Markets for Renewable Energy and Energy Efficiency Products in Thailand

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Introduction

Background

The Department of the Navy (DON) is a consumer of renewable energy and energy efficiency products. Statutes and Executive Orders require DON to conserve energy and make use of renewable energy on U.S. military installations [1 - 5]. In addition, DON is exploring whether being more energy efficient and using renewable energy at forward operating bases and on weapon platforms could create tactical and logistical advantages and reduce expenditures [6], [7].

To support DON's efforts related to energy efficiency and renewable energy, the Office of Naval Research (ONR) conducts and supports research and development (R&D) in new renewable energy (RE) and energy efficiency (EE) technologies and products [7], [8]. For instance, ONR funds the Hawaii Technology Development Venture (HTDV) [9] and Asia Pacific Technology Education Program (APTEP) [10].

HTDV works with small- and medium-sized U.S. businesses that are based in Hawaii to develop new technologies for use in various defense and homeland security programs. HTDV puts special focus on technologies and products with "dual use" potential, which is the potential that they can also be used in the civilian sector. HTDV is currently supporting the development of new renewable energy and energy efficiency (RE&EE) technologies and products for possible use by DON, as well as by the civilian sector.

APTEP's goal is to promote commerce and partnerships between the United States and nations in the Asia-Pacific region. ONR seeks to achieve this goal by working with U.S. academic institutions and small- and medium-sized businesses, as well as members of nations in the Asia-Pacific region.

Promoting exports of U.S. RE&EE products is also a priority of the U.S. government as a whole (as of the time of writing). Numerous

U.S. government departments and agencies are currently working on promoting U.S. exports of RE&EE products under the Renewable Energy and Energy Efficiency Export Initiative [11, 12].

Tasking

To assist with its energy efforts, ONR asked CNA to do the following:

- Examine energy markets in member countries of the Association of Southeast Asian Nations (ASEAN) and describe the types of energy that are currently used in these countries, as well as the major consumers and suppliers of energy and potential consumers of U.S. RE&EE products. There are 10 ASEAN countries: Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam [13].

- Assess whether different types of renewable energy and energy efficiency products are in demand or likely to be in demand over the next five years in each ASEAN country,[1] and the extent to which they will be in demand.

- Determine the potential for U.S. small- and medium-sized businesses (SMBs) to supply RE&EE products to ASEAN countries.

- Determine actions that the U.S. government and U.S. firms can take to facilitate the successful entry of U.S. small- and medium-sized businesses into the markets for RE&EE products in ASEAN countries.

In this publication, we provide an in-depth assessment of the market for RE&EE products in Thailand. Thailand's government has been promoting energy efficiency and the use of renewable energy for longer than any other country in ASEAN [14]. In a separate publica-

[1] RE&EE products include physical equipment such as micro-hydro turbines and wind turbines, and services such as consulting on how to manage the construction and operation of geothermal power plants and how to increase the output of farms growing feedstock to refine into biofuels.

tion, we provide brief assessments of the markets for RE&EE goods in each of the other ASEAN countries.

The types of renewable energy covered in this report are wind, solar, geothermal, bioenergy (biomass, biogas, and biofuels), and small-scale, run-of-the-river hydroelectric power. We distinguish between the use of renewables to generate electricity (e.g., solar photovoltaic (PV) panels) and the use of renewables to generate or capture thermal energy (e.g., biomass can be burned to generate heat for industrial processes or for cooking, and solar water heaters can be used to capture heat from the sun). We also examine energy storage products, such as batteries and pumped hydroelectric storage. These products are used to store energy that is generated by intermittently available renewables such as wind and solar.

In this paper, we use the definition of energy efficiency products that is used by the U.S. Trade Promotion Coordinating Committee Working Group on Renewable Energy and Energy Efficiency. They define these products as,

> goods or services that are specifically designed to use less energy to perform the same function, to improve performance with the same energy inputs, or to incorporate previously wasted by-products to reduce overall energy use. Examples of energy efficiency goods and services include green building design services and materials; industrial energy efficiency applications such as combined heat and power; district energy systems; and, where clear standards can be identified, appliances and electronics designed and marketed as energy efficient. [11]

We categorize certain electric grid projects—specifically, projects to expand electric grids, upgrade existing electric grids, or build new electric grids using energy-efficient grid technologies such as smart grid technologies[2]—as one type of energy efficiency products.

RE&EE products include both physical equipment (e.g., wind turbines) and services (e.g., labor to install equipment or consulting services for siting wind farms or determining how to best manage the construction of a geothermal electricity plant).

In assessing the demand for RE&EE products, our definition of "demand" is the expected level of sales of these products, measured in quantitative terms when possible such as dollars of sales revenue or megawatts (MW) of installed electricity generating capacity, or qualitative terms when it's not possible to quantify demand using available information. For instance, it is impractical to define thresholds on whether the product is "energy efficient" for some types of energy efficiency and energy conservation products, such as energy-efficient air conditioners, building envelopes and boilers. As a result, it is impractical to measure sales of these products in quantitative terms [11], but we can describe government programs and incentives to encourage households and firms in Thailand to conserve energy.

[2] In a recent study by the Pacific Northwest National Laboratory on the deployment of smart grids in member countries of the Asia-Pacific Economic Cooperation organization, smart grids are defined and described as follows: "Smart grid technology uses digital technology and communication to coordinate the actions of intelligent devices and systems throughout the electricity system: from large scale generation networked with transmission infrastructure, to the distribution of power to consumers (factories, commercial buildings, and residences), and down into the equipment and systems that use electricity in these facilities. Through automation, better information, and coordination, smart grid technology can help provide the flexibility needed to integrate variable generation that is a characteristic of some renewable resources such as wind and solar generators. Smart grid technology can also enhance efficiencies in the transmission and distribution delivery infrastructure, generation, and end-use systems by optimizing system performance and increasing asset utilization" [15].

Approach

In assessing the demand for renewable energy and energy efficiency products, we examine several factors. These factors have been identified by the U.S. Energy Information Administration (EIA) [16], by the International Energy Agency [17], and by the Intergovernmental Panel on Climate Change (IPCC) [18] as being the key drivers of growth in the use of renewable energy and the best available predictors of future growth in the use of renewable energy.

First, we present information on RE&EE projects that were either completed recently or in progress as of the time of writing, because sales of products in the near future are often similar to the level of sales in the recent past. We also present information about plans of private-sector and state-owned utility companies to purchase more RE&EE products in the near future, such as the companies' plans to construct new wind farms, solar farms, and hydroelectric dams.[3]

Second, we look at the policies of the government of Thailand to determine whether there are subsidies or other financial incentives for using RE&EE products and whether the government has set targets for how much new renewable electricity capacity they would like the country to install. An example of this is Thailand's targets of building 1610 MW of new biomass power plants by 2016 and building an additional 480 MW of new biomass power plants by 2022.

For subsidies and other financial incentives, we pay special attention to the feed-in-tariffs (FiTs) Thailand has enacted for renewable power generation. The IEA describes FiTs as follows:

> Feed-in tariffs (FiTs) guarantee the generator of renewable electricity a certain price per kilowatt hour (kWh) at which

[3] This approach is similar to that taken by the U.S. Energy Information Administration's (EIA's) World Energy Projection System Plus (WEPS+) model to forecast how much renewable electricity generating capacity each country in the world will have in each year over the next five years, for different types of renewables. These forecasts rely on data on renewable energy projects that are currently under construction and on proposed renewable energy projects that have a high probability of beginning being under construction in the next five years [16].

> the electricity will be bought. The tariff is set over a long period of time, commonly 20 years. Note that the tariff is fixed during the entire period of support (and sometimes indexed to inflation); adjustments to the tariff apply only to power plants which are built or whose owners sign power purchasing agreements after the adjustments to the tariff are made.... Some governments have put annual caps on the amount of capacity that can benefit from FiT support in a certain time period, in order to restrict the overall policy costs. [17].

Numerous studies reviewed in recent IEA and IPCC reports [17], [18] have found that well-designed and well-implemented FiTs have been the most effective support policy for incentivizing private-sector companies to build new renewable energy power plants and for increasing the share of electricity generated in a country that comes from renewable sources.

With regard to the targets for installing new capacity, we examined estimates from the EIA, from the IEA, from industry associations (e.g., Global Wind Energy Council (GWEC) [19] and European Photovoltaic Industry Association (EPIA) [20]), and from other organizations (e.g., non-government organizations) on how close Thailand will come to meeting these targets.[4] Our approach in examining how close Thailand will get to these targets and goals is similar to that taken by the EIA WEPS+ model to forecast how much renewable electricity generating capacity each country in the world will have in 5 years, 10 years, and 15 years [16].

We also considered the quality of the natural resources Thailand has for producing renewable energy. For instance, some countries have higher average wind speeds than others, and can, therefore, more

[4] For instance, the EIA has estimated how close different countries will come to achieving their renewable capacity targets "based on available government incentives for that goal, the country's success rate with previous renewable targets, and the time horizon of the goal compared to the country's current renewable capacity growth rate" [16]. The IEA has examined how the Government of Thailand has in recent years adjusted its target of how much solar electricity generating capacity it would like to install in response to decreases in the price of solar photovoltaic devices [17].

readily produce wind energy. We note that if we found that a country had recently conducted an assessment of its natural resources for using renewables, we took that as a signal that the country was considering increasing its use of renewable energy.

Finally, we collected information on the number and percentage of people in remote rural regions of Thailand that have no access to electricity. Currently, renewables are more likely to have cost advantages over fossil fuels in generating electricity for off-grid and mini-grid applications in remote areas not near large grids than they are at having cost advantages over fossil fuels at supplying electricity to large electric grids. Shipping fossil fuels to remote regions far from large electric grids can be expensive. In addition, diesel generators are a relatively expensive way of generating electricity and small-scale fossil-fuel-fired electricity generating plants tend to be less efficient at converting fossil fuels into electricity than large plants are [21], [22], [23].

As stated above, for some types of energy efficiency products, it is infeasible to measure sales in dollar terms; our approach to assessing demand for these products consists of examining government programs and incentives to encourage or require firms, households, and government agencies to conserve energy. We also examine the availability of funding from the World Bank, ADB, and other financial institutions for financing energy conservation and efficiency investments.[5] However, electric grid projects (some of which use energy efficiency products) are generally planned far in advance and have a large amount of government participation (in Thailand as in the other ASEAN countries, state-owned companies own and operate the electric grid or grids in the country). As such, we were able to find plans and discussions about proposed projects to expand electric grids and to make existing grids more efficient, often in the 20-year Power Development Plan of Thailand's state-owned electric utility company [26].

[5] In on-going, proposed, and completed projects, the World Bank and ADB educate members of firms, households, and local banks about technologies and products that can be used to save energy and how to evaluate when energy conservation investments are likely to save money [24], [25].

In looking at the potential for U.S. small- and medium-sized businesses to supply RE&EE products to Thailand, we examine trade agreements and tariffs between Thailand and the United States and between Thailand and countries besides the United States that manufacture and export RE&EE products. Examining these agreements and tariffs allows us to determine whether U.S. businesses would be at a disadvantage relative to companies in foreign countries and relative to domestic producers of RE&EE products in Thailand. We also examined data on the amount of RE&EE and related goods, such as other electric power system goods and electronics, that the United States has exported to Thailand recently; past success at exporting goods provides information on the likely ability of U.S. companies to export RE&EE goods in the future.

To determine actions that the U.S. government and U.S. firms could take to facilitate the successful entry of U.S. small- and medium-sized businesses into the markets for RE&EE products in Thailand countries, we first provide information on who the possible purchasers of RE&EE products are in Thailand (i.e., government agencies, private companies, or households), and who often has influence over these purchasing decisions. For instance, we found that the World Bank is often an influential source of policy recommendations in the energy sectors of some ASEAN countries.

Summary of main findings

The following types of renewable energy products, and services related to these products, will be in demand in Thailand over the next five years: solar energy products (solar photovoltaic (PV) panels and concentrated solar power (CSP) electricity generation plants), biomass energy products, biogas energy products, small hydro power plants, and wind turbines (specifically, larger wind turbines for supplying electricity to large electric grids, rather than smaller wind turbines for off-grid and micro-grid applications). Solar hot water heaters, municipal solid waste (MSW) energy generation products, and agricultural consulting services related to increasing supplies of feedstock for producing ethanol and biodiesel may also be in demand. Thailand has already installed some biogas electricity generators at smaller farms, and Thailand's Ministry of Energy (MOE) intends to support other types of village-scale, household-scale, and small-farm-scale-

sized biomass, biogas, and MSW energy products between 2012 and 2022.

Thailand does not appear to have any demand for building new ethanol and biodiesel refineries at present. However, there may be some demand for new farm equipment for use at sugar, cassava, and palm oil plantations that grow feedstock for biofuels, and for agricultural consulting services on how to increase yields at sugar, cassava, and palm oil plantations in Thailand.

The Government of Thailand supports energy efficiency investments in the industrial, commercial building, residential building, and transportation sectors and has budgeted $1 billion USD to promote energy efficiency investments between 2011 and 2015. The U.S. Commercial Service states that Thailand is an emerging market for energy-efficient and environmentally friendly "Green Building" products.

The Electricity Generation Authority of Thailand is investing in reducing distribution losses in its existing transmission lines and in expanding its transmission grid using energy-efficient equipment. The Provincial Electricity Authority of Thailand has begun investing in smart grid technologies. There does not appear to be demand for new energy storage products in Thailand,[6] other than one new 500 MW pumped storage hydroelectric facility, and possibly some replacement batteries for 203,000 solar home systems that were installed in off-grid areas in 2005.

The following list shows Thailand's targets for installing new renewable energy electricity generation capacity (measured as additional capacity above total capacity in 2009):

- Biomass: 1610 MW (megawatts capacity) by 2016 and 2090 MW by 2022
- Biogas: 44 MW by 2016 and 74 MW by 2022
- Municipal solid waste: 125 MW by 2016 and 155 MW by 2022

[6] Assuming no radical technological changes and no dramatic price reductions in energy storage products over the next few years.

- Small hydro: 235 MW by 2016 and 278 MW by 2022
- Wind: 324 MW by 2016 and 799 MW by 2022
- Solar PV and CSP: 63 MW by 2016 and 468 MW by 2022

We forecast that Thailand:[7]

- will achieve approximately 65 percent of its target for biomass;
- will exceed its targeted capacity for biogas;
- will make little progress toward its MSW target over the next five years, but may make more progress after five years;
- will achieve at least 65 percent of its target for small hydro;
- will achieve approximately half of its targeted capacity for wind; and
- will greatly exceed its targeted capacity for solar, perhaps by as much as 400 percent (as Thailand's MOE is considering officially increasing its solar target for 2022 to 2,000 MW).

The potential for U.S. firms to export RE&EE products and services to Thailand is somewhat limited because a number of other countries that export these products (Australia, China, India, Japan, and Malaysia) have more favorable trade agreements and lower tariffs with Thailand than the United States does. However, RE&EE firms from the United States and elsewhere can sometimes obtain waivers so that they do not need to pay tariffs when selling to Thai businesses.

With regard to market entry, in Thailand both private sector firms and state-owned utility companies are potential buyers of RE&EE products. U.S. firms that would like to sell RE&EE products to both private- sector and public-sector firms should consider meeting with

[7] These forecasts were made by considering the following factors: Thailand's progress in adding new renewable energy capacity in recent years; the number and planned capacity of planned renewable energy power plant projects in Thailand that have received power purchasing agreements or have been budgeted for by the Government of Thailand; the level of Thailand's feed-in-tariffs (FiTs) for each type of renewable energy; and on Thailand's estimated technical potential to use each type of renewable.

government officials in Thailand's Ministry of Energy and the Electricity Generation Authority of Thailand (EGAT) in order to inform them of their products. This is because introductions from government officials are an effective way of approaching potential business contacts in Thailand, and Ministry of Energy officials must approve power purchasing agreements between private-sector firms that own power plants and EGAT.

Organization of the remainder of the paper

This paper is organized into four main sections. In the first section, we examine the energy market in Thailand and describe the types of energy that are currently used in Thailand, as well as the major consumers and suppliers of energy and potential consumers of U.S. RE&EE products. In the second section, we assess whether different types of renewable energy and energy efficiency products are in demand or likely to be in demand over the next several years in Thailand, and the likely extent to which they will be in demand. In the third section, we present our findings on the potential for U.S. small- and medium-sized businesses to supply RE&EE products to Thailand. In the fourth section, we discuss actions that the U.S. government and U.S. firms can take to facilitate the successful entry of U.S. small- and medium-sized businesses into the markets for RE&EE products.

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Energy market in Thailand: consumers, suppliers, and types of energy currently used

In this section of the paper we examine the energy market in Thailand and describe the types of energy that are currently used in Thailand, as well as the major consumers and suppliers of energy and potential consumers of U.S. RE&EE products. We begin by discussing the market structure of the energy supply sector in Thailand. We then present information on the population and GDP of Thailand, which gives information on the number of energy consumers in Thailand and their ability to afford energy products. Afterwards, we discuss the percentage of Thailand's population that has electricity from large electric grids and from off-grid and mini-grid sources of electricity. We then describe energy use by sector, fuel source, and form, as well as fossil fuel imports and recent levels and trends in fossil fuel use.

Market structure of the energy supply sector in Thailand

Role and priorities of Thailand's Ministry of Energy

Thailand's Ministry of Energy (MOE) attempts to shape the country's energy markets through its regulating powers over state owned companies and private sector companies in the energy sector. The MOE's main objectives are (1) to promote energy security for the country, (2) to provide supervision of energy sector, (3) to develop and promote research in alternative energy, (4) to promote energy conservation and efficient use of energy, and (5) to encourage energy exploration and use that emphasizes the importance of the environment [26]. These objectives are consistent with Thailand's policy efforts to incentivize the production and use of renewable energy and to promote energy efficiency. We discuss these policies in detail in the subsequent sections of this report.

Market structure of electricity supply sector

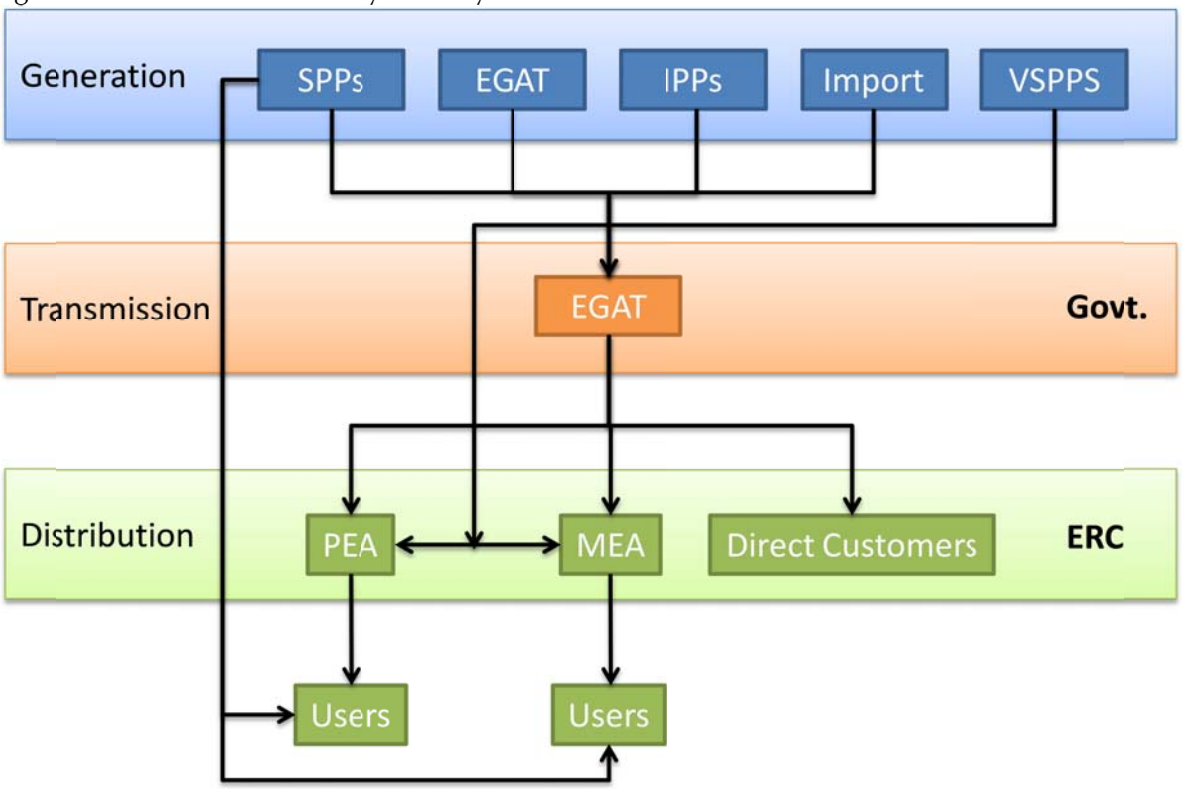
The electricity market in Thailand is organized around the Electricity Generating Authority of Thailand (EGAT). EGAT is the largest producer of electricity in Thailand and the only wholesale purchaser of electricity in the country. It is responsible for operating and controlling the dispatch of power generation to distributing authorities via its transmission network; see EGAT's 2010 Annual Report [27]. EGAT, which is a state enterprise, is managed by the MOE and, in most cases, it manages its power purchasing agreements (PPAs) with independent power producers (IPPs) [27].

EGAT dispatches power to the Provincial Electricity Authority (PEA), a distribution authority (68.15 percent), the Metropolitan Electricity Authority (MEA) (another distribution authority—29.87 percent), a small number of direct customers (1.02 percent), neighboring-country utilities (0.84 percent), and other minor customers (0.11 percent) (EGAT [27]). The transmission and distribution part of the market is regulated by the Energy Regulatory Commission (ERC), which is part of MOE.

As shown in figure 1, Thailand's demand for electricity is met through EGAT's own power generation, which corresponds to 48.50 percent of the total, and through EGAT purchases from independent producers, which accounts for 51.50 percent of the total electricity distributed by EGAT. Regarding the electric power is produced by independent producers, domestic Independent Power Producers (IPPs) provide 39.30 percent of the electricity consumed in Thailand, and Small Power Producers (SPPs) and Very Small Power Producers (VSPPs) provide 7.06 percent.[8] The remaining 5.14 percent comes from producers in Laos and Malaysia [27].

[8] EGAT's Power Development Plan for 2010 through 2030 states that IPPs are larger independent power producers whose electric power plants have a capacity in excess of 90 megawatts (MW). SPPs have capacities below 90 MW but above 10 MW, and VSPPs have less than 10 MW of capacity [28].

Figure 1. Thailand's electricity industry structure



Source: Information from EGAT [27] and Tongsopit and Greacen [31]. See text for definition of acronyms.

Market structure of transportation fuels supply sector

The largest company in Thailand's petroleum and transportation fuels sector in terms of market share is PTT (Petroleum Authority of Thailand) Public Company Limited. PTT is a state-owned company that has large amounts of private capital. However, Thailand's petroleum industry has active private-sector participation from upstream to downstream, including foreign participants. The private sector operates well over half of the retail oil and gas stations in Thailand [29]. Therefore, both PTT and private sector companies are potential distributors and retail sellers of biofuels in Thailand. The USDA Foreign Agricultural Service, in its Thailand Biofuels Annual for 2011, reports that private-sector firms are involved with growing biofuels feedstock and operating biofuels refineries in Thailand [30].

Since biofuels are a substitute for petroleum-based transportation fuels (such as gasoline and diesel), demand for biofuels in Thailand may fluctuate with the price of gasoline and diesel. The prices of gas-

oline and diesel in Thailand are primarily set in an open market with no price controls [29].[9] The Government of Thailand does influence the price of petroleum products through taxes, however; whole-sale petroleum prices reflect an excise tax, a municipality tax, a contribution to the Oil Fund, a contribution to the Energy Conservation Promotion Fund (ENCON Fund), and a value added tax (VAT) [29].

Thailand imports well over half of its oil, leaving its economy vulnerable to oil price shocks [29], [30]. This has encouraged the Government of Thailand to promote the conservation of gasoline and diesel and to promote the domestic production of biofuel substitutes for gasoline and diesel, as we discuss further below in the section on biofuels.

Other important actors in Thailand's energy sector

As noted above, both private-sector and state-owned companies are important suppliers of energy services in Thailand. This means that they are both potential buyers of RE&EE products. We investigated whether any third parties (e.g., multilateral development banks or non-governmental organizations) provide influential advice on or financing for energy product purchase decisions to private sector electricity and transportation fuels in Thailand and to EGAT and Thailand's Ministry of Energy.

One nonprofit organization with some influence in and extensive knowledge of the Thai energy sector is Palang Thai. This group

> works with Thai NGOs, universities, businesses and government agencies to analyze electricity planning and policy from a public interest perspective,...provides hands-on solar and micro-hydro training for villages on both sides of the Thai/Burma border,... [and] helped draft Thailand's original VSPP regulations, [which] allow small community-owned or small entrepreneur-owned renewable energy generation to connect to the grid and sell excess electricity to utilities. [32]

[9]. A common example of a price control in the petroleum market is restrictions on the maximum price that can be charged for a gallon of gasoline, such as the gasoline price controls seen in the United States during the 1970s.

Although the World Bank and Asian Development Bank (ADB) have provided some support for several renewable energy and energy efficiency projects in Thailand in the recent past and continue to provide financial support [33 - 35], these multilateral development banks do not appear to have a large degree of influence over decisions to purchase RE&EE products in Thailand. Since Thailand is now considered an upper-middle income country [36], [37], it may no longer qualify for a large amount of assistance from the World Bank Group and ADB. In addition, the MOE personnel and EGAT have become well informed about the technology, economics, and management of the energy sector and may no longer require extensive advice from third parties on energy issues.

We also found that at least one university in Thailand is active in the research and development of RE technologies; Naresuan University has a School of Renewable Energy Technology, which has collaborated with a number of foreign universities, government agencies, and firms to develop and evaluate new RE technologies and products, including an advanced concentrated solar power technology [38], [39].

Thailand's energy consumers: population and GDP

Thailand's population and gross domestic product define the number of energy consumers in Thailand and their ability to afford energy products. Thailand has a population of 67 million people and, according to the CIA World Factbook [40], it had the 20th largest population in the world in 2011. Thailand's population size makes it a potentially large market for goods and services of any type, including RE&EE products. Thailand had a Gross Domestic Product (GDP) per capita of U.S. $9,700 in 2011, making it 88 out of 196 countries in the world[10] [40]. This ranking, close to the world's median, is a primary determinant of Thailand's ability to pay for RE&EE products. Note that GDP per capita in the United States in 2011 was U.S. $48,387 and that Thailand has the fourth-highest GDP per capita in

10. The data on GDP per capita in Thailand have been adjusted for purchasing power parity (PPP). The adjustment is made to produce measures of GDP per capita that are comparable across different countries, as different countries have different price levels for goods and services and labor and different costs of living.

ASEAN, after Malaysia (U.S. $15,600) and the city-states of Brunei Darussalam and Singapore (U.S. $49,400 and $59,900, respectively).

Recent research by the International Energy Agency (IEA) has found that countries with higher GDP per capita tend to have higher growth rates in the use of renewable energy [41]. Certainly, many other factors besides GDP per capita are also important determinants of demand for renewable energy products; we examine these other factors below. However, Thailand's GDP per capita does provide a measure of its ability to afford to reach its renewable energy use and energy conservation goals.

Thailand's energy consumers' access to electricity and the electric grid

In this subsection, we present data on the percentage of Thailand's population that have access to electricity, as well as on the percentage that are connected to large electricity grids. According to the Alliance for Rural Electrification, the Renewable Energy Policy Network for the 21st Century (REN21), and the National Renewable Energy Laboratory (NREL), renewables often have cost advantages over fossil fuels in bringing electricity to areas that are not connected to large utility grids [21], [22], [36], [37]. So when large numbers of people in rural areas do not have access to electricity and when large numbers of people are not connected to or near existing large electric grids, demand for RE products in a country or region tends to be relatively high, all else equal. When we assess demand for hydroelectric, geothermal, wind, solar, biomass, and biogas products in Thailand later in this report, we will also need to know and distinguish between whether these products would be in demand in remote regions of Thailand that are not connected to large electric grids or if they will be in demand as power plants that will be connected to large electric grids (or both). Certain types of renewable energy products are designed specifically for on-grid use while others are designed specifically for off-grid use (e.g., some smaller wind turbines are designed specifically for off-grid use).

The IEA's World Energy Outlook 2012 Electricity Access Database [42] reports that 100 percent of the urban population and 99 per-

cent of the rural population in Thailand has access to electricity.[11] Furthermore, nearly all of Thailand's population gets its electricity from connections to a large, centralized electric grid. Few Thais get their electricity from off-grid or mini-grid renewable energy-based electrification projects or from off-grid and mini-grid diesel generators [43]. According to Chris Greacen, an expert on renewable energy issues in Thailand at the nonprofit group Palang Thai, Thailand met its goal of providing electricity to everyone in the country almost entirely by expanding its large electric grid [43]. In 2004, after a 20-year government program, 59 micro-hydro village electrification mini-grid projects had been built. Of those built, less than half were still operating in 2004 [43]. By comparison, by 2004 the national grid had extended to over 69,000 villages [43]. In a different effort in 2005, the government provided a solar panel and a battery for each of the 203,000 households that were still un-electrified in 2004 [44], [45], [46]. Given that nearly all Thais are connected to Thailand's main electric grid, rather than living in off-grid areas, demand for renewable energy products specifically designed for off-grid and micro-grid use will be relatively low in Thailand.[12]

Energy use by sector, fuel source, and form in Thailand

In this section we present data on current levels of energy use in Thailand, by sector, fuel source, and form. Sectors are the residential, commercial, and industrial sectors, as well as the transportation sector. Fuel sources are the sources used to generate energy, such as coal, petroleum, natural gas, biomass, hydropower, and so forth. "Form" refers to whether the energy was delivered to the end user as

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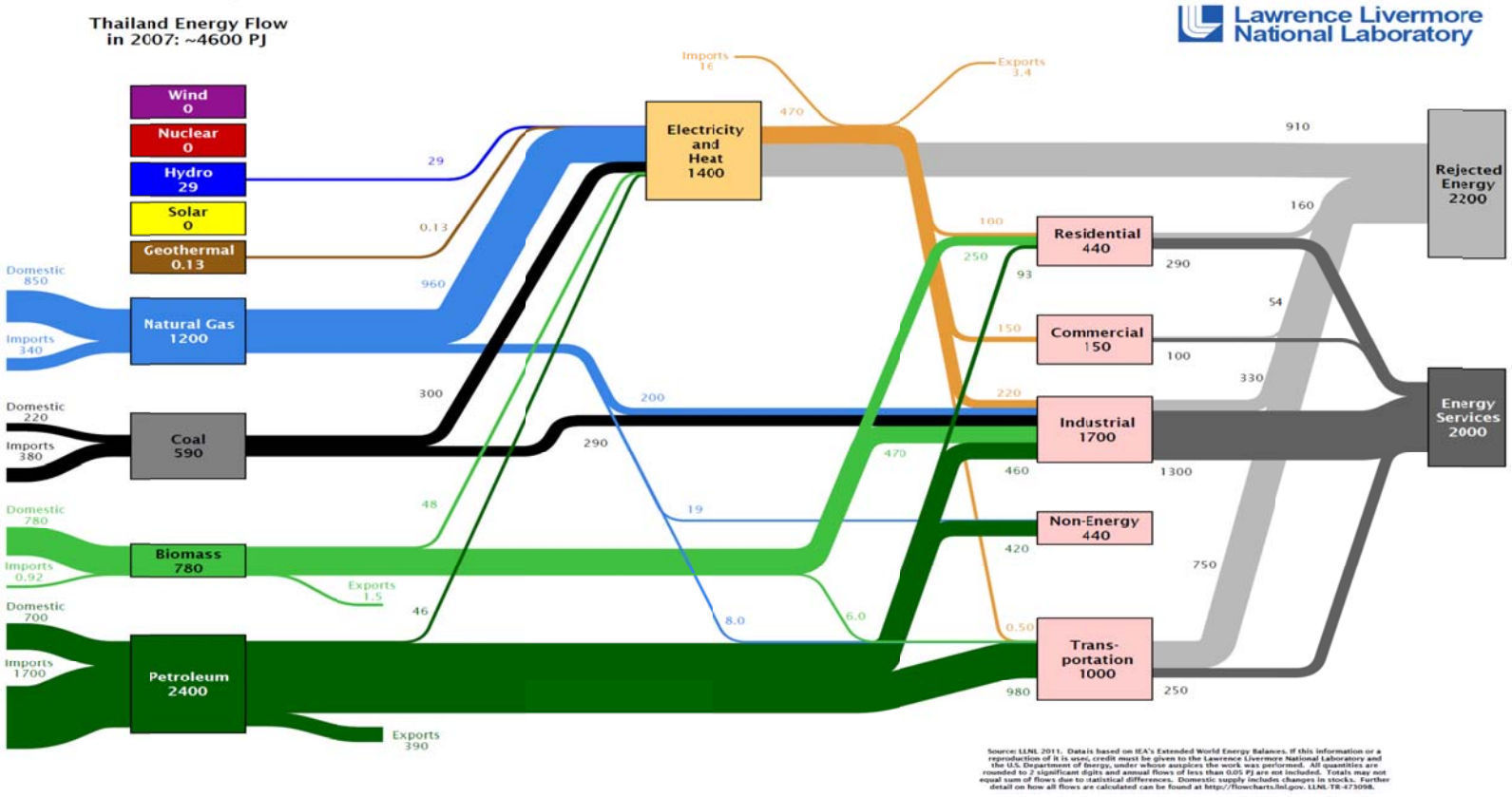
[11]. Since Thailand is a country with a population of 67 million, this means that only about 400,000 people in rural areas don't have access to electricity.

[12] The solar panel and battery program was implemented at a cost of USD$200 million. As described by Greacen, as of October 2007, the Government of Thailand had no maintenance plan for these 203,000 solar home systems, and 20 percent of the systems in surveyed villages failed within the first two years [44]. As a result, there may be demand for services to better maintain these systems (a service that Palang Thai has provided in the past [32]) or demand for replacement parts, such as batteries.

electricity or in another form; for needs for heat in the residential, commercial, and industrial sectors and for transportation needs, energy does not need to be delivered to the end user as electricity. Instead, fuels can be burnt to directly produce heat or to power the engines of vehicles.

In our evaluation of demand for energy conservation and energy efficiency products and services later in this chapter, we will need to know energy use by sector because demand for these products by sector may be proportional to the amount of energy each sector uses. Information about the fuel sources that Thailand uses at the current time tells us what types of fuels renewables will be competing against in the near future (i.e., what types of fuels would be replaced or augmented by renewables). The data in this section also provide information on the overall size of the market for all energy-related goods and services in Thailand and on how demand for energy in Thailand is divided among demand for electricity, demand for heat, and demand for transportation fuels. Figure 2, from the publication "International Energy Flows" by Lawrence Livermore National Laboratory [47], presents a detailed illustration of how much energy is used in different sectors in Thailand. The figure also shows where the energy used in each sector comes from—whether it's from fossil fuels or renewable sources, and what portion of each type of energy was imported to Thailand from other countries [47]. Figure 2 is based on data from 2007—the data, then, are five years old. However, more recent data on energy consumption in Thailand from the Ministry of Energy [48] and from the U.S. Energy Information Administration [49] show that energy consumption patterns in Thailand in 2007 and 2010 were very similar. There are two main exceptions: natural gas consumption increased by 67 percent and renewable energy generation and consumption also increased (see the "Recent Levels and Trends in Fossil Fuel and RE use" section below).

Figure 2. Thailand energy flow



Source: Lawrence Livermore National Laboratory [47].

Note: Data from IEA's Extended World Energy Balances. All quantities are rounded to two significant digits, and annual flows of less than 0.05 PJ are not included. Totals may not equal the sum of flows because of statistical differences. Domestic supply includes changes in stocks. Further detail on how all flows are calculated can be found at http://flowcharts.llnl.gov.

Fossil fuel imports

Thailand's MOE's *Energy Statistics of Thailand* publication [48] and the data in Figure 2 show that Thailand is a net importer of petroleum, coal, and natural gas, and that about 60 percent of the fossil fuel consumed by Thailand is imported. This reliance on fossil fuel imports makes Thailand's economy vulnerable to price shocks in the global market for fossil fuels [26]. Thailand, then, has an incentive to use energy more efficiently and to rely more heavily on domestic sources of renewable energy. Given this incentive we can expect the Government of Thailand to have some level of commitment to its energy efficiency and renewable energy goals and policies that we describe and assess later in this paper. This expectation is supported by research conducted by the International Energy Agency (IEA), which shows that worldwide, countries that are more dependent on imported fossil fuels for energy tend to have higher growth in the demand for renewables [41].

Recent levels and trends in fossil fuel and RE use

In this section we present data on levels and trends in fossil fuel and renewable energy use in Thailand in recent years. Growth in the use of RE in the recent past often indicates a commitment to continued growth in the use of RE in the future [16].[13] Furthermore, when a country already has some experience using a certain type of RE technology, it often makes it easier to increase its use of that technology in the future [50], [51].[14]

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[13] Growth in the use of RE in a country in the recent past is one of the main factors used by the EIA's World Energy Projection System Plus Model to forecast growth in the use of RE in that country over the next five years [16].

[14] The World Bank has made the observation that a country that already has some experience using a certain type of RE technology often has an easier time increasing its use of that technology in the future. In making loans to countries to finance renewable energy projects, the World Bank seeks to spark new growth in the renewable energy sectors of countries that have not built any new renewable energy power plants in the recent

Electricity market

Table 1 presents data from 2005 through 2010 on net electricity generation in Thailand by type of fuel source:[15]

Table 1. Electricity net generation by type (billion kWh)

		Renewable energy							
Year	Nuclear	Hydro-electric	Geo-thermal	Wind	Solar	Biomass and waste	**Total RE**	**Total conventional fossil fuel thermal**	**Total net generation**
2005	0.00	5.74	0.002	0.001	0.000	3.80	9.54	115.79	125.33
2006	0.00	8.04	0.002	0.001	0.001	3.60	11.65	119.82	131.46
2007	0.00	8.03	0.002	0.000	0.001	4.60	12.64	122.56	135.20
2008	0.00	7.04	0.001	0.000	0.003	5.10	12.15	126.82	138.96
2009	0.00	7.08	0.001	0.001	0.009	5.60	12.69	127.13	139.82
2010	0.00	5.32	0.001	0.001	0.010	6.00	11.34	136.61	147.95

Source: EIA [49]

From Table 1 we see that Thailand's electricity generation from fossil fuels, solar, and biomass and waste increased between 2005 and 2010. However, in 2010, electricity generation from hydropower fell because of the large floods in Thailand that year [27].

Transportation fuels market

Table 2 below shows data on Thailand's annual consumption and production of fuel ethanol and biodiesel between 2005 and 2010. Table 2 also presents data on oil production and petroleum consumption in Thailand. From the table we see that biofuel production and consumption are a small but growing portion of the transportation fuels market in Thailand.

past [50], [51]. The World Bank expects that after the power plants it finances are constructed, the countries will gain the institutional and technological knowledge necessary to build more new power plants without having to rely as heavily on support from experts from foreign countries [50], [51].

[15] The data on hydroelectricity generation include data on electricity generated at large hydroelectric dams. The output of these large generating facilities can fluctuate from year to year depending on rainfall patterns.

Table 2. Production and consumption of biofuels, oil, and petroleum

Year	Production				Consumption			
	Fuel ethanol (KBPD)[a]	Bio-diesel (KBPD)	Total biofuels (KBPD)	Total oil supply (KBPD)	Fuel ethanol (KBPD)	Bio-diesel (KBPD)	Total biofuels (KBPD)	Total petroleum (KBPD)
2006	2.2	0.4	2.6	337.3	2.2	0.1	2.3	952.1
2007	3.0	1.2	4.2	369.2	3.0	1.1	4.1	941.3
2008	5.7	7.7	13.4	392.7	5.5	7.7	13.2	933.0
2009	6.9	10.5	17.4	401.6	8.0	10.5	18.5	913.5
2010	7.5	11.0	18.5	406.8	7.0	11.0	18.0	960.2

Source: EIA [49].

a. KBPD: Thousands barrels per day

Expected demand for renewable energy and energy efficiency products in Thailand over the next several years

In this section of the paper we present our assessments of the extent to which different types of renewable energy and energy efficiency products will be in demand in Thailand over the next several years. Here, we define "demand" as the likely level of sales of the products, measured in quantitative terms such as megawatts (MW) of new power generating capacity when it is possible to do so. We begin by presenting information on the Government of Thailand's targets and mandates for the use of different types of renewable energy, and its estimates of Thailand's technical potential to use renewable energy. We then describe Thailand's feed-in-tariff scheme for giving private sector utility companies incentives to build RE power plants. Then, in separate sections on hydropower, geothermal power and ground source heat pumps, wind energy, solar energy, bioenergy (biomass, biogas, and municipal solid waste), biofuels, energy storage, energy efficiency products other than electric grid products, and electric grid products, we assess how much demand there is likely to be in Thailand over the next several years for these different categories of RE&EE products. For the types of RE products for which Thailand's government has set targets for use, we assess how close Thailand is likely to get to reaching each target.

The Government of Thailand's targets and mandates for RE use and its estimates of Thailand's technical potential

The Government of Thailand has set targets and mandates for how much additional renewable energy it would like the country to use over the next 10 years. Thailand's MOE has also estimated Thailand's technical potential to use each different type of renewable energy. Technical potential is how much renewable energy generation capacity Thailand could have if it were to use all its available natural resources (i.e., agricultural byproduct biomass, moving water in streams

and rivers, sunlight and windspeed, and land available to grow feedstock for biofuels) to generate electricity and produce biofuels. In subsequent sections, we will be describing Thailand's plans for achieving these targets and we will provide our assessment of how close we expect Thailand to come to achieving its targets. This assessment is our estimate of demand for RE products in Thailand.

Table 3 presents Thailand's RE goals as outlined in the MOE's *Renewable Energy Development Plan* [52]. The goals are also presented in EGAT's *Power Development Plan* [26]. The goals were set in 2008.[16] The column titled "Technical potential" gives MOE's assessment of Thailand's technical capacity for different types of renewables. For example, if solar panels were placed on all suitable available land and building rooftops, Thailand's capacity for solar generation would be over 50,000 MW. In the case of biomass, given the amount of biomass available in Thailand,[17] Thailand could have up to 4,400 MW of biomass electricity generating capacity. The other columns in table 3 show Thailand's capacity for renewables in 2008 and its targets for the end of 2011, 2016, and 2022. In setting these goals, MOE considered how much of its technical potential would be realistic and desirable to use [30], [52].[18]

[16] Some newer, more ambitious targets are laid out in the *Renewable and Alternative Energy Development Plan* for 25 Percent in 10 Years (AEDP 2012–2021) by the Department of Alternative Energy Development and Efficiency within MOE [53]. However, it is unclear to us whether the entire Ministry has endorsed these new targets.

[17] In Thailand, biomass mainly takes the form of agricultural byproducts such as bagasse, rice husks, rice straw, and sugar cane leaves.

[18]. The aim of this report is to look at demand for RE&EE products now and in the near future—the next 1 to 5 years, roughly. Targets for 2022 are still often relevant to demand for RE&EE products now and in the near future because of the long planning and construction periods required for many RE and electric grid projects. The average construction times for various types of renewable power plants in several different countries and regions around the world are given in the IEA's World Energy Outlook 2011 [54].

Table 3. *Renewable Energy Development Plan Goals* set in 2009

Type of Energy	Tech-nical potential	Existing capacity (2008)	Target of capacity by: 2011		2016		2022	
Electricity	MW	MW	MW	ktoe	MW	ktoe	MW	ktoe
Solar	>50,000	32	55	6	95	11	500	56
Wind energy	1,600	1	115	13	375	42	800	89
Small hydro power	700	56	165	43	281	73	324	85
Biomass	4,400	1,610	2,800	1,463	3,220	1,682	3,700	1,933
Biogas	190	46	60	27	90	40	120	54
Municipal solid waste	400	5	78	35	130	58	160	96
Total		1,750	3,273	1,587	4,191	1,907	5,608	2,313
Biofuel	m lt/d [a]	m lt/d	m lt/d	ktoe	m lt/d	ktoe	m lt/d	ktoe
Ethanol	10	1.24	3	805	6.2	1,686	9	2,447
Biodiesel	5	1.56	3	950	3.64	1,145	4.5	1,415
Total		6	1,755	9.84	2,831	13.5	3,986	
Renewable energy ratio		ktoe		ktoe		ktoe		ktoe
Total energy consumption		66,248		70,300		81,500		97,300
Total energy from RE		4,237		7,492		10,319		13,709
Renewable energy ratio		6.4%		10.6%		12.7%		14.1%

Source: Thailand's Department of Alternative Energy and Efficiency [52].

Note: "Small hydro power" includes small, mini, and micro hydropower; see text below in the section on hydropower. Empty cells indicate no that no data were available. ktoe = million tonnes of oil equivalent

a. Millions of liters per day

As explained in the previous section ("Recent levels and trends in fossil fuel and RE use: Electricity Market"), the fact that Thailand already has a non-trivial amount of renewable energy generation capacity (especially for solar, small hydro, biomass, biogas, and biofuels) bodes well for Thailand in its efforts to meet its RE capacity targets. This is because countries that already have experience using a certain type of renewable energy technology and building capacity of it tend to have an easier time increasing capacity in the future.

Information in EGAT's Power Development Plan gives us a sense of the size and ambition of Thailand's targets for renewable energy capacity growth. In 2009, the country had 29,212 MW of total electricity generating capacity, a total that includes fossil fuel and large hydro plants [26]. EGAT's Power Development Plan for 2010 through 2030 includes having 65,547 MW of total electricity generating capacity by 2030. This total also includes fossil fuel and large hydro plants as well as a nuclear power plant [26]. In comparison, Table 3 shows that Thailand's target for total renewable electricity generating capacity in

2022 across all types of renewables is 5,608 MW—8.5 percent of the 65,547 MW target for total capacity in 2030. It is also informative to compare the sizes of the different renewable energy capacity targets with the sizes of the fossil fuel and nuclear power plants that Thailand intends to build over the next decade. Representative examples include three new fossil fuel plants with 800 MW of capacity each and a new nuclear power plant with a capacity of 1000 MW [26].

Thailand's feed-in-tariffs (FiTs) and other government support policies for renewable energy

Thailand's plans for achieving the renewable electricity use targets discussed in the previous section are centered on two main strategies.[19] One strategy consists of plans to have the state-owned electric utility company EGAT build new small-scale hydroelectric power plants. We discuss these plans in the section on hydroelectric power below. The second and more important strategy is the feed-in-tariff (FiT) scheme created and managed by the Government of Thailand. This scheme is designed to give private-sector power producers (Independent Power Producers (IPPs), Small Power Producers (SPPs), and Very Small Power Producers (VSPPs)) incentives to build renewable energy power plants and supply the electricity generated by these plants to Thailand's main electric grid. We describe the FiT scheme here so that we can later discuss its likely effects on demand for RE products.

Thailand's FiTs for renewables are a combination of a standard feed-in-tariff paid to any private-sector electricity producer, including those that have fossil fuel power plants, and adder rates. An adder rate is an additional tariff that power producers who use renewable energy sources receive for sending a kilowatt hour of electricity to the grid, over and above the normal tariff that a fossil-fuel-using private-sector electricity producer (an IPP, SPP, or VSPP) receives [52]. Thailand's adder rates vary by type of renewable (e.g., wind farm or solar farm), by the size (capacity) of the renewable power plant, and the type of producer (VSPP or SPP). There are special adder rates that

[19] Plans for achieving the biofuels targets are discussed in the "Biofuels energy" section below.

apply to the southern regions of the country. There are also special adder rates that apply when a power producer replaces electricity generated by diesel generators with electricity generated with renewables in the PEA. Table 4 shows the levels of these different adder rates. Note that the standard rate given to non-renewable electricity produced by VSPPs, onto which these adders are added, was 2.58 Bhat per kWh in 2011 (about US$0.085) [57], and the retail price paid by households in Thailand for electricity was US$0.094 kWh in 2008 [49].

Table 4. Adder rates for RE power production by type and capacity

Fuel	VSPP USD/kWh	SPP USD/kWh	Special adder[b] USD/kWh	Support period (Years)
Biomass				
Installed capacity <= 1 MW	0.016	Bidding	0.033	7
Installed capacity > 1 MW	0.010		0.033	7
Biogas (all production sources)				
Installed capacity <= 1 MW	0.016	Bidding	0.033	7
Installed capacity > 1 MW	0.010		0.033	7
Waste (community waste, not hazardous industrial and inorganic waste)				
Landfill and digester	0.082	0.082	0.033	7
Thermal process	0.115	0.115	0.033	7
Wind power				
Installed capacity <= 50 kW	0.148	0.115	0.049	10
Installed capacity > 50 kW	0.115		0.049	10
Mini and micro hydropower				
Installed capacity 50–200 kW	0.026	Not	0.033	7
Installed capacity < 50 kW	0.049	Applicable	0.033	7
Solar power				
Solar power	0.262[a]	0.262[a]	0.049	10

Source: Adder and exchange rate (1USD = 30.5 Baht) from Thailand's Department of Alternative Energy and Efficiency [52].

a. Solar adder reduced to 0.217 USD/kWh (231 percent) in 2010 (Thailand's Department of Alternative Energy and Efficiency [52]).

b. Special adders apply to facilities in the three southern most provinces of the country and to diesel generator replacement on PEA system.

The Government of Thailand set the adder and tariff rates at levels that they expected would be high enough to induce private companies (IPPs, SPPs, and VSPPs) to build many new renewable power plants. Specifically, enough capacity of new power plants that Thai-

land would make reasonable progress toward achieving the country's goals listed in the previous section [58].[20] The government expected that at these rates it would be profitable for private companies to build some biomass, biogas, waste, wind, hydro, and solar power plants and sell electricity to the electric grid. The adder and tariff rates determine the revenue a company can get if it builds a renewable power plant and supplies electricity to Thailand's electric grid. Revenue is defined in Bhat per kWh of electricity produced. Companies will find it profitable to build renewable energy power plants in Thailand if revenues from building the plants exceed the costs. The cost of producing a kWh of electricity with a power plant is given by a measure known as the levelized cost of electricity. As described the EIA,

> Levelized cost represents the present value of the total cost of building and operating a generating plant over an assumed financial life and duty cycle, converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation. Levelized cost reflects overnight capital cost, fuel cost, fixed and variable O&M cost, financing costs, and an assumed utilization rate for each plant type. [59]

Data on levelized costs of different types of renewable energy technologies in different countries and regions of the world are available in the *REN21 Renewables 2011* and *2012 Global Status Reports* [36],[37] and in the *IEA's World Energy Outlook 2011* [54]. The costs vary across geographic areas by the quality of the renewable energy resources in the area (amount of sunlight, wind speed, availability and accessibility of biomass resources, and so forth).

Comparing the ranges of levelized costs for different types of renewables that are given in these sources with Thailand's adder and tariff rates, we see that the adder and tariff rates are above the lower ends of the ranges of levelized costs for the different types of renewables, indicating that it is likely that private firms will find it profitable to build some amount of new renewable electricity power plants in

[20] Reference [58] by Chris Greacen at Palang Thai and Sopitsuda Tongsopit also provides information on Thailand's adder rates in place in 2007, 2009, and from 2010 through May 2012.

Thailand. In the sections that follow on the market for each type of renewable energy product in Thailand and our assessments of how close Thailand is likely to get to achieving each of its renewable energy use targets, we discuss further whether private firms will find it profitable to build renewable electricity power plants in Thailand under the country's adder and tariff scheme.

In addition to the adder and tariff scheme, the Government of Thailand has created a number of other programs and incentives designed to promote the use of renewable energy and energy efficiency. These programs include an income tax holiday and duty-free importing that apply to investments in both energy efficiency and renewable energy equipment and machinery. There are also government grants and subsidized loans for investments in both energy efficiency and renewable energy. These programs are described in publications prepared by Thailand's MOE and by the Asia-Pacific Energy Research Center [56], [60].[21] However, for renewable energy products, FiTs are by far the most important program for encouraging private-sector firms to build renewable energy power plants [17], [18], [30].

Markets for specific categories of renewable energy products and energy efficiency products

In this section we provide our assessment of the amount of demand for different categories of renewable energy and energy efficiency products in Thailand now and in the near future (out to approximately five years). We include subsections on different types of renewable energy products: one section on hydroelectric power products, one section on geothermal electricity generation products and ground source heat pumps, one section on wind energy products, one section on solar energy products, one section on bioenergy (biomass, biogas, and municipal solid waste), and one section on biofuels. There is also a subsection on energy storage products that can be used with intermittent sources of energy (e.g., solar and wind). Finally, we include a subsection on the market for all types of energy efficiency products in Thailand other than electric grid products, as

[21] The programs that apply to energy efficiency are discussed in more detail in the sections on markets for energy efficiency products below.

well as a subsection on the market for electric grid products in general and smart grid products in particular.

Hydroelectric power projects

Summary of demand for hydroelectric power projects in Thailand:

Thailand's MOE's targets for building new small, mini, and micro hydroelectric power plants are modest in relation to the its targets for developing new solar, biomass, and fossil fuel power plant capacity. The targets for hydro are building 116 MW of new small, mini, and micro hydroelectric plants between 2012 and 2016 and an additional 43 MW between 2017 and 2022 [26], [52]. Based on the number and capacity of new hydro projects that have already been planned and designed according to EGAT and Thailand's MOE [26], [56], [57], and the fact that at least 13 new small power plants were under construction in Thailand as of February 2011 [26], [56], it appears that at least two-thirds of this targeted capacity will be constructed. Progress toward these targets will be made primarily through building small hydro plants (plants with capacities between 200 kW and 25 MW), as only eight new proposed mini (50 to 200 kW) and micro hydro plants (5 to 50 kW) had reached the planning stages in Thailand as of December 2011 [57]. It appears that there is no market for pico-sized hydro plants (below 5 kW) in Thailand.

Additional information on demand for hydroelectric power projects in Thailand:

There are five different categories of sizes of hydroelectric generators.[22] "Large hydro" projects are dams that interrupt the flow of rivers. Generally they are larger than 25 MW in capacity [22], [61]. Many in the RE field do not categorize them as renewable sources of energy because changing the natural flow of a river or stream with a dam can cause ecological damage and displace residents of communities upstream of the dam [61 - 64]. "Small hydro" projects are hydro-powered generators that are generally no larger than 25 MW [22], [61], but still larger than 200 kW. Hydroelectric generators be-

[22] For a detailed technical description of the types of hydroelectric generators in each of these five categories, see "Small Hydropower for Developing Countries" by the European Small Hydropower Association [61].

tween 50 and 200 kW are defined as "mini" hydro by MOE, and those with capacity below 50 kW are defined as "micro" [26], [57]. A final category of hydro generators also exists: "pico hydro," with capacity less than 5 kW. Pico hydro generators are small devices that are capable of powering lights and a number of electronic devices and appliances in one or two rural Thai households [65]. Small, micro, mini, and pico hydroelectric generators are generally "run-of-the-river devices" that cause negligible change to the natural flow of a river or stream. They are generally not dams, although some are small dams on small streams.

MOE's Department of Alternative Energy Development and Efficiency assesses that Thailand's potential capacity to generate electricity using small, micro, mini, or pico hydro generators totals 700 MW [28]. That is, there are enough rivers, streams, and canals in Thailand that are suitable locations to install these generators such that up to 700 MW of new capacity of these types of generators could be installed in Thailand. This 700 MW of potential capacity includes 56 MW of capacity that were already installed in 2009. The 700 MW is an estimate of the ability of currently existing small, micro, mini, and pico hydro generation technology to convert power from moving water into electricity; technological improvements would increase this potential by allowing for more electricity to be extracted from available sources of moving water. Chris Greacen at Palang Thai states that this 700 MW of hydro potential is spread out across thousands of sites in different streams, rivers, and canals in the country [44], [62]. He also notes that Thailand has constructed very few micro and mini hydro plants. Only 59 were constructed before 2004. Since then, Palang Thai has constructed four.

Table 3 also presents the Government of Thailand's targets for installing small, micro, mini, and pico hydro generators. These are as follows: 109 MW of new capacity installed between 2008 and 2011 (165 MW capacity by 2011 minus the 56 MW already in place), 116 MW between 2012 and 2016, and 43 MW between 2017 and 2022, for a total of 268 MW between 2008 and 2022.

Table 4 presents the subsidy (adder rate) and FiTs provided by the Government of Thailand to Very Small Power Producers (VSPPs) who supply electricity to the grid using micro-hydro and mini-hydro generators. Small hydro power plants do not qualify for an adder.

However, they do qualify for the standard tariff given to all VSPPs, including VSPPs that use fossil fuels (which, as stated above, was approximately $0.085 USD in 2011). A comparison of the level of this adder rate and tariff to data on the ranges of levelized costs of electricity production for small hydro, mini-hydro, and micro-hydro power plants worldwide [36], [37] suggests that under Thailand's adder and tariff rates, it will be profitable for private companies to build some small, mini, and micro-hydro power plants in Thailand. Furthermore, the Government of Thailand, through EGAT and MOE's Department of Alternative Energy Development and Efficiency, has plans to build 90 small hydro plants totaling 250.6 MW in capacity over the next 15 years. This includes 48 small hydropower plants incorporated into existing irrigation dams that are not currently used to generate electricity, 13 of which were already under construction as of February 2011 [26], [56].

Thailand's target for building new small, mini, and micro hydro plants is to build 268 MW of new plants between 2008 and 2022. We reviewed specific plans for building new small, mini, and micro hydro plants in Thailand in the Power Development Plan for 2010-2030 released in April 2010 [26], and also reviewed more recent information from February and December 2011 from Thailand's Ministry of Energy about plans of Thailand's government and VSPPs in Thailand to build new small, mini, and micro hydro plants [56], [57]. From these, we see that as of December 2011, 258.5 MW of new small, mini, and micro hydro plants had already been sited and designed and either were being constructed or were ready to begin being constructed [26], [56], [57]. Given this progress to date, we think that Thailand should achieve at least two-thirds of its targets. We note, however, that in December 2011, there were only six new mini and micro hydro plants in the planning and design phase in Thailand [57]. Demand for new mini and micro hydro plants appears to be much lower than demand for new small hydro plants.

We found no evidence of demand for pico hydroelectric generators in Thailand, even though over 60,000 pico hydro generators have been installed in neighboring Laos [65] and over 130,000 in Vietnam [61]. Given that in 2005 Thailand gave out solar panel systems with backup batteries to each of the 203,000 households that weren't connected to Thailand's electric grid, it seems more likely that there would be demand for replacing the original solar panels and batter-

ies installed in 2005 with new panels and batteries than for replacing worn-out panels and batteries with pico hydro generators.

Thailand plans to build two new large hydro plants in the near future. EIA's database on renewable energy projects that have been planned and those that are under construction around the world lists a 100 MW hydropower plant called "Song Bung-2" that had been designed and received financing in May 2010 [55]. EGAT's Power Development Plan for 2010–2030 also describes plans to build two new 250 MW pumped storage hydropower generation units at an existing reservoir, the Lam Takhong Reservoir. The reservoir already has two 250 MW pumped storage units in place; the new units will be mounted 300 meters underneath the original units. Thailand plans to build the two new units by June 2017 [26]. Finally, the International Journal on Hydropower and Dams 2011 World Atlas and Industry Guide reports that "Thailand is monitoring and upgrading its existing major dams and hydropower facilities." For the most part, the existing dams were built a few decades ago [67].

Geothermal electric power plants and ground source heat pumps

We have not found any evidence of demand for building geothermal electric power plants in Thailand. Geothermal energy is not a top priority renewable energy development plans in Thailand. There are no stated targets or incentives specific for geothermal energy generation in Thailand's Renewable Energy Development Plan (see table 3 and table 4 above). Similarly, neither EGAT's Power Development Plan for 2010–2030 nor the database of proposed and under-construction renewable energy power plants used in the EIA's World Energy Projection System Plus model [26], [55] list plans to build geothermal power plants in Thailand. The biggest reason for this is the lack of technical potential. According the IEA, Thailand simply does not have the physical resources (underground sources of steam and heat from hot springs and hot rocks) to use geothermal energy to generate electricity [68].

However, one technology that could be applied to heat and cool buildings in at least in some parts of Thailand, including Bangkok, is ground source heat pumps. Heat pumps make use of temperature differences between the earth's surface and areas approximately 5 to 20 feet below the surface [69]. According to a recent article pub-

lished in *Bulletin of the Geological Survey* of Japan, ground source heat pumps could be used to cool buildings in some regions of Thailand and other tropical regions within Southeast Asia [69]. As an energy efficiency technology, ground source heat pumps may be covered under government incentives for energy efficiency. Ground source heat pumps sometimes are a more energy-efficient way of cooling buildings than conventional air conditioners. However, ground source heat pumps are not mentioned directly in official Thailand MOE documents such as the Government Energy Policy [26] and the 20-Year Energy Efficiency Development Plan [52]. Furthermore, according to the *Bulletin of the Geological Survey* [69] and the IEA [68], [70], ground source heat pumps have rarely been used in Thailand. Therefore, it appears that there will be little demand for ground source heat pumps in Thailand over the next five years.

Wind energy

Summary of demand for wind energy power projects in Thailand:

Thailand's target for installing new wind capacity is 800 MW by 2022, with interim targets of 115 MW by the end of 2011 and 375 MW by the end of 2016. Even though Thailand's adder and FiTs for wind are generous enough (in comparison to the levelized costs of electricity for wind) that numerous private companies would like to build wind farms in Thailand, these plans to build wind farms have run into difficulties because the areas of Thailand with high wind speeds are in national parks and other protected government-owned lands controlled by government agencies other than Thailand's MOE. Although one of these agencies has recently started to given permission for some wind farms to be built on some of the lands it controls, finalizing a land use lease is time consuming and difficult. Thailand fell well short of its interim wind capacity installation target for 2011. As such, we assess that Thailand is likely to achieve only half of its wind capacity targets.

Demand for wind turbines in Thailand is limited to demand for larger turbines for supplying electricity to large electric grids. We found no evidence of any demand for smaller wind turbines used in off-grid and micro-grid applications. This is likely because nearly all of Thailand's population is connected to Thailand's large, centralized electric grid.

Additional information on demand for wind energy power projects in Thailand:

Thailand has a target of 800 MW of installed wind capacity by 2022, with a sub-target for 2011 of 115 MW. However, as reported by *Windpower Monthly Magazine*, there were only between 5.1 MW and 7.2 MW of installed wind capacity in Thailand in August 2011 [71].[23]

Partially because of the adder rates and tariffs and other incentives put in place by the government, there are also about 300 MW of new wind projects that have been approved by the MOE [71]. Two of the projects, totaling 18 MW of capacity, are under construction. Another nine, with a total projected capacity of 387 MW, are in the approval process [71].[24]

While these are encouraging signals that there is demand for wind energy in Thailand, the country is falling short of its scheduled targets. Several factors affect Thailand's ability to reach its goal. Only a few areas have high enough average wind speeds to make investment attractive given current technology. In a recent update of Thailand's Wind Development Potential Assessment, the MOE's Department of Alternative Energy Development and Efficiency found that most areas of the country had relatively low average wind speeds [52]. The only areas with higher wind speeds that make wind power development economically feasible are in the south and northeast, and in small portions of the western part of the central region [52]. Figure 3, taken from [52], shows average wind speeds across Thailand.

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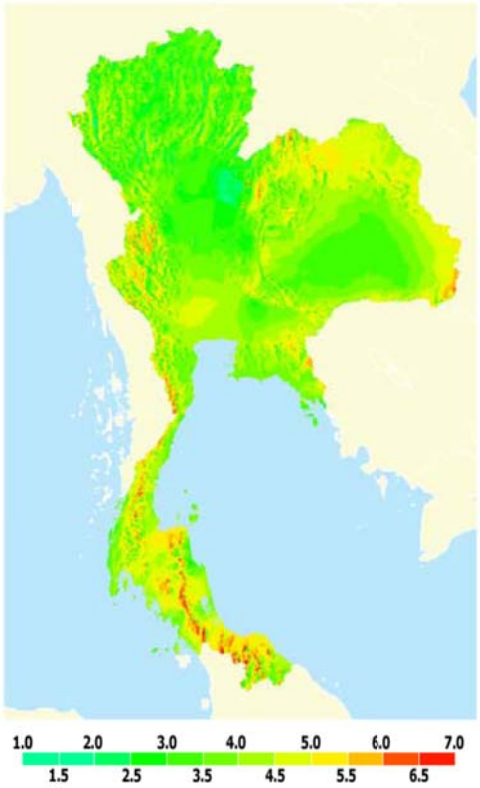
[23]. Less than 0.5 MW of these projects are by VSPPs [57].

[24]. In December 2011—four months after the publication of the *Windpower Monthly Magazine* article— the EPPO reported that SPPs have proposed wind projects, totaling about 500 MW of installed capacity, and are waiting for MOE and EGAT to approve PPAs for these projects [57].

Figure 3. Thailand's yearly average wind speed (m/s)



Source: Department of Alternative Energy Development and Efficiency [52]

Note: Elevation: 90 meters

Moreover, most of the areas with higher average wind speeds fall in protected government-owned lands [56], [71]. Though the Agricultural Land Reform Office (ALRO) has recently issued a new regulation allowing some public lands to be leased for use as wind farms [56], obtaining such a lease can be time consuming and difficult [71]. Projects promoted by BOI have priority, but still require processing time [71].

In addition, because Thailand has little experience with installing wind turbines (as seen by its low amount of wind capacity in 2011), it may not have enough expertise to develop its new wind projects quickly [71]. This is contrary to Thailand's experience with solar—the country already has a reasonably large amount of solar capacity installed and a regulatory, technical, and project management skill base.

Solar energy

Summary of demand for solar energy power projects in Thailand:

Thailand is on pace to exceed its target of installing 500 MW of solar capacity. This is largely because of recent decreases in the price of solar PV products. In addition to demand for solar PV, we expect that there will be demand for concentrated solar power (CSP) products in Thailand in the next five years. Two CSP plants were installed in 2011. Thailand's government also provides some support for use of solar hot water heaters.

Additional information on demand for solar energy power projects in Thailand:

Thailand has good technical potential for solar energy [72], and the government's support of this renewable has created significant growth in its use. According to the Thailand PV Status Report 2011 [45], the country has surpassed its solar capacity target for 2011 and is well on its way to surpassing its 500 MW goal for 2022 [45]. In fact, the Thailand PV Status Report says that Thailand may revise its solar capacity goal for 2022 upwards to 2,000 MW [45], and the MOE's Department of Alternative Energy Development and Efficiency has already endorsed the new 2,000 MW target [53]. Demand for solar projects in Thailand has been quite large in the last few years because of government support policies—particularly the adder rates. As Thailand's government adjusts these adder rates in response to declines in the price of solar PV and CSP, we believe growth in the market will slow down, but remain strong.

Table 5 gives information on the completed or nearly completed solar PV farms in Thailand. All were scheduled to be ready by the end of 2011. The total generating capacity of these farms will be 142 MW, but so far only 104 MW of capacity has been reached. This is largely the result of the floods that affected Thailand last year. Construction on farms in Ayutthaya and Lopburi were delayed.

Table 5. Solar farms in Thailand

No.	Location	Company	Module/Installation type	Capacity (MWp)	Electricity generation (kWh/Year)	Commercial Operation Date
1	Mae Hong Son	EGAT	Poly c-Si/ Fixed	0.504	618,000	9-Apr-04
2	Chachoengsao	BSP	Thin film a-Si/ Fixed	1.495	2,168,000	5-Oct-07
3	Udonthani	BSP	Thin film a-Si/ Fixed	0.282	443,000	1-Jul-08
4	Petchaburi	BSP	Thin film a-Si/ Fixed	2.144	3,268,000	10-Feb-09
5	Angthong	BSP	Thin film a-Si/ Fixed	1.136	1,799,000	11-Feb-09
6	Udonthani	BSP	Thin film a-Si/ Fixed	1.563	2,451,000	2-Apr-09
7	Nakhon Sawan	BSP	Thin film a-Si/ Fixed	0.547	865,000	1-Nov-09
8	Nakhon Ratchasima	Solar Power	Poly c-Si/ Fixed	5.94		30-Apr-10
9	Lopburi	BSP	Thin film a-Si/ Fixed	2.225	3,525,000	25-May-10
			Poly c-Si/Tracking & Fixed	0.891		
10	Ubonrachathani	EGAT	Thin film a-Si/Track. & Fixed	0.121	1,760,000	30-Dec-10
11	Nakhon Ratchasima	BSP	Thin film a-Si/ Fixed	1.114	1,741,000	1-Jan-11
12	Prajuabkirikan	BSP	Thin film a-Si/ Fixed	1.949	2,972,000	1-Feb-11
13	Sakonnakhon	Solar Power	Poly c-Si/Fixed	5.94		1-Feb-11
14	Nakhon Phanom	Solar Power	Poly c-Si/Fixed	5.94		22-Apr-11
15[a]	Ayutthaya	Bangchak	Poly c-Si/Fixed	30	51,831,000	Jun-12
				8	14,408,000	Mar-12
16[a]	Lopburi (Phase 1 of 7)	NED	Thin film a-Si/ Fixed	73	120,000,000	22-Dec-11

Source: Thailand PV Status Report 2011 [45].

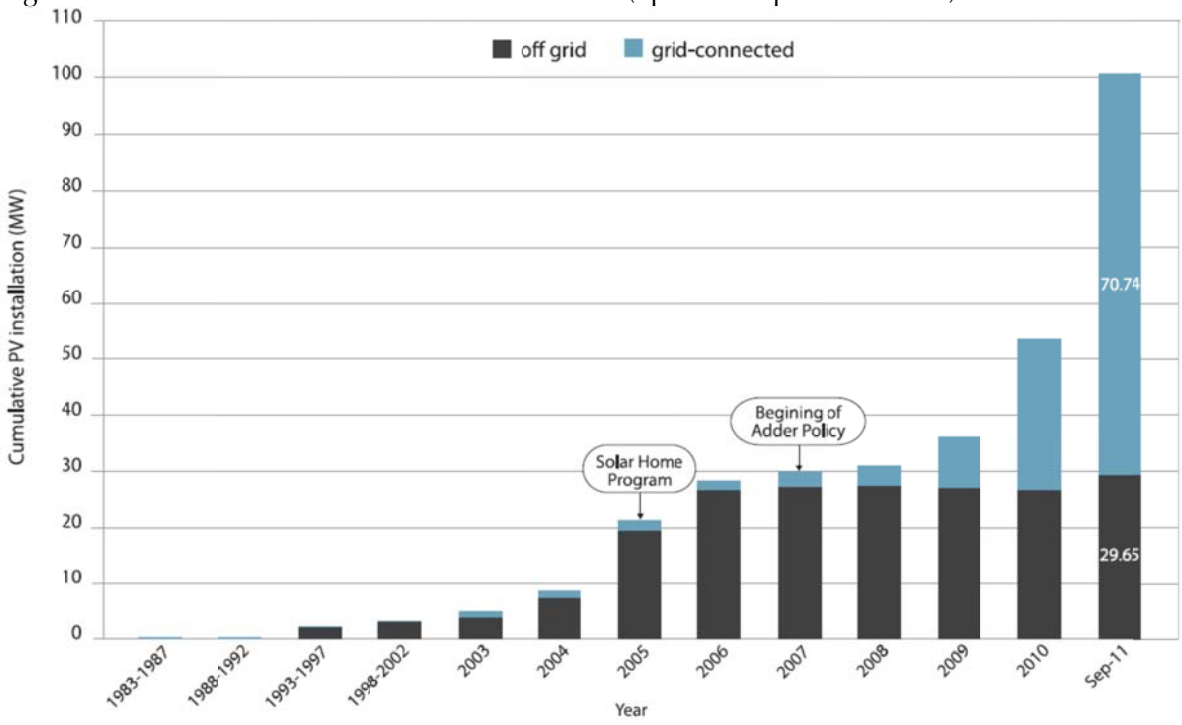
a. Project under construction

Thailand has two CSP plants—one in operation and one under construction. The plants use concentrated solar heat to generate electricity using steam turbines rather than PV panels. Further details are available Solarlite GmbH's website. Solarlite GmbH, a German company, built the first plant and is building the second one [73]. TSE 1, which is in Kanchanaburi Province, Thailand, came online in December 2011, and has a capacity of 5 MWe (MW electricity). This project was incentivized by the additional adder benefits for solar projects built by VSPPs. TSE 2 is under construction in Suphanburi Province and has a capacity of 9 MWe [73]. Numerous other plans to build CSP plants in Thailand have been made, and many of these have signed PPAs with EGAT [57].

The growth in the use of solar in Thailand up through 2006 was mainly in off-grid capacity. The "Solar Home" program (2004–2006) for rural areas boosted off-grid capacity from 6 to 30 MW [45]. Much of the growth was also driven by the cost advantages that solar and other RE technologies offer over fossil fuels in remote areas that are costly to reach using the grid [21], [22].

In the last few years, however, nearly all of the growth in solar capacity has been in on-grid capacity, and the major driver of on-grid capacity growth has been the adder policy, as we can see in figure 4 (which is taken from [45]). In fact, the total on-grid solar capacity currently proposed in plans submitted to Thailand's MOE by SPPs and VSPPs is 3,581 MW (both solar PV and solar thermal projects)—seven times higher than the 2022 target set at 500 MW [56]. However, we point out that only a fraction of this proposed capacity is currently under construction.

Figure 4. Cumulative PV installation in Thailand (updated September 2011)



Source: Thailand PV Status Report 2011 [45].

Thailand responded to the larger-than-expected number of solar projects proposed by SPPs and VSPPs by capping applications to get a PPA and be paid an adder for solar and by reducing the adder rates for solar [56]. Nonetheless, the expectation is that Thailand will surpass its 2022 goals.[25] We estimate that the pace of construction will

25. For more details on the factors that contributed to this "PV bubble," please refer to *Deploying Renewables 2011: Best and Future Policy Practice*. International Energy Agency (IEA). 2011. [41].

follow approved plans (proposed projects that already obtained PPAs before EGAT temporarily stopped approving new PPAs for solar projects [56], [57]) over the next few years, which indicates a significant market for solar power related products. The European Photovoltaic Industry Association forecasts that Thailand will install at least 1,650 MW of new solar PV capacity between the end of 2011 and the end of 2016 [20].

Demand for solar hot water heaters in Thailand

Thailand also has targets for solar thermal energy. According to the targets from the Renewable Energy Development Plan, heat produced by solar thermal energy should increase by 5 ktoe in in 2011 (compared to 2007) [52]. According to the IEA, in 2008 and 2009, government policies and incentives in Thailand supported the installation of 4,000 m^2 and 3,000 m^2 of solar collector surface, respectively [70]. The target for 2011 was to install 10,000 m^2 [70]. We have not found data on whether Thailand was able to achieve this target for 2011. However, given financial incentives provided by Thailand's government for use of solar thermal products, we anticipate that there will be some demand over the next few years for solar thermal products in Thailand.

Bioenergy: biomass, biogas, and municipal solid waste energy

Summary of demand for bioenergy power projects in Thailand:

Thailand's targets for building new biomass, biogas, and municipal solid waste (MSW) capacity between 2009 and 2022 are 2,090 MW of biomass, 74 MW of biogas, and 155 MW of MSW, respectively. Interim targets call for significant capacity increases between 2009 and 2011 and between 2012 and 2016. Based on recent growth in capacity, the level of adders and FiTs available to these types of renewable energy in Thailand compared to ranges of levelized costs of electricity for these types of RE internationally, and recent assessments from the MOE and industry insiders on the amount of unutilized agricultural byproduct biomass and MSW still available in Thailand, we anticipate that Thailand will achieve at least two-thirds of its goals for biomass and biogas. However, Thailand's MOE reports that most MSW projects planned by SPPs and VSPPs have encountered obstacles, and it appears likely that Thailand will have difficulty making progress towards its MSW target over the next few years.

Recent growth in biomass, biogas, and MSW capacity in Thailand has occurred amongst both SPPs (whose plants are between 10 MW and 90 MW in capacity) and VSPPs (whose power plants are below 10 MW). This indicates demand for biomass, biogas, and MSW plants of a variety of different sizes, and demand for the physical components and services needed to build them. In addition, Thailand's adder for biomass and biogas is $0.06 USD higher for projects smaller than 1 MW in capacity than for projects larger than 1 MW, and Thailand's MOE has recently stated an intention to "Promote and support biogas production at household level" and "Promote and support producing energy from MSW in small communities" [53], [56]. This indicates that there may be demand in Thailand in the near future for small-scale biomass, biogas, and MSW power plants.

Additional information on demand for biomass, biogas, and municipal solid waste energy power projects in Thailand:

Biomass, biogas, and municipal solid waste energy are all areas of potential growth for Thailand, and we expect that that Thailand's biomass, biogas, and MSW capacity are likely to continue to grow in the near future as they have in the recent past. Biomass accounts for more than half of the total renewable energy generation in Thailand and about 80 percent of total renewable energy if hydroelectric energy is excluded from the computation.[26] The sources of biomass for energy production in Thailand are agricultural products and by-products. The government of Thailand has cataloged and estimated the amount of this material available for energy production and provided targets and incentives for its use [46], [56]. We point out that some of the targeted growth in this area has already occurred—much of it in large operations.[27] This indicates that future growth is likely to occur from identifying and utilizing new sources of feedstock, rather than bagasse (which is fibrous matter that remains after sugarcane or sorghum stalks are crushed to extract their juice) and rice husks, the most commonly used sources of biomass electricity and heat in the

26. See table 1 above for renewable electricity generation.

27. As examples of these types of projects, the WEPS+ model's renewable project database includes the 20 MW Northeast biomass project, under contract in 2010, and the 31 MW Phoenix Mills project that came online in 2009.

past. See Thailand's MOE [56] and Biomass Magazine [74]. However, Biomass Magazine also reports that a new $17 million USD, 9.9 MW biomass plant that will use bagasse and rice husks is under construction in Thailand, so not all future growth will be using other types of biomass [75].

Table 6. Biomass, biogas, and municipal solid waste targets

			Target of Capacity to have by:					
	Potential Capacity	Existing Capacity (2008)	2011		2016		2022	
Type of Energy								
Electricity	MW	MW	MW	ktoe	MW	ktoe	MW	ktoe
Biomass	4,400	1,610	2,800	1,463	3,220	1,682	3,700	1,933
Biogas	190	46	60	27	90	40	120	54
Municipal Solid Waste	400	5	78	35	130	58	160	96
Thermal	ktoe	ktoe		ktoe		ktoe		ktoe
Biomass	7,400	2,781	3,660	5,000	6,760			
Biogas	600	224	470	540	600			
Municipal Solid Waste		1		15		24		35

Source: Thailand's Department of Alternative Energy and Efficiency [52].

Agricultural products and byproducts used for biomass energy production include: woody biomass residues from forest plantations, agricultural residues such as sugar cane leaves, bagasse, oil palm empty bunch, rice husk, rice straw, corn cobs and stems, biomass for ethanol production such as cassava, sugar cane, etc., and biomass for biodiesel production such as palm oil, jatropha oil, etc.[28] [46]. Industrial wastewater from agro-industry, sewage from municipal wastewater treatment plans, and livestock manure are also available for biogas projects. The type and availability of feedstock can have an effect on the types of biomass products that will be in demand in the near term in Thailand.

According to the MOE EPPO website [57], as of December 2011, there was about 1,790 MW of biomass capacity installed in Thailand, and another 2,070 MW of planned additional capacity that had signed PPAs with EGAT but had not yet been constructed—with most of this planned additional capacity coming from VSPPs (power plants below 10 MW capacity in size). In the near term, these planned ca-

[28]. We cover biodiesels separately below.

pacity additions are the projects that will drive the demand for biomass products in Thailand. Further, between January 2010 and December 2011, biomass capacity in Thailand increased by 154 MW [26], [57], indicating that the adder rates and FiTs for biomass were effective at causing SPPs and VSPPs to build new biomass power plants. However, as seen from Table 6 above (an excerpt from Table 3), Thailand did fall short of its targeted biomass capacity for the end of 2011. Nonetheless, given the technical potential to use more biomass and the availability of the adder and FiT, we anticipate that Thailand will continue to build additional new biomass capacity over the next five years, likely enough to achieve roughly 65 percent of its biomass capacity target. Further, Thailand's MOE has some plans for giving firms incentives to retrofit older biomass plants with more efficient boilers, and for having EGAT build new transmission lines to facilitate the construction of new biomass plants in southern areas of Thailand with unused biomass resources [53].

For biogas, MOE EPPO reports that there are about 115 MW of installed capacity as of December 2011, and another 83 MW of planned but not-yet-constructed projects with signed PPAs [57]. We note that all of this capacity is from VSPPs, and also that biogas capacity in Thailand increased by 62 MW between January 2010 and December 2011 [26], [57], indicating that the adder rates and FiTs for biogas were similarly effective at causing SPPs and VSPPs to build new biogas power plants. It appears likely that Thailand will actually exceed its target of having 120 MW of biogas capacity by the end of 2022, and new biogas plants will continue to be built in Thailand over the next several years. Thailand's MOE anticipates that new biogas plants will be built at both livestock farms and agro-processing facilities that process starch, palm oil, and ethanol, and also intends to promote biogas production at the household and village level in rural areas [53], [56]. Palang Thai reports that Thailand does have some experience using small-scale biogas at smaller-sized farms [44].

Thailand also had 92 MW of MSW in place as of December 2011, an increase in capacity of 60 MW since January 2010 [26], [57]. This indicates that Thailand's adder rates and FiTs for MSW were successful in causing SPPs and VSPPs to build new MSW plants. However, the near term growth in MSW capacity is likely to be low in Thailand. The MOE reports that SPPs and VSPPs plans to build new MSW plants are encountering "problems and obstacles such as: the protest from local

community, related rules and regulations, loan offering and benefit sharing at not right proportion between investor and garbage owner" [57]. In the longer term, however, the MOE's Department of Alternative Energy Development and Efficiency has plans to "Promote and support producing energy from MSW in the medium and small sized Local Administration Organizations" and "Promote and support producing energy from MSW in small communities, for instances: schools, temples, communities, local organizations" [53]. So, Thailand's target of 160 MW of MSW by 2022 may still be attainable.

Biofuels energy

Summary of demand for biofuels and products and services for the biofuels industry in Thailand:

Thailand's biofuels market is described in depth in the United States Department of Agriculture (USDA) Foreign Agricultural Service's Biofuels Annuals [30]. Thailand has targets and subsidies for ethanol and biodiesel production, as well as a partially enforced mandate for biodiesel consumption [30].[29] Thailand is unlikely to import either ethanol or biodiesel, and there does not appear to be any demand for building new ethanol and biodiesel refineries in Thailand at the current time. However, there may be some demand for new farm equipment for use at sugar, cassava, and palm oil plantations in Thailand that grow feedstock for biofuels, and for agricultural consulting services on how to increase yields at sugar, cassava, and palm oil plantations in Thailand.

Additional information on demand for biofuels and products and services for the biofuels industry in Thailand:

Table 7, an excerpt from Table 3 above, shows Thailand's biofuels goals, through 2022:

[29] The statutory mandate requires that diesel sold in Thailand be a "B5" blend that is at least 5 percent biodiesel, but feedstock shortages have caused Thailand's government to enforce B2, B3, and B4 standards instead at different times over the past few years.

Table 7. Biofuel goals

Type of Energy	Potential Capacity	Existing Capacity (2008)	Target of Capacity to have by: 2011		2016		2022	
Biofuel	m lt/d	m lt/d	m lt/d	ktoe	m lt/d	ktoe	m lt/d	ktoe
Ethanol	10	1.24	3	805	6.2	1,686	9	2,447
Biodiesel	5	1.56	3	950	3.64	1,145	4.5	1,415

Ethanol

According to the USDA, Thailand is unlikely to import ethanol [30]. A substantial price differential between ethanol and gasoline discourages the consumption of ethanol. The consumption of natural gas for vehicles is highly subsidized, which also discourages consumption of ethanol. Further, Thailand is able to produce enough ethanol to meet its current demand.

Thailand is an ethanol exporter. In 2010, exports increased to 48.2 million liters. This represents an 8-percent increase relative to the prior year. The increase was not planned. Ethanol was in excess supply because Thailand's consumers prefer gasoline at current prices and ethanol production is subsidized, which increases the supply of ethanol. Ethanol producers receive an excise tax exemption on ethanol of 7 baht/liter ($0.80/gallon) when selling ethanol for E85[30] production. Refineries receive a subsidy of 13.5 baht/liter of E85 produced for the domestic market.

The subsidies are part of the government's effort to reach goals for domestic ethanol production of 3.0 million liters/day in 2011, 6.2 million liters/day in the next five years, and 9.0 million liters/day in ten years. Producing only 1.2 million liters/day, Thailand fell short of its goal in 2010.

Despite poor ethanol demand and an excess refinery capacity of 40 to 50 million liters/month, Thailand plans to expand its production. The country will add five new ethanol plants in 2012 with a capacity of about 1.8 million liters/day. However, as of July 2011 there were no plans to build any more new ethanol plants after 2012 beyond these

[30] E85 is a blend of 85 percent ethanol and 15 percent gasoline.

five. The decision to expand ethanol production is predicated on a large expected increase in ethanol demand. Thailand's demand for ethanol is expected to grow as its consumers are expected to purchase more E20 and flex-fuel vehicles[31]. In turn, the country's demand for sugar molasses and tapioca – Thailand's primary feedstock for ethanol production—will increase. This could possibly create opportunities for suppliers of sugar and tapioca farm equipment, and for agricultural consulting services about how to maximize yields of these crops, to sell their products and services in Thailand.

Biodiesel

Thailand's government set as its country's goals for biodiesel the production of 3.02 million liters/day this year, 3.64 million liters/day in 5 years, and 4.50 million liters/day in 10 years.

As Thailand tries to meet its goals for biodiesel, its demand for palm oil will grow [30]. The country is already facing feedstock challenges, which are, in part, due to weather conditions. Thailand fell 0.80 million liters/day short of its goal for biodiesel production in 2011 because of feedstock shortages. This shortage of feedstock could potentially create opportunities for agricultural consulting services on how to increase yields at palm plantations.

Thailand is unlikely to export biodiesel because domestic production has been entirely absorbed by domestic consumption. The country is also an unlikely importer. Thailand has 13 biodiesel refineries operating at 50 percent capacity, which suggests that Thailand is unlikely to want to invest in additional biodiesel refinery capacity in the near future.

Energy Storage

Energy storage products, such as batteries, pumped hydroelectric storage, and flywheels can be desirable to use in conjunction with intermittent sources of renewable energy such as wind and solar, and even small-scale hydro-based microgrids; see Alliance for Rural Electrification, U.S. DOE, Lawrence Berkeley National Laboratory and

[31] E20 is a blend of 20 percent ethanol and 80 percent gasoline.

NREL [21], [77 – 81].[32] However, we have found no direct evidence of large demand for energy storage in Thailand, at least in the next few years. According to The International Journal on Hydropower and Dams 2011 World Atlas and Industry Guide [67], Thailand had 1,030 MW of pumped storage hydro capacity already in place at the end of 2010. There are plans to build an additional 500 MW of pumped storage hydro capacity in Thailand [26]. Also, the batteries in the solar PV panel and battery systems that Thailand distributed in 2005 to 203,000 homes that were not connected to the electric grid and had not had electricity may need to be replaced periodically [44], [45], [46]. However, additional demand for energy storage beyond this is unlikely because Thailand does not plan to get a high enough percentage of its electricity from wind and solar that Thailand would require additional amounts of energy storage. Even if Thailand achieves its target of 800 MW of wind capacity by 2022 and achieves the target of 2,000 MW of solar by 2022 endorsed by the MOE's Department of Alternative Energy Development and Energy Efficiency, EGAT's Power Development Plan for 2010-2030 calls for Thailand to have approximately 50,000 MW of total electricity generation capacity in 2022 including fossil fuel and large hydro power plants and RE plants that are much less intermittent than solar and wind (small hydro, biomass, biogas, and MSW power plants). Thus, Thailand is expected to have less than 10 percent of its electricity generation capacity in 2022 come from solar and wind power plants. Recent studies by the U.S. DOE, NREL, and Lawrence Berkeley National Laboratory about integrating intermittent renewables (wind and solar) into electric grids in the United States have estimated that these U.S. grids would be able to obtain over 10 percent of their electricity from wind and solar without any new energy storage capacity (beyond the pumped storage hydroelectric facilities that already exist in the United States) being added to these grids [78], [79], [80], [81]. This suggests that Thailand will not have any demand for ener-

[32]. Solar and wind generation are intermittent by nature. Without other, dispatchable sources of energy such as fossil fuels or biomass, energy storage is required to meet energy requirements at times when sunlight is unavailable (night) or low (during cloudy weather) or during times when there is no wind.

gy storage products for use with its electric grid, other than the 500 MW of new pumped hydro storage that have already been planned.

Market for energy efficiency products other than energy-efficient electric grid products

Summary of findings on the market for energy efficiency products in Thailand

The Government of Thailand has a number of programs and incentives in place to encourage energy conservation and more efficient use of energy in every energy-using sector in Thailand (industry, commercial buildings, residential buildings, and the transportation sector). Furthermore, Thailand's MOE has a budget of $1 billion USD to support energy efficiency and energy conservation programs and projects between 2011 and 2015, and some of these funds will be used to provide low-interest loans to the private sector to finance energy conservation and efficiency projects. Therefore, we are fairly certain that there will be some demand for EE products and EE-related services in the industrial, commercial, residential, and transportation sectors in Thailand over the next few years.

Detailed findings on the market for energy efficiency products in Thailand

The Government of Thailand has an energy conservation and efficiency plan that maps out targeted reductions in energy intensity through 2030, with a final goal of achieving a 25 percent reduction in energy intensity by the end of the planning period, relative to energy intensity in the baseline year of 2005.[33] The government has shown support for these energy efficiency objectives by committing funds from its Energy Conservation Fund (ENCON Fund) and other sources for energy conservation and energy efficiency investments over the next several years.

[33] "Energy intensity" is energy use per dollar of GDP; see the Compendium of Energy Efficiency Policies of APEC Economies from the Asia Pacific Energy Research Centre (APERC) [82], which also summarizes and describes Thailand's energy conservation and efficiency plans and programs.

The ENCON Fund alone provides an approximate budget of USD$131 million a year to support RE&EE efforts. Adding in other sources of funding raises this total to USD$200 million a year for the 2011 to 2015 period, according to Thailand's 20-Year Energy Efficiency Development Plan [52]. The government has also included several types of incentives in its plans to help the country move toward its energy efficiency goals.[34] Table 8 illustrates the types of energy savings that would be accomplished in different sectors if the targets for the energy efficiency development plan are achieved. These targets were set based on feasibility studies of the potential to conserve energy in Thailand. These feasibility studies compared current average energy consumption of buildings, industrial facilities, and vehicles in Thailand with the energy consumption of the most energy-efficient buildings, facilities, and vehicles in Thailand and internationally [52].

Table 8. Share of energy savings by economic sector in 2030

Economic Sector	Technical Potential			Specified Target (ktoe)	Share (%)
	Heat (ktoe)	Electricity (GWh)	Total (ktoe)		
Transportation	16,250		16,250	13,400	44.7
Industry	10,950	33,500	13,790	11,300	37.7
Commercial Building & Residential					
• Large Commercial Building	410	27,420	2,740	2,300	7.6
• Small Commercial Building & Residential	1,690	23,220	3,670	3,000	10
Total	29,300	84,140	36,450	30,000	100

Source: Thailand's 20-Year Energy Efficiency Development Plan [52].
Note: ktoe=thousand tonnes of oil equivalent.

To create an environment in which the desired changes are likely to occur, the government has set policy to promote energy conservation in all sectors, with a particular focus on industry, transport and households [46], [60]. Thailand's main efforts are through:

[34]. For more information see APERC, a presentation on Thailand's Renewable Energy Development Plan by the Deputy Director-General of DEDE [46], and Thailand's 20-Year Energy Efficiency Development Plan for 2011-2030 [60].

- public campaigns that foster "energy-saving discipline" and awareness—also promoting efficient energy use;
- creating the right incentives to induce the private sector to choose energy saving appliances;
- creating incentives to reduce household energy consumption at peak times;
- supporting research and development, and setting standards for electrical appliances and energy-efficient buildings; and
- supporting the development of public mass transportation and railway systems to improve energy efficiency.

One of the main objectives of these policies is to improve energy security. Thailand currently imports approximately 60 percent of the energy it consumes—making the country, and its economy in particular, vulnerable to energy price volatility [60], [46]. This is especially true for volatility in the price of oil.

In its efforts to target energy efficiency improvements in the industrial sector, the Thai government has implemented revolving funds, tax incentives, and other investment promotion measures through the Board of Investment (BOI). This includes an 8-year income tax holiday plus an extra five years of a 50-percent tax reduction that applies to investments in both energy efficiency and renewable energy [46]. It also supports duty free importing for imports of RE&EE equipment and machinery [46].

In total, the plan includes six strategies to help Thailand achieve its RE&EE goals:[35]

1. Tax incentives such as the tax holiday and eliminations of duties mentioned above
2. Technical assistant from the Ministry of Energy
3. Investment grants that apply to biogas (max. 10 to 30 percent of project cost), municipal waste (25 to 100 percent), and solar

35. See Thailand's Renewable Energy Policies and Wind Development Potential [52] for more detail.

hot water (30 percent) up to a maximum of about USD$1.6 million

4. Soft loans for RE&EE projects financed from the ENCON Fund

5. The ESCO Fund which gives priority to Energy Service Companies (ESCO) to support projects in Clean Energy, Renewable Energy, and Energy Efficiency. So far this effort is valued at about USD$150 million a year.

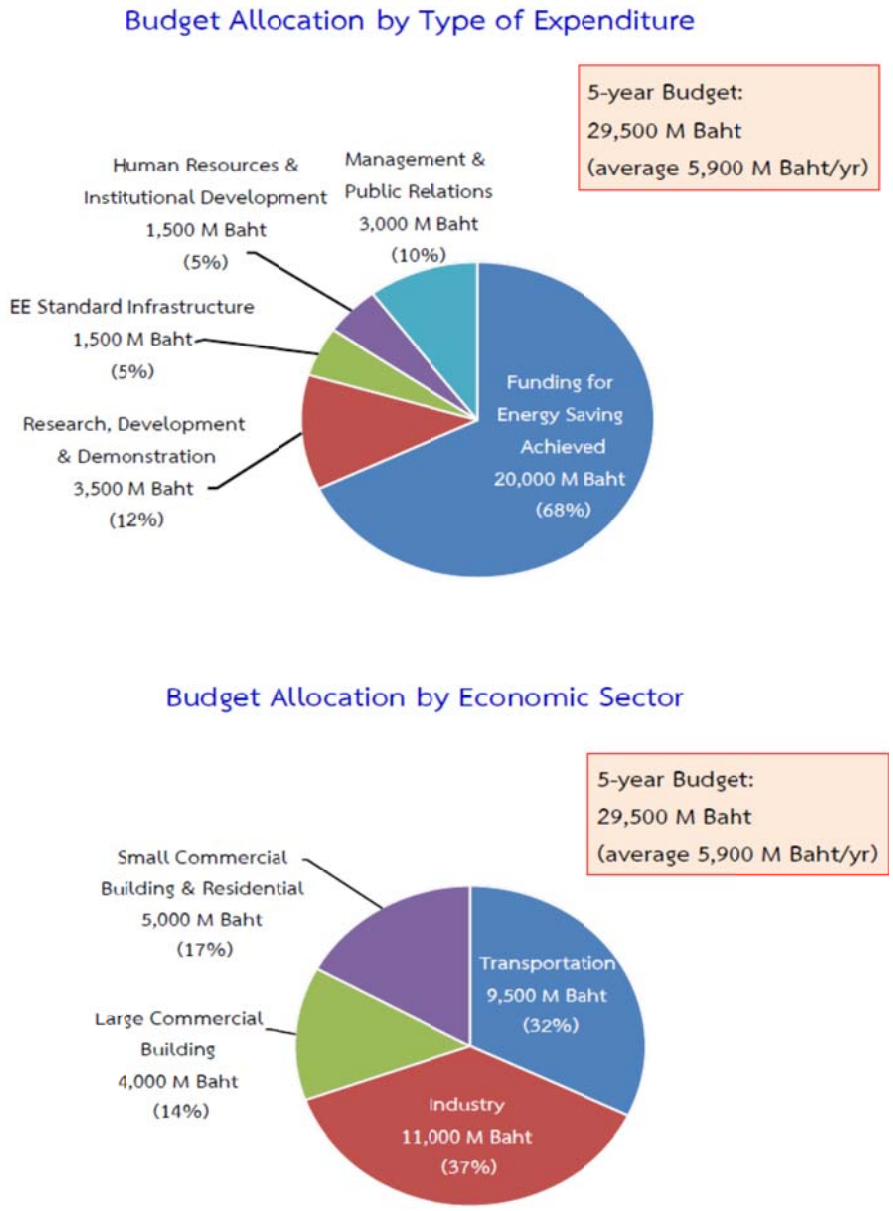
6. The adder rates that supplement the normal purchasing tariff received by power producers and vary according to the type of renewable energy technology[36]

These measures are aimed at creating incentives for foreign and local investments in RE&EE. Moreover, the government also provides subject matter experts to assist small- and medium-sized enterprises in conducting energy audits and to give advice on efficient energy management. They supplement these programs by providing grants for firms in the industrial sector to replace equipment with energy efficient alternatives [60].

To support these goals, the Government of Thailand has a budget of approximately one billion U.S. dollars (29,500 Million Thai Baht) allocated for 2011 through 2015 [52]. As shown in Figure 5, most of this money (68 percent) will go to fund efforts directly related to saving energy. The rest will be divided into management and public relations (10 percent); research, development, and demonstration (12 percent); energy efficiency standard infrastructure (5 percent); and on human resources and institutional development (5 percent). By economic sector, these resources will be allocated to industry (37 percent), transportation (32 percent), small commercial building and residential sector (17 percent) and large commercial building (14 percent).

[36] Adder rates were described in detail in the section on feed-in-tariffs above.

Figure 5. Budget implementation for the first five years



The U.S. Commercial Service of the U.S. Department of Commerce recently assessed the market for incorporating energy-efficient products into the construction of new commercial buildings and renovation of existing commercial buildings in Thailand [83]. These products are goods and services such as architectural design and engineering services, energy-efficient HVAC systems, energy-efficient

lighting systems, building management systems, and building products that meet Leadership in Energy and Environmental Design (LEED) standards. The U.S. Commercial Service views Thailand as an emerging market for these products that is expected to grow considerably in the foreseeable future. It also notes that in 2009, Thailand's government implemented regulations about energy efficiency standards into building codes for buildings with over 2,000 square meters of floor space.

Market for electric grid products, including smart grid products

Section summary

Thailand has begun to make some of its planned investments in upgrading portions of its electric grid to reduce distribution losses, and to incorporate smart grid technologies into portions of its electric grid.

Additional detail on demand for electric grid products in Thailand

In 2010, EGAT's transmission network comprised 30,639 circuit-kilometers of transmission lines and 208 substations with 532 delivery points [27]. At current capacity, Thailand electric grid covers 99.3 percent of the country's population. So, while there are efforts to expand the grid to accommodate new generating capacity, most of the efforts are on improvements to the existing grid to reduce transmission losses and to create interconnections with producers within Thailand and in neighboring countries, specifically Laos and Malaysia [27].

EGAT has several ongoing transmission projects, several others under approval, and a portfolio of research and development projects to improve service. The projects include bulk power supply for the Greater Bangkok area, which is intended to come online by 2013. The projects also include transmission line projects for power purchase from IPP projects in the Eastern Area of the country that became operational in 2011 and in other areas that were ready for service in 2012; a package of transmission expansion and reinforcement in provincial areas to be completed in 2013; and other projects in the approval process to become operational between 2014 and 2015 (EGAT[26]). A map showing all of the planned future transmission lines and substations in Thailand, as well as planned future fossil

fuel power plants, can be found on page 69 of EGAT's Power Development Plan [28].

The United States Department of Commerce U.S. and Foreign Commercial Service and United States Department of State's "Doing Business in Thailand: 2011 Country Commercial Guide for U.S. Companies" publication lists electrical power systems, including transmission infrastructure, substations, distribution networks, transformers, converters, energy efficiency and conservation equipment, and switching equipment to maintain existing power systems to support future expansion, as a leading sector for U.S. export and investment to Thailand over the next few years [84].

Smart grid technologies

Thailand's MOE has recently announced plans to increase the role and use of smart grid technology to optimize the operation of their power system [15], [53]. PEA is investing to modernize its information infrastructure and has recently completed one of the largest and most sophisticated fiber optic networks in the world. With this infrastructure in place, PEA began testing automatic meter reading with 36,000 of its largest consumers [15].

As described by the Pacific Northwest National Laboratory in a 2011 report on the plans and initial efforts of Asia Pacific Economic Cooperation (APEC) countries to build smart grids, smart grid technologies are used to coordinate the actions of systems and devices throughout the grid. These technologies are based on digital technology and communication. They allow coordination at every stage of the system, from generation, to transmission, to distribution to consumers—down to the equipment and appliances used by final consumers [15].

Smart grid technology can provide the flexibility needed to integrate variable generation—a characteristic of some intermittent renewable generation technologies, in particular solar and wind [15].

In terms of the potential market for smart grid products, the efforts of PEA in adding fiber optic networks and testing smart grid technology, together with the expected growth use of solar and also wind electricity generation in Thailand, indicate the potential for future growth in the smart grid technology market in Thailand. This in-

cludes information technology, infrastructure, as well as the market for smart meters, equipment, appliances that can benefit from smart grid improvements in the system.

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Potential for U.S. firms to supply RE&EE products to Thailand

In this section, we discuss issues related to the potential for U.S. small- and medium-sized businesses to supply RE&EE products to Thailand. We evaluate this potential by examining Thailand's trade relations with the United States and other countries that export RE&EE products.

Trade relations between the United States and Thailand and between Thailand and other countries besides the United States that export RE&EE products are described in the U.S. Department of Commerce and Department of State's annual *Doing Business in Thailand: Country Commercial Guides for U.S. Companies* [84], [85]. Most countries that export to Thailand, including the U.S., pay an average tariff rate of 9 percent on industrial (i.e., non-agricultural) products. However, Thailand does have free trade agreements with the other nations in ASEAN. Thailand also has a limited bilateral free trade agreement with China and a partial agreement with India, and Thailand has free trade agreements with both Australia and Japan. U.S. firms that produce RE&EE products that are very similar to RE&EE products produced by ASEAN, Australian, Chinese, Indian, and Japanese firms may have difficulty selling their products in Thailand due to higher tariff rates being applied to the U.S. products.

The CIA World Factbook [40] reports that in 2009, 18.5 percent of goods imported into Thailand came from Japan, 13.4 percent came from China, 6.3 percent came from the United Arab Emirates, 5.9 percent came from the United States, 5.4 percent came from Malaysia, and 4 percent came from South Korea.[37] So, in the past Japan and

[37] U.S. RE&EE firms seeking more fine-grained information on the different types of goods that the U.S. has exported to Thailand in the past should consult U.S. Department of Commerce data [86]. and information on what types of goods have been exported from foreign countries to Thailand and in what volumes are available from the Global Trade Atlas [87].

China have succeeded in exporting more goods to Thailand than the U.S. has. Despite this, U.S. firms that sell RE&EE products with some advantages over RE&EE products made by firms in the countries with more favorable trade agreements with Thailand can potentially take advantage of the following: Thai businesses that purchase RE&EE products can choose to take advantage of waivers of import taxes [60]; a waiver of income and import taxes is one of three possible tax breaks that Thai businesses that purchase RE&EE equipment can choose from.

We also noted above that Thailand's MOE responded to the recent large drop in the price of solar PV products by increasing its targeted capacity of new solar plants for 2016 and 2022, and deciding to approve additional power purchasing agreements with private firms seeking to build solar power plants. This indicates that if a U.S. firm were to enter the market in Thailand with a new RE product that was less expensive than its competitors' products, the government and private sector firms in the Thai market may decide to purchase more of that type of product than they would have in the absence of the price decrease.

Recommendations for entering the RE&EE market in Thailand

General recommendations for U.S. firms of all sizes that sell any type of product or service and wish to enter the Thailand market are given in the U.S. Department of Commerce and Department of State's annual *Doing Business in Thailand: Country Commercial Guides for U.S. Companies* [84], [85]. We believe that these recommendations are applicable to U.S. firms selling RE&EE products. These recommendations include "Obtaining a local partner, such as an agent or distributor" as this "is still the preferred means of entering the Thailand market for the first time as it is one of the most efficient and effective ways to reach Thai buyers." The U.S. Foreign Commercial Service of the U.S. Commerce Department and the American Chamber of Commerce in Thailand are able to provide assistance to U.S. RE&EE firms in obtaining local agents and distributors [85], [88].

Both state-owned companies in Thailand (the Electricity Generation Authority of Thailand (EGAT) and the Provincial Electricity Authority (PEA) and the Metropolitan Electricity Authority (MEA)) and private sector companies in Thailand are potential buyers of RE&EE products. The government is the most likely buyer of small hydroelectric power plants and related products and services and of electric grid products. Private firms are more likely to purchase other types of RE&EE products. For the other types of RE&EE products, it may still be worthwhile for a U.S. firm to attempt to inform government officials in MOE and EGAT about their products. The *Doing Business in Thailand* guides note that,

> Although Thailand is a relatively open and friendly society, it is advisable to approach potential business contacts with a prior introduction or personal reference. They will be more receptive if you arrive with an introduction or letter from a known government official or business contact. [85]

Furthermore, government familiarity with the RE products that a Thai private firm intends to use in building a RE power plant might

increase the likelihood that that firm will get approval from MOE to get a PPA with EGAT.

The Thailand PV Status Report 2011 [45] states that Thailand is considering becoming more active in the design and manufacture of RE products, rather than relying on importing them from foreign countries. U.S. RE firms seeking to enter the Thai market may wish to partner with Thai firms in designing and manufacturing their products, or to license their technology to Thai firms. This may help U.S. firms avoid tariffs that they normally would pay when exporting products manufactured solely in the U.S. to Thailand (assuming the Thai buyer does not obtain a waiver of import duties. The possibility of obtaining such a waiver was explained in the previous section). However, the *Doing Business in Thailand* guides advise U.S. firms that want to license technology to Thai firms or to collaborate with Thai firms in product design to take specific precautions against intellectual property violations [84], [85].

A number of U.S. government agencies provide assistance (loans, risk insurance, funding for feasibility studies for larger projects, and assistance with interacting with officials in foreign governments) to U.S. companies that seek to export their products to developing countries. These agencies are the Export-Import Bank of the United States, United States Trade and Development Agency, and the United States Overseas Private Investment Corporation. Each of these agencies participates in the Renewable Energy and Energy Efficiency Export Initiative led by the U.S. Department of Commerce [11], [89], [90], [91]. However, in the case of Thailand, our review of these agencies' Annual Reports indicates that in recent years, these agencies have not provided support for U.S. firms seeking to export to Thailand [92], [93], [94]. This is because Thailand is now a middle income country that does trade extensively with the United States and is not a difficult country for U.S. firms to export to [94], and a large amount of support from a U.S. Government Department or Agency is no longer necessary in order for a U.S. firm to enter the Thailand market.

Glossary

List of acronyms and abbreviations

ADB	Asian Development Bank
AEDP	Alternative Energy Development Plan
APEC	Asia-Pacific Economic Cooperation
APERC	Asia Pacific Energy Research Center
APTEP	Asia Pacific Technology and Education Program
ASEAN	Association of Southeast Asian Nations
BNEF	Bloomberg New Energy Finance
BOI	Board of Investment
CIA	Central Intelligence Agency
CHP	Combined heat and power
CSP	Concentrated solar power
CTF	Clean Technology Fund
DOD	Department of Defense
DOE	Department of Energy
DON	Department of the Navy
EE	Energy efficiency
EEDP	Energy Efficiency Development Plan
EGAT	Electricity Generating Authority of Thailand
EIA	Energy Information Administration

ENCON	Energy Conservation
EPIA	European Photovoltaic Industry Association
ESCO	Energy Service Companies
Ex-Im	Export-Import Bank
FiT	Feed-in Tariff
GDP	Gross domestic product
GWEC	Global Wind Energy Council
GWh	Gigawatt hours
HTDV	Hawaii Technology Development Venture
IEA	International Energy Agency
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
ktoe	Kilotonnes of oil equivalent
kW	Kilowatt
kWh	Kilowatt hours
LCOE	Levelized cost of electricity
LEED	Leadership in Energy and Environmental Design
LLNL	Lawrence Livermore National Laboratory
MOE	Ministry of Energy
MSW	Municipal solid waste
MW	Megawatt
NGO	Non-governmental organization

NREL	National Renewable Energy Lab
ONR	Office of Naval Research
OPIC	United States Overseas Private Investment Corporation
PDP	Power Development Plan
PEA	Provincial Electricity Authority
PNNL	Pacific Northwest National Laboratory
PPA	Power purchasing agreement
PV	Photovoltaic
PWC	PricewaterhouseCoopers
R&D	Research and development
RE	Renewable energy
RE&EE	Renewable energy and energy efficiency
REDP	Renewable Energy Development Plan
REN21	Renewable Energy Policy Network for the 21st Century
SMB	Small and medium sized business
SPP	Small Power Producer
U.S.	United States of America
USAID	United States Agency for International Development
USD	United States Dollars
USDA	United States Department of Agriculture
USTDA	United States Trade and Development Agency
VSPP	Very Small Power Producer
WEPS+	World Energy Projection System Plus

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