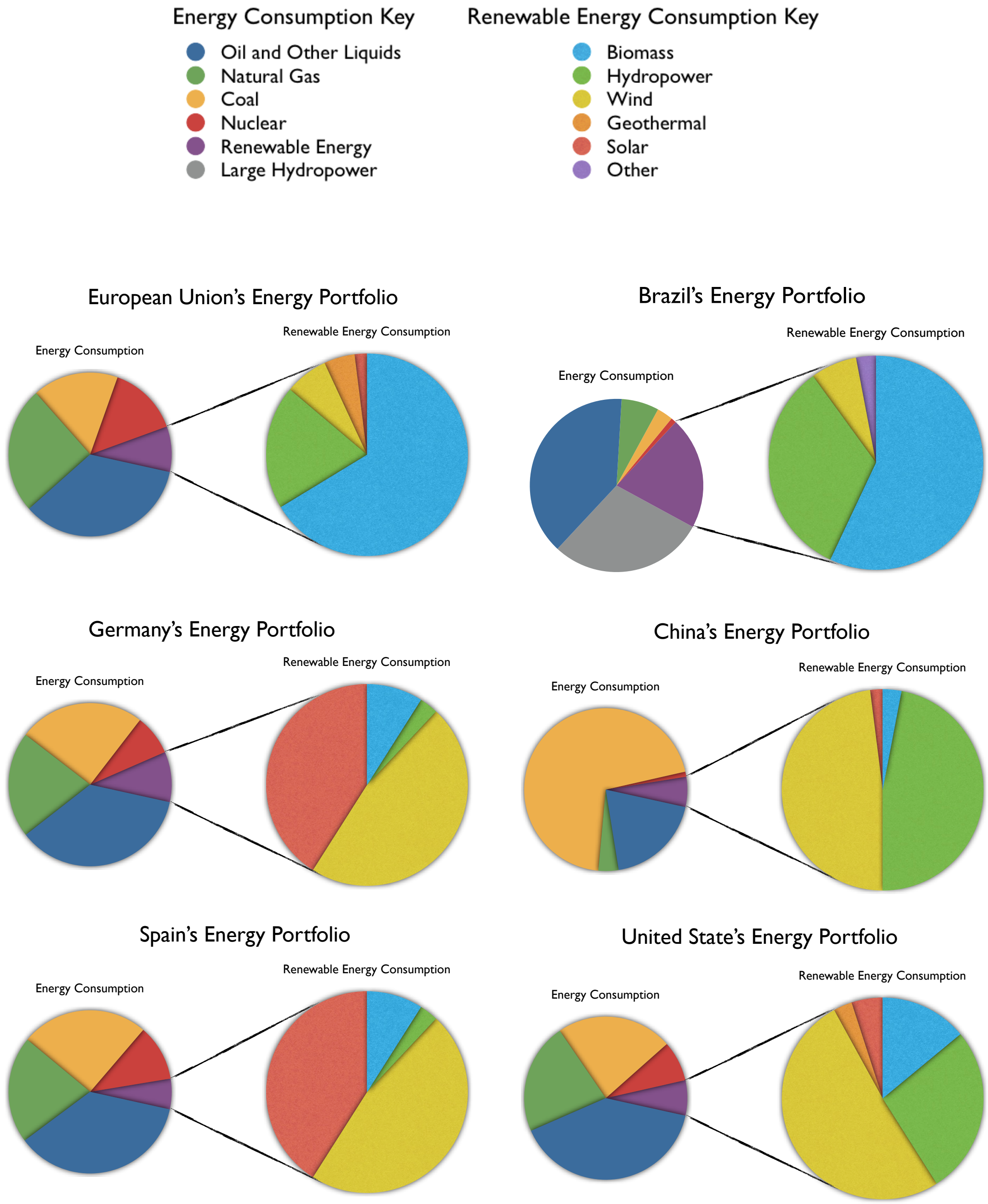

Figure 3.2: Renewable energy portfolios for the European Union and five case study countries. The renewable energy portfolio constitutes an outcome of the interactions of the exogenous variables and decision-making environments in the IADF. Data source: British Petroleum, 2012; Brana, 2010; Energy Information Administration, 2012; Eurogas, 2010; The Pew Charitable Trusts, 2012; Romero et al., 2012

The goal of the study was to include high RE users while also making sure they were geographically diverse. The European Union (EU) has taken great strides towards RE implementation. Each country within the EU could be used as a case study. However, the top two users were chosen: Germany and Spain. A more in-depth explanation of the sample selection process is found in the following section.

This chapter then continues by briefly describing the EU context, in order to better show how Germany and Spain have been a part of the EU movement, and how it has taken this movement and brought it down to the national level. Otherwise, each of the other case-study countries represent a major geographical area, with the exclusion of Australia, who at this time remains out of the top five and even out of the top ten. An analysis of these cases will formulate institutional similarities among them that are leading to successful energy transitions. A list of institutional drivers that lead to transitions will be created.

3.2 SAMPLE SELECTION

Because of the complexity of an energy system at the national level, understanding an energy transition in a country would require the accumulation of a very large amount of data. A career could be spent examining energy transitions in a large number of cases. For the purpose of a dissertation, this is simply not feasible. While a large sample size is the ideal, practical considerations often limit sample sizes and this dissertation is no exception. In my sample selection, I tried to balance the capacity to analyze each case in sufficient detail with incorporating enough cases in the study to capture a reasonable amount of variation across cases. This balancing act led to a sample size of six cases. Further, I focused on finding countries that represent successful, progressive cases. While fully aware of the sample bias problems associated with looking at successful cases, the cases I picked are appropriate for addressing my overarching research question - What constellation of institutional, biophysical, and social factors are essential for an energy transition? Finally, the nature of a solutions-oriented dissertation led me to search for countries that are successfully implementing RE technologies and experiencing an energy transition.

The purpose of this dissertation is to analyze and search for patterns of success. Ostrom spent her career searching for cases representing the successful management of common pool resources. She had the ability to look at hundreds of cases over decades. My dissertation follows her methodology but on a much smaller scale. My research analyzes the successful management of energy systems, and explains how institutional drivers may be leading to energy transitions in the case study countries. To look at unsuccessful cases would not provide any useful or interesting information regarding whats leads to success. The absence of an institutional driver in an unsuccessful case does not necessarily generate any useful information about what leads to an energy transition. Also, since my research is solutions-oriented, analyzing failures, even if we could find any, is not fruitful.

As mentioned earlier, six case studies were chosen: Spain, Germany, Brazil, China, the United States, and Thailand. The first five cases are used to determine the institutional drivers necessary for RE use to succeed in a country. These drivers were then used to better understand Thailand's current energy transitions. Thailand was chosen for a number of reasons including being geographically unique and having similar implementation mechanisms of some of the top RE using countries. These and other reasons to study Thailand are elaborated in Chapter 4.

To determine the first five case study countries, I developed three criteria for how to define success. A table representing where the case study country falls among the list of criteria can be found in Figure 3.3. The first criteria is that the cases are to be geographically diverse. An entire dissertation could be focused on analyzing the successful energy transitions of countries within the European Union. However, this could create a sample bias since this one geographic location could be, and most likely is, completely unique from the rest of the world. The case studies represent four of the seven continents, along with both developed and mid-developed economies.

The second criteria for success was that the case study countries had to have a high percentage of their energy coming from large-scale, grid connected renewable sources. The country had to have a high total renewable electricity net generation, in kWh, for 2011. By having a high percentage of grid connected RE, the share of RE in a country's energy portfolio increases, as represented in purple in Figure 3.2. Large-scale RE projects also require higher financial investments, which require policy initiatives. These policy initiatives represent a strong governmental push for RE use. All of the case study countries have governments that support large-scale RE projects and policy initiatives. However, there is also a reasonable range of large-scale

RE implementation within the cases so that the comparison is useful. In other words, not all of the countries are in the same stage of RE development. For the purpose of my research, renewable sources include: wind, solar, geothermal, hydro, and biomass. The five case study countries are all among the top ten highest RE users in the world.

The final criteria is that the case study country had to be one of the leaders, and among the G-20 top ten, in RE investments in 2011. It is important to differentiate between RE use and RE investment since RE use gives a sense of where a country is, but investment gives a sense of where the country is heading. However, it is important to note that in terms of RE ranking, use and investment do not always coincide. A country could have a high current RE use but a low RE investment for 2011. (Or perhaps vice versa.) However, low investment does not necessarily mean that the country does not value RE use. Perhaps a country has such high RE use that they no longer need to have a high RE investment. Lower RE investment may represent a relative high maturity of RE in a country. (This may be the case with Germany.) Still, the case studies chosen are five of the leading investors in RE. Further details on how these countries are successfully transitioning is discussed below.

3.3 INSTITUTIONAL ANALYSIS AND DEVELOPMENT FRAMEWORK

The Institutional Analysis and Development Framework (IADF) is a tool developed by Elinor Ostrom (2005) to facilitate institutional analysis. The IADF "focuses the analyst's attention on individuals who make decisions over some course of action" (Koontz, 2003, p. 3). The IADF provides insight on how people behave in a collective action dilemma.[2]

The IADF has (recently) been most-often used to study the management of common-pool resources since common pool resource problems "are among the core social dilemmas facing all people" (Ostrom, 2005, p. 219). The Framework has been used to develop major databases related to studying common-pool resources, such as International Forestry Resources and Institutions research program and social-ecological systems library mentioned in Chapter 1.

[2] A collective action is an action that aims to improve the standings of a certain group of people. A collective action dilemma arises when multiple people would benefit from a certain action, but it is impossible for any one person to act alone. Thus, the group must work together to solve the problem for the benefit of everyone.

	Criteria 1: Geographic Location & Economic Status	Criteria 2: Global renewable energy use ranking (2011)	Criteria 3: G-20 renewable energy investment ranking (2011)
Spain	European Union & Developed	10	9
Germany	European Union & Developed	7	3
Brazil	South America & Mid-developed	3	10
China	Asia & Mid-developed	1	2
United States	North America & Developed	2	1

Figure 3.3: Case studies in terms of the criteria for success. Data source: EIA, 2012; Pew Charitable Trusts, 2012

Although it has been used to study some commodities, the IADF rarely, if ever, has been used to study energy systems.[3] Ostrom's IADF can be applied to organize key issues and themes of energy management and dynamics by identifying the key decision-making factors. This chapter uses Ostrom's (2005) Institutional Analysis Development Framework (IADF) (Figure 3.4) to examine energy transitions. The Framework is a useful tool to understand the energy-implementation decision-making process of countries because the energy sources a country or individual uses depend on how energy is managed.

Energy management happens at many different scales, from the country scale to the individual scale. Countries have the choice to invest in large-scale RE projects and/or to implement RE policies that aid in the implementation of such projects. Within governments, energy decision making can either be centralized or decentralized. Decision making can either be the sole responsibility of one ministry or department within the government, or it can be decentralized and spread throughout ministries and departments. The individual also has the opportunity to invest in RE projects, but at a much smaller scale.

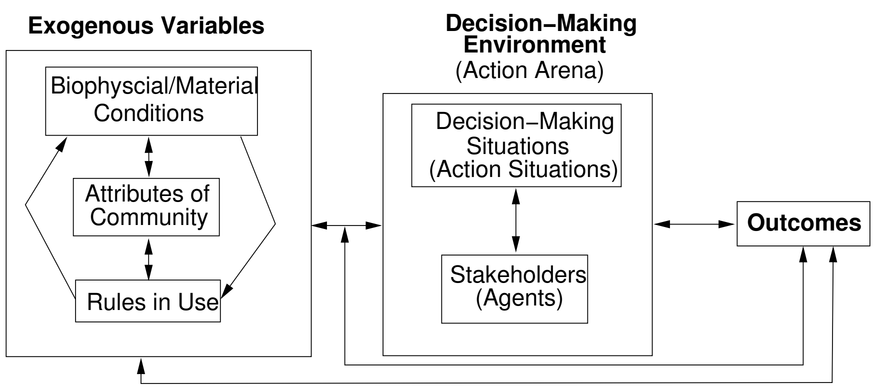

Figure 3.4: Slightly modified Institutional Analysis and Development Framework (IADF). Original labels for the IAD appear in parenthesis where appropriate. Adapted from: Ostrom, 2005.

[3]At the time of writing, the only article publicly available is a book chapter by Wang and Liang, who studied "how provincial governments implement energy conservation targets assigned by the central government."

The research in this chapter applies the IADF to analyze strengths and weaknesses in the institutional arrangements involved in supplying an essential commodity, energy, from common-pool resources (i.e., most renewable sources). By applying the IADF to the case studies, key features emerge as important for the success of collective action and governance:

1) Credible commitment, in this case the government - e.g., a country sets a Renewable Portfolio Standard;
2) Polycentric governance, defined as a system where citizens are able to organize not just one but multiple governing authorities at differing scales, and where self-organized resource-governance systems may be special districts, private associations, or parts of a local government (Ostrom, 2005) - e.g., the American Council on Renewable Energy;
3) Stakeholder engagement - e.g., a power development company holds a public forum before deciding where to place a wind farm;
4) Information rules promoting transparency - e.g., a country releases yearly data on energy production and consumption;
5) Scope rules leading to innovation - e.g., universities are developing innovative energy technologies;
6) Formal rules that force a country to follow the Kyoto Protocol - e.g., most Annex I countries have signed and ratified the Kyoto Protocol;
7) Constitutional rules impacting infrastructure and grid connectivity - e.g., RE projects that are grid connected; and
8) Collective choice rules leading to informal and formal monitoring - e.g., a country sets disincentives to noncompliance of RE targets.

Ostrom used the IADF to generate eight design principles. Using a similar method, my research analyzes energy transitions to develop eight institutional drivers that stem from the list above. (The institutional drivers will be further developed below.) My definition of an institutional driver stems directly from the IADF. For the purpose of this research, the decision-making environment is the energy production/consumption system of a country. Ostrom focused more on understanding the rules in use and did not fully discuss the interaction between technology, rules, and people. My research is looking at the combination of the exogenous variables that are associated with successful energy transitions. My research uses the term institutional driver to understand certain combinations of biophysical conditions, community attributes, and rules that generate a decision-making environment in which an energy transition occurs.

In each of the cases, the exogenous variables and decision-making environments that have been most influential in the country's RE development are highlighted in the text. The exogenous variables are identified in Figures 3.5 and 3.6.

The biophysical conditions show that natural resources are spread throughout the country for all of the case studies. This increases the country's ability to take advantage of these natural resources, without necessarily the need of a centralized grid system, and have a diverse energy portfolio. If a centralized grid system is necessary, then perhaps not all RE sources could be taken advantage of.

The analysis of the attributes of the communities in each of the case-study countries suggests that all of the case study countries have many opportunities to increase RE use. However, there are some barriers. Two common barriers in all of the case studies is price tolerance and infrastructure lock-in. Currently, the cost of RE is much higher than nonrenewable energy. Without institutional change, RE will most likely never be price competitive with nonrenewable energy sources. Most people value the environment and using RE. However, price can hinder their ability to invest in RE. They may want to invest, but with price being so high, they are unable to.

Also, all of the case studies have a relatively old grid infrastructure system that can primarily only support nonrenewable energy sources, causing them to be locked-in to nonrenewable energy use. Similar to price, the community may value RE use, but may be unable to transition to RE use because of infrastructure lock-in. The community may feel that they are unable to invest and promote RE use, because their grid system does not allow for it.

All of the case study countries have a variety of rules in use, especially scope and payoff rules. Most of the countries rely on a Renewable Portfolio Standard, a scope rule, along with a multitude of financial incentives, payoff rules, to increase RE use. My analysis suggests that it is a diversity of rules, and not the reliance on just one rule, that allows a country to experience an energy transition.

	Type	Area	Opportunities	Barriers
China	Biomass	Countrywide	-Largest investor in RE -National and provincial RE incentives/standards -Hierarchical approach to RE -Cooperation mechanisms with organizations and other governments -Innovative governmental decision-making	- Minimal stakeholder involvement - Largest carbon emitter in world - Lacking grid connectivity of renewable energy
	Wind	N, NE		
	Solar	W		
	Hydropower	SE, NE		
	Geothermal	SW		
U.S.	Biomass	Countrywide except C	- Goal of national security and energy independence - Strong state incentives for renewable energy implementation - Renewable energy positively impacts tourism	- Weak national policies - Policies change depending on political values of President - Only reactive during times of crisis - Innovation is demand-side - Noncompliance determined on state-by-state basis
	Wind	C, NE		
	Solar	SW		
	Hydropower	NW		
	Geothermal	W		
Brazil	Biomass	N, NW	- Democratic government - Good relations with neighboring countries - Most industrialized country in Latin America - Strong governmental push for renewables - Off-grid solar implementation in rural communities - Ethanol price is market-driven	- One of the largest growing GDPs in world - Inequitable income distribution - Most solar PV systems are off-grid - Minimal stakeholder investment
	Wind	NE coast, E		
	Solar	Small potential in EC		
	Hydropower	Countrywide		
	Geothermal	S		
Germany	Biomass	Small potential in S	- Progressive renewable energy laws - Large employment within renewable energy sector - Strong push for renewable energy from citizens - Innovative economic mechanisms for renewable implementation - Innovative grid system - Many stakeholders involved in renewable energy implementation	- Even with strong incentives, renewable energy is still subsidized
	Wind	N		
	Solar	S		
	Hydropower	S, SW		
	Geothermal	N		
Spain	Biomass	Countrywide	- Investigation, development, and innovation within energy companies and the government - Low population density, so little public opposition - National, provincial and city mandates - Pioneer of photovoltaic investigation - Job creation from renewable energy implementation - Looking for ways to reduce debt - Renewable energy generation information relayed immediately to citizens via website	- Minimal adoption of solar energy even with the natural resource and technology innovation - Major debt problem - Complex permitting process for renewable energy - Consumers rarely involved in decision-making process
	Wind	S, C		
	Solar	S		
	Hydropower	Countrywide		
	Geothermal	E		

Figure 3.5: Renewable energy potential by country and geographical location (Biophysical Conditions). N = North, E = East, S = South, W = West, C = Central. Opportunities and barriers to renewable energy adoption by country. For most countries there are many more opportunities than barriers (Attributes of the Community).

	Important Acts, Plans, and Laws	RPS	Government subsidies/ rebates	Carbon Cap	Tax incentives	Feed-in Tariffs	Loans	Procurement	Renewable Energy Credits	Net metering
China	Renewable Energy Law	20% by 2020	Yes	Working towards implementation	Yes	Yes	Yes	Potential in future	Yes	No
U.S.	Energy Policy Act 2005; Energy Independence and Security Act 2007; American Recovery and Reinvestment Act 2009	State-by-State	National and State-by-State	No	Yes	State-by-State	National and State-by-State	Yes	State-by-State	State-by-State
Brazil	Ten Year Expansion Plan	75% by 2030	Yes	Yes	Yes	2002-2007	Yes	Yes	No	No
Germany	Renewable Energy Sources Act	23% by 2020; 100% by 2050; 100% nuclear phase out by 2022	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spain	Renewable Energy Plan	20.8% by 2020	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Working towards implementation

Figure 3.6: Renewable energy policies and mandates by country (Rules). Most countries have implemented a variety of policies and mandates. Data Source: KPMG International, 2011; The Pew Charitable Trusts, 2012

An analysis of all three classes of exogenous variables is required to understand a country's energy transition. In addition, each exogenous variable impacts and is impacted by the other exogenous variables. The rules in use and attributes of the community allow for a country to take advantage of the biophysical conditions to increase RE use. Rules in use can also remove barriers of the attributes of the community, such as price, by decreasing the price of RE. The biophysical conditions determine which rules in use will have the greatest impact on RE use. An example of the connection between the exogenous variables ensues. If a country has local RE resources (biophysical condition), then a net metering law (rules in use) would effectively increase RE penetration into the grid, increasing the likelihood that investors will invest in RE (attributes of the community).

3.4 CASE STUDIES

Europe

The EU uses the largest amount of grid-connected, large-scale RE in the world. The EU's executive body, the European Commission (EC), played a major role in drafting the Kyoto Protocol and developed the first multi-country emissions-trading system (Potocnik, 2007). Within the EU, Germany and Spain are the leaders in progress towards RE implementation. However, energy transitions are also occurring in the Netherlands, Denmark, Sweden, Switzerland, France, and Italy. Europe's 20-20-20 by 2020 energy and climate package (2009) set three important goals: to reduce greenhouse gas emissions by 20% from 1990 levels, to improve the EU's energy efficiency by 20%, and to increase RE use by 20%. The EU also set mandatory Renewable Portfolio Standards (see Text Box 1 for a definition) for each of its member countries, but left each country free to establish national policies to meet its goal. Each country must also meet interim targets, and was required to develop a national RE action plan by June 30, 2010 (Schuman and Lin, 2012).

Both the EU and its member countries are using a variety of mechanisms to successfully implement RE, thanks in large part to its governance model. The EU represents a federation of independent countries, as opposed to the United States, where there is a federation of states who are not fully independent. By being a member of the EU, the countries must follow EU-set rules and regulations, but how they follow these are up to their own discretion. The U.S. states must also follow federal rules and regulations, but they have less autonomy. Also, there is no federal Renewable Portfolio Standard, so while some states, like California, are progressively pushing for RE implementation, other states, such as Alabama, are doing nearly nothing to further implement RE. (The U.S. will be further discussed below.)

In 2005, the EU created the Emissions Allowance Trading Scheme, the first of its kind in the world. "The EU countries can buy and sell their rights to emission within bounds fixed for all of the European Union" (Romero et al., 2012, p. 323). Individual countries, most notably Germany and Spain, have also used feed-in tariffs (see Text Box 1 for a definition) (Schuman and Lin, 2012).

Key Definitions

Renewable Portfolio Standard (RPS): "An RPS is a policy that ensures that a minimum amount of renewable energy (such as wind, solar, biomass, or geothermal energy) is included in the portfolio of electric-generating resources serving a state. RPS regulations generally impose obligations that increase over time " (Yin and Powers, 2010, p. 1140).

Renewable Energy Credit (REC): "Most RPS policies are enforced through a credit-trading mechanism. When electricity is generated from a renewable source in states that have a renewable energy credit program, there are two resulting products - the electrons that are fed into the grid, and the environmental attributes associated with producing reduced-carbon or carbon-free electricity. In most states, these environmental attributes are accounted for in the form of renewable energy credits, or RECs. Each REC represents one MWh of electricity generated from an eligible renewable energy resource" (Yin and Powers, 2010, p. 1143).

Feed-in tariff (FIT): "The feed-in tariffs guarantee a price that the grid company will pay to the renewable generator, in order to ensure that developers of more expensive renewable generation sources can recover their costs and earn an appropriate profit" (Schuman and Lin, 2012, p. 8).

Text Box 1: Definitions for different institutional arrangements for promoting renewable energy.

The EC's 2012 "Smart Cities and Communities European Innovation Partnership" allows cities and states to pool energy, transportation, and communication technologies to leverage smart-technology development in cities. Almost 75% of European citizens live in cities, and these citizens consume 70% of Europe's energy (European Commission, 2012). (In comparison, about 51% of people live in cities globally. Countries such as Bahrain, Qatar, and Singapore have nearly 100% of their population in cities, while Ethiopia, Sri Lanka, and Uganda have less than 20% of their population in cities (Population Reference Bureau, 2012).) The partnership aims to decrease greenhouse gas emissions by 40% by 2020. Energy Commissioner Gunther Oettinger stated, "Innovation drives Europe's competitiveness and is the best means of addressing energy efficiency.

Thanks to this partnership, high efficiency heating and cooling systems, smart metering, real-time energy management, or zero-energy buildings neighborhoods solutions will spread among more and more European cities" (European Commission, 2012). The partnership will provide annual funding for urban technology projects, with €365 million ($445 million) available in 2013 (European Commission, 2012).

Consumer buy-in has had significant impact on successful RE implementation. A 2006 poll indicated that 55-80% of Europeans favored RE (Potocnik, 2007). Increasing RE use can spur economic growth, create jobs, and mitigate climate change impacts. If the EU uses about 13% less energy than it did in 2007, it could save €100 billion ($130 billion) and reduce carbon dioxide emissions by nearly 780 metric tons each year (Potocnik, 2007). An increase of 12% in RE use would create 500,000 jobs (Romero et al., 2012, p. 323). For example, in 2007, the wind-energy sector alone provided 154,000 jobs (Romero et al., 2012, p. 323).

The following two sections will take an in-depth look at Germany and Spain's RE use and energy transition. While both countries are members of the EU, and thus must follow EU regulations, their energy transition strategies are quite different.

Germany

Within Europe, Germany's population is especially concerned about the environment. When the German government pushed for nuclear energy development after the 1970s oil crisis, German citizens pushed back, calling for RE development because "...only reliance on renewables and efficiency would be compatible with the basic values of a free society, and that this would be less expensive than the development of a plutonium-based electricity supply as envisioned at that time" (Jacobsson and Lauber, 2006, p. 261). By 1993, a survey conducted in 24 countries indicated that German citizens were the most concerned about global warming. This was mainly due to the Chernobyl disaster, forest die-back from acid rain, and a growing awareness of global climate change (Jacobsson and Lauber, 2006).

Germany is on its way to becoming the world's first country to use 100% RE, thanks to its implementation of a progressive RE law. It is also installing a smart grid (see Text Box 2 for a definition), which will make it easier to harness electricity from RE sources and distribute it to citizens. Germany's RPS calls for a 23% RE share by 2020 and a 100% share by 2050, with a 100% phase-out of nuclear energy by 2022.

Smart Grid

Definition: An electrical grid that uses a two-way automated communication system between the producer and the consumer of electricity to gather and act on immediate behavior information. This new electrical grid system improves the efficiency, reliability, economics, and sustainability of the production and distribution of electricity (Office of Electricity Delivery and Energy Reliability, 2013).

Text Box 2: Definition of a smart grid.

Germany is a world leader in innovative economic mechanisms for RE, especially its FIT system, initiated in 1990 and expanded in 2000 by the Renewable Energy Sources Act. FITs now cover virtually all RE sources including solar, offshore and onshore wind, geothermal, hydro, biomass and landfill gas, sewage gas, and mine gas (Schuman and Lin, 2012). Germany's renewable-energy-credit (REC) trading system (the often-copied German Auction Model), facilitates RE implementation. Germany's system provides a fixed volume of MW for auction; purchasers can buy a fraction of this amount (Pereira, 2012).

Germany has also been innovative in its grid system, amending the Germany Renewable Energy Sources Act in 2008 to make grid operators responsible for prioritizing the purchase, transmission, and distribution of electricity from renewables. The amendment encourages upgrades to grid infrastructure and increasing renewable power predictability (Schuman and Lin, 2012).

Germany holds market shares in several RE technologies. In 2004, it manufactured 40% of wind-energy systems, 30% of solar PV systems, and 14% of biomass systems worldwide. While many manufacturing companies have moved to the developing world because of cheaper labor costs, Germany is still considered an attractive location for technology production because of its domestic market for renewables, the availability of qualified personnel, good infrastructure, and strong research in RE (Lehr et al., 2008).

Germany is a leader not only in the development of RE technologies but also in their use. The country uses 25% of all the solar thermal energy generated in the EU, making it the current EU leader. It also leads the EU in using electricity supplied from waste incineration (Romero et al., 2012). By the end of 2002, Germany had more than one-third of all of the wind turbines in the world (Jacobsson and Lauber, 2006). However, China and the United States are the current wind turbine leaders.

RE implementation has created many jobs in Germany. In 2007, over 250,000 people worked in Germany's RE industry; 50,000 (20%) of them in the wind industry (Germany Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety, 2011; Lehr et al., 2008).

RE development started in Germany in the late 20th century, most notably with the 1,000 Solar Roof Program. Between 1991 and 1995, solar PV was highly subsidized, with 50% of the cost covered by the federal government and 20% by the provincial government. This program surpassed its goal, equipping 2,250 roofs with solar PV, generating about 5 MW (Lauber and Mez, 2004). The success of the program led to lobbying for large-scale implementation. The result was Eurosolar's 100,000 roof program, which was successfully completed in 2004. These programs demonstrate that modest government support can be leveraged to create large-scale success (del Rio and Unruh, 2007).

A variety of important stakeholders have influenced Germany's RE projects and policies. The government, universities, nongovernmental organizations, and local markets have created policies and initiated the research and development necessary to get new technologies implemented. The Green Party advocated for RE in parliament. Small-scale RE projects initiated by the government and private sector were precursors to larger, federal programs. Nongovernmental organizations and enterprises, such as the German Solar Energy Industries Association, the Institute of Ecology for Freiburg, Forderverein Solarenergie, and Eurosolar have all played crucial roles in the large-scale implementation of RE in Germany (Jacobsson and Lauber, 2006).

It is safe to say that Germany is the most progressive country in the world in terms of RE policy and project implementation. While Germany's biophysical context may not be as strong as some other countries, their rules-in-use and community attributes are the main drivers of RE implementation. Not only has the government made a strong commitment towards implementation, but citizens have strongly pushed for RE as well. Although Spain operates within the EU institutional superstructure, its RE implementation story is quite different than Germany's.

Spain

Spain is a leader in several RE sectors, both in Europe and the world. It is first in Europe in solar thermal, second in wind power and solar PV, and third in hydropower. Worldwide is ranks second in solar thermal and PV, and fourth in wind power (Romero et al., 2012). Natural and demographic factors have contributed to the country's successful RE implementation. Spain has abundant wind and solar energy, is the second most mountainous region in Europe (behind Switzerland), and is one of the least densely populated countries. Therefore, there has been little public opposition to the installation of wind and solar farms in the country.

Both the national government and private energy companies have invested in innovation, research, and development of RE technologies (Romero et al., 2012). Spain's Renewable Energy Plan, which implemented a FIT policy, is the most important RE implementation law to date (Gamboa et al., 2005). Unfortunately, in 2012, the Spanish government responded to the then ongoing economic crisis by suspending the FIT policy. As a result, Spain is considering net metering as a replacement for the FITs to encourage consumer-based RE projects.

Three groups of stakeholders make decisions about RE in Spain: the government, which provides subsidies; the banks, which contribute the upfront funds; and the development companies, which install the technology (Cristobal, 2011). The role of private individuals has been insignificant compared to other countries, and only a handful of visionary entrepreneurs have increased the development and adoption of wind power (del Rio and Unruh, 2007). Lack of public participation can lead to the failure of RE projects. For example, the Catalan wind parks project nearly failed because the lack of public involvement in the decision-making process lead to public opposition to the project (Gamboa et al., 2005).

Wind dominates Spain's RE market because wind-technology and energy-generation costs are low. Economies of scale, research and development efforts, mass production, and technological improvements all allow for a relatively high return on investment (del Rio and Unruh, 2007). Spain is beginning to build offshore wind farms in Cantabria, Catalonia, and the Canary Islands (Romero et al., 2012). Until recently, 85% of projects have been located in Galicia (the leader), Castilla-La Mancha, Castilla, Leon, and Aragon (Romero et al., 2012).

Although Spain is a leader in wind-energy development, it has some of the best insolation in Europe. However, solar energy has not been widely used due to its high cost. "The result is a vicious circle where the technology is not adopted because it is expensive, and it is expensive because it is not adopted" (del Rio and Unruh, 2007, p. 1507).

Solar PV was installed in national parks in Catalonia as early as 1994. The Park Service decided to solve its in-park electrification problem by installing solar PV on farmhouses within the park. The panels were subsidized, and for €20 ($26) a month, the Park Service provided the farmers with insurance, technical supervision, and free maintenance (Gamboa et al., 2005). Spain has recently begun to focus on increasing implementation of solar PV. Many large cities have made it mandatory to install solar PV on new buildings, and some provincial plans prioritize the use of solar PV. "PV is much more cost-effective if installed during construction, where the impact on the total building costs is low" (del Rio and Unruh, 2007, p. 1509).

While implementation of solar PV has been weak, technology development has been strong. Spain is the leading European manufacturer of solar PV and the industry is "highly competitive and recognized for its quality, flexibility, innovativeness and commercial dynamism" (del Rio and Unruh, 2007, p. 1509). The industry exports "85% of its production, representing 40% of European and 7% of world production...Currently 4,000 jobs are linked to the PV sector in Spain (2,500 are direct) and the socioeconomic benefits of PV make it attractive for local communities" (del Rio and Unruh, 2007, p. 1509).

Spain is a world leader in RE innovation. Its National Renewable Energy Center is working on the hybridization of solar and biomass energy, something that has never been accomplished (Romero et al., 2012). Also, Spain has developed an innovative information system that relays immediate wind power information to the public every 12 seconds (Romero et al., 2012; Schuman and Lin, 2012).[4]

If Spain continued with its original RE plans, then RE implementation could help Spain with its current debt problem. If Spain reached its goal of 20% renewables by 2020, more than half a million jobs would be created (Romero, 2012). These jobs include both direct and indirect jobs, stemming from more than 1000 companies in the industry. Spanish wind developers and

[4] This information is relayed to the public via the following website: https://demanda.ree.es/eolica.html.

manufacturers are competitive on the international market, and there are more than 75 industrial wind-technology development centers in the country, 18 of which are wind turbine assembly lines (Romero et al., 2012).

Spain's governmental institutional arrangement is the one notable barrier to RE implementation. The authorization procedures for construction, connection to the grid, and initiating production of RE are complicated. A project must go through several applications and permits at the national, regional, and municipal levels (del Rio and Unruh, 2007). For example, for the deployment of a wind farm there are "...60 different regulations involving 40 different procedures between different administrative levels and causing lead times of 4 to 8 years" (del Rio and Unruh, 2007, p. 1505). With such a complex permitting procedure, "different groups of decision-makers become involved in the process, each group bringing along different criteria and points of view, which must be resolved within a framework of understanding and mutual compromise" (Cristobal, 2011, p. 498).

Spain's biophysical context is one of the main drivers to RE implementation. It has abundant wind and solar energy resources spread throughout the country. Also, since Spain is one of the least dense countries, there is limited opposition from the community for RE implementation. Although not as progressive as Germany, Spain has still implemented a number of RE rules and regulations, and they are a world leader in RE technology innovation. However, the government is hindering an increase in future RE deployment through its complicated authorization procedure.

Both Spain and Germany have progressive RE goals, thanks in part to their affiliation with the EU. Not only are they supported by EU rules and regulations, but they have implemented their own rules and regulations. The remaining three case studies, Brazil, China, and the United States, all operate under their own sovereignty. RE implementation in these countries is enforced solely within their own nation. Unlike Spain and Germany, the remaining case study countries have less enforcement mechanisms and less rules and regulations that they must follow. Spain and Germany must not only focus on attaining national policy goals, but also EU policy goals.

Brazil

Brazil is the most industrialized country in Latin America, with a GDP of around $2 trillion. It is the world's second fastest growing economy, and is estimated to have an annual GDP growth of 5.1% over the next 10 years (Pereira, 2012). Much of Brazil's GDP is produced by energy-intensive industries such as aluminum and steel, and by the growth in residential and commercial energy services.

The Brazilian government has been a strong advocate for RE use, especially biofuels, as is evident in its policies (Figure 3.6). Brazil has the second largest share of the world's ethanol production market (Pereira, 2012). Brazil accomplished this feat by initiating the Brazilian Ethanol Program (i.e., Proalcool) to offset petroleum-based fuels with biofuels; initiating the program after the oil shocks of the 1970s, to reduce its vulnerability to the global petroleum-based energy market (Pereira, 2012; Geller, 2004). At the time, oil imports consumed half of Brazil's hard-currency export income. The program required gasoline to include up to 25% ethanol, and encouraged car manufacturers to make engines that could run on 100% hydrated ethanol. The program was accepted by all key stakeholders, from consumers to farmers to car manufacturers, despite the fact that it was initiated by a military regime (Goldemberg, 2007).

In 2009, the Brazilian government initiated the Ten Year Plan for Energy Expansion (2010-2019) which included investing $28.2 billion in small hydropower, wind energy, and biomass, and $39 billion in biofuels (Pereira, 2012). Separately, the Program for Energy Development of States and Municipalities, installed 5,700 off-grid solar PV systems, mainly in northern and northeastern Brazil (Geller, 2004; Pereira, 2012).

Brazil's RPS of 10% RE by 2020, set by the Programme of Incentives for Alternative Electricity Sources, was recently changed to 75% by 2030. Brazil has made it easier for small-scale RE producers to enter the market. For example, the Regulatory Electric Power Agency allows for energy generated by small hydropower plants to enter the grid for free. The plants are also exempt from having to pay municipalities and state governments for the use of water resources. In 2005, Brazil also launched a program to encourage small-scale biodiesel production (Pereira, 2012).

Brazil has a progressive RE auction system, which is similar to the one used in France (up until 2000), Ireland, Germany, and the UK. "This system consists of establishing a total number of alternative sources of renewable electricity to be installed into the system and after several auction sessions, the projects with the lowest costs are selected" (Pereira, 2012, p. 3799). This system is used for biomass, biodiesel, wind energy, and small and large hydropower plants. It encourages as many bidders as possible, allows for transparent use of energy sources, and sets a fair price for electricity (Pereira, 2012).

Most of Brazil's renewable electricity comes from hydropower. Brazil is the second highest user of hydropower, behind China.[5] It has more than 400 large and medium-scale hydropower plants, which generate about 93% of Brazil's electricity. About 80% of new hydropower plants will be installed along the Amazon River (Pereira, 2012). Brazil's use of hydropower reflects the continent's historical use and biophysical context. "The continent's long, powerful rivers have provided the source of much of South American electricity through hydroelectric power stations" (Lambrides, 2006, p. 78).

While most of Brazil's electricity comes from hydropower, the country is known worldwide for its ethanol production. Ethanol provides economic, environmental, and social benefits. Cost is always a motivating factor for using (or not using) an energy source. In 1980, the cost of ethanol was about three times the cost of gasoline, so Brazil's government provided $30 billion over 20 years to subsidize ethanol production. The subsidy was more than recompensed by $50 billion saved on gasoline imports during this time. Although initially the government had to subsidize ethanol, by 2004, the subsidies were no longer necessary, and ethanol became fully competitive with gasoline on the international market (Goldemberg, 2007; Pereira, 2012). According to the World Bank, Brazil can make ethanol for 50% less than it costs, internationally, to make gasoline.

Ethanol use has also had important environmental impacts. Ethanol use has allowed "... the phasing-out of lead additives and MTBE (methyl tertiary butyl ether) and reduced sulfur, particulate matter, and carbon monoxide emissions. It helped mitigate greenhouse gas emissions efficiently, by having a net positive energy balance (renewable energy output versus fossil fuel inputs)" (Goldemberg, 2007, p. 809-810). However, there has been global controversy over using

[5] Brazil uses 374 TWh, or 12.1%, and China uses 485 TWh, or 15.8%.

land to produce biofuels instead of food. Brazil demonstrates that this controversy can be avoided if biofuel is sourced and used efficiently. Sugarcane for ethanol production requires about 3 million hectares. Another 2.6 million hectares of land is used to produce sugar. These uses account for about 10% of total cultivated land and 1% of total arable land. If Brazil expanded ethanol production by a factor of 10, to 30 million hectares, it could produce enough ethanol to replace 10% of gasoline consumed globally (Goldemberg, 2007).

In Brazil, "Both the Biomass Users Network-Central America and The Renewable Energy and Energy Efficiency Partnership are trying to create a culture of entrepreneurs in the energy sector" (Lambrides, 2006, p. 79). Brazil is trying to increase its use of both solar thermal (for heating) and solar PV (for lighting, pumping, and communication). Currently, most solar PV systems in Brazil are off-grid (Pereira, 2012). The country is trying to increase its use of on-grid solar energy through a leasing structure (Lambrides, 2006).

Brazil started using wind power in 1992 on Fernando de Noronha, an island off the northeast coast (Geller, 2004). With a total potential of 143 GW of wind energy, Brazil reached 931 MW in 2010. This represents almost half of Latin America's total wind-energy capacity (Pereira, 2012). Multinational companies have established themselves in Brazil to manufacture and/or assemble wind-power equipment and provide services. This has increased employment in the wind-energy sector and has encouraged universities and technical colleges to provide courses on wind energy (Pereira, 2012).

Brazil faces fewer obstacles to RE development than other Latin American countries, which must deal with policy and financial barriers "...including arrangements that favor low upfront costs and continued fuel costs (fossil fuel) over high upfront costs and low fuel costs (renewable energy)" (Lambrides, 2006, p. 78). Most Latin American countries focus on short-term energy prices and invest in projects with short construction time and low initial investment costs. Thus, they do not implement large-scale RE projects.

Brazil is a democracy and has good relationships with its neighbors, much like the other case-study countries. However, among the case-study countries, Brazil, like China, is an outlier because it is not a developed country, but a mid-developed country. It has a per capita income of around $10,500, but income distribution is highly inequitable. In northern Brazil, about 50% of families earn less than $150 per month (Geller, 2004). However, Brazilians are starting to climb out of the poverty trap. Between 2005 and 2009, "...16 million Brazilians rose above the poverty line [and] around 12 million Brazilians obtained access to electricity" (Pereira, 2012, p. 3787). Because of improved living standards, Brazil will need to invest $564 billion in the energy sector over the next ten years (Pereira, 2012).

Brazil's biophysical context has lead it to be the biomass and hydropower powerhouse that it is considered today. Along with the U.S., Brazil is the largest producer and user of biofuels in the world. Unlike any other RE source in any other country, Brazil's biofuel market no longer requires subsidies and is cost competitive with gasoline. The community has fully adopted biofuels as their main form of fuel for transportation. Also, Brazil has the second most progressive RPS behind Germany; they hope to have 75% of their energy coming from renewable sources by 2030.

While both Germany and Spain are considered developed countries, Brazil and China are still mid-developed and have relatively low per capita GDPs. (Brazil ranks 103rd and China ranks 118th (CIA Factbook, 2013).) While Brazil has focused on expanding its biofuels market, China's RE push has been driven by its need to reduce its consumption of coal.

China

China is currently the largest carbon dioxide emitter in the world, slightly ahead of the United States. In 2007, 93% of China's energy came from fossil-fuel resources and approximately 75% of that energy was from coal. China also has the largest population in the world at 1.4 billion in 2011 (19% of world total). It has a GDP development goal of 7.2% per year between 2000 and 2020 (Wang et al., 2010). China's population size and its GDP development goal will increase energy needs. In order to curb its fossil-fuel use, China invested $45.5 billion in RE in 2011 and set an RPS of 20% by 2020.

The Chinese government has implemented several important RE policies; the most important being the Renewable Energy Law (REL) passed in 2005. Its purpose is "...to promote the development and utilization of RE, increase energy supplies, improve the energy structure, guarantee energy security, protect the environment and realize economically and socially sustainable development" (Schuman and Lin, 2012, p. 2). The REL includes four key mechanisms:

1) a national RPS and a development plan; 2) net metering; 3) a FIT system where the price for RE stays above the wholesale electricity price for desulfurized coal-fired power; and 4) a surcharge on electricity consumption to pay for FITs, grid-connection projects, RE grids, research on renewables, pilot projects, rural use of renewables, and renewable-resource assessments. Each province and all four provincial-level municipalities have also set an RPS (Schuman and Lin, 2012).

China's Renewable Power Quota Regulations require that generators and grid companies meet their RPS targets by the target date, not on an annual basis. However, they must report progress toward these targets to the local branch of the National Energy Administration on a monthly basis (Schuman and Lin, 2012). Although the reporting rules encourage transparency of information, there is no penalty for non-compliance.

China has chosen a policy framework similar to that used in Germany: it emphasizes priority connection for RE, a purchase policy for renewable generators, and FITs. However, "China appears to have the most unified, top-down approach to implementing renewable energy policies and programs, whereas the EU and US systems have a greater degree of autonomy and diversity among their member states in terms of setting renewable policies" (Schuman and Lin, 2012, p. 11). On the other hand, China is taking the first steps towards developing a carbon market. Following the EU, China has set up a cap-and-trade system for greenhouse gas emissions in the cities of Beijing, Tianjin, Shanghai, Chongqing and Shenzhen, and the provinces of Hubei and Guangdong (Marshall, 2012). By setting this cap, China hopes to meet its carbon-dioxide-reduction goals stated in the Twelfth five-year plan to 17% reduction by 2015, compared to 2010 levels (Marshall, 2012; Wang et al., 2010).

China also initiates and funds much RE research and development. In 2007, China implemented a cooperative RE program to demonstrate its commitment to RE use and greenhouse gas reduction through the creation and exchange of technological innovation. China wants to establish a dialogue and a mechanism for cooperating with foreign governments, research institutions, and enterprises (Zhao et al., 2011). By May 2010, China had established 63 such bilateral or multilateral cooperation mechanisms.

China and the EU began cooperating in 1994 with the China-EU Energy Cooperation Forum. This relationship has led to environmental protection, technological exchange, industrial cooperation, and research and development. Cooperation between China and the U.S. began in the 1990s and has led to demonstration projects, technological cooperation, and the establishment of a dialogue mechanism. China has also developed a relationship with Japan, which has significantly improved wind-power technology in both countries. The relationship has also led to environmental protection, energy conservation, and emissions reduction. Relationships between China and Germany and China and the Netherlands have led to the implementation of small-scale projects in rural areas. Germany helped bring small hydropower plants to Tibet, and the Netherlands helped install 78,000 solar PV systems in remote homes (Zhao et al., 2011).

China has actually surpassed the U.S. as the country with the largest amount of installed wind-capacity in the world. In 2010, China met its 2020 wind-power goal of 30 GW (Schuman and Lin, 2012). In 2005, the Chinese government mandated that 70% of wind-power equipment must be produced domestically. However, in December 2009, this requirement was dropped to provide new opportunities for foreign manufacturers (Zhao et al., 2011). China has set wind-turbine implementation standards, and all turbines must undergo stringent testing before connecting to the grid. All turbines that are already in place must be retrofitted to meet the standard (Schuman and Lin, 2012).

One of the major barriers to China's RE implementation is grid connectivity. Grid enterprises have almost no incentive to build or expand grids to accommodate RE. Four factors disincentivize grid expansion: 1) most RE plants are located in rural areas far from the existing grid; 2) grid enterprises will bear part of the higher cost of installing RE infrastructure; 3) since RE still accounts for only a small share of total electricity generation, grid enterprises will have little opportunity to recoup their investment in infrastructure; and 4) since RE is intermittent and sensitive to seasonal and climatic changes, it may cause grid instability and increase the complexity of grid management (Wang et al., 2010).

China has perhaps the most top-down implementation plan for RE. Almost all RE decisions have been made by the government, and most RE projects are large-scale. Unlike the other case study countries, there is little citizen participation in RE policies and projects. However, China is one of the only countries to have implemented a Renewable Energy Law. A characteristic it shares with Germany and Spain.

China's recent push for RE implementation has lead it to be one of the top RE investors in the world. It currently holds the number one spot for total installed wind capacity, just behind the U.S.

United States

The U.S. is home to about 4.5% of the world's people who consume about 25% of global fossil-fuel resources (Institute for Energy Research, 2012). However, the U.S. consistently produces at least 25% of global GDP (U.S. Department of Agriculture, 2012). The country is known as a major user of nonrenewable-energy sources, emitting a large share of the world's emissions. However, the U.S. continues to make the implementation of sustainable energy systems a priority, and in 2011, it led RE investment with $48 billion. Between 2008 and 2010, RE accounted for more than 50% of new electricity capacity in the U.S., with wind accounting for 90% of electricity from renewables (Wang et al., 2010). RE policies and projects are initiated at the state and federal level.

Sustainable Energy Implementation At The Federal Level

Since the oil crisis of the 1970s, energy independence has been an important U.S. goal. President Nixon initiated Project Independence in 1973, and President Ford continued this project and called for an increase in domestic RE use. President Carter then took the initiative a step further by heavily funding the development of new renewable technologies, and setting a timetable for their entry into the market (Grossman, 2009).

The Energy Policy Act (EPAct) of 2005 established Federal renewable production and consumption requirements. EPAct requires the Secretary of Energy to "ensure that, to the extent economically feasible and technically practicable" the Federal government consumes the following amount of RE:

- Not less than 3% in fiscal years 2007-2009;
- Not less than 5% in fiscal years 2010-2012; and
- Not less than 7.5% in fiscal year 2013 and thereafter (U.S. Department of Energy: Energy Efficiency and Renewable Energy, 2012).

Although the U.S. set these requirements, there are a number of issues that arise. First, the requirements do not define "economically feasible and technically practicable." These are both quite subjective. These requirements have also not been defined as a Renewable Portfolio Standard, and thus are not strongly enforced nor are required for the nation as a whole. In addition, the percentage requirements are quite low, especially compared to the other case study countries. Lastly, there is no plan to continue to increase RE use beyond 7.5% beyond 2013. The government has not planned for continuous growth of RE beyond a very short time scale.

The Energy Independence and Security Act of 2007 established Federal energy-management goals and requirements beyond RE percentage requirements. It updated the 1978 National Energy Conservation Policy Act. The Act set standards in a number of areas including:

- Energy-reduction goals for federal buildings;
- Facility management/benchmarking;
- Performance and standards for new building and major renovations;
- High-performance buildings;
- Energy savings performance contracts;
- Metering;
- Energy-efficient product procurement;
- Office of Management and Budget reporting; and
- Reducing petroleum and increasing alternative fuel use (U.S. Department of Energy: Energy Efficiency and Renewable Energy, 2010).

Energy independence is necessary to achieve the goal of national security, so it has been promoted from both sides of the political spectrum as an important reason for focusing on domestic energy production (Grossman, 2009). "Broadly what is meant by security is the maintenance of a political order conducive to US access to the [Middle East] region's oil supplies, markets and communication routes and protection of related US investments and assets" (Salameh, 2003, p. 1085-1086).

Although there are few federal mandates, some federal financial mechanisms promote RE generation, most notably the production tax credit (PTC) and the investment tax credit (ITC). The PTC, first established in the Energy Policy Act of 1992, provided project owners in 2010 a tax credit of $22/MWh for wind, closed-loop biomass and geothermal, and $11/MWh for open-loop biomass, qualified hydroelectric, landfill gas, municipal solid waste, and marine and hydrokinetic power. The ITC was created by the EPAct of 2005, with the goal of reducing federal income taxes for RE project owners based on the capital investment value of the project. In 2010, the ITC provided a 30% tax credit for solar, small wind, and fuel cells, and a 10% tax credit for geothermal, combined heat and power, and micro-turbines. Both the PTC and the ITC have undergone changes on an annual or bi-annual basis, resulting in inconsistent policy support for renewables (Schuman and Lin, 2012).

In 2009, the government enacted the American Recovery and Reinvestment Act, which created a new 1603 Treasury Grant program. During the economic crisis of 2008, banks stopped taking advantage of the PTC due to profit instability, which lead to a reduction in available tax equity capital. The Act provides qualified project developers with cash grants up to 30% of capital costs of a project, in lieu of the PTC and ITC (Schuman and Lin, 2012).

The Department of Energy (DOE), launched by President Jimmy Carter in 1977, was another response to the energy crisis of the 1970s. The DOE centralized the responsibilities of the Federal Energy Administration, the Energy Research and Development Administration, the Federal Power Commission and other energy-related government programs into a single cabinet-level department. The current mission of the DOE is "to ensure America's security and prosperity by addressing its energy, environmental and nuclear challenges through transformative science and technology solution" (2012). The Department became "responsible for long-term, high-risk research and development of energy technology, federal power marketing, energy conservation, energy regulatory programs, a central energy data collection and analysis program, and nuclear weapons research, development and production" (Department of Energy, 2012). The DOE also funded the creation of the Database of State Incentives for Renewables and Efficiency, which provides easily accessible and transparent information about how to finance a RE and/or energy-efficiency project.[6]

RE can impact, and be impacted by, tourism. People are interested in seeing RE technology in action (Polatidis and Haralambopoulos, 2004). They are also interested in staying at hotels and going to restaurants that use energy sustainably. The Green Hotel movement has boomed in recent years. There is even a Renewable Energy in Tourism Initiative, which is a joint venture of the University of Colorado Energy Initiative, East Carolina University's Center for Sustainable Tourism, and the U.S. National Renewable Energy Lab, each of which represents different stakeholders.

A barrier to RE implementation at the federal level in the U.S. is that RE is prioritized primarily as a response to crises. But when projects are implemented in times of crisis or too quickly they are likely to fail (Grossman, 2009). States are more consistently innovative in the energy sector than is the federal government.

Sustainable Energy Implementation At The State Level

Federal policies are fewer and less innovative than state policies, which sets the U.S. apart from the other case-study countries. Most federal energy policies must be periodically renewed, which reflects a lack of long-term commitment. The U.S. has yet to set a national RPS, mandatory national RE targets, or FITs. Yet most states have an RPS, and some states and cities are experimenting with FITs (Schuman and Lin, 2012). For example, in California, "investor owned utilities are required to procure an additional 1% of retail sales per year from renewable sources...and all utilities are required to achieve 33% of their electricity from renewables by 2020" (Schuman and Lin, 2012, p. 13).

State-level RPS targets depend on a number of variables, including natural resources, political influence (majority Democrat versus Republican), and the organization of the RE industry within the state. Also, states regulate their RPS differently, with some states imposing a financial penalty for noncompliance (Yin and Powers et al., 2010).

[6]For a list of federal incentives see Appendix A.

In addition to an RPS, states have used a number of other policy instruments to encourage RE development.[7] One such instrument is the mandatory green power option: a utility company provides consumers with the option to buy green power, which the utility must then generate through direct RE implementation, or by purchasing RECs to equal the amount of green power purchased by the consumers. Some states have created a public benefit fund, either charging consumers a small amount or having utilities pay to support local energy efficiency and RE projects. Many states have also enacted net metering laws and interconnection standards, both of which facilitate the implementation of small-scale consumer-generated RE projects (Yin and Powers, 2010).

The strength of state-level policies is determined by a number of institutional factors. Currently, electricity prices are higher when a greater amount of RE is consumed. Thus, states with a higher income are more likely to develop a greater number of RE projects. There will also be a stronger demand for RE projects in a state where citizens value the environment. A state with fewer natural fossil-fuel resources will also be more likely to develop RE in order to diversify its energy portfolio and reduce its dependence on outside sources of energy (Yin and Powers, 2010).

In Summary

Unlike the four other case studies, the U.S. Federal government is not the strongest driver of RE implementation in the country. Almost all RE policies and projects are initiated and deployed at the state level. This has allowed some states to lead the way in RE implementation, California can even be considered a world leader, while other states, like Alabama and West Virginia, do very little. This is most likely because although the country is currently led by a democratic president, states can be either majority Democrats or Republicans. Republican governments have historically been much more pro-nonrenewables and anti-renewables than democratic governments. (California is currently strongly democratic, while both Alabama and West Virginia are led by republican governments.)

Renewable Energy Governance At The International Level

The International Energy Agency (IEA) was founded in the 1970s after the oil crisis to "... ensure reliable, affordable and clean energy for its 28 member countries and beyond." The IEA focuses on energy security, economic development, environmental awareness, and engagement

[7]For a list of state-level mandates please see Appendices B and C.

worldwide. A Working Party on Renewable Energy Technologies within the IEA "promotes the development, demonstration and deployment of technologies to meet challenges in the energy sector" (International Energy Agency, 2012).

The International Renewable Energy Agency (IRENA) is an intergovernmental agency dedicated to increasing the adoption and sustainable use of RE technologies. The Agency was founded in Germany in 2009, and includes 158 countries and the EU. One hundred of these countries, and the EU, have ratified the Agency's Statute (International Renewable Energy Agency, 2012).[8] IRENA has published a number of reports, papers, and brochures, on topics such as electricity storage, job and cost analyses, country profiles, and scenarios and strategies for implementation.

3.5 CASE STUDY COMPARISONS: INSTITUTIONAL DRIVERS

Government Commitment

Government commitment is quite strong in all of the case study countries. Germany is recognized globally for its RE policies and financial mechanisms. The government has not only passed an RE law, but the country has also set the strictest RPS: 100% renewables by 2050. The government has truly listened to the needs of the people; German's have historically been some of the most concerned with the negative consequences of global climate change. The citizens, along with the German government, have acted quickly to mitigate these consequences by implementing strong RE policies and financial mechanisms.

Spain's government has also taken a strong initiative to implement RE policies and projects. Like Germany, Spain has implemented an RE law. However, unlike Germany, where citizens have strongly fought for RE, Spain is one of the least dense countries, so while citizens may not strongly push for RE, they also do not oppose it. The NIMBY effect is rarely a problem in the country. Spain's government could improve their RE implementation strategy by making the authorization process less complicated. Allowing projects to proceed smoothly would allow Spain to reach its RPS goal of 22.7% by 2020 quicker. Spain's government is also the only one to have implemented a

[8] To read the Statute please visit: http://www.irena.org/menu/index.aspx?mnu=cat&PriMenuID=13&CatID=126. Note: the dash at the end of the line is a line break, not part of the url.

FIT policy, and then removed it during the financial crisis. Spain's government must either reinstate the FIT policy, or implement a net metering law, in order to achieve its RE goals.

Brazil's government recognized the problems with being reliant on fossil fuels much earlier than almost any other government. Following the oil crisis of the 1970s, Brazil worked diligently to reduce its dependency on foreign oil, and focused on developing its biofuels industry. Thanks to this push, biofuels are now competitive on an international market with gasoline, without the need for subsidies. Brazil's government has also implemented a progressive RE auction system, similar to the ones successfully used in Europe. By being innovative, but learning from other countries, Brazil is quickly progressing to achieve its strong RPS goal of 75% renewables by 2030.

In China, the government is the number one driver of RE implementation. China is already a very hierarchical system, with the government driving most of the economic development. This is no different for RE implementation. The government is one of the only Asian countries to have passed an RE law. This makes RE implementation a legal action, and not only necessary for growth, but a requirement. China's government has also chosen a RE policy framework similar to that used in Germany, which is globally known for its RE implementation strategy.

While government commitment is relatively high in the U.S., President Obama is consistently pushing for RE implementation, the strongest RE policies have been implemented at the state, rather than the federal, level. The government has yet to implement a national RPS, while most states have. The federal government's reluctance to implement stronger RE policies is most likely due to special interests. Lobbyists have a strong influence in the U.S., and oil lobbyists have successfully kept national RE policies to a minimum. (In 2010, oil and gas lobbyists spent nearly $112 million, while RE lobbyists spent almost $40 million, about one third as much of the oil and gas lobbyists (Lacey, 2010).) Also, politicians potentially hold office for a relatively short period of time, and a great deal of their term is spent preparing for future campaigns. This leaves little time to focus on implementing RE policies.

It is clear from the case studies that success with renewables requires government commitment. In all five countries, governments have prioritized RE implementation by setting standards and providing financial incentives. Except for the U.S., all of the case-study countries have set a national RPS. In the U.S., 29 states (58%) have set an RPS. "RPS goals emphasize the importance of establishing long-term, consistent targets and price signals for renewable energy to encourage sustained investment in renewable energy projects" (Schuman and Lin, 2012, p. 14).

Establishment of an implementation guide that outlines key steps and/or benchmarks is another kind of commitment that characterizes successful energy transitions (e.g., China, Spain, Brazil, and Germany). Such a guide acts as a transition plan for change at all levels, from national to local. Local-level plans are important because they can incorporate local knowledge about what kinds of changes are most likely to succeed in a given community. Previous research suggests that transition plans need to be flexible and adaptable since "International regimes...undergo continuous transformations in response to their own inner dynamics as well as to changes in their political, economic, and social environments" (Young, 1982, p. 291).

The analysis of the case studies suggests that no single financial mechanism will lead to high RE use. Governments must create an array of financial incentives, rebates, and subsidies. The case-study countries have each used a variety of financial incentives to promote RE implementation. The most common are tax incentives and government subsidies, rebates, and loans. In Brazil, the market, and not the government, drives the price for biofuels. Therefore, sustainable financial schemes should aim ultimately to replace government support with market-based support.

The case studies support the idea that innovation and proactivity at local and provincial/state levels can promote a transition in a country that may face barriers to innovation at the national level. This is especially true in the U.S. The U.S. allows state governments to establish their own RE standards and incentives, following the advice of Schuman and Lin: "The central government should not prevent a province from taking such proactive measures should it choose to pursue a more aggressive renewable energy policy" (2012, p. 17).

In at least four of the five case-study countries, formal rules accommodate consumer needs and preferences. Among these four, Germany is especially notable because the strong citizen commitment to alleviating climate change is reflected in extremely ambitious governmental policies.

All of the case-study countries have multiple organizations acting to promote RE. This supports Ostrom's (2005) argument that intentional change should be a multi-agency effort. Ministries and departments need to communicate with each other to coordinate implementation and avoid overlap. Multi-agency efforts increase research and development as well as the successful deployment of RE technology.

These cases show that long-term RE implementation is strongest in a country where the government listens to the people, and creates policies that are not only beneficial for the nation, but for the citizens as well. Government's that have implemented the strongest RE policies and RPS, such as Germany and Brazil, have done so thanks in part to a push by the citizens.

The case studies demonstrate that national approaches make it possible to implement large-scale RE projects, such as wind and/or solar farms, hydropower plants, and/or biogas plants. It is these large-scale projects that most increase a country's RE use.

Polycentricity

A self governed, polycentric system is one "where actors, who are major users of the resource, are involved over time in making and adapting rules within collective choice arenas regarding the inclusion or exclusion of participants, appropriation strategies, obligations of participants, monitoring and sanctioning, and conflict resolution," and thus, "participants make many, but not necessarily all, rules that affect the sustainability of the resource system and its use" (Ostrom, 2008, p. 8). Polycentricity can impact the scale at which different energy sources are used, as well as the rate at which technologies are implemented. All of the case studies allow for some form of polycentricity in RE implementation.

The European Union is emphasizing bottom-up energy management. In the 1990s, the European Commission initiated the SAVE and SAVE II Programmes, focusing on regional and urban energy management. Both of these Programmes encourage local and regional action, resource use, and sustainable development. In 2004, SAVE co-funded the creation of autonomous Energy Management Agencies at the local and regional levels, under the the framework of the Intelligent Energy Europe-Programme. By 2013, about 80 of these energy agencies had been created (ManagEnergy, 2013; European Commission: Intelligent Energy Europe, 2013).

As mentioned above, German citizens have pushed and been supportive of the many RE policies and projects. There has also been a number of political and non-government organizations that have helped in the research and development, education, and deployment of RE technologies.

The Green Party has also been a major proponent of RE in parliament. The German Renewable Energy Federation BEE acts as the political umbrella organization with 22 associations and over 30,000 individual members and companies. The organization promotes RE through hearings, studies, and legislative and media support (Bundesverband Erneuerbare Energie e.V., 2013). There are also a number of powerful RE nonprofit organizations in Germany, including the World Wind Energy Association, the International Photovoltaic Equipment Association, and the European Association for Renewable Energies, otherwise known as EUROSOLAR.

While citizen engagement is lacking in Spain, the government, banks, and industry have played an important role in RE implementation. Many industry groups belong to the Spanish Association of Renewable Energy Producers, created under the SAVE Programme mentioned above. Also, Spain is driving technology innovation at the National Renewable Energy Center.

Stakeholders have been very supportive of RE policies and projects in Brazil, especially the Proalcool program. While lacking in citizen-led organizations, Brazil does have three notable market facilitation organizations that are supporting the growth of RE markets: Biomass Users Network Brazil, Brazilian Renewable Energy Companies Association, and Winrock Brazil, which is focusing on empowerment and civic engagement.

Although China's RE policies are very top-down, there are examples of polycentricity. For example, a greenhouse gas emissions cap-and-trade system has been deployed in the cities of Beijing, Tianjin, Shanghai, Chongqing and Shenzhen, and the provinces of Hubei and Guangdong. Also, in 2000, China established the China Renewable Energy Industries Association (CREIA), with a membership of over 200 from industry, organizations, academies, and individual experts. CREIA promotes the deployment of RE technologies by developing and disseminating studies and surveys, workshops, and expert groups (Europe-China Clean Energy Centre, 2013). In addition, the China Sustainable Energy Program, established in 1999, consists of scientists, analysts, policy makers, and business leaders who help deploy RE policies and projects through reports, workshops, and grants (The China Sustainable Energy Program, 2013).

The U.S. allows for polycentricity in a number of different arenas. At the federal level, RE lobbyists support the missions of their organizations. These organizations can lobby to politicians for the use of RE technologies and the implementation of RE policies. The top four RE lobbyists in 2010 were the American Wind Energy Association, the National Rural Water Association, Growth Energy, and Renewable Fuels Association, spending nearly $5.4 million (Lacey, 2010). The U.S. also allows for polycentricity at the state, and even city, level since governments at this level can lead their own initiatives in setting RE policies and projects. There are also a number of organizations at various levels promoting RE development, including: the National Renewable Energy Laboratory, the only federal laboratory dedicated to the research, development, commercialization, and deployment of RE; the United States Renewable Energy Association, a volunteer advocacy group; and the American Council on Renewable Energy, a 501(c)(3) non-profit organization focusing on RE education.

Polycentricity is strongest in countries that allow for a variety of self governance regimes at different scales. Germany and the U.S. are arguably the most polycentric in terms of RE among the case study countries. Both countries allow for citizen engagement through a variety of nongovernmental organizations. Both countries also have RE lobbyists at the political level and umbrella organizations for RE industries. While Spain, Brazil, and China have industry groups, none of these countries have powerful citizen-led organizations.

Stakeholder Participation And Community Building

All of the case-study countries have engaged a variety of stakeholders, although not all have involved all of them, and all have continually revised their RE laws and/or plans. Small-scale and rural RE projects in all of the countries emphasize the use of local knowledge.

Stakeholder engagement, especially at the local level, has been a priority in Germany, where citizens highly value the environment and the services it provides. Stakeholder engagement "...involves many layers and kinds of decisions, and requires the construction of a dialogue process among many social actors, individual and collective, formal and informal, local and not" (Gamboa et al., 2005, p. 3).

China's lack of engagement with diverse stakeholders is probably due to its highly centralized, nondemocratic government structure. "When neighborhood residents share a sense of community they are more likely to feel attached to the neighborhood, engage in neighboring behavior, and participate in collective efforts to make the neighborhood better" (Anderson and

Milligan, 2006, p. 36). This sense of community is a characteristic of citizens living in a democratic country. These citizens tend to value social capital that "...has come to be associated with a host of behaviors and outcomes that are positive for individuals, social groups, communities, and society at large" (Anderson and Milligan, 2006, p. 25).

In a democracy, local communities and stakeholders can influence national policy. This power is exemplified in the U.S., where progressive state policies have preceded and served as models for national policies (e.g., California's emissions standards and Massachusetts' health-care reform). It is likely that state-level RE policies will have a similar impact. As noted above, many smaller-scale energy transitions, such as those seen in states, can lead to a national energy transition. If each state sets an RPS, and achieves this target, then the U.S. as whole will be experiencing an energy transition.

In all of the case-study countries, RE use can increase employment opportunities. Renewables are "...more labor-intensive, requiring more workforce per unit of energy than conventional fossil fuels" (Goldemberg, 2007, p. 808). Both large-scale and small-scale projects create new jobs.

Transparency of Information

Transparency is facilitated by stakeholder engagement and documentation (Ostrom, 2005). Sharing of knowledge and technologies also increases transparency. All of the case-study countries have policies or mechanisms to make RE projects transparent, although some more strongly than others.

Stakeholder engagement is one of the driving forces of transparency in Germany. The citizens have pushed the government to create policies mitigating the impacts of climate change, and the government has done so with some of the most successful RE policies and financial mechanisms in the world. Germany has also been quick to share its success with other countries interested in following its lead. Germany holds market shares in a number of RE technologies, and it has helped other countries implement RE projects and policies. (The German FIT system has been copied by many other countries, including China.)

Spain's RE implementation is also transparent, thanks in large part to its innovation in RE technologies. For example, some of the top wind turbine manufacturing companies are in Spain, and Spanish wind turbines can be seen around the world. Spain also has developed an innovative information system that relays immediate wind power information to the public every 12 seconds. However, stakeholder engagement in Spain is relatively low. The role of private individuals in RE project and policy implementation has been insignificant compared to other countries, such as Germany.

Brazil's Proalcool program is well known as one of the top biofuel programs. It has been widely successful because all stakeholders were in agreement to make the transition to ethanol fuels, from consumers to farmers to car manufacturers. Brazil has also encouraged citizens to get involved as RE entrepreneurs by allowing for small-scale RE projects, such as solar and biodiesel production. Brazil's RE auction system has also increased transparency within the country.

China's transparency lies in its RE law. Smaller-scale projects can connect to the grid via China's net metering regulation. Also, all citizens take part in the energy transition since there is a surcharge on electricity consumption to pay for RE projects. Electricity generators and grid companies are also transparent since they must meet RPS targets by a certain date, and they must report progress towards these targets monthly. Lastly, China has increased transparency through numerous bilateral and multilateral cooperation mechanisms. By 2010, it had 63 such collaborations.

Although the U.S. has yet to set national RE goals or targets, RE implementation is still transparent in the country thanks to state initiatives and publicly available information. RE policies and financial mechanisms, both at the federal and individual state level, are available via the Database of State Incentives for Renewables and Efficiency website. Many states allow for small-scale RE implementation thanks to its net metering policies. The DOE also provides up-to-date information on energy consumption and production in the country, for both nonrenewable and renewable energy sources.

Organizations have also played a role in making RE transparent in the international community. Both the IEA and IRENA produce up-to-date information about international RE production and use. A primary focus of the IEA is to engage the international community. IRENA's main purpose is to increase adoption of RE technologies. Both organizations rely on country membership, and both also publish all relevant data.

All of the case study countries facilitate transparency. Every government provides an annual report on energy production and consumption, including RE. Making information available to the public raises public awareness, encouraging public discussions and analysis of RE policies potentially making them stronger. Public information can also lead to additional RE investments "by providing investors with confidence and predictability regarding the expected development of RE in a particular region" (Schuman and Lin, 2012, p. 17).

All of the case study countries have demonstrated that trading information and ideas not only promotes energy transitions but also makes them transparent. Trading information and technology creates collaborative networks, and makes more people aware of both current and potential RE implementation. Trading and sharing information promotes more effective project monitoring, which in turn increases the likelihood of project success. Transparent societies can become sustainable societies because they "are good neighbors that reach out to engage in cooperative, peaceful, and mutually beneficial relationships with all people through trade, cultural exchange, and the sharing of information and technology" (Cavanagh, 2004, p. 84).

Pilot Programs And Technology Innovation

All of the case-study countries have made use of pilot projects to initiate RE implementation. They also invest in technology innovation programs. Using pilot programs to test innovative technology helps a country evaluate the feasibility of larger-scale projects. All of the case-study countries have university and technical training programs that prepare workers to use and maintain RE technology.

Compliance With The Kyoto Protocol

All of the case-study countries signed the Kyoto Protocol; the U.S. is the only country that also did not ratify it. The Kyoto Protocol required countries to reduce their greenhouse gas emissions 5% below 1990 levels between 2008-2012. This commitment created a strong initial incentive for the case-study countries to implement RE policies and projects.

Grid Connectivity

Grid connectivity is a common barrier to RE implementation in the case-study countries. In all of the countries, it is still difficult to feed RE into the grid. All of the case-study countries will either have to retrofit existing grids or create new grid systems. Germany recognizes this requirement and has the strongest policies to meet it.

Monitoring

A common barrier to RE implementation in the case studies is a lack of disincentives to noncompliance. To achieve RE targets, countries need formal and informal institutions that monitor compliance. Formal institutions include fines and other strong disincentives for violating laws and failing to meet RPSs that deter future noncompliance (Schuman and Lin, 2012). Informal institutions include self-policing and gossip (Anderson and Milligan, 2006). "Social preferences such as shame, guilt, and reciprocity may allow coordination of the actions of large numbers of people in their mutual interest...[and] most successful communities do not rely entirely on good will, but supplement it with mutual monitoring and punishment for transgression of norm" (Bowles, 2006, p. 131, 148).

3.6 APPLYING THE IADF TO THE INSTITUTIONAL DRIVERS

An institutional analysis of the five case studies has produced eight institutional drivers that are necessary for an energy transition:

- Government commitment;
- Polycentricity;
- Stakeholder participation and community building;
- Transparency of information;
- Pilot programs and technology innovation;
- Compliance with the Kyoto Protocol;
- Grid connectivity; and
- Monitoring.

For RE use to be successful, both top-down and bottom-up drivers are necessary. Government commitment represents a top-down approach, while stakeholder participation and community building represents a bottom-up approach. A combination of both of these drivers allows for polycentricity. As mentioned earlier, an energy system is complex and, for the most part, invisible to most end users. This is why it is so difficult to change. Transparency of information makes the system more visible and creates a relationship between the user and the energy. Pilot programs and technology innovation connects scope and payoff rules to change the biophysical conditions and attributes of the community. Monitoring is necessary otherwise the rules in use that are put in place are ineffective.

These eight institutional drivers directly stem from the Institutional Analysis and Development Framework (IADF). The first driver, government commitment, represents a combination of rules and monitoring; monitoring being one of Ostrom's design principles. The government also provides the policies and resources, such as financial mechanisms, that ensure that RE technologies can be implemented on a large scale. Polycentricity, the second driver, represents the interaction between the attributes of the community and rules in use. This driver matches power and decision making to the right biophysical context.

Thirdly, stakeholder participation and community building combines the attributes of the community and rules in use. The driver defines who is involved in decision making. The driver also ensures that community building becomes a norm. The fourth driver, transparency of information, is an information rule, but also represents an active effort to provide information to the relevant stakeholders. Fifthly, pilot programs and technology innovation generate new decision-making environments that have not yet been constructed. These new environments allow for the deployment and long-term assurance of large scale RE technologies.

The sixth driver, compliance with the Kyoto Protocol, is essentially a norm. The community in this case is very large, since there are many countries that have signed and/or ratified the Kyoto Protocol. Thus, it is the combination of the attributes of the community and biophysical context that is going to drive the implementation and success of the Protocol. A country that chooses to enforce the Kyoto Protocol has a population that believes it is important and has the technology and resources available to use RE. Most countries that have signed and ratified the Protocol do not have infrastructure lock-in; countries like the United States and Australia have been hesitant to comply because doing so is financially and technologically expensive.

The Kyoto Protocol has also not been successful because of a lack of international agreements. There is no global enforcement mechanism that can monitor and/or sanction compliance of the Protocol. This is why the success of the Protocol comes down to whether a country makes it a norm. Thus, the biophysical conditions becomes essential.

However, a similar protocol, the Montreal Protocol, has been cited as being a great success in reducing emissions of ozone-depleting chemicals (Sunstein, 2006). The underlying cause of the differences in success of the two protocols is the payoff structure. Sunstein argues that

> *"Both the success of the Montreal Protocol and the mixed picture for the Kyoto Protocol were largely driven by the decisions of the United States, and those decisions were driven in turn by a form of purely domestic cost-benefit analysis. To the United States, the monetized benefits of the Montreal Protocol dwarfed the monetized costs, and hence the circumstances were extremely promising for American support and even enthusiasm for the agreement. Remarkably, the United States had so much to lose from depletion of the ozone layer that it would have been worthwhile for the nation to act unilaterally to take the steps required by the Montreal Protocol. For the world as a whole, the argument for the Montreal Protocol was overwhelmingly strong"* (2006, p. 5).

Complying with the Kyoto Protocol does not produce the same monetized benefits to the U.S. that the Montreal Protocol did, thus leading to its partial failure.

The seventh driver, grid connectivity, representing the biophysical conditions, has proven to be one of the largest limiting factors. Even if the attributes of the community show that stakeholders are pushing for RE use, and the rules in use are implemented to allow for RE use, without the biophysical conditions, (in this case, a grid system that allows for RE penetration) RE will not be successful long-term.

The last driver, monitoring, has also been one of the major limiting factors to successful RE implementation. This driver relates directly back to one of Ostrom's eight design principle, also titled monitoring. Ostrom argues that "...rules must be enforced in some manner to achieve robust governance" (2005, p. 265). Without monitoring, the rules in use are ineffective. Even if a country has RE targets as a norm, without proper monitoring, sanctioning, and enforcement of the targets, RE goals may ultimately fail.

3.7 CONCLUSION

The case studies suggest that initial RE implementation was a response to oil crises and mitigating the effects of climate change. Regardless of the kind of RE available and the kind predominantly used, RE implementation rests on a handful of institutional drivers. The most essential of these drivers to increase a country's RE share in its energy portfolio is government commitment. Among the case-study countries, the goals for RE share range from 20% by 2020 in China and Spain to 100% by 2050 in Germany. To meet these goals, every country has created laws, policies, regulations, and/or financial mechanisms.

Every country plays a significant global role in technology innovation. These countries represent the most innovative along with the highest implementors of RE technologies. Each country also provides for some degree of transparency and stakeholder participation. Although important, transparency and stakeholder participation may not be necessary for a country to initially invest in RE implementation, as is the case with China. However, long term implementation relies on these two features, as the other case studies show.

All of the countries share two common barriers, grid connectivity and monitoring. Thus, all of the countries need to create policies and financial mechanisms to increase investment in retrofitting and/or building new grids, along with implementing effective monitoring systems. Also, lack of disincentives for non-compliance seem to be as important as the existence of incentives for investment.

Although polycentric governance and stakeholder engagement seem to be crucial for RE implementation, China shows that these two features are not necessary. Countries with a highly hierarchical government may end up being the short-term RE leaders. This concept can be further expanded by researching RE implementation in nondemocratic countries, such as Cuba, Qatar, Saudi Arabia, North Korea, and the United Arab Emirates.

The following chapter applies the above eight institutional drivers to a sixth case study country, Thailand. Thailand has been quite innovative in its RE implementation strategies. This is highly unusual considering its geographic location and unique history - unlike most developed countries, Thailand was never colonized. Chapter 4 will provide an in-depth look at Thailand's energy system and will analyze whether the eight institutional drivers have promoted the use of RE in the country.

Chapter 4

INSTITUTIONAL DRIVERS OF RENEWABLE-ENERGY IMPLEMENTATION IN THAILAND

4.1 INTRODUCTION

While many countries could have been chosen for an in-depth case study, Thailand has proven to be quite an interesting case. To begin with, Thailand is geographically unique with three main characteristics that set it apart from other Southeast Asian countries. First, Thailand has never been colonized. Second, Thailand has a strong infrastructure system, including a water, road, and energy system that is similar to those found in the developed world. Third, it is no longer considered a developing country but a mid-developed country. In addition, Thailand has renewable energy (RE) implementation mechanisms similar to those implemented in some of the top RE using countries. (The importance of these characteristics with respect to energy transitions will be expanded upon below.)

Thailand's energy resource story can be simplified to a transition from large-scale hydropower to coal to natural gas. Originally, large-scale hydropower plants dominated Thailand's energy sector. However, in the 1980s, Thais started heavily protesting hydropower because of the impacts the reservoirs, created by the dams, had on the environment. These reservoirs flooded out farmland and pristine ecosystems. The government decided to move away from large-scale hydropower and focus on using coal resources. Again, there were major protests against the high-polluting resource. Thailand then shifted its focus to using natural gas, a resource imported and extracted from natural gas fields in the Gulf of Thailand. However, there is only about a 15-20 year time horizon of domestic supply left (C. Greacen, personal communication, March 7, 2013). Thailand thus has two options: it can import its energy or increase RE use. Although imports do a play a role in Thailand's energy system, RE has seen a large amount of political support in Thailand, and the government has implemented a number of RE policies and financial mechanisms.

Thailand implemented its first RE policy in 2002 when the Cabinet passed the Very Small Power Producers (VSPP) regulation leading to a significant deployment of RE, especially in rural areas (C. Greacen, personal communication, March 7, 2013). (The VSPP allows for RE projects under 10 MW to tie into the grid.) However, until 2008, Thailand's Parliament had implemented "no direct legislative or regulatory guidelines...specifically designed for promotion of sustainable energy" (Uddin et al., 2010, p. 72). In 2008, Thailand's Ministry of Energy launched the 15-Year Renewable Energy Development Plan (REDP), with a target of 20% RE use by 2022 (Chantanakome, 2008). In 2012, the plan was replaced by the Alternative Energy Development Plan (2012-2021), with a more ambitious target of 25% by 2021.

This chapter presents a case study of Thailand's planning for and progress towards an energy transition. It discusses Thailands existing energy structure, RE projects, and policies associated with renewables. The institutional drivers defined in the previous chapter are then applied to Thailand. The chapter then ends with a brief discussion of the cultural context of Thailand's energy transition. Thailand demonstrates how a country can be energy efficient while still developing.

4.2 ENERGY SITUATION

Energy Production and Consumption, 1980-2011

Historically, Thailand industrialized much faster than most Southeast Asian nations. Between 1980 and 2001, Thailand's energy consumption grew faster than that of any other country in Southeast Asia (Table 4.1). In 2010, net energy consumption cost Thailand 1.52 trillion Baht ($50 billion) (Nakornthap, 2011). Though consumption has increased rapidly, along with economic development, so has production (Figure 4.1). Nevertheless, Thailand consumes about twice as much energy as it produces. This high consumption is due in part to an increasing electricity demand, the highest in Southeast Asia: nearly 100% of villages and 87% of households have access to electricity (S. Gheewala, personal communication, March 5, 2013; Tongsopit and Greacen, 2012; Department of Alternative Development and Efficiency, 2010).

Energy sources changed significantly from 1980 to 2011 (Figure 4.2). In 1980, Thailand's energy fuel share was comprised mostly of petroleum and a small amount of coal and hydropower. Petroleum imports grew steadily between 1985 and 1995, and have since fluctuated but not increased. Meanwhile, coal and natural gas comprised a negligible share of fossil fuel imports until 1992, when coal imports began to increase steadily. Although Thailand has some coal resources,

Country	Absolute Growth rate	Annualized Growth Rate
Thailand	480%	23%
Malaysia	475%	23%
South Korea	344%	16%
Indonesia	309%	15%
Vietnam	300%	14%

Table 4.1: Growth Rates Based on Energy Consumption in Selected Southeast Asian Countries, 1980-2001. Thailand had the largest absolute growth rate during this time period. Data Source: Energy Information Administration, 2012

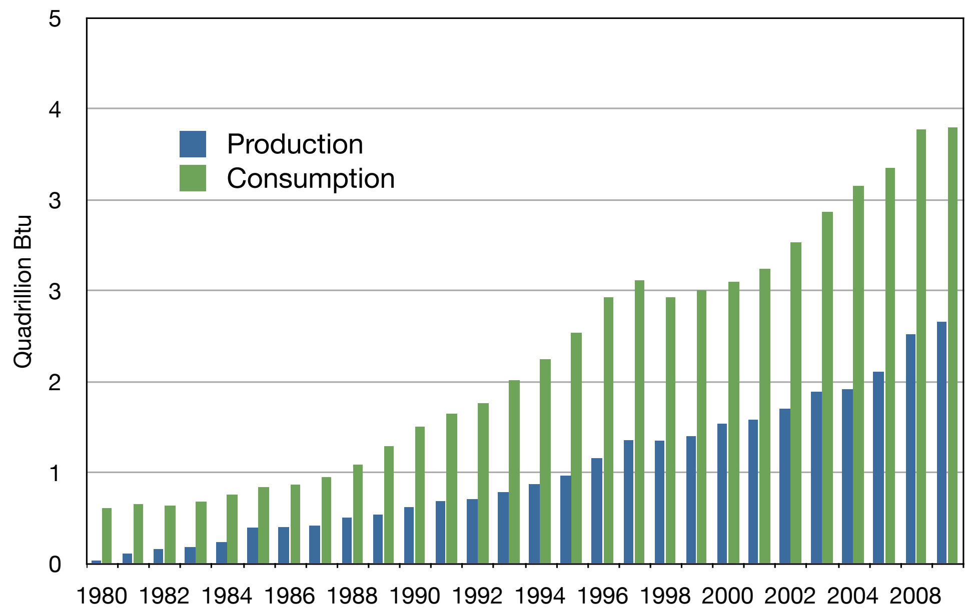

Figure 4.1: Thailand's energy production and consumption. Both production and consumption have tripled in 30 years. Data Source: Energy Information Administration, 2012

it imports most of its coal from Indonesia and Australia, but Burma, Laos, China, and Cambodia also export some of their coal to Thailand (C. Greacen, personal communication, March 7, 2013). Natural gas imports began to increase sharply in 1999, when Thailand began importing natural gas from Myanmar.

In 1980, Thailand produced neither oil nor natural gas and only two million short tons of coal (Energy Information Administration, 2012). By 2011, Thailand produced about 400 thousand barrels of oil per day, 1,300 billion cubic feet of natural gas per year, and about 24 million short

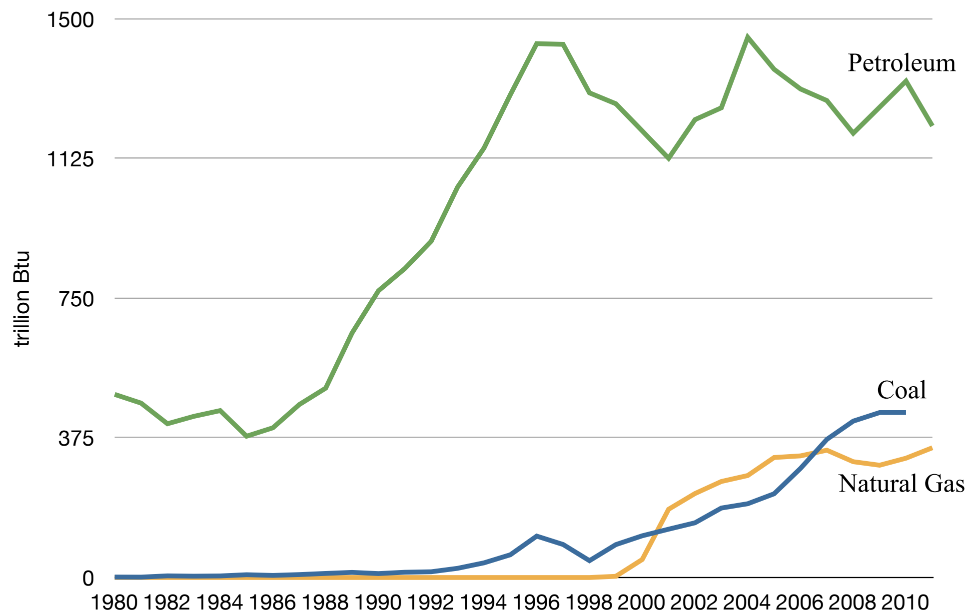

Figure 4.2: Fossil fuel imports, 1980-2011. Fossil fuel imports are beginning to level off. Data Source: Energy Information Administration, 2012

tons of coal per year (Energy Information Administration, 2012). These numbers represent 42% of the oil, 79% of the natural gas, and 69% of the coal consumed in the country; domestic fossil fuel production has increased dramatically.

Thailand continues to build nonrenewable-energy plants partly because of take-or-pay contracts.[1] Energy producers make profits from having installed capacity that is available to be dispatched, and the actual fuel generation is a pass through. Thus, companies have a high incentive to build power plants whether or not they are being used. This has led to an excess of power plants in Thailand. Currently, total installed capacity is greater than peak demand by about 20% (C. Greacen, personal communication, March 7, 2013).

Thailand remains substantially dependent on imported crude oil, making it vulnerable to oil shocks. Because of energy security concerns, Thailand is curbing its fossil fuel imports. In 2009, Salamander Energy PLC, an independent oil exploration and production company based in Asia, began drilling in the Gulf of Thailand's Bualuang oil field. Over the past three years, this field has

[1]A take-or-pay contract is an agreement between two parties where one party agrees to either buy the product or service by a certain date or to pay them even if that party does not need the product or service on that date (Farlex Financial Dictionary, 2012).

produced an average of 8,300 barrels of oil equivalent per day (bopd). In 2012, Salamander began "drilling the first of 16 development wells that will drive production up to between 11,000 bopd and 14,000 bopd in 2013" (Salamander Energy, 2012). This demonstrates Thailand's continuing efforts to produce more domestic oil.

As seen in Figure 4.3 natural gas is Thailand's primary fossil fuel resource, found mainly in the Gulf of Thailand (C. Greacen, personal communication, March 7, 2013). In 1980, hydropower was the only renewable resource that Thailand used to generate electricity. Large-scale hydropower makes up the largest share of RE production mainly because of the still operational Bhumipol and Srinagarind Dams. Large-scale hydropower plants are no longer constructed in Thailand, and the country has began focusing on other sources of RE, such as biomass, solar, and wind (Kongbuamai et al., 2012).

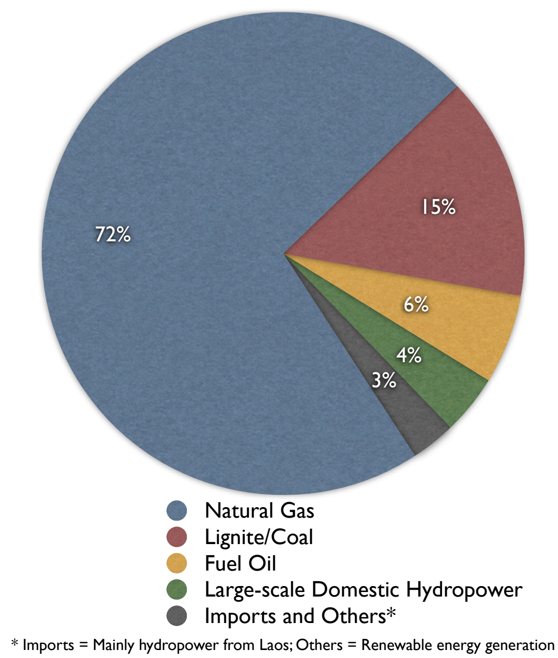

Figure 4.3: Thailand's electricity production, 2009. Thailand relies heavily on its domestic natural gas supply. Data Source: World Alliance for Decentralised Energy and The Energy Conservation Center of Thailand, 2009

In terms of the energy sectors, manufacturing and transportation are the biggest consumers of energy (Figure 4.4). Although high, Thailand's consumption of energy for transportation is similar to that of other Asian countries (Energy Information Administration, 2011).

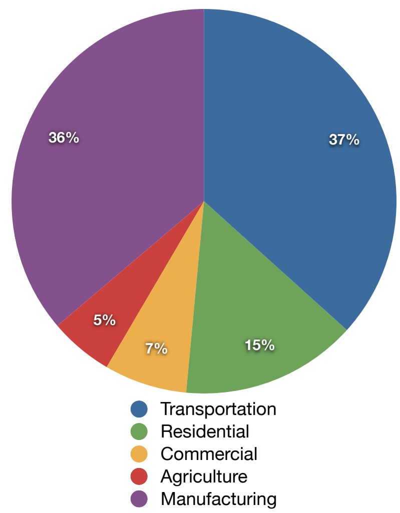

Figure 4.4: Energy consumption by economic sector, 2007. Thailand's manufacturing and transportation sectors are the most energy intensive. Data Source: Department of Alternative Development and Efficiency, 2007

The transition to renewables

Thailand's renewable energy governance model

Figure 4.5 outlines the governance structure that impacts and is impacted by energy decisions (including RE polices and projects) made by the various governmental ministries and departments in Thailand. Although King Bhumibol Adulyadej can influence decisions made in the Cabinet, he does not directly write policy. The Cabinet, which is ran by the Prime Minister, represents the highest degree of decision-making in Thailand.

The Office of the Prime Minister directly helped implement RE projects in Thailand with the Government Sustainability Challenge. This Challenge deployed small-scale solar PV projects in rural villages throughout Thailand. The Office of the Prime Minister houses the National Economic and Social Development Board (NESDB), which has made a variety of over-arching goals for Thailand including the Sufficiency Economy Plan and the Gross National Happiness framework.

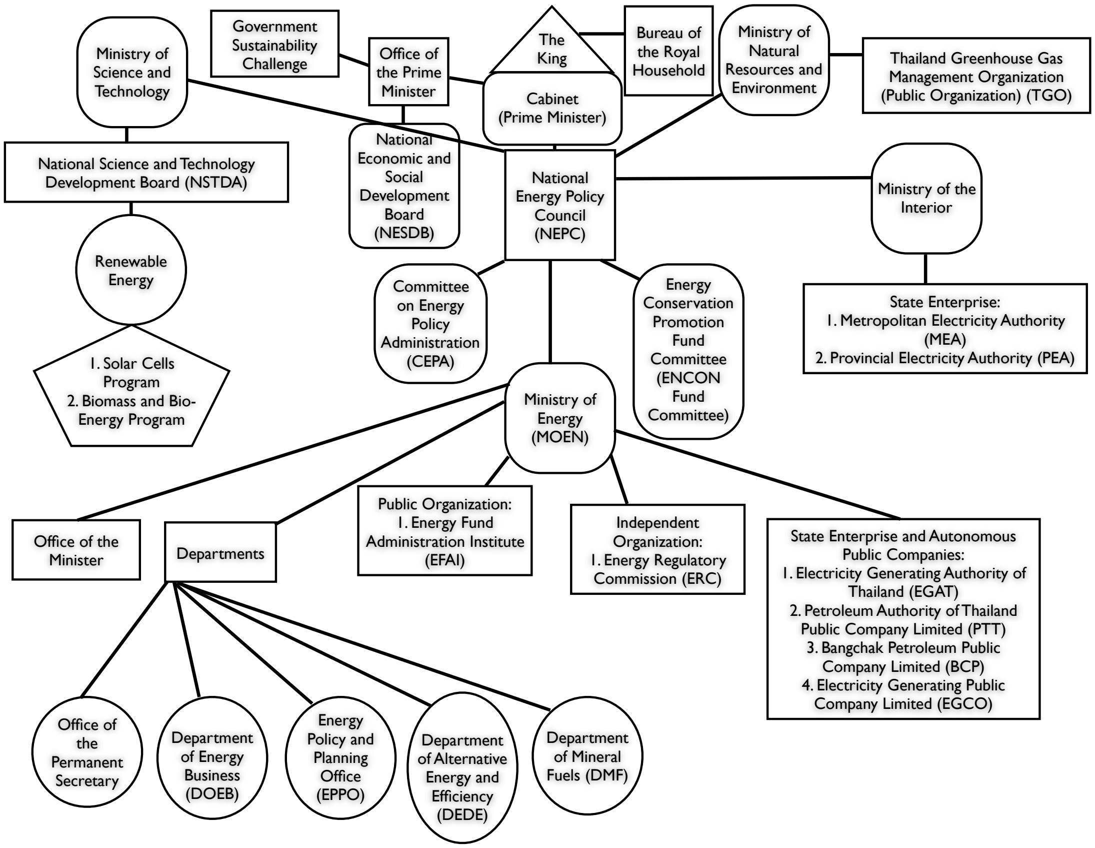

Figure 4.5: Thailand's RE governance structure. Renewable energy polices, productive, distribution, and innovation fall under the responsibility of a variety of Thailand's ministries and departments.

As will be described below, both of these goals are impacting RE decision-making throughout the RE governance framework.

Below the Cabinet is the National Energy Policy Council (NEPC). The Council determines the overarching energy goals for the country, and ensures that these goals are met. They provide the ministries with the National Energy Policy and National Energy Management and Development Plan. The Council "monitor[s], supervise[s], coordinate[s], support[s] and expedite[s] the operations of all committees with the powers and duties related to energy" (Adulyadej and Panyarachun, 1992, sec. 6).

NEPC is in charge of: the Committee on Energy Policy and Administration (CEPA), which handles the administrative needs of NEPC; the Energy Conservation Promotion Fund Committee

(ECON Fund Committee), which manages the ENCON fund further discussed below; and the Ministries of Natural Resources and Environment, Science and Technology, the Interior, and Energy. The Ministry of Natural Resources and Environment houses the Thailand Greenhouse Gas Management Organization (TGO). TGO is responsible for greenhouse gas emissions reduction and complying with the Kyoto Protocol.

The National Science and Technology Development Board, housed in the Ministry of Science and Technology, works on energy innovation projects, and has a separate Renewable Energy department. This department is currently working on an innovative solar-bio hybrid project.

The Ministry of the Interior houses the two state electricity enterprises that distributes electricity: the Metropolitan Electricity Authority, responsible for Bangkok and the surrounding area, and the Provincial Electricity Authority, responsible for the rest of Thailand. Both Authorities ensure that all Thai citizens have access to electricity.

The Ministry of Energy (MOEN) is the main energy hub in the governance framework. Within MOEN is:

1. The Office of the Minister;
2. Five key energy departments;
3. One state enterprise and two public companies that generate energy;
4. The Energy Fund Administration Institute (EFAI), which regulates gasoline prices; and
5. The Energy Regulatory Commission (ERC), which monitors the energy market.

Within the Ministry of Energy are five departments: Office of the Permanent Secretary, Department of Energy Business, Energy Policy and Planning Office (EPPO), Department of Alternative Energy and Efficiency (DEDE), and Department of Mineral Fuels. Both DEDE and EPPO have a great impact on RE deployment in Thailand, primarily through the development of RE policies (mainly by DEDE) and financial mechanisms (mainly by EPPO), such as the adder program. Both EPPO and DEDE will be further discussed below.

The Electricity Generating Authority of Thailand (EGAT) is a state enterprise that generates about 50% of Thailand's domestic energy supply. Although originally petroleum companies, the Petroleum Authority of Thailand (PTT) and Bangchak Petroleum (BCP) both work with private investors to implement large-scale RE projects. The Electricity Generating Public Company Limited (EGCO) was the first Independent Power Producer in Thailand, established in 1992.

Having such a hierarchical system ensures that RE gets implemented through a variety of mechanisms. However, because there is no formal connection between most of these ministries and departments, the work being done in one is separate from the work being done somewhere else. Although NEPC is in charge of ensuring that all energy plans are met, formal and informal discussions between the ministries and departments would allow for discussions and innovation that may take too long if the NEPC had to regulate them.

Renewable energy as a win-win

Thailand is proud of its comparatively successful RE deployment, and the government wants to be considered part of an international community dedicated to implementing RE technologies (C. Greacen, personal communication, March 7, 2013; S. Kumar, personal communication, March 8, 2013). Thailand was never colonized and has always had a lot of pride in its ability to be self-reliant and self-sufficient (S. Kumar, personal communication, March 8, 2013). Thailand has emphasized RE implementation for a variety of other reasons including:

1. Stabilizing rural livelihoods - Small-scale RE projects have not only provided electricity to rural communities, but have allowed these communities to grow economically, since small-scale projects are able to connect to the grid.
2. Greenhouse gas emissions reduction - After signing and ratifying the Kyoto Protocol, RE projects have been one of Thailand's key greenhouse-gas-emissions mitigation strategies.
3. Promoting the use of agricultural bi-products - Thailand's economy is highly reliant on agriculture, and Thailand has a large amount of agricultural bi-products that can be transformed into energy.

4. Energy security through a diversity of energy resources - Thailand imports a great deal of its electricity needs, and using RE allows the country to reduce imports while increasing domestic electricity production (G. Ali, personal communication, March 15, 2013; S. Dhakal, personal communication, March 13, 2013; S. Gheewala, personal communication, March 5, 2013; S. Kumar, personal communication, March 8, 2013; W. Ongsakul, personal communication, March 21, 2013; A. Salam, personal communication, March 21, 2013).

Thailand's government has found that implementing RE policies and projects is a win-win situation. The country can develop economically while also protecting the environment. (The country used the signing and ratifying of the Kyoto protocol as a jumping off point for RE policies.) The country is able to be self-reliant, while still being a member of the international community. (RE developments in the country increases transparency both within the country and the international community.) Thailand has also been able to apply its cultural values to RE policy and project deployment. (This has increased stakeholder approval for RE policies and projects.)

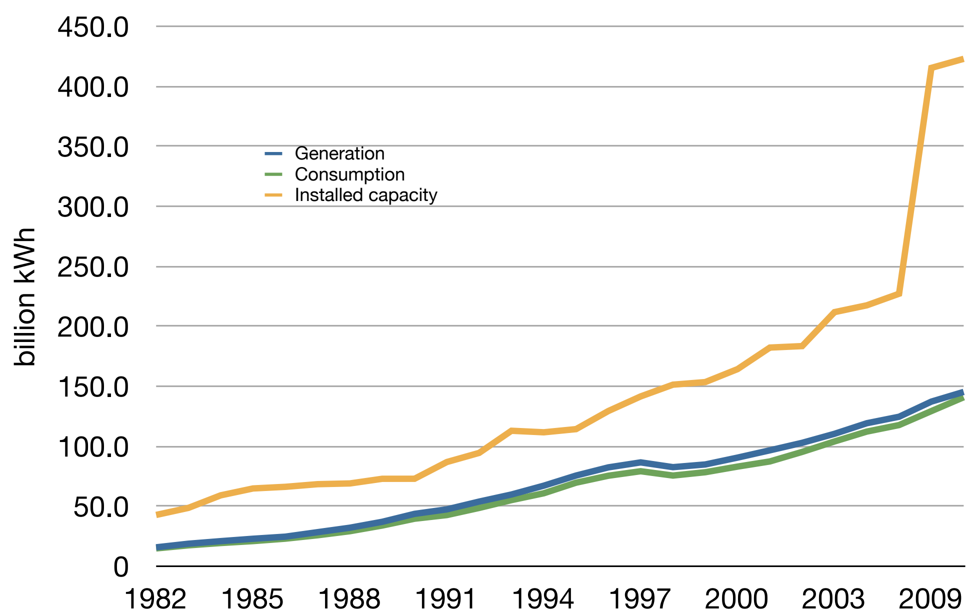

Figure 4.6: Thailand's electricity generation, consumption, and installed capacity, 1980-2010. Installed capacity is the theoretical production if all power plants worked at 100% capacity. Installed capacity has seen a surge in the last decade, mainly by Independent Power Producers. Data Source: Energy Information Administration, 2012

Thailand is currently increasing its RE use and decreasing its fossil fuel import budget (G. Ali, personal communication, March 15, 2013). Not only does it have a relatively abundant supply of RE sources, but RE projects allow for energy security and an increase in local livelihoods (S. Dhakal, personal communication, March 13, 2013; S. Gheewala, personal communication, March 5, 2013; W. Ongsakul, personal communication, March 21, 2013; A. Salam, personal communication, March 21, 2013). Electricity generation in Thailand has increased steadily since 1980, as the country became more industrialized (Figure 4.6). More recently, energy sources for electricity generation has shifted from petroleum to natural gas, coal, and renewables. (Natural gas is also widely used in the transportation sector - most taxis run on natural gas - thus increasing Thailand's natural gas needs.)

Industrialization increased energy consumption, creating a need to replace costly imported energy sources with domestic sources. In December 1978, the Petroleum Authority of Thailand (PTT) (Figure 4.5) was established to cope with the energy crisis of the 1970s and to increase domestic fossil fuel production. Two new refineries in Thailand, in 1995 and 1996, reduced imports of finished petroleum products such as petrol. The government instituted energy conservation programs (ENCONs), regulated by the ENCON Fund Committee (Figure 4.5), to reduce fossil fuel imports in 1997-99, 2001-03, and 2007. Oil taxes were used for energy conservation, efficiency, and RE projects (S. Kumar, personal communication, March 8, 2013). Perhaps, the 2001-03 program was part of Thailand's commitment to the Kyoto Protocol, but the other two were responses to global financial crises.

While many countries in the developing world have used nuclear energy to reduce fossil fuel use, Thailand remains on a see-saw. In every decade since the 1960s, a nuclear project has been proposed but ultimately rejected (Bijoor et al., 2007; Wiriyapong, 2008). The country has chosen to focus on RE deployment, rather than growing its nuclear energy industry.

The privatization plan and development of the VSPP

RE policy deployment in Thailand started with the government pushing a strong privatization agenda. The government wanted to create a power pool.[2] However, the utilities were not interested

[2]A power pool is a power structure where there are separate generation companies and separate transmission companies. The power from the different generators is then pooled and a system operator dispatches the power based on

in being broken up. (For example, the Electricity Generating Authority of Thailand (EGAT) (Figure 4.5) owns the transmission and half of the generation, and the power pool program would have been financially detrimental.) After the power sector crisis in California, the Thai government slowed down its push for the power pool structure, but they still emphasized a somewhat more privatized system (C. Greacen, personal communication, March 7, 2013).

At the time, Dr. Chris Greacen, founder of the nonprofit organization Palang Thai, had been pushing for micro-hydro projects at the village level, and his main project was about to be connected to the grid. He went to the government and explained his micro-hydro project and provided them with information on Delaware's net metering regulations, some of the strongest at the time. This was an ideal way to privatize power generation, by allowing small scale projects to connect to the grid. Therefore, the government decided to implement the Very Small Power Producers (VSPP) program, the first official RE policy in Thailand (C. Greacen, personal communication, March 7, 2013). This program has been highly successful, and currently, about 40-50% of Thailand's energy comes from Independent Power Producers (IPPs) installed in just the past 10 years (S. Kumar, personal communication, March 8, 2013).

The VSPP program interested the private sector because RE projects were becoming commercially viable. Also, the formal institutions in place for a VSPP project make it much easier for a project to get connected to the grid, and quickly. There are fewer mandatory requirements and standards than larger-scale projects, and projects are exempt from performing an Environmental Impact Assessment, a process that can easily stymie a project (Kongbuamai et al., 2012).

Renewable-energy deployment

Thailand's first efforts to implement RE was the Bhumipol Dam, formerly known as the Yunhee Dam, which began generating electricity in 1964; its current installed capacity is 779.2 MW. The Bhumipol Dam is the second largest generating (GWh) hydropower plant in Thailand, barely behind the Srinagarind plant (1,183 GWh versus 1,320 GWh) (Department of Alternative Development and Efficiency, 2010). (These two plants account for 45% of total hydropower generation in the country.) Thailand then went on to build dozens of large-scale hydropower plants, funded by the World Bank,

increasing marginal cost. This system is commonly used in England and California (C. Greacen, personal communication, March 7, 2013).

USAID, and other international funding agencies, with a common interest in halting the spread of communism. These large projects inundated farmland, forests, and hundreds of small villages. After years of public opposition, the government stopped large-scale hydropower construction in the mid-1990s (Greacen and Palettu, 2007).

In 1993, Thailand and Laos signed a memorandum of understanding (MOU) agreeing that Laos would supply up to 1,500 MW of hydropower to Thailand. The MOU has been expanded multiple times, most recently in 2007; Laos will supply 7,000 MW of hydropower to Thailand by 2020 (Phomsoupha, 2009). While Laos must deal with the environmental and social burdens of large-scale hydropower dams, Thailand reaps the benefits.

Pig farmers were some of the earliest adopters of the VSPP program. Pig farms release a very strong, negative odor, and they can have negative effects on the natural environment. Implementing biogas digesters at the pig farms reduced the smell and the impact on the environment. The digesters were also quite profitable, creating a win-win solution for both the farmers and the local citizens (C. Greacen, personal communication, March 7, 2013).

After strong protests against large-scale hydropower dams, Thailand's government has made development of small-scale hydropower a priority, and has created incentives for implementation. Currently, the government only approves new plants at the request of a village. But few villages know that such requests can be made. However, village-level hydropower plants have been installed. One such example is the Mae Kam Pong plants built in Chiang Mai. Mae Kam Pong 1 was built in 1983, but it not grid-connected. About ten years later, Maw Kam Pong 3 was built, and has the ability to be grid connected. However, grid-connection have been stymied by bureaucratic red tape and has repaid virtually none of the grid-connection cost (Greacen, 2007).

Wind power is the newest entrant into Thailand's energy portfolio. Although Thailand has limited on-shore wind potential, it has considerable off-shore wind-power potential, especially in the southeastern region of the Gulf of Thailand (Figure 4.7).

In 2010, 5.2 MW of wind energy had been installed; 45 40m high wind turbines and 23 90m high wind turbines were installed by the Ministry of Energy (Figure 4.5) (Sutabutr, 2010). These turbines, located in the middle of the country and along the peninsula, are considered demonstration projects. The government still relies on private investors to develop larger projects. Thailand has

Wind Rating and Speed	Poor (< 6m/s)	Fair (6-7m/s)	Good (7-8m/s)	Very Good (8-9m/s)
Land Area (square km)	470,000	37,000	748	13
Percentage of Total Land Area	93%	7%	0.2%	0.003%
MW Potential	-	150,000	2,990	52

Figure 4.7: Thailand's wind power potential. Thailand's highest potential for wind power is found off-shore, where wind power ranges from fair to very good. Data Source: Australian Business Council for Sustainable Energy, 2005

agreements with Resource Group International and General Electric to develop 125 MW of wind power on wind farms.

Some small-scale wind technology has been installed in the country. However, many of these turbines are no longer functioning, thus creating a negative public perception of the effectiveness of wind installations. There is also no local wind turbine manufacturing or distribution capacity in the country, making it difficult to convince the public that wind energy is necessary (Australian Business Council for Sustainable Energy, 2005).

Thailand has a high potential for solar energy. Thailand receives about 5.0-6.5 kWh/m^2/day of sun (Thai Solar Energy Company, Ltd., 2011). This is roughly equivalent to the amount received in the American southwest, well known for its solar energy capabilities. Not only does it have high insolation (a great deal of sunlight hitting its surface), but Thailand also has the land area appropriate for building solar plants. Old shrimp farms that have highly salinized the soil, making future agriculture impossible, would make the perfect location for solar power plants (C. Greacen, personal communication, March 7, 2013).

A number of solar photovoltaic (PV) projects are already in operation, some of which are Millennium Development Goals and Tsunami Recovery projects (Australian Business Council for Sustainable Energy, 2005). Solar Power Company Limited (SPC), a Thai developer of grid-tied, megawatt-scale PV projects, has licenses for 33 6 MW projects, and the International Finance Corporation (an arm of the World Bank) has invested in a 20% stake in four of the projects (Shields, 2010). These solar power plants would be the largest in Southeast Asia; however, they are small compared to plants around the world. For example, the largest plant in the United States produces 48 MW of power.

Micro-scale projects dominate Thailand's solar development because of the Very Small Power Producers (VSPP) program which allows for RE projects under 10 MW to tie into the grid. At the micro level, the Thai government has signed contracts to develop 1,800 MW of solar energy but only 32 MW (1.8%) had come online by 2008.

In 2006, Thailand's Office of the Prime Minister initiated the Government Sustainability Challenge (Figure 4.5). As part of the Challenge, the government installed 203,000 solar-home systems in rural Thailand, at a cost of $200 million. Within the first year, more than 20% of systems failed in the Tak province alone. Some failures were due to misplacement of the systems; many were placed in the shade. The NGO Palang Thai is now training villagers to repair, maintain, and operate their home systems.

The people of rural Thailand seem to have little input into public-private projects of any scale. This is significant because when solar panels are placed in villages, it is the local citizens who must operate and maintain them. Villagers know how solar exposure changes over the seasons in their own villages, so they can make sure that panels are placed appropriately. The Government Sustainability Challenge had a high initial failure rate because it did not incorporate local knowledge.

Thailand has some potential for geothermal power, but they have yet to tap into this resource. At the time of writing, they only had one small geothermal plant, in northern Thailand, which has been in operation for the past 20 years (S. Dhakal, personal communication, March 13, 2013).

Thailand has a high potential for bio-based RE such as biogas from biomass and waste, municipal solid waste (MSW), agricultural residues, biofuels, and crops (Chaiprasert, 2011). As a result of its feed-in tariff program, Thailand's bio capacity has grown from nearly zero to 1.6 GW in 10 years, and this is expected to double within the next six years (World Bank, 2012). Currently, you can get gasoline with a 20% biofuel blend at the gas pump (S. Dhakal, personal communication, March 13, 2013). By 2021, Thailand hopes to have 66% of its electricity and 91% of its heat being generated by biomass (Kongbuamai et al., 2012). Currently however, many businesses with a potential bio residue stream are unaware of the opportunities of turning that residue into energy, and are reluctant to invest in technology that they know little about (The Thailand Report, 2005). Of the 400 investors who have expressed interest in BtE projects by becoming VSPPs, only 63 projects have been connected to the grid (Kongbuamai et al., 2012).

Still, bio is being implemented at both the micro and macro scales. In Roi Et province, a 9.8 MW plant generates power from rice husks. At the Korat Waste-to-Energy biogas plant, cassava wastewater is transformed to methane and produces 30 MW of thermal gas for all of the plant's heating requirements, as well as 3 MW of electricity. In Ratchaburi, eight 70 kW generators create biogas from pig-farm waste. The plant reduces air and water pollution by reducing methane emissions and runoff from the pig waste, while producing fertilizer and electricity. All three projects were subsidized by the VSPP program (Greacen, 2007).

Provinces and municipalities have installed MSW anaerobic digestion plants to create energy.[3] (In 2008, 0.2% of Thailand's waste was anaerobically digested. Most of the waste is thrown into open dumps.) However, most of these plants have failed mainly from mechanical breakdowns from the lack of routine maintenance of the plant. "Since Thailand has a different type of waste composition from the countries where these technologies have been developed, the design of the plant machinery may not suit Thailands MSW" (Cherdsatirkul, 2012, p. 12). Also, MSW treatment plants usually yield lower revenue than originally expected (Cherdsatirkul, 2012).

[3]"Anaerobic digestion (AD) consists of the degradation of organic material in the absence of oxygen. It produces mainly 55% methane and 45% carbon dioxide gas and a compost product suitable as a soil conditioner...A well-designed AD fosters sustainable development since it recovers energy thus reducing fossil fuel use and reducing greenhouse gas sources" (Verma, 2002, p. i, ii).

4.3 WHO INSTITUTES THE ENERGY TRANSITION

Ostrom (1990) identified institutional changes in the management of common property resources by analyzing them at three levels: operational, collective choice, and constitutional. Changes at the operational level are characterized by appropriation, provision, monitoring, and enforcement processes. Changes at the collective choice level are characterized by policy making, management, and adjudication processes. And changes at the constitutional level are characterized by formulation, governance, and modification processes (Ostrom, 1990). These levels can be applied to understand who decides which RE technology gets implemented at which scale and where.

The decision to institute an energy transition in Thailand was made at the constitutional level. As of 2012, Thailand had five separate long-term energy plans: the long-term Power Development Plan (PDP 2010-2030), the Alternative Energy Development Plan (AEDP 2012-2021), the 20-Year Energy Efficiency Development Plan, the Natural Gas Plan, and the Natural Gas Vehicle Roadmap. Each of these plans corresponds to a single or group of energy resources and is governed by a different government department; there is no unified energy plan that integrates all of these plans, and there is little coordination between departments to determine how the plans can contribute to meet joint goals. Also, Thailand currently lacks an RE law (Tongsopit and Greacen, 2012).

Of the five above mentioned plans, only one focuses exclusively on increasing RE production and use in Thailand. Thailand's Department of Alternative Energy Development and Efficiency (DEDE), within the Ministry of Energy (Figure 4.5), established a clear target of increasing the proportion of RE use to 20% of the total energy consumed by 2022. Their plan was known as the 15-year Renewable Energy Development Plan (REDP). It set clear objectives to reach this target:

1. Replace oil imports with renewable energy;
2. Strengthen energy security;
3. Promote renewable energy use to create an integrated green community;
4. Support the renewable-energy industry; and
5. Research, develop, and promote high-efficiency renewable-energy technologies.

DEDE hoped to implement its objectives in three terms: short, medium, and long (Figure 4.8).

Short Term (2008-2011)	**Medium Term (2012-2016)**	**Long Term (2017-2022)**
Focus on promoting already existing technologies, especially: Biofuels, Biomass, Biogas Implement financial mechanisms	Promote alternative energy technology industry and development of new technologies for higher economical cost-effectiveness Promote new biofuel technologies Develop Green City prototype which strengthens local alternative energy production	Promote cost-effective alternative energy technologies, such as hydrogen Support Thailand in becoming the hub for biofuel and alternative energy technology imports in the ASEAN region

Figure 4.8: Thailand's Department of Alternative Energy Development and Efficiency goals. By separating goals out into three different terms, Thailand is ensuring that it succeeds in its various RE and efficiency goals.

The 15-year REDP was recently replaced by the Alternative Energy Development Plan (AEDP 2012-2021), perhaps because it was on track to surpass the original targets (S. Kumar, personal communication, March 8, 2013) and as a response to recent climatic changes (C. Greacen, personal communication, March 7, 2013).[4] The new plan sets higher targets for most RE types (biomass and MSW energy targets remain the same). The plan also sets a total RE target of 25% renewables by 2021. The Ministry of Energy has outlined six strategies for accomplishing this new target:

[4] In recent years, Thailand has experienced some of the worst flooding in history. Also, the cool season, which used to last for months, now only lasts a few weeks (C. Greacen, personal communication, March 7, 2013).

1. Promote community collaboration to produce and consume RE;
2. Adjust the incentive measure to increase private investment;
3. Increase laws and regulation to promote RE development;
4. Improve energy infrastructure, including transmission lines, power distribution lines, and developing a smart grid system;
5. Improve public relations and citizen knowledge; and
6. Promote in-country RE research.

Figure 4.9 shows the individual technology targets of the AEDP 2012-2021, and additional government targets related to energy are shown in Figure 4.10.

In the past, collective-choice decision making halted the development of large-scale hydropower plants. Decision making about hydropower now occurs at the operational level, since it is up to villagers to request a hydropower project from the government. The government subsidizes the cost of the project, and gives the community the opportunity to sell electricity back to the Provincial Electricity Authority (PEA) (Figure 4.5). Palang Thai provides villages with micro-hydro training and helps with installation, maintenance, and operation.

Wind power decisions are made at the collective choice level. While the government wants to develop wind power, it cannot do so without outside financial investment, and so it has instituted policies allowing for these investments. There is little opportunity for decision making at the operational level since most wind resources are located off-shore, and thus require major investments to be developed.

There are three main actors in Thailand's solar industry: the government, private companies, and non-governmental organizations. Decisions are made at the collective choice level. The government has created incentives for private companies to install solar power plants with the help of NGOs. The private companies must get their projects approved by the government, and in return, the government provides subsidies and feed-in tariffs for the project. Companies rely on organizations such as the World Bank to help offset their costs.

Bio energy is being implemented at both the micro and macro scales through operational and collective-choice decision making. Bio energy may be the technology that requires the strongest

TYPE	EXISTING in 2008	POTENTIAL	AEDP 2021 Target	DETAILS
Solar Energy	32 MW (0.2%)	>50,000 MW	2,000 MW (12.6%)	- Rural areas -On-grid solar homes -Royal initiative projects -Installing area at 0.1%
Small-scale Hydro Energy	50 MW (0.3%)	700 MW	Mini + Micro + Pumped Storage = 6,108 MW (38.5%)	- Multiple rivers in northern Thailand
Wind Energy	1 MW (0.006%)	1,600 MW	1,200 MW (7.6%)	- Wind farm in southern Thailand and in Gulf of Thailand
Biomass	1,610 MW (10.1%)	4,400 MW	3,630 MW (22.9%)	-Industry of: sugar, palm, paper, rubber, rice mill, sawmill
Biogas	46 MW (0.3%)	190 MW	600 MW (3.8%)	- Industry sub-sector of: starch, palm, food processing, livestock/ animal farm
Municipal Solid Waste	5 MW (0.03%)	400 MW	160 MW (1.0%)	- Bangkok metropolitan - Municipality/Sub-District
Tidal Wave	0 MW	-	2 MW (0.01%)	- Expected potential under the Sarasin bridge in Phuket and the surrounding areas of Koh Sa Mui-PA Ngna and Koh Tan
Geothermal	0 MW	-	1 MW (0.006%)	-Government in process of developing maps - Over 112 hot springs across the country in Chiang Rai, Chiang Mai, Mae Hong Son, Ranong and Surat Thani provinces

Figure 4.9: Thailand's RE potential. Not only does Thailand has a great deal of RE potential from a variety of sources, but the AEDP targets reflect this potential. Thailand is continuously hoping to expands its energy portfolio to include all sources of RE. Note: All percentages are based on Thailand's 2010 electricity consumption of 15,871.14 MW (Energy Information Administration, 2013).

participation of the community; to determine the size of a plant, the developer (whether it be a private firm, government, or a community) must understand what the villagers are producing and how much of it is being produced.

4.4 INSTITUTIONAL DRIVERS

Government Commitment

Historically, Thailand's government emphasized financial stability and creditworthiness over investment and economic expansion (Haggard, 1995). Because the country was never a colony,

	AEDP (2012-2021)
Energy Targets	
Fossil fuel substitution	25%
Power generation from RE	9,201 MW
Petroleum substitution	44%
Economic Targets	
Reduction in oil imports	574 billion baht/year ($19 billion/year)
Investments from private sector	442 billion baht/year ($14.6 billion/year)
Environmental Targets	
Carbon dioxide reduction	76 mt/year in 2012
Revenue from selling carbon credits	23 billion baht ($770 million)

Figure 4.10: Thailand's AEDP 2012-2021 targets. While increasing RE use, Thailand also hopes to reduce its nonrenewable imports and greenhouse gas emissions.

its government conducted diplomacy abroad, modernized administration, and built infrastructure free of colonial domination. However, with the goal of increasing RE use, Thailand's government now pushes and relies on private investments.

Thailand has always been a monarchy; in 1932 it became a constitutional monarchy. (The capital is in Bangkok and the country is divided into 77 provinces.) However, until 1973, military dictatorships controlled the country. Between 1973 and 2007 Thailand see-sawed between democratic and military regimes. In 2007, democratic rule was restored and remains in place at the time of this writing.

A transition to democratic rule can allow for a shift to adaptive governance. Folke et al. defines adaptive governance as "a process by which institutional arrangements and ecological knowledge are tested and revised in a dynamic, ongoing, self-organized process of learning by doing" (2005, p. 448). Resource management systems are developed by various organizations at different levels, with a focus on tailoring the system to a specific place and situation. In this process, governments learn how to respond to and shape change (Folke et al., 2005).

Adaptive governance relies on the collaboration of stakeholders who share management powers and responsibilities. They are freed from suppression of bureaucracy, and thus can innovate.

These social networks do not replace the accountability of the exiting hierarchical bureaucracies but instead complement them (Folke et al., 2005).

In adaptive governance, leadership is important to build trust, make sense, manage conflicts, link actors, initiate partnerships, compile and generate knowledge, and mobilize broad support for change (Folke et al., 2005). In Thailand, the central government has made sustainable energy development a priority, and dispersed responsibility for development among many separate ministries and departments.

Thailand's RE policies have always been very top-down (S. Gheewala, personal communication, March 5, 2013). However, the policies have been continuously pushed because both key parties (both the red shirts and the yellow shirts) have been supportive of RE policies. There has been diplomatic consistency (C. Greacen, personal communication, March 7, 2013).

Thailand's energy policies aim to accomplish five goals: 1. Securing energy resources (e.g., oil, natural gas, electricity, and RE), 2. Make RE a national priority, 3. Encourage energy conservation, 4. Ensure that the price of energy reflects the genuine cost of production, and 5. Preserve the environment (Nakornthap, 2011).

To meet its RE targets, the Energy Policy and Planning Office (Figure 4.5) has created a multitude of financial incentives, including: feed-in tariffs, or "adder,"[5], an ESCO fund[6], an ENCON fund[7], soft loans, carbon credits, and a Board of Investment (BOI) run by private investors.

Thailand was the first Asian country to implement a feed-in tariff (FIT), or adder, program. (These two words can be used interchangeably.) The FIT for RE use for Small (10-90 MW) and Very Small (<10 MW) Power Producers (SPP and VSPP, respectively) provides an incentive to improve commercial viability of RE projects and increase private investment in Thailand's energy system. The FIT program goals are to:

[5]For more details on Thailand's adder program, please read: Tongsopit and Greacen, 2012 and Amranand, 2008

[6]ESCO = Energy Service Company, and the ESCO fund encourages private investments in renewable energy and energy efficiency projects in the form of equity investment (up to 50 million Baht or $1.7 million), venture capital, equipment leasing, and Clean Development Mechanism (CDM) project

[7]ENCON = Energy Conservation Promotion, and the ENCON fund is collected from a tax per liter on all petroleum products sold in Thailand

- Increase RE use;
- Increase private investments;
- Stimulate economic growth;
- Develop rural areas;
- Use agricultural waste;
- Diversify fuels;
- Reduce local pollution; and
- Reduce the trade deficit (Tongsopit and Greacen, 2012).

The adder program is most likely the strongest financial incentive for the implementation of RE technologies, especially solar energy (S. Gheewala, personal communication, March 5, 2013; S. Kumar, personal communication, March 8, 2013; W. Ongsakul, personal communication, March 21, 2013). "The rate structure is simple and easy for investors to integrate into investment plans" (Tongsopit and Greacen, 2012, p. 16). The adder program also provides secure contracts so that investors are not forced to cancel or have their projects revoked after they have signed a contract.

Although the FIT program is innovative, it is not yet completely successful. It has a weak regulatory framework that creates bottlenecking during the application process, and there has been no public discourse on what constitutes an acceptable cost to consumers (Tongsopit and Greacen, 2012).

The BOI provides an eight year tax holiday and other incentives to private RE investors. Soft loans for energy development are also available to private investors. In addition to the ESCO fund, the government also provides some direct subsidies (ranging from 10-30%) for biogas, solar hot water, and municipal solid waste. The country has set up an Energy Conservation Fund from a petroleum levy, and is a leader in appliance-efficiency standards and labeling. A combination of the tax holiday and subsidies have been the strongest incentives for biofuels (S. Gheewala, personal communication, March 5, 2013).

As discussed above, the Cabinet approved the Very Small Power Producer (VSPP) program in 2002 to incentivize development of RE at a small scale. Projects are limited to 10 MW, and contracts usually last from seven to ten years. The power produced can be sold to PEA, one of two government owned distribution companies (Figure 4.5).

However, as of 2011, only 8,543 MW (27%) of generation is currently online. This is mainly due to government interference. Under the original VSPP program design, "utilities were required to grant projects permission to interconnect if they met basic safety and power quality standards, subject to substation capacity" (Tongsopit and Greacen, 2012, p. 14). In 2010, new rules and regulations created "additional paperwork requirements, including proof of sound financial status, which are designed to prove the projects' readiness to follow through until project completion" (Tongsopit and Greacen, 2012, p. 14). These new rules have increased subjective judgement of projects and have stalled the application process since there is no set timeline on how long the review process is supposed to last (Tongsopit and Greacen, 2012).

Thailand's government commitment to increase RE use is very strong. The original development of the VSPP program, the AEDP, and the variety of financial mechanisms (the strongest being the adder), all initiated by the government, have played a dominant role in helping Thailand achieve its RE goals. Thailand has a high potential for domestic RE use, but it relies on outside firms to support the high upfront costs of RE projects.

Polycentricity

In a polycentric system, citizens are able to organize governance at different scales and to have some influence on what resources are used and where. In Thailand, authority for RE development rests primarily with the government, but citizens, nonprofit organizations, and private investors also play important roles.

The government emphasizes RE implementation within its own domain; different ministries and department are responsible for different aspects of research, development, and implementation (Figure 4.5). For example, the National Science and Technology Development Board, a sub-department of the Ministry of Science and Technology, has a solar cells program and a biomass and bio-energy program. Separately, the Office of the Prime Minister initiated the Government

Sustainability Challenge (Figure 4.5). As part of the Challenge, the government installed 203,000 solar-home systems in rural Thailand.

Historically, the dispersal of responsibility among different government units "has hindered the performance of the energy sector in Thailand due to differing and often overlapping policies and legislation governed by a diverse range of agencies and ministries that are associated with energy activities including renewables" (Uddin et al., 2010, p. 73). For example, the VSPP program and the Renewable Energy Development Plan have arisen out of different government sectors, none of them collaborating with each other (C. Greacen, personal communication, March 7, 2013). This has led to many coordination and collective-action problems. Bowles, an important scholar in the field of collective action, notes that, "differences among the players [i.e., departments/ministries] - in wealth, skills, political rights, group identity, information - will influence both the nature of the coordination problem and the types of solution that may be implemented" (2006, p. 164). These differences can create a great deal of variation in program success.

Thailand has not taken full advantage of local knowledge when drafting policies, an important component of polycentric governance; doing so would make RE more successful. Currently, the NGO Palang Thai is the only citizen group that has helped write policies. RE policies are very top-down in Thailand. The government sets the policies and citizens have had little direct say in how, which, and where RE technologies are implemented (S. Gheewala, personal communication, March 5, 2013; C. Greacen, personal communication, March 7, 2013).

As noted earlier, the solar panels installed as part of the Government Sustainability Challenge had a high failure rate because local citizens were not involved in determining their placement. "Effective knowledge networking and effective communication between government institutions and local people are seen as a first step to encourage further market penetration of renewable energy systems" (Uddin et al., 2010, p. 75). If citizens were able to organize and partake in the decision-making process, then projects such as these would have a much lower failure rate.

Polycentricity also involves spreading knowledge from one area to another. To date, only one NGO, Palang Thai, has spread knowledge from one village to another. Thailand could meet its RE targets faster if they encouraged more participation by its citizens.

Thailand values citizen engagement and participation (S. Dhakal, personal communication, March 13, 2013). For example, in 2011, the Thai government started to implement the "Pracha Wiwat" or "People's Agenda," a policy initiated during Thailand's reform process which hopes to solve three urgent issues: the economic crisis, the cost of living, and public safety. In writing the policy, "70 officials from 30 governments, local, and private organizations...interviewed more than 1,000 people" (Thai Government Public Relations Department, 2011, n.p.). Also, woman are very active in the workforce, especially compared to other neighboring countries (S. Dhakal, personal communication, March 13, 2013). However, although valued, stakeholder participation may not be high in the development of RE policies and projects.

Stakeholder participation and community building in Thailand has been emphasized through protests and opposition (C. Greacen, personal communication, March 7, 2013). Citizens become involved when they are threatened by power plants, especially large-scale hydro and coal plants, planned in their neighborhood (C. Greacen, personal communication, March 7, 2013). For RE use to increase in a country, renewable technologies and policies must be accepted at the sociopolitical, community, and market levels.

Sociopolitical acceptance refers to whether stakeholders agree that RE implementation is important. Many times, policy-makers overlook sociopolitical acceptance, because in opinion polls, the broad majority of people tend to agree with the idea of RE development (Wustenhagen et al., 2007). Before RE implementation can gain community and market acceptance, it must be accepted by individual citizens.

Community acceptance requires that those who will use the technology agree to where the technology will be placed. NIMBYism (NIMBY = Not In My Back Yard) is an important obstacle to community acceptance. Many people want RE, but do not want the technology to generate it placed near their homes. Others actually want, or do not object, to the technology being placed nearby, and it is often the case that once the technology is installed, opposition decreases. It is also important that the community trusts that costs and benefits will be shared equitably and that there will be fair decision making. Finally, to accept renewable technologies, the community must trust that both the intentions and information provided by outside investors and actors are good (Wustenhagen et al., 2007).

Market acceptance is the adoption of both small and large-scale innovation by the market. However, "While energy technologies continue to be bound to infrastructures that make them inherently more complex for diffusion of innovation than other products" it may be easier for market acceptance of small-scale RE projects like micro-hydropower and individual solar and wind use (Wustenhagen et al., 2007, p. 2685). Small-scale RE projects can enter the market easier than large-scale projects because locations "where residents (including tenants) get the opportunity to "switch" to renewable energy supply without being actually involved in the physical generation, is probably the area where market adoption can almost completely be isolated from the broader social acceptance picture, reducing barriers to diffusion" (Wustenhagen et al., 2007, p. 2685)

Many rural communities favor RE technologies (A. Salam, personal communication, March 21, 2013) thanks to the RE policies and projects implemented by the Thai government and Palang Thai (Figure 4.11). Palang Thai is a nonprofit organization that works to ensure that energy transformations are economically rational, and that they augment, rather than undermine, social and environmental justice and sustainability. Currently, Palang Thai is working in four areas. They are working with Thai NGOs, universities, businesses, and governmental agencies to analyze electricity planning and policy from a public-interest perspective. They have also developed the Border Green Energy Team (BGET), which provides hands-on solar and micro-hydro training for villages in both Thailand and Myanmar. They are also involved in the Thai Net Metering Project, which promotes the implementation of small-scale, grid-connected RE projects. Lastly, Palang Thai has helped create computer training centers in Burma refugee camps in Thailand. The computers are powered by a 1 kW PV and diesel-generator hybrid system. In 2009, there were seven hybrid systems, each system powering 12 computers (Palang Thai, 2009).

Pubic participation is starting to become more common in the RE decision-making arena. As noted above, protests have been quite successful in keeping unwanted power plants and dams from being implemented. Also, many government committees and groups invite academics to join as experts on certain energy-related committees and technology development discussions (S. Kumar, personal communication, March 8, 2013).

Technology	Location	Size	Cost
Small Hydro	Mae Ya	1 MW	-
Micro Hydro	Mae Kam Pong, Chiang Mai	40 kW	$130,000
Rice Husk Fired Power Plant	Roi Et	9.8 MW	-
Biogas from Pig Farm	Ratchaburi	8 x 70 kW	-
Waste-to-Energy	Korat	3 x 1 MW	-
Solar PV	Bangkok	1 MW	-

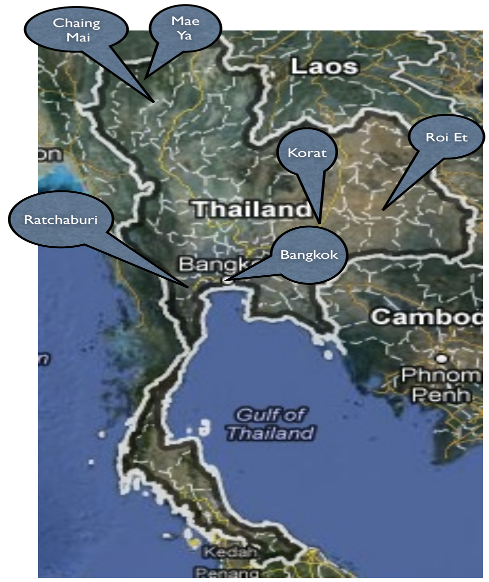

Figure 4.11: Example and location of Palang Thai's projects. Palang Thai is helping deploy small and medium-scale RE projects throughout the country.

Stakeholder participation does occur in the development of large-scale projects. All companies that are developing projects greater than 10 MW must prepare an Environmental Impact Assessment (EIA), which can increase transparency. Not only do EIAs allow for documentation, but they include a stakeholder participation process (W. Ongsakul, personal communication, March 21, 2013). Citizens have also been involved in large-scale projects in the form of protests, especially against large-scale hydropower projects and coal power plants (S. Gheewala, personal communication, March 5, 2013).

Thailand could increase public participation by becoming an affiliated member of the International Association for Public Participation (IAP^2). The current affiliated members are: Australasia, Canada, France, Southern Africa, the United States, Indonesia, and Italy. (Germany, Portugal, and Western Africa will soon become affiliates as well.) IAP^2 organizes public participation into five levels: inform, consult, involve, collaborate, and empower. The organization believes that good public participation leads to better decision making (International Associated for Public Participation, 2013). By being a member, Thailand could ensure that its RE projects would have a higher success rate. Also, more investors would become aware of the VSPP program. This would increase Thailand's RE share.

Transparency of Information

Transparency is accomplished by engaging stakeholders and making information public (Ostrom, 2005). Thailand has achieved a high level of transparency, considering it is a mid-developed country. The Department of Alternative Energy Development and Efficiency (DEDE) (Figure 4.5), is responsible for making energy information public. It keeps up-to-date RE maps, and relays information from RE demonstration sites. DEDE also produces a yearly document entitled, "Electric Power in Thailand." This document aims to "disseminate data and information on electricity installed capacity, generation, consumption, import, export, tariffs, fuel requirement for power generation and other details" (Department of Alternative Development and Efficiency, 2010). DEDE aims to be the "one-stop service" for information on RE potential in Thailand.

NGOs can also increase transparency. Palang Thai provides all of their information online, including project sizes and locations, and any document written by the leaders of the organization, including Dr. Chris Greacen. Palang Thai has also helped write key RE policies, such as the VSPP program.[8] It also provides in-person information on RE technologies to rural communities.

[8]For more information on Palang Thai and its projects, please visit: http://www.palangthai.org/.

Thailand also collaborates with other countries, sharing information and technology. Two such collaborations are the Agency for the International Promotion of French Technology and Trade, which has a branch in Thailand, and the Italian-Thai Power Company, Limited. As part of these, and other, collaborations, Thailand is home to one of the largest global RE conferences: Renewable Energy World-Asia.

In addition to sharing knowledge, some of Thailand's RE projects have been funded by international lenders, such as the Asian Development Bank (ADB) and the World Bank's International Finance Corporation (IFC). ADB initiated the Solar Energy Initiative, providing funding for two Bangchak Petroleum (Figure 4.5) solar power plants (totaling 34.5 MW and 9.3 MW, respectively) and for a Natural Energy Development solar-electric power plant (totaling 73 MW). In addition, two 6 MW solar power projects are being funded by IFC and the Clean Technology Fund (Tongsopit and Greacen, 2012).

Recently, Thailand's financial schemes seem to be less transparent, especially the VSPP and adder programs. Between 2007 and 2010, Thailand's adder program was one of the most transparent of the RE financial incentives. Private sector representatives were able to suggest improvements to the adder program to Thailand's Energy Policy and Planning Office; some of these suggestions were then incorporated into the policies. Policy makers also allowed for public participants to provide comments on draft policies. However, after June 2010, policies were carried out without public participation and major changes were made to the adder rate and regulations (Tongsopit and Greacen, 2012). Experts are unsure of why there was a sudden change (C. Greacen, personal communication, March 7, 2013).

In Thailand, policy announcements are transparent, but the pathways to achieve these policies are less so (S. Gheewala, personal communication, March 5, 2013; W. Ongsakul, personal communication, March 21, 2013). New regulations in 2010 made it much more difficult for VSPP projects to connect to the grid. The process for project implementation also became less transparent. "There is no channel that allows the public to monitor the work of this committee, hence causing confusion and doubts whether the process is fair and clean of business interests and political intervention (Tongsopit and Greacen, 2012, p. 14). There are also no guidelines nor timelines set that inform which projects will receive approval first and which projects advance quickest. This had led to a decrease in VSPP project applications.

Pilot Programs and Technology Innovation

Thailand started implementing RE pilot projects in the 1990s with the world's largest solar battery charging stations. These batteries were used to power people's homes. There was also a small solar rooftop program for Bangkok homes. People who installed solar panels were able to use the electricity they needed and then send the rest to the grid. This project was successful, but has since ended, and minimal follow-up information is available (S. Kumar, personal communication, March 8, 2013).

Thailand's National Science and Technology Development Agency (NSTDA) (Figure 4.5) considers itself to be the driving force for science and technology innovation in Thailand. It aims to play a key role in developing a knowledge-based society by developing human resources, facilitating technology transfer, and developing science and technology infrastructure (National Science and Technology Development Agency, 2009).

NSTDA is helping industries in Thailand reduce their dependence on fossil fuels and produce more environmentally friendly products. The agency conducts research and development on biogas, bio-energy, and solar cells. Its Solar Cells Program is developing a high-efficiency thin-film solar panel, a hybrid solar-cell prototype which is better suited to Thailand's tropical climate, and an organically based solar cell. The department's research in biogas and bio-energy helps increase the efficiency of wastewater systems, lower electricity consumption, minimize odor, and reduce the use of polluting chemical treatments. In addition, Thailand is currently the largest solar panel producer in the Association of Southeast Asian Nations (ASEAN) (National Science and Technology Development Agency, 2009).

Research and development is happening in the private sector as well. In January 2013, the Federation of Thai Industries announced that it would invest $1.9 million in a pilot biomass gasification project in Saraburi. The project will use technology developed in Spain.

Compliance with Kyoto

Many experts agree that the signing (1999), ratifying (2002), and enforcement (2005) of the Kyoto Protocol was a major driver of RE policies and projects in Thailand (G. Ali, personal communication, March 15, 2013; S. Dhakal, personal communication, March 13, 2013; S. Gheewala, personal communication, March 5, 2013; W. Ongsakul, personal communication, March 21, 2013; A. Salam, personal communication, March 21, 2013). Complying with the Kyoto Protocol is the responsibility of the Office of Climate Change Coordination under the Ministry of Natural Resources and Environment (Figure 4.5).

Thailand's carbon dioxide emissions have increased rapidly since it began industrializing in the 1980s (Figure 4.12). Under the Protocol, Thailand agreed to reduce its emissions by 5% below its 1990 level, between 2008 and 2012.[9] As a non-Annex 1 country, Thailand is not bound to the agreement, but has chosen to enforce it on its own.

The power sector is consistently the number one producer of carbon dioxide emissions in Thailand (Figure 4.13). It is also the only sector that has continuously increased carbon dioxide emissions in the four years represented. This means that Thailand can substantially reduce its emissions by generating more power from RE sources.

[9] Although the figure does not show a reduction, data is not yet available to determine if Thailand has accomplished this goal.

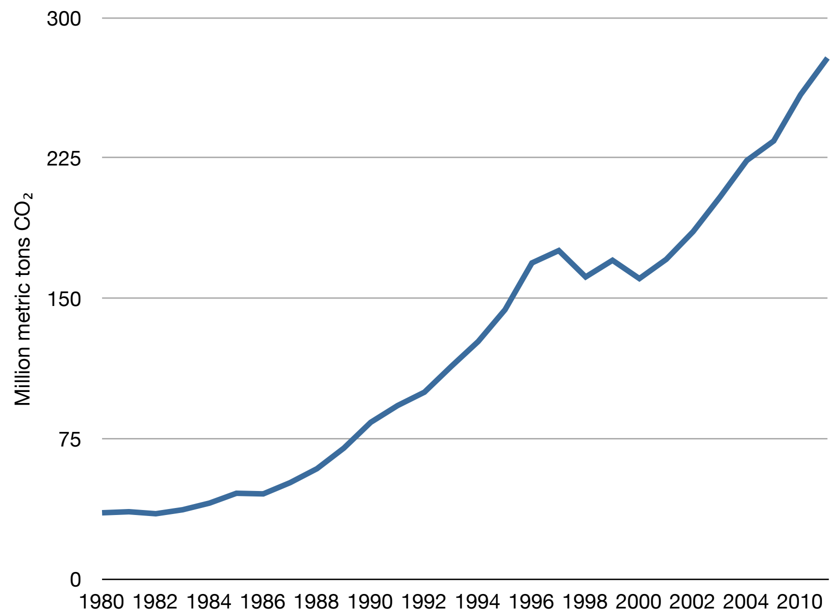

Figure 4.12: Thailand's ever growing carbon dioxide emissions. Energy conservation measures in the mid-1990s reduced the growth of carbon dioxide emissions. However, with continuous development, carbon dioxide emissions have again continued to grow. Data Source: Energy Information Administration, 2012

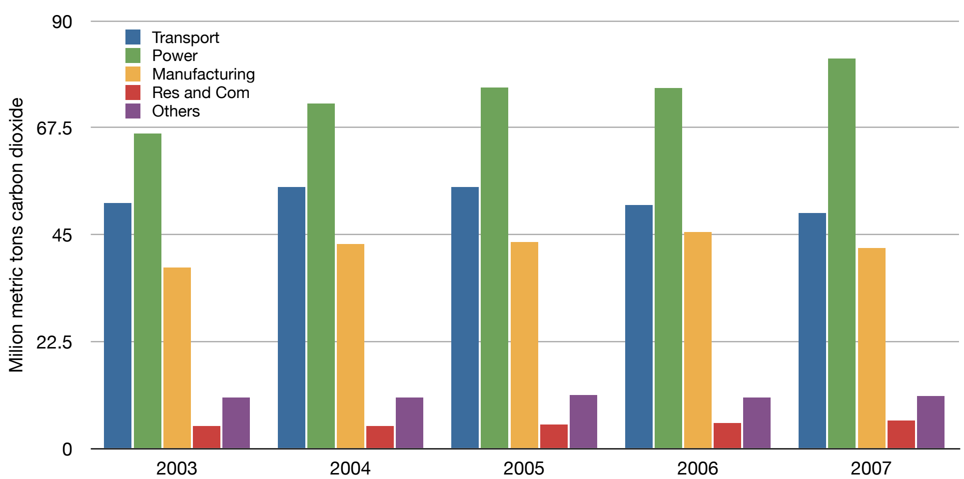

Figure 4.13: Thailand's carbon dioxide emissions by sector. The power sector is the largest carbon dioxide emitting sector, showing a great potential for RE use. Data Source: Department of Alternative Development and Efficiency, 2007

Thailand has a number of Clean Development Mechanism (CDM) programs.[10] As of March 2013, the Thailand Greenhouse Gas Management Organization (TGO) had a list of 125 registered projects with an expected average annual Certified Emission Reductions (CERs) of 6,123,393 tons of carbon dioxide. Some of these projects include wastewater treatment plants with biogas technology, rice husk power plants, landfill gas to electricity plants, and waste-to-energy plants (Thailand Greenhouse Gas Management Organization, 2013).

TGO has issued letters of approval for 221 projects with an expected average annual CERs of 12,710, 309 tons of carbon dioxide (Thailand Greenhouse Gas Management Organization, 2013). This is equivalent to removing 2.4 million vehicles from the road or removing 3.3 coal fired power plants (Environmental Protection Agency, 2013).

Some of these projects were implemented before any of Thailand's RE policies (S. Dhakal, personal communication, March 13, 2013). However, Thailand had already been implementing RE projects beforehand, so experts are unsure of the exact impact that the CDM projects have had on current RE policies and projects (S. Kumar, personal communication, March 8, 2013).

[10] A CDM, as defined in Article 12 of the Kyoto Protocol, "allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO2, which can be counted towards meeting Kyoto targets" (United Nations Framework Convention on Climate Change, 2013). For further details on CDM projects, please visit: http://unfccc.int/kyoto_protocol/mechanisms/clean_development_mechanism/items/2718.php.

Grid Connectivity

Compared to the other ASEAN countries, Thailand has a strong infrastructure system, especially for water, roads, and power (S. Kumar, personal communication, March 8, 2013).[11] The Provincial Electricity Authority of Thailand (Figure 4.5) has successfully connected 100% of villages and 87% of citizens to the grid (DEDE, 2010). This makes Thailand a geographic outlier considering the neighboring countries of Laos, Myanmar, and Cambodia only have 48%, 13%, and 24% of its citizens connected to the grid, respectively (Integrated Regional Information Networks, 2008; Dapice, 2012). Now that Thailand has almost all of its citizens connected to the grid, it is starting to emphasize RE grid-connected projects.

Thailand's AEDP 2012-2021 emphasizes grid-connected solar and wind farms. In December 2012, the BOI granted tax incentives for 32 projects valued at 108 billion Baht ($3.6 billion), mostly for RE projects. The Petroleum Authority of Thailand (PTT) (Figure 4.5), in partnership with Thai Solar Energy, will invest about 1.45 billion Baht ($48 million) to build a solar power plant. Thai Solar Energy currently has two solar parks (21 MW total) in development, one in Suphan Buri province, and the other in Kanchanaburi Province. Coenergy won the contacts for both of the parks. The parks together will cover almost 500,000 square meters, providing energy for roughly 14,000 homes. The parks are expected to be on-grid by 2013 (Coenergy, 2012).[12]

In September 2012, Bangchak Petroleum (Figure 4.5) began operating two commercial solar power plants, one at 10 MW capacity, and the other at 34.5 MW capacity. The plants were built with the help of a 15-year direct loan from the Asian Development Bank (valuing at $134 million). The plants will sell 30 MW to the Electricity Generating Authority of Thailand and 8 MW to the Provincial Electricity Authority.

[11] Thailand's power infrastructure system is relatively simple. The Electricity Authority of Thailand (EGAT) is the single buyer and owns about half of the power generation capacity and the transmission system. EGAT sells power to two distribution utilities: the Metropolitan Electricity Authority, which is responsible for selling electricity to consumers in Bangkok and the surrounding area, and the Provincial Electricity Authority, which is responsible for the remainder of the country. Individual power producers (IPPs) sell electricity directly to one of the two electricity utility companies under power purchase agreements. IPPs represent the second half of the power generation capacity (Amranand, 2008).

[12] Coenergy recently was awarded contracts to build three addition solar parks, bringing the total installed capacity to 52.5 MW (Coenergy, 2013).

The Electricity Generating Public Company Limited (EGCO) is one of the largest nonrenewable, and renewable, energy Independent Power Producers in Thailand. As of August 2012, there were 20 active EGCO power plants, with a combined installed capacity of 7,303 MW. Six of these plants are solar plants, with an installed capacity of 113 MW. Three other plants also use RE sources: rice husk (10 MW), parawood (i.e., rubberwood) (23 MW), and hydropower (1,087 MW). EGCO plans to build nine more power plants by 2019: two solar plants (63 MW), one wind plant (7 MW), one waste plant (7 MW), and one hydropower plant in Laos, which will import energy to Thailand (1,285 MW) (Electricity Generating Public Company Limited, 2013). EGCO's solar plants are the first privately-owned projects with solar tracking systems, making the plants much more efficient (20% efficiency versus the usual 8-15%). EGCO hopes to increase its RE generating capacity to 300 MW by 2015.

Despite 100% of villages being connected to the grid, Thailand still struggles with the power quality and stability requirements of increasing RE penetration into the grid. Also, grid-connected RE projects are limited to a few well-established investment companies. To balance this, grid-entry regulations are periodically revised. However, the regulations may be too limiting to allow for the large-scale RE implementation that the government is hoping for. If large-scale RE projects are to enter the grid, utilities will have to study the impact of proposed projects at specific locations on the grid, "rather than blanket studies and blanket policies that may miss location-specific or context-specific opportunities for greater renewable energy penetration" (Tongsopit and Greacen, 2012, p. 20).

Monitoring

Although Thailand has RE targets, there are no financial disincentives for noncompliance, nor are there incentives for compliance. This is in large part because Thailand has not set clear pathways to achieve their various energy plans. The AEDP sets percentages of energy sources, and years for achieving these percentages, but the Plan does not clearly state how these percentages will be achieved. The Plan does not outline who the investors of RE projects will be, the number of small- versus large-scale projects, and where these potential projects could be implemented.

As Dhakal noted in his interview, a lot of RE plans can be rhetorical. Targets and RE plans are set, but there is little monitoring in terms of whether these targets and goals are achieved (S. Dhakal, personal communication, March 13, 2013). Also, the plans and targets are not mandatory, so there is no formal monitoring (W. Ongsakul, personal communication, March 21, 2013).

The Energy Conservation Center of Thailand and the World Alliance for Decentralised Energy created a Master Plan and Roadmap for "Enhancing institutional capacities for the market development of decentralized energy systems in Thailand." Although slightly outdated, the final draft was made in 2009, an updated version of this document could be used to set the necessary pathways for reaching Thailand's RE targets.

4.5 THE CULTURAL CONTEXT FOR THE TRANSITION TO RENEWABLES

Ideally, Thailand's government measures success according to how well it maintains traditional culture, how happy people are, and how well it meets the goals of its Sufficiency Economy Plan (SEP) for energy independence and economic growth.

The SEP was developed by the National Economic and Social Development Board (NESDB), part of Office of the Prime Minister (Figure 4.5, with the goal of combating poverty in Thailand. The Plan is based on principles of moderation, reasonableness, and self-immunity (i.e., resilience). "It emphasizes sustainable development, sound macroeconomic policies, and the equitable sharing of the benefits of economic prosperity. At the same time, it shuns excessive risk-taking, untenable inequalities, and the wasteful use of natural resources" (United Nations Development Programme, 2007, p. iii).

The Gross National Happiness framework and index were also developed by NESDB (Figure 4.5). The concept of Gross National Happiness originated in Bhutan in 1972. Thailand's index consists of 35 indicators of happiness. To be happy, Thai citizens must have a good quality of life and enjoy emotional, physical, and intellectual well-being. They must also live peacefully with other humans and avoid damaging the environment.

For happiness to be possible, the country must be just, democratic, economically strong, and in a balanced condition. Individuals must live in a contented family, and have a strong sense of community. Finally, the natural environment must be healthy (Gozzoli, 2007).

The third measure of success is maintaining traditional culture. One analysis characterizes traditional Thai society as thrifty, collectivist, unassertive, persevering, hierarchical, risk averse, highly unequal, resistant to change, having rigid gender roles, and having a low tolerance for uncertainty (Hofstede, 2013).

Obviously, some disparities exist between the SEP and traditional cultural characteristics. The Plan explicitly aims to create equal distribution of power and wealth. While a goal of the Plan is to achieve energy independence, the traditional cultural characteristics of risk aversion, resistance to change, and low tolerance of uncertainty may hinder innovation and progress. However, the government is instigating change from the top down, which is in fact congruent with the hierarchical nature of the traditional culture.

Because both SEP and the Gross National Happiness framework were initiated under the Office of the Prime Minister, these two policies seep through the RE governance model (Figure 4.5). Practically all of the ministries and departments in Thailand, and their respective policies, must work to fulfill these two policies.

RE is a major component of the SEP, and RE policies support the goals of the SEP (W. Ongsakul, personal communication, March 21, 2013). Moderation, one of the Plan's main principles, can be interpreted as finding the right balance between all of the available natural resources, including fossil fuels and RE sources. Reasonableness, another principle of the Plan, is reflected in the attainable RE goal of 25% renewables by 2021. Self-immunity, the third principle, is reflected in the Plan's goal of energy independence.

Thailand's energy goals are also congruent with Gross National Happiness. Thailand achieves energy balance through a diverse energy portfolio. By incentivizing RE technologies, the government promotes economic growth and makes energy available to all citizens. The country is improving environmental quality by reducing the need for fossil fuels.

The government's skillful integration of traditional cultural values into policy goals may be a reason why RE development has been successful. The country's cultural values reflects its religious foundations: Confucianism, Taoism, and Buddhism. Confucianism emphasizes responsibility, compassion, humility, and self-restrain. Taoism emphasizes the importance of health and vitality and of allowing nature to take its course. Taoists seek three "Jewels:" compassion, moderation, and humility. One should plan in advance and carefully consider each action before taking it. A Taoist is kind to other individuals without expecting a reward (Robinson, 2009). Buddhism emphasizes egolessness. Release from suffering can be attained by a right view of the world, right intention, right speech, right discipline, right livelihood, right effort, right mindfulness (precision and clarity), and right concentration or absorption. All of these have to do with self-restraint, responsibility, and compassion for all living things. Buddhists communities in Thailand focus on living sustainably, in harmony with the environment. Ninety-five percent of Thais are Buddhists.

4.6 CONCLUSION

This chapter summarized Thailand's push for RE implementation. Thailand seems to be as innovative as some of the top RE users in the world, mentioned in Chapter 3. It is implementing RE through its strong government commitment, stakeholder engagement and community building, transparency of information, pilot programs and technology innovation, compliance to the Kyoto Protocol, even though it is not an Annex 1 country, and grid connectivity.

Thailand has a strong foundation to successfully implement RE technologies. However, it still faces many barriers that keep it from reaching its full potential. For example, most RE polices focus on supply, and little has been done to increase RE demand (S. Gheewala, personal communication, March 5, 2013; Tongsopit and Greacen, 2012). Also, although RE targets have been set, there are no direct pathways to achieve these targets laid out. It could be argued that a renewable energy law (REL) could help determine these pathways.

Some experts advocate for an REL (Painuly, 2001; WADE, 2009; Wang et al., 2010; Schuman and Lin, 2012; Tongsopit and Greacen, 2012; C. Greacen, personal communication, March 7, 2013), yet Thailand has not implemented one. An REL would provide legal mandates for its various RE plans and financial mechanisms. Perhaps if a law were in place, then incentives for compliance and disincentives for noncompliance could be implemented. Targets would become mandatory, making formal monitoring possible. An REL has been successfully used in Germany, China, and Spain (World Alliance for Decentralised Energy and The Energy Conservation Center of Thailand, 2009).

However, an REL is the essence of a commons dilemma and represents a Leviathan, as discussed in Ostrom (1990). A Leviathan is a coercive force external to the users of the commons. An REL would represent the government's use of a strict regulation to force power producers to internalize the externalities that they generate, in this case carbon dioxide emissions. Power producers would have to follow the REL, and if they failed to do so, there would be formal consequences, such as a fine. However, these power producers are in charge of meeting energy needs, and nonrenewable energy sources are still required to meet Thailand's growing energy needs. Also, Thailand is embedded within a larger, international system, and unless all countries implement an REL, then Thailand can loose competitiveness at the global scale. Therefore, instead of implementing an REL, Thailand should ensure that power producers at all scales can effectively and economically deploy RE projects that are able to connect to the grid and be distributed. I believe that with policies such as the VSPP and the adder program, Thailand is doing just this.

Currently, the marginal cost of electricity is high at the times when peak load is high. Thailand needs institutional changes where the price signal gives investors the opportunity to invest (C. Greacen, personal communication, March 7, 2013; W. Ongsakul, personal communication, March 21, 2013), while reducing the temptation for companies to outsource projects to receive subsidies and save money (A. Salam, personal communication, March 21, 2013). There needs to be a fundamental change within the utility business model so that investors are encouraged to invest in RE technologies. Prices for RE are starting to compete with those of nonrenewable energy sources, even without subsidies (C. Greacen, personal communication, March 7, 2013). Hopefully, this can help increase and strengthen RE investments.

Lastly, Thailand could have stronger coordination of actions and policy making between the various departments and ministries. For example, the Electricity Authority of Thailand (EGAT) created the Power Development Plan which lays out what power plants of what types of power are installed, and when they are installed, to meet energy projections. EGAT's Plan has no connection to the AEDP goals, which sets targets for the various RE resources but not a pathway for achieving these targets. If the Power Development Plan and the AEDP were combined, then pathways for the targets could be determined, and Thailand would be sure to meet its RE targets.

The final chapter will draw out the relationships between all of the case studies and the institutional drivers that have lead to energy transitions in these countries. I will determine the success of the institutional drivers. I will also apply the case studies to Ostrom's Social-Ecological Systems Framework to answer the question: When will a country experience an energy transition? I will briefly discuss lessons about transitions, and then describe how other countries can successfully implement RE. I will then outline a potential order of implementation for success. I will apply the institutional drivers to Cavanagh's "sustainable society" to see if energy transitions support a sustainable society. I will conclude by briefly discussing future research opportunities.

Chapter 5

INNOVATION WITHIN TRADITION

5.1 INTRODUCTION

After nearly 170 years of dependence on fossil-fuel energy, and the unsustainable consequences of such dependence (e.g., climate change), many countries are making an energy transition away from a nonrenewable-based energy system to one which includes and may be dominated by renewable energy (RE).

The purpose of this research was to provide information about the energy transitions currently underway in six case-study nations (i.e., Brazil, Spain, Germany, China, the United States, and Thailand) that would help other countries understand the elements that facilitate RE implementation. My research has found that there are three factors that link the exogenous variables from the Institutional Analysis and Development Framework (IADF) and that promote successful long-term RE implementation. The first factor is that in order for RE innovation to spread, a society must have a strong pro-environmental culture. This factor relates to the attributes of the community. The society should also contain eight institutional drivers that link the biophysical conditions with the rules in use, the second factor:

- Government commitment;
- Polycentricity;
- Stakeholder participation and community building;
- Transparency of information;
- Pilot programs and technology innovation;
- Compliance with the Kyoto Protocol;
- Grid connectivity; and
- Monitoring.

It is important to note that in all of the countries studied, these drivers do not conflict with the country's traditional cultural values, the third factor. This represents the relationship and positive interaction between all three exogenous variables to drive RE use. Because the eight institutional drivers do not conflict with culture, the RE sources within a country (biophysical context), pro-environmental values (community attributes), and financial and policy mechanisms (rules in use) can be augmented to promote an energy transition. The values, beliefs, and norms of a culture help determine whether RE implementation is feasible. Innovation can only happen in a cultural setting which is open to it. The combination of a pro-environmental culture, institutional drivers, and the alignment of these drivers with a country's traditional cultural values permits innovation within tradition.

5.2 DETERMINING THE SUCCESS OF THE INSTITUTIONAL DRIVERS IN THE CASE STUDY COUNTRIES

Cox et al. (2010) compared the relationship between each of Ostrom's design principles with the success or failure of 91 cases of common-pool resource management to determine if theory matched reality. In the same spirit, Figure 5.1 shows which drivers are strongly or weakly represented for each of the case study countries. Figure 5.2 is a similar comparison to Cox et al. but uses the eight institutional drivers discussed above instead of Ostrom's eight design principles. The figure shows whether the driver is strongly or weakly present in the six case study countries: Germany, Spain, Brazil, China, the United States, and Thailand.

Drivers with strong evidence are those where RE has been historically driven by these drivers. Transparency of information, as defined and outlined above, and pilot programs and technology innovations are the two strongest institutional drivers. All of the case study countries have successfully implemented these drivers. Government commitment and compliance with the Kyoto Protocol are the next two strongest drivers. The United States is the only case study country that has not strongly implemented these drivers. This is mainly because many RE policies and projects get implemented at the state rather than the federal level.

While China and Thailand are the two case study countries that have only weakly implemented the stakeholder participation and community building driver, Spain and Brazil, along with China and Thailand, have weakly implemented the polycentricity driver. Both Asian countries have a history of top-down decision-making and limited involvement of citizens. Fortunately, both countries (with Thailand leading over China) are beginning to involve the public at a deeper level.

Country	Strong Driver(s)	Number of Strong Drivers	Weak Driver(s)	Number of Weak Drivers
Germany	Government commitment; Polycentricity; Stakeholder participation and community building; Transparency of information; Pilot programs and technology innovation; Compliance with Kyoto Protocol; Grid connectivity	7	Monitoring	1
Spain	Government commitment; Stakeholder participation and community building; Transparency of information; Pilot programs and technology innovation; Compliance with Kyoto Protocol	5	Polycentricity; Grid connectivity; Monitoring	3
Brazil	Government commitment; Stakeholder participation and community building; Transparency of information; Pilot programs and technology innovation; Compliance with Kyoto Protocol	5	Polycentricity; Grid connectivity; Monitoring	3
China	Government commitment; Transparency of information; Pilot programs and technology innovation; Compliance with Kyoto Protocol	4	Polycentricity; Stakeholder participation and community building; Grid connectivity; Monitoring	4
United States	Polycentricity; Stakeholder participation and community building; Transparency of information; Pilot programs and technology innovation	4	Government commitment; Compliance with Kyoto Protocol; Grid connectivity; Monitoring	4
Thailand	Government commitment; Transparency of information; Pilot programs and technology innovation; Compliance with Kyoto Protocol	4	Polycentricity; Stakeholder participation and community building; Grid connectivity; Monitoring	4

Figure 5.1: Determination of whether a driver is strongly or weakly represented for each of the case studies. Germany has the largest number of drivers strongly represented, and arguably is experiencing the fastest energy transition.

Spain, having very low population density, has not experienced much citizen opposition to RE, and thus, has limited citizen-led organizations. It can be assumed that because of the success of Brazil's Proalcool program, citizens have not felt the need to organize and create organizations.

Although connecting RE technologies to the grid is a barrier in all of the case study countries, Germany is the only country progressively moving towards changing their existing grid system to make RE adoption easier. Lastly, none of the case study countries have strongly implemented a monitoring system to improve the success of RE policies and projects. None of the countries have incentives for compliance or disincentives for noncompliance. However, Germany, Spain, and China have implemented an RE law, and it can be assumed that breaking the law will result in some form of punishment. However, what this punishment is, has not yet been identified.

Institutional Driver	Strength	Evidence	Percent Representation (N=6)
1. Government commitment	Strong	Germany, Spain, Brazil, China, Thailand	83%
	Weak	United States	17%
2. Polycentricity	Strong	Germany, United States	33%
	Weak	Spain, Brazil, China, Thailand	67%
3. Stakeholder participation and community building	Strong	Germany, Spain, Brazil, United States	67%
	Weak	China, Thailand	33%
4. Transparency of Information	Strong	Germany, Spain, Brazil, China, United States, Thailand	100%
	Weak	-	0%
5. Pilot programs and technology innovation	Strong	Germany, Spain, Brazil, China, United States, Thailand	100%
	Weak	-	0%
6. Compliance with the Kyoto Protocol	Strong	Germany, Spain, Brazil, China, Thailand	83%
	Weak	United States	17%
7. Grid connectivity	Strong	Germany	17%
	Weak	Spain, Brazil, China, United States, Thailand	83%
8. Monitoring	Strong	-	0%
	Weak	Germany, Spain, Brazil, China, United States, Thailand	100%

Figure 5.2: Relationship between each institutional driver and strong or weak presence in the case study countries. A strong presence shows that the particular driver is necessary for an energy transition.

I would argue that long-term RE commitment will depend on seeing a transformation of weak drivers to strong drivers. Countries should prioritize these transformations, with polycentricity being the highest priority, then grid connectivity, then monitoring. Polycentricity is the first driver to prioritize because it has been useful in driving RE use in two of the leading RE using countries (Germany and the United States). Polycentricity has also been found to be a strong driver in solving collective-action problems that arise when managing common-pool resources, such as reducing the risks associated with greenhouse gas emissions (Ostrom, 2008; Ostrom, 2010). While Germany has focused on grid connectivity, its, along with the other case study countries, initial RE push was able to occur without changing the original grid system. Thus, grid connectivity is second on the priority list. None of the case study countries have augmented monitoring mechanisms to promote RE use, and yet they have still been relatively successful. Therefore, monitoring is prioritized last.

While the current strong drivers have led the way, the remaining drivers are the ones that will continue the push and lead to long-term commitments to RE deployment. At the organization and engagement level, polycentricity may ensure that all stakeholders, from government to industry to citizens, have a say in RE policies and projects. This will ensure that strong support for RE is maintained, and that local knowledge and resources will be augmented.

On the technical side, grid connectivity is a major requirement for large-scale RE deployment. Countries must invest in retrofitting old infrastructure, and if possible, research and deploy a Smart grid. Otherwise, RE will not be able to be stored, and we will continue to experience intermittency problems.

To assure long-term success of RE implementation, countries should implement formal monitoring and augment informal monitoring. One potential starting point would be to implement a Renewable Energy Law, thus creating a pathway for formal monitoring. Local governments and industries that do not achieve certain targets would be sanctioned or otherwise punished. However, as mentioned in Chapter 4, governments should be sure that the implementation of an REL will not lead to a Leviathan (Ostrom, 1990). As RE implementation becomes a norm, informal monitoring (e.g., gossip, finger-pointing, and poor media attention) at all levels will ensure that governments and industries continue to successfully deploy RE policies and projects. Perhaps, it will eventually be a stigma to have limited RE policies and projects.

All in all, it is a clustering of drivers that is necessary for long-term success of RE in a country. All of the case study countries have focused on augmenting at least four of the eight institutional drivers. While initial investment and implementation may only require a clustering of a few drivers (most notably government commitment, polycentricity, stakeholder participation and community building, transparency of information, and pilot programs and technology innovation), I argue that to ensure long-term, successful RE implementation, the case study countries should augment all eight institutional drivers. China, Thailand, and the United States have augmented the fewest drivers, four each. The United States should focus on increasing government commitment, most notably setting a national Renewable Portfolio Standard. The U.S. must also increase stakeholder participation and community building, create a grid system that allows for the easy deployment of RE technologies, and enforce RE use through monitoring and sanctioning. Although the U.S. does not need to comply with the Kyoto Protocol, it can implement its own greenhouse gas emissions reduction plan that could lead to an increase in RE use.

Thailand and China should increase stakeholder participation and community building. This may lead to an increase in polycentricity as well, a driver that both countries lack. Like most of the other case study countries, Thailand and China may need to retrofit its grid to allow for easier deployment of RE technologies. Both countries must also implement a monitoring system.

Spain and Brazil have augmented five drivers each. Both countries need to become more polycentric, retrofit their existing grid system, and create and enforce a monitoring system. Germany has augmented the greatest number of drivers, seven, and I would argue that it is the global leader in RE implementation and may be the first country to experience a full energy transition. The only driver it has yet to augment, like the other case study countries, is the development and enforcement of a monitoring system.

5.3 APPLYING OSTROM'S SOCIAL-ECOLOGICAL SYSTEMS FRAMEWORK TO THE CASES

In 2009, Ostrom published an updated general framework for analyzing the sustainability of social-ecological systems, otherwise known as the Social-Ecological Systems (SES) Framework. This Framework allows for a holistic understanding of a complex system by separating out the components and seeing how they interact. She separates these components into tiered variables.

Chapters 3 and 4 describe the energy transitions taking place in six case study countries: Germany, Spain, Brazil, China, the United States, and Thailand. With an understanding of these systems, I have adapted the SES Framework to better understand national energy systems. The SES Framework allows for an analysis of an energy system in any country. The SES Framework can be used to answer the questions: When will a country experience an energy transition? What variables are necessary for this transition to take place? Figure 5.3 represents the first tier of variables to better understand an energy production system in the country being studied.

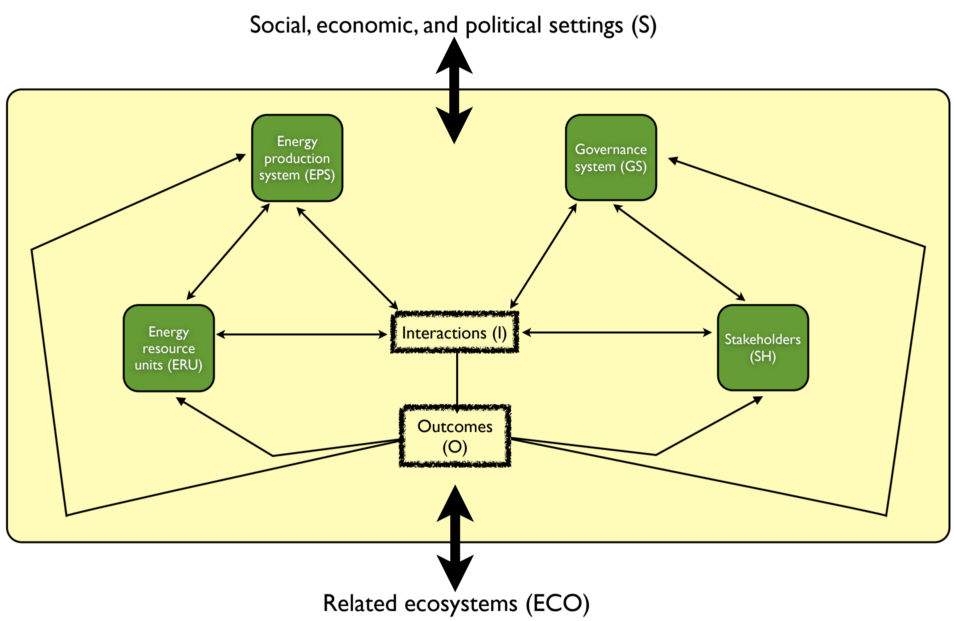

Figure 5.3: Adaptation of the Social-Ecological System Framework to understand an energy production system. Adapted from: Ostrom, 2009

There are four subsystems in the SES Framework: 1) energy production system (i.e., the energy system laid out by a particular country); 2) energy resource units (e.g., the types of energy being produced and consumed); 3) governance system (e.g., the government and organizations that manage the energy system, the rules-in-use, and how these rules were made); and 4) stakeholders (e.g., those that produce and consume energy).

Each of the subsystems is characterized by a list of second-tiered variables (Figure 5.4). Some of these variables can also be broken down into third, and sometimes, fourth-tiered variables. All of these variables can be used to better understand when a country will experience an energy transition. These variables were developed using the six case studies analyzed in this dissertation: Germany, Spain, Brazil, China, United States, and Thailand.

Social, economic, and political settings (S)
S1 Economic development. S2 Demographic trends. S3 Political stability. S4 Government resource policies. S5 Market incentives. S6 Media organization.

Energy production system (EPS)
EPS1 Sector (i.e., nonrenewable, renewable, or both)
EPS2 Clarity of system boundaries (i.e., energy produced domestically versus imported)
EPS3 Size of the energy system (i.e., managed at the national government, state, or provincial level)
EPS4 Human-constructed facilities (for both nonrenewables and renewables)
EPS5 Predictability of system dynamics
EPS6 Storage characteristics (for both nonrenewables and renewables)
EPS7 Location of production and consumption
EPS8 Infrastructure (i.e., typical grid system versus smart grid)
EPS9 New resource developments (e.g., oil field discoveries)

Energy resource units (ERU)
ERU1 Type of resource (i.e., nonrenewable or renewable)
ERU2 Growth or replacement rate (i.e., replacing nonrenewable technologies with renewable technologies)
ERU3 Interaction among resource units (i.e., hybrid energy systems)
ERU4 Price per unit of energy (for both nonrenewable and renewables
ERU5 Number of units (for both nonrenewable and renewable technologies)
ERU6 Spatial and temporal distribution

Governance System (GS)
GS1 Government organizations
GS2 Nongovernment organizations
GS3 Independent Power Producers
GS4 Network structure
GS5 Property-rights system
GS6 Operational rules
GS7 Collective-choice rules
GS8 Constitutional rules
GS9 Monitoring and sanctioning processes

Stakeholders (SH)
SH1 Number of producers
SH2 Number of consumers
SH3 Socioeconomic attributes of consumers (may vary for nonrenewable versus renewable)
SH4 History of use
SH5 Location
SH6 Entrepreneurship and innovation
SH7 Norms/social capital
SH8 Traditional culture of consumers
SH9 Knowledge of technology types (both nonrenewable and renewable)
SH10 Technology used

Interactions (I) ⟶ Outcomes (O)

I1 Energy usage of consumers
I2 Information sharing among users
I3 Deliberation processes
I4 Conflicts among users
I5 Investment activities
I6 Lobbying activities
I7 Self-organizing activities
I8 Networking activities

O1 Social performance measures (e.g., efficiency, equity, accountability, sustainability)
O2 Ecological performance measures (e.g., depletion of nonrenewables, resilience, sustainability)
O3 Externalities to other SESs

Related ecosystems (ECO)
ECO1 Climate change. ECO2 Pollution emissions. ECO3 Water system. ECO4 Food system. ECO5 Transportation system.

Figure 5.4: Examples of second-tier variables under first-level core subsystems (S, EPS, GS, ERU, SH, I, O, and ECO) in a framework for analyzing an energy system. These variables are not listed in order of importance, because their importance varies in different countries. Adapted from: Ostrom, 2009

The variables listed in Figure 5.4 are posited to affect the likelihood of a country to experience an energy transition. To explain why these variables are potentially important for an energy transition, I will briefly discuss how they have impacted energy transitions in the case study countries.

Social, economic, and political settings (S): To begin, a country's social, economic, and political setting will be the first set of variables to determine whether an energy transition is even possible in the country. A country with a growing economy (S1), such as China and Thailand, can use RE technologies as part of their growth plan. Also, the demographics (S2) can help determine whether the people of the country are interested in personally investing in RE. All of the case study countries are characterized by political stability (S3); the country can focus on energy resources rather than facing political instability challenges. All case study countries also have government resource policies (S4) that create RE targets and/or Renewable Portfolio Standards. Research has shown that RE technologies are quickly implemented when there are market incentives (S5); Brazil's biofuels program is the perfect example of the market incentivizing use. There must also be a media organization (S6) to bring the information to the public. This ensures RE project and policy transparency.

Energy production system (EPS): To better understand the energy production system of a country, and whether the country is transitioning to RE use, I have identified nine second-tier variables. We must first understand the sector (EPS1) of energy, whether it is solely nonrenewable-energy based, RE-based, or a combination of both. All of the case study countries have a combination of both, but Germany is progressing towards a solely RE-based sector. Clarity of the system boundaries (EPS2) identifies whether a country only produces energy domestically, or, like all of the case study countries, they rely on some external energy sources. For example, Thailand imports hydropower from Laos and the United States imports oil from the Middle East. Although studying energy at the national scale, some energy production systems may be governed at a different or multiple scale(s) (EPS3). The states within the U.S. govern their own energy production systems, and in China, provinces also govern their own systems. Human-constructed facilities (EPS4) can be classified as either nonrenewable or renewable. A third-tiered variable here would be the different types of technologies (e.g., natural gas plant, solar farm, wind farm) that are being constructed. Energy systems are inherently unpredictable on a certain time scale (EPS5), but some technologies may allow for stronger predictability than others. For example, a country is most like going to know on which days the sun will shine versus when a new oil field may be discovered. Storage characteristics (EPS6) for nonrenewables versus renewables are quite different. Currently, renewables require a battery system for storage. It is important to know the location of production and consumption (EPS7) of the various energy types within a country. Although all countries currently have an existing grid infrastructure (EPS8), Germany is on track to implement a smart grid infrastructure, making it easier to connect RE projects to the grid. New resource developments (EPS9) are a common occurrence in all of the case study countries. However, while some countries continue to search for new oil and natural gas fields (e.g., Thailand), others are focussing on RE discoveries (e.g., Germany).

Energy resource units (ERU): With a focus on the energy resource units, six second-tier variables have been identified. The type of resource(s) (ERU1) being used in a country will show whether an emphasis is placed on nonrenewables or a transition to renewables use. The growth or replacement rate (ERU2) of technologies, especially the replacement of nonrenewables with renewables, clearly shows if a country is transitioning. Some countries, such as Thailand and Germany, are innovatively creating energy systems that allow for an interaction among the resource units (ERU3). Price per unit of energy (ERU4) is currently very different for nonrenewables than renewables; nonrenewables are currently less expensive than renewables. Once renewables are price competitive, then a transition will most likely occur, as is the case with Brazil's biofuels program. The number of units (ERU5) of the different types of technologies shows how quickly a country is transitioning to RE use. The spatial and temporal distribution (ERU6) of the different energy sources shows how quickly a country is transitioning as well.

Governance system (GS): Nine second-tier governance system variables have been identified. The number of government organizations (GS1) shows how spread out through the government energy decisions are. For example, in Thailand, energy polices and projects are the responsibility of a variety of government organizations. The number of nongovernment organizations (GS2) can characterize whether a country is involving stakeholders in the decision-making process and how transparent energy decisions are in the country. Some countries, such as the U.S., have a great deal of nongovernmental organizations that play a role in policies and projects, as where other countries, such as China and Thailand, have limited nongovernmental organizations. Most decisions in these two countries are done by the government. Some countries, have a great deal of Independent Power Producers (GS3). In Thailand, IPPs represent 50% of energy generation. The network system (GS4) of a country helps lay out the energy governance system. The property-rights system (GS4) identifies whether energy projects are being done on land that is public, private, or a combination of both. This can also identify the scale of implementation of the energy technologies. Operational, collective-choice, and constitutional rules (GS6, GS7, GS8) help determine which technology gets implemented at which scale and where. Monitoring and sanctioning processes (GS9) will determine formal and informal consequences to compliance or noncompliance of RE targets.

Stakeholders (SH): Ten second-tier variables characterizing the stakeholders have been identified. To begin, a country must determine the number of producers (SH1) and the number of consumers (SH2) of energy. The socioeconomic attributes of the consumers (SH3) may vary based on the energy type. For example, in some states in the U.S., consumers can choose to add a certain price amount to their electricity bill to ensure that their electricity company invests in RE. Of course, only consumers who can afford this added cost will choose to increase their bill. All energy technologies have their own history of use (SH4). Energy types that have been used for a long period of time, such as fossil fuels, may be more difficult to stop using than newer, innovative technologies. The location (SH5) of the stakeholders determines whether they will choose to personally use a certain technology, such as installing solar panels on their home, or whether they are located far from the energy source, and thus may not be aware of its negative consequences. Entrepreneurship and innovation (SH6) can lead to further RE technology development and deployment. The norms/social capital (SH7) of a country will shape what technologies are most likely to be used. Traditional culture of consumers (SH8) will also affect the use of different technologies. For example, Thailand's traditional culture, i.e., Buddhism, seems to play a role in its energy transition. Whether a stakeholder is knowledgeable of different technology types (SH9) will determine which technologies are most likely to be used and/or provided funding for. Lastly, the technology being used (SH10) by a stakeholder will determine whether more RE technologies are used or whether stakeholders are only investing in nonrenewable-energy sources.

Interactions (I): There are eight second-tier variables that characterize the interactions within an energy system. Since most consumers rely on a variety of energy sources, the energy usage of the consumers (I1) can determine if more renewables, rather than nonrenewables, are being used. Information sharing among users (I2) can spread knowledge about the differences between nonrenewable and RE sources. Community members and government officials may experience a deliberation process (I3) to determine energy policies and projects. Conflict among users (I4) can halt the development of certain energy projects, both nonrenewable and renewable. Investment activities (I5) of consumers can drive RE use. Especially in the U.S., lobbying activities (I6) by fossil fuel companies have slowed the energy transition process. The ability for people to self-organize (I7) can lead to small-scale RE projects and increases polycentricity in a country. Networking activities (I8) within and among consumers, producers, and governments can lead to greater RE use.

Outcomes (O): There are three second-tier outcomes variables that characterize an energy system. There are social performance measures (O1) such as efficiency, equity, accountability, and sustainability, that can inform a researcher about RE use in a country. Ecological performance measures (O2) such as depletion of nonrenewable sources, resilience of energy systems, and sustainability can also be an information tool. Lastly, externalities to other SESs (O3), such as carbon externalities, can push a country to increase RE use.

Related ecosystems (ECO): There are five second-tier related ecosystems variables that have been identified. Climate change (ECO1) has been shown to be a main driver of RE use, since energy systems, especially those dominated by nonrenewable-energy use, greatly impact climate change. Similar to climate change, pollution emissions (ECO2) will determine what types of energy technologies will be used. The water, food, and transportation systems (ECO3, ECO4, ECO5) all impact and are impacted by energy systems. Changes in one of these systems can have great impacts on the other. For example, the water system relies on energy to transport water from the source to the user. The food systems is dependent on energy systems in the agricultural process. And the transportation system relies on energy systems for fuel.

All of these variables, and the interactions and outcomes associated with them, can identify to an analyzer whether a country is experiencing an energy transition or not. A country can also leverage these variables to ensure that RE technology use increases, and that all stakeholders are involved in the decision-making process, ensuring that RE implementation is long-lasting.

5.4 LESSONS ABOUT TRANSITIONS

This dissertation has uncovered two key lessons about transitions. First, the trouble with an energy transition, especially in a developed country, is that the existing system is based on infrastructure that has been in place for a long time. Infrastructure is the energy-system component which is the most costly to change. Therefore, infrastructure tends "to be locked-in to unsustainable states for long periods" (Truffer et al., 2010, p. 259). In countryies where rural communities still lack connection to the grid, there is the potential to innovatively connect them to the grid through the use of RE. Rural communities in the developing world are not stuck in the infrastructure lock-in that many developed countries are. These countries can create new infrastructure that allows for easy RE connectivity.

The second lesson is that to make sure that RE implementation is long term, a country should have a transition plan. It is likely not sufficient to take initial steps toward transitioning to RE and hoping that the transition will carry through. A transition plan may ensure follow through and long-term goal setting. Having a transition plan "increases transparency, reflexivity and communication substantially" (Truffer et al., 2010, p. 263). A transition plan not only includes an RE target to be achieved by a certain date, but a strategy for achieving this target. The strategy can include mile markers along the way, individual energy-source targets, and/or decision-making processes that are "participative (respecting different knowledge perspectives and value positions), open to experimentation and learning (to enhance prospects for alternative system configurations), flexible (relative to changing context conditions) and reflexive (with regard to value considerations of different stakeholder groups and the long-term orientation of a sustainable sector future)" (Truffer et al., 2010, p. 262).

Countries that aspire to make an energy transition should leverage these two lessons from the outset.

5.5 MAKING RENEWABLE-ENERGY IMPLEMENTATION SUCCESSFUL

There are three factors that seem to lead to successful RE implementation:

- Pro-environmental culture;
- Eight institutional drivers; and
- Compatibility of the eight institutional drivers with traditional cultural values.

Although all of the case-study countries are implementing RE, not all of them are characterized by all three factors. I argue that Germany and Thailand are the two case studies that contain all three.

In most of the case-study countries, one or more of the eight institutional drivers conflicts with the traditional cultural values of the country. For example, the U.S. places strong emphasis on consumption and individuality. Americans are not used to strong government regulation, the way Europeans are. This is why the U.S. has yet to set a national RE target, and instead allows states to take their own individual initiatives. Historically, decision making in China is not characterized by polycentricity, nor by stakeholder participation and community building. Although the Chinese government is strongly committed to RE implementation, the users of the energy have not been able to participate in the decision making. This may lead to RE failures in the near future.

Not only do both Germany and Thailand have a pro-environmental culture, but the eight institutional drivers reflect this, and other, traditional cultural values. The citizens in both countries have had a strong influence on which energy technologies have, and have not, been used. In the early 1990s, German citizens were some of the most concerned about global warming. They pushed for RE implementation. They have stood up against the implementation of large-scale hydropower dams, and their protests have halted the development of many such dams. Both governments have also made strong government commitments to RE implementation, and both have also mapped out a transition plan to achieve their RE targets.

5.6 HOW OTHER COUNTRIES CAN IMPLEMENT RENEWABLE ENERGY

Although a country's traditional cultural values may clash with one or more of the eight institutional drivers, this does not mean that RE implementation is impossible. In fact, many values can be shaped to accommodate the drivers.

Fortunately, in no culture do people value destroying the environment over protecting it. However, many cultures value the environment for different purposes, such as aesthetic beauty, natural resources, or for its recreational opportunities. RE implementation can be pushed by a government or industry to capture all three of these values: RE technologies are more aesthetically pleasing than a coal power plant, RE sources occur naturally all over the world, and using RE sources protects natural areas from being exploited for their fossil fuels.

Of the eight institutional drivers, two appear to be crucial (government commitment and grid connectivity), while the other six tap more into the traditional cultural values of a country (polycentricity, stakeholder engagement and community building, transparency of information, pilot programs and technological innovation, compliance with the Kyoto protocol, and monitoring). Whether these last six exist in a country or not is dependent on whether they are culturally expected or not. A consultant can make a plan for RE development in any country by first understanding the traditional cultural values and then fitting the institutional drivers within them.

Almost every country has signed and/or ratified the Kyoto Protocol (with the notable exception of the U.S.). One of the best ways to meet the requirements of the Protocol is to implement RE technologies. A consultant would begin by emphasizing the importance of strong government commitment. Government commitment could begin with the implementation of a national RE target and a transition plan to achieve this target over the desired time frame. The consultant would then talk to citizens and convene stakeholder groups and forums, where citizens would have a say in which RE technologies were implemented, and where. The consultant would help establish a polycentric governance system, and emphasize that stakeholder engagement and community building are some of the strongest characteristics of successful RE implementation.

If the consultant is working in a developing country, then creating a grid system which is able to handle RE loads will be much easier than it would be in a developed country. However, off-grid, small-scale RE projects are always an option when larger-scale, grid-connected projects are too challenging. Whether a project is large-scale or small-scale, monitoring will increase its success. Both formal and informal incentives for compliance, and disincentives for noncompliance, may be implemented, depending on the culture and the scale of the project.

Stakeholder engagement and monitoring help make RE information transparent. A consultant would encourage the government to publish the RE transition plan and all information on energy use. The decision-making process should be transparent at all levels.

The consultant would emphasize the importance of RE research and development to spur technological and social innovation. Pilot programs and technological innovation can occur at many scales and levels. The government can provide grants for universities to develop technologies and analyze current RE information. Industries can organize intra- and extra-mural competitions to provide incentives for RE innovation.

5.7 APPLICATION OF CAVANAGH'S SUSTAINABLE SOCIETY PRINCIPLES TO RENEWABLE ENERGY TRANSITIONS

Since this dissertation is written as part of the requirements of the School of Sustainability, I would like to orient my research within the field of sustainability science. In 2004, John Cavanagh proposed "Ten principles for sustainable societies." He argues that sustainable societies

> *"vest power in institutions that measure their performance by their contribution to the long-term well-being of people, community, and nature and distribute power equitably among all of society's stakeholders. Such societies are measured by their essential qualities, primarily the well-being of all their people. Each sustainable community and nation seeks to achieve sufficient self-reliance in meeting basic needs-including food, shelter, clean water, energy, education, health, political participation, and culture-to assure the livelihoods, civil liberties, and sense of meaning and identity of each of its members"* (2004, p. 78).

Because of how Cavanagh defines it, a sustainable society shares many common characteristics with one experiencing an energy transition. A number of these principles support a transition to RE implementation. In addition, the eight institutional drivers developed above also share characteristics with a sustainable society. (This will be further elaborated on below.) The ten principles that Cavanagh proposes are:

1. New democracy, characterized by: (a) accountability, (b) governance systems that give a vote to those who will bear the costs of the decision, and (c) "people organizing and taking risks to assert control over their lives and resources in order to advance the common good" (p. 80).
2. Subsidiarity, where "whatever decisions and activities can be undertaken locally should be" (p. 83).
3. Ecological sustainability, where the society is certain that "(a) rates of resource exploitation do not exceed rates of regeneration; (b) rates of resource consumption do not exceed the rates at which renewable replacements can be phased into use; and (c) rates of pollution emissions and waste disposal do not exceed the rates of their harmless absorption" (p. 85).
4. Common heritage resources that are our birthright and must be shared equitably, including (a) life needs such as water, air, and forests, (b) culture and knowledge, and (c) public services that governments perform on behalf of all people, such as education, public health, and public safety.
5. Diversity of architecture, landscapes, languages, lifestyle, dress, and values.
6. Human rights, including political, civil, economic, social, and cultural rights.
7. Jobs, livelihood, and employment, where every person has the "right to work, to free choice of employment, to just and favorable conditions of work, and to protection against unemployment" (p. 97).
8. Secure and safe food sources that are localized and culturally appropriate.
9. Equity among nations and within them.
10. The Precautionary Principle is maintained with the caveat that "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental damage" (p. 101).

Principles 1, 2, 3, 4, 7, and 10 relate directly to RE implementation, and several of these principles are foundations of RE implementation in every case-study country (Table 5.1).

Cavanagh's Principles	**Case Study Country(ies)**	**Explanation**
New Democracy	Brazil, Spain, Germany, China, United States, and Thailand	Although not all of the case-study countries may be newly democratic, they are all characterized by Cavanagh's definition of New Democracy.
Subsidiarity	Brazil, Spain, Germany, United States, and Thailand	China is the only country that does not emphasize local, small-scale RE projects.
Ecological Sustainability	Brazil, Spain, Germany, China, United States, and Thailand	All of the countries are increasing ecological sustainability by choosing to replace fossil-fuel resources with renewable resources.
Common Heritage	Brazil, Spain, Germany, China, and Thailand	All of the countries, except the United States, have made RE a public service by setting a national RE target.
Jobs, Livelihood, and Employment	Brazil, Spain, Germany, China, United States, and Thailand	RE implementation is providing employment in all of the case-study countries.
The Precautionary Principle	Brazil, Spain, Germany, China, and Thailand	All of the countries, except the United States, signed and ratified the Kyoto Protocol, thus emphasizing the importance of protecting the environment.

Table 5.1: Relationship Between Cavanagh's Principles and the Case-Study Countries. These relationships signify the importance of an energy transition in a sustainable society.

In every case-study country, New Democracy, Ecological Sustainability, and Jobs, Livelihood, and Employment help to drive the energy transitions. The principles of Subsidiarity, Common Heritage, and the Precautionary Principle contribute to transitions in five of the six case-study countries. Cavanagh (2004) states that, "To achieve truly sustainable societies, all international, national, and regional economic policy rules and institutions should be designed to conform to the ten basic principles" (p.78). The eight institutional drivers examined in this research are contained within six of Cavanagh's ten principles for sustainable societies.

5.8 FUTURE RESEARCH

There are a number of ways that this research can be expanded on. A mathematical model could be developed to quantitatively analyze the relative influence of the institutional drivers on the energy transitions discussed in this research.

Future research could also analyze the impact of guilt and social pressure on RE implementation, at the levels of country, community, and individual. Past research on factors that lead to pro-environmental behavior (e.g., Borden and Francis, 1978; Eisenberg and Miller, 1987; Kollmuss and Agyeman, 2002) could be applied to understand the pro-environmental behavior of RE implementation.

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APPENDIX A

FEDERAL INCENTIVES, RULES, REGULATIONS, AND POLICIES FOR RENEWABLES AND EFFICIENCY IN THE U.S.

The current U.S. federal incentives are:

- Corporate Deduction
  - Energy-Efficient Commercial Buildings Tax Deduction
- Corporate Depreciation
  - Modified Accelerated Cost-Recovery System (MACRS) + Bonus Depreciation (2008-2012)
- Corporate Exemption
  - Residential Energy Conservation Subsidy Exclusion (Corporate)
- Corporate Tax Credit
  - Business Energy Investment Tax Credit (ITC)
  - Renewable Electricity Production Tax Credit (PTC)
- Federal Grant Program
  - Tribal Energy Program Grant
  - U.S. Department of Treasury - Renewable Energy Grants
  - USDA - High Energy Cost Grant Program
  - USDA - Rural Energy for America Program (REAP) Grants
- Federal Loan Program
  - Clean Renewable Energy Bonds (CREBs)
  - Energy-Efficient Mortgages
  - Qualified Energy Conservation Bonds (QECBs)
  - U.S. Department of Energy - Loan Guarantee Program
  - USDA - Rural Energy for America Program (REAP) Loan Guarantees
- Personal Exemption
  - Residential Energy Conservation Subsidy Exclusion (Personal)

- Personal Tax Credit
  - Residential Renewable Energy Tax Credit

The current rules, regulations, and policies for renewables and efficiency in the U.S. are:

- Appliance/Equipment Efficiency Standards
  - Federal Appliance Standards
- Energy Standards for Public Buildings
  - Energy Goals and Standards for Federal Government
- Green Power Purchasing
  - U.S. Federal Government - Green Power Purchasing Goal
- Interconnection
  - Interconnection Standards for Small Generators

APPENDIX B

STATES WITH ENACTED RULES, REGULATIONS, AND POLICIES FOR RENEWABLES AND EFFICIENCY

The table below show which states and territories have enacted a variety of rules, regulations and policies.[1]

State	Access Laws	Construction & Design Policies	Equipment Certification	Interconnection	Net Metering	Public Benefit Fund	Renewable Portfolio Standard	Required Green Power
Federal		X		X				
Alabama								
Alaska	X			X	X			
Arizona	X	X	X	X	X		X	
Arkansas		X		X	X			
California	X	X		X	X	X	X	
Colorado	X	X		X	X	X	X	X
Connecticut		X		X	X	X	X	
Delaware	X	X		X	X	X	X	
Florida	X	X	X	X	X		X	
Georgia	X	X		X	X			
Hawaii	X	X		X	X	X	X	
Idaho	X				X			
Illinois	X	X		X	X	X	X	
Indiana	X	X		X	X		X	
Iowa	X	X		X	X		X	X
Kansas	X	X		X	X		X	
Kentucky	X			X	X			
Louisiana	X			X	X			
Maine	X	X		X	X	X	X	X
Maryland	X	X		X	X		X	
Massachusetts	X	X		X	X	X	X	
Michigan		X		X	X	X	X	
Minnesota	X	X	X	X	X	X	X	
Mississippi								
Missouri	X	X		X	X		X	
Montana	X			X	X	X	X	X
Nebraska	X			X	X			
Nevada	X	X		X	X		X	
New Hampshire	X	X		X	X		X	
New Jersey	X	X		X	X	X	X	
New Mexico	X			X	X		X	X
New York	X	X		X	X	X	X	
North Carolina	X	X		X	X		X	
North Dakota	X				X		X	
Ohio	X	X		X	X	X	X	
Oklahoma		X			X		X	
Oregon	X	X		X	X	X	X	X
Pennsylvania		X		X	X	X	X	
Rhode Island	X	X		X	X	X	X	
South Carolina		X		X	X			
South Dakota	X	X		X			X	
Tennessee	X							
Texas	X	X		X	X		X	
Utah	X	X		X	X		X	
Vermont	X	X		X	X	X	X	
Virginia	X	X		X	X	X	X	X
Washington	X	X		X	X		X	X
West Virginia	X			X	X		X	
Wisconsin	X	X		X	X	X	X	
Wyoming		X		X	X			
District of Columbia		X		X	X	X	X	
Palau								
Guam		X			X		X	
Puerto Rico		X	X	X	X	X	X	
Virgin islands	X	X			X		X	
N. Mariana Islands							X	
American Samoa					X			

Table 5.2: Rules, Regulations & Policies for Renewable Energy. Source: DSIRE, 2012

[1] A detailed description of these rules, regulations, and policies can be found at http://www.dsireusa.org/glossary/.

APPENDIX C

STATES WITH ENACTED FINANCIAL INCENTIVES FOR RENEWABLES AND EFFICIENCY

The table below shows which states have enacted a variety of financial incentives for RE. [2]

State	Bonds	Corporate Tax	Grants	Industry Support	Loans	Perform-ance-Based Incentive	Personal Tax	Property Tax	Rebates	Sales Tax
Federal		X	X		X		X			
Alabama			X		X	X	X		X	
Alaska			X		X	X		X		
Arizona		X		X	X		X	X	X	X
Arkansas				X	X				X	
California				X	X	X		X	X	
Colorado			X		X	X		X	X	X
Connecticut			X	X	X	X		X	X	X
Delaware					X	X			X	
Florida		X		X	X	X			X	X
Georgia		X	X		X	X	X		X	X
Hawaii		X			X	X	X	X	X	
Idaho	X		X		X		X	X	X	
Illinois	X		X	X	X	X		X	X	X
Indiana			X		X	X	X	X	X	X
Iowa		X			X	X	X	X	X	X
Kansas				X				X	X	
Kentucky		X	X	X	X	X	X		X	X
Louisiana		X			X		X	X	X	
Maine			X		X	X			X	X
Maryland		X			X	X	X	X	X	X
Massachusetts		X	X	X	X	X	X	X	X	X
Michigan			X	X	X	X		X	X	
Minnesota			X		X	X		X	X	X
Mississippi				X	X	X			X	
Missouri		X			X	X		X	X	
Montana		X	X	X	X		X	X	X	
Nebraska		X			X		X	X	X	X
Nevada					X	X		X	X	X
New Hampshire			X		X			X	X	
New Jersey			X	X	X	X		X	X	X
New Mexico	X	X		X	X	X	X	X	X	X
New York		X		X	X	X	X	X	X	X
North Carolina		X		X	X	X	X	X	X	
North Dakota		X			X		X	X	X	X
Ohio				X	X	X		X	X	X
Oklahoma		X		X	X			X	X	
Oregon		X	X	X	X	X	X	X	X	
Pennsylvania			X	X	X	X		X	X	
Rhode Island		X	X		X	X		X		X
South Carolina		X			X	X	X		X	X
South Dakota					X			X	X	X
Tennessee			X	X	X	X		X	X	X
Texas		X	X	X	X	X		X	X	
Utah		X		X			X		X	X
Vermont		X	X		X	X		X	X	X
Virginia				X	X	X	X	X		
Washington			X	X	X	X			X	X
West Virginia		X					X	X	X	
Wisconsin		X	X		X	X	X	X	X	X
Wyoming					X				X	
District of Columbia					X	X		X	X	
Palau										
Guam										
Puerto Rico			X	X			X	X	X	X
Virgin islands			X		X				X	
N. Mariana Islands										
American Samoa										

Table 5.3: Financial Incentives for Renewable Energy. Source: DSIRE, 2012

[2] A detailed description of these financial incentives can be found at http://www.dsireusa.org/glossary/.

APPENDIX D

INTERVIEW RECRUITMENT SCRIPT BY E-MAIL

Dear X,

I am a graduate student under the direction of Dr. John (Marty) Anderies in the School of Sustainability at Arizona State University. Dr. Anderies is a colleague of Dr. Ganesh Shivakoti from the Asian Institute of Technology. I am conducting a research project to identify the drivers of renewable-energy implementation in Thailand.

From March 3-23, 2013, I will be visiting Bangkok to gain a better understand on why and how Thailand has implemented renewable-energy technologies. I have been reading literature on renewable energy in Thailand, and I would like to learn from people with firsthand experience and expertise. To that end, I am contacting experts, such as people working in your organization, for interviews. Interviews should last roughly 45 minutes, and they will either be in person or over Skype, depending on what is most convenient for you. If you are interested, please let me know. I would be happy to talk more about my own background and research interests.

You must be 18 or older to participate in the study.

The interview will be neither audio nor video taped. I will take notes during the interview, and if there is any information that you would like not included, I will be sure to mark this in my notes.

Your participation in this study is voluntary. If you have any questions concerning the research study, please contact me at +1 (401) 742-9873 or by e-mail at auriane.koster@asu.edu.

Also, please feel free to let others in the field know that I am looking for interviewees, pass on my contact information, or pass on their contact information to me.

Thank you for your time, and I look forward to hearing back from you.

Kind regards, Auriane Koster

APPENDIX E

INFORMATION LETTER TO INTERVIEWEES

Institutional Drivers of Renewable Energy Implementation in Thailand

Date:

Dear _____________________:

My name is Auriane Koster, and I am a Ph.D. candidate under the direction of Dr. John (Marty) Anderies at the School of Sustainability at Arizona State University. I would like to invite you to participate in a research study about renewable energy implementation in Thailand. To understand the drivers of renewable energy implementation in Thailand, I am interviewing experts in the field.

I am inviting your participation, which will involve an interview, either in person or via Skype, which will last roughly 45 minutes. I will ask a series of questions about drivers of renewable energy use in Thailand. You have the right not to answer any question, and to stop the interview at any time.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. You must be 18 or older to participate in the study.

This interview may be audio recorded. The sole purpose of this is to provide me with detailed notes/answers that I may miss in my handwritten notes. If at any point you would like me to stop recording, please let me know, and I will do so immediately. You have the option to not be recorded.

There are no foreseeable risks or discomforts to your participation. Although there may be no direct benefits to you, the research may facilitate the adoption of further renewable energy policies and projects in Thailand and other developing countries.

Your responses will be confidential unless you wish to be quoted. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you unless you so choose. You will also be given a copy of any material that includes your name and/or quotes so that you may review it for accuracy before it is presented or published.

If you would like to allow us to quote you (using your name & affiliation, with an option to review the quote before publication) please sign here:

Signature: ____________________ E-mail: _______________ Ph: _____________

(Signing on this line and providing contact information signifies your willingness to have your name and affiliation included in the study and allowing me to contact you for follow up purposes.)

If you have any questions concerning the research study, please contact the research team:

Dr. John (Marty) Anderies – Phone: +1 (480) 965-8712; E-mail: Marty.Anderies@asu.edu
Auriane Koster – Phone: +1 (401) 742-9873; E-mail: Auriane.Koster@asu.edu

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at +1(480) 965-6788. Please let me know if you wish to be part of the study.

Figure 5.5: Information letter to interviewees.

APPENDIX F

INTERVIEW GUIDE

Institutional Drivers of Renewable Energy Implementation in Thailand

Renewable Energy expert interview guide

Instructions for using this guide

Use this interview guide to conduct semi-structured interviews for the research project "Institutional Drivers of Renewable Energy Implementation in Thailand." Text appearing in italics can be read verbatim or paraphrased. Make sure that formal consent has been obtained before starting interviews (see below). Regarding time management, spend more time on questions about the institutional driver of renewable energy implementation, such as monitoring, government commitment, and stakeholder engagement. These are more relevant for the goals of the research and deserve in-depth conversation.

Interviewer introduction

Read the following to introduce yourself to the interviewee:
Hello, my name is Auriane Koster, and I will be interviewing you about the drivers of renewable energy implementation in Thailand. During the interview, I would like to cover the following topics: formal and informal monitoring of compliance of renewable-energy targets, the government's commitment to renewable energy implementation, the involvement of various stakeholders in renewable energy policies and projects in Thailand, and the role that traditional, culture has played in Thailand's renewable energy use.

Consent

Before starting the interview, make sure that you have a signed copy of the consent form from the participant. Ask the participant if he or she has any questions about the consent form.

Interview topics

1. Why do you think Thailand is implementing renewable energy technologies?
2. Why do you think Thailand originally implemented the 15 year Renewable Energy Development Plan?
3. Why do you think Thailand revamped the 15 year Renewable Energy Development Plan and replaced it with the Alternative Energy Development Plan (2012-2021)?
   a. Additional question: Do you think it is because Thailand was on track to surpass the original targets?
4. Do you think the signing and ratifying of the Kyoto Protocol played a role in Thailand's renewable energy implementation targets?

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Figure 5.6: Interview guide page 1.

5. Do you think that traditional, culture, such as Buddhism, has played a role in Thailand's renewable energy policies?
6. What do you think is Thailand's strongest financial incentive for renewable energy development?
    a. Additional question: Do you think the feed-in tariff or "adder" program has been successful?
7. Based on my research, the NGO Palang Thai seems to be a main driver of small-scale and rural renewable energy implementation. How large of a role do you think Palang Thai has played in implementing small-scale renewable energy projects in Thailand?
8. What do you see as the barriers of connecting rural communities to the grid?
9. Do you think polycentricity is happening in Thailand?
    a. Explanation (if needed): In a polycentric system, citizens are able to organize governance at different scales and to have some influence on what resources is used and where.
10. Do you think renewable energy projects and policies are transparent in Thailand?
    a. Explanation (if needed): Transparency is succeeded through stakeholder engagement and documentation. Thailand's Ministry of Energy produces the document "Thailand's Energy Situation" on a yearly basis.
    b. Additional question: Do you believe that enough citizens have access to renewable energy related documents?
11. What is driving the continuous exploration of fossil fuel based energy sources?
    a. Additional question: If Thailand is not using all of the natural gas they agreed to buy through the Myanmar agreement, then why not shut down natural gas exploration and oil refineries?
        i. Explanation (if needed): In September 1994, Myanmar and Thailand signed a natural gas agreement. The agreement stated that Thailand was to purchase $400M/year worth of natural gas for a period of 30 years starting in 1998. In 2000 natural gas officially began to flow into the Ratchaburi power station. However, sales were only $50M and not $400M as was originally agreed upon (Vokes, 2002). This was because Thailand did not need all of the gas that they originally agreed upon. However, they were still forced to pay based on the original agreement.
12. Do you think there is any formal and/or informal monitoring of renewable energy implementation in Thailand?
    a. Explanation (if needed): A common barrier to renewable energy implementation is a lack of disincentives to noncompliance. To achieve renewable energy targets, countries need formal and informal

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Figure 5.7: Interview guide page 2.

institutions that monitor compliance. Formal institutions include fines and other strong disincentives for violating laws and failing to meet Renewable Portfolio Standards. Informal institutions include self-policing and gossip.

CLARIFYING QUESTIONS

These can be used after any question to elicit more information from the interviewee about his or her response.

- Uh-huh probe
    - When to use: Use this anytime, but using it too often will make it seem like you are not paying attention to the interviewee's responses.
    - Instructions: Make affirmative comments, like “Uh-huh,” or “Yes, I see,” or “Right, uh-huh,” and so on.
- Echo probe
    - When to use: This is a way to make sure you, the interviewer, correctly understand what the person is saying.
    - Instructions: Repeat the last thing the participant said, and ask him or her to continue.
- Silent probe
    - When to use: Use this during an uncomfortable silence to elicit a more revealing response.
    - Instructions: Remain quiet and wait for the interviewee to continue.
- Tell-me-more probe:
    - When to use: Use this anytime, but using it too often will make it seem like you are not paying attention to the interviewee's responses.
    - Instructions: Ask any variation of the following questions: Can you expand a little on this? Can you tell me anything else? Can you give me some examples?

Interview conclusion

Thank you very much for your participation and for your time. It is very valuable for my research, and hopefully the results will be valuable for your work, as well. If you would like to see the results of this study, please let me know, and I will send them once I have finished collecting and analyzing data.

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Figure 5.8: Interview guide page 3.

APPENDIX G

INTERVIEW LIST

Interviewee	Position	Date	Location
Gary Dirks, Ph.D.	Director, Global Institute of Sustainability, Arizona State University	8.28.2012	Tempe, Arizona
Shabir Gheewala, Ph.D.	Professor, The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi	3.5.2013	Bangkok, Thailand
Chris Greacen, Ph.D.	Founder, Palang Thai	3.7.2013	Bangkok, Thailand
Sivanappan Kumar, Ph.D.	Professor, School of Environment, Resources and Development, Asian Institute of Technology	3.8.2013	Bangkok, Thailand
Shobhakar Dhakal, Ph.D.	Associate Professor, School of Environment, Resources and Development, Asian Institute of Technology	3.13.2013	Bangkok, Thailand
Ghaffar Ali, Ph.D. Student	School of Environment, Resources and Development, Asian Institute of Technology	3.15.2013	Via Email
P. Abdul Salam, Ph.D.	Associate Professor, School of Environment, Resources and Development, Asian Institute of Technology	3.21.2013	Bangkok, Thailand
Weerakorn Ongsakul, Ph.D.	Dean, School of Environment, Resources and Development, Asian Institute of Technology	3.21.2013	Bangkok, Thailand

Figure 5.9: Interview list.

APPENDIX H

IRB APPROVAL

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	John Anderies ASU School
From:	Mark Roosa, Chair Soc Beh IRB
Date:	02/07/2013
Committee Action:	**Exemption Granted**
IRB Action Date:	02/07/2013
IRB Protocol #:	1302008762
Study Title:	Institutional Drivers of Renewable Energy Implementation in Thailand

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

You should retain a copy of this letter for your records.

Figure 5.10: IRB approval.

BIOGRAPHICAL SKETCH

Auriane Magdalena Koster was born in Cambridge, New York to a French mother and an American father. Her younger sister was born 4.5 years later. At 12 years old, her family moved to Rhode Island, where she completed high school in 2003, and immediately began attending the University of Rhode Island (URI). At URI, Auriane received a B.S. in Environmental Science and Management, a B.S. in Applied Mathematics, completed the Honors Program, and graduated Summa cum laude. She started the Ph.D. program in 2008 in the School of Sustainability at Arizona State University immediately after graduating with her undergraduate degrees. Once completing her Ph.D., Auriane was hired by the Mary Lou Fulton Teachers College at Arizona State University as a Lecturer teaching the course "Sustainability Science for Teachers."