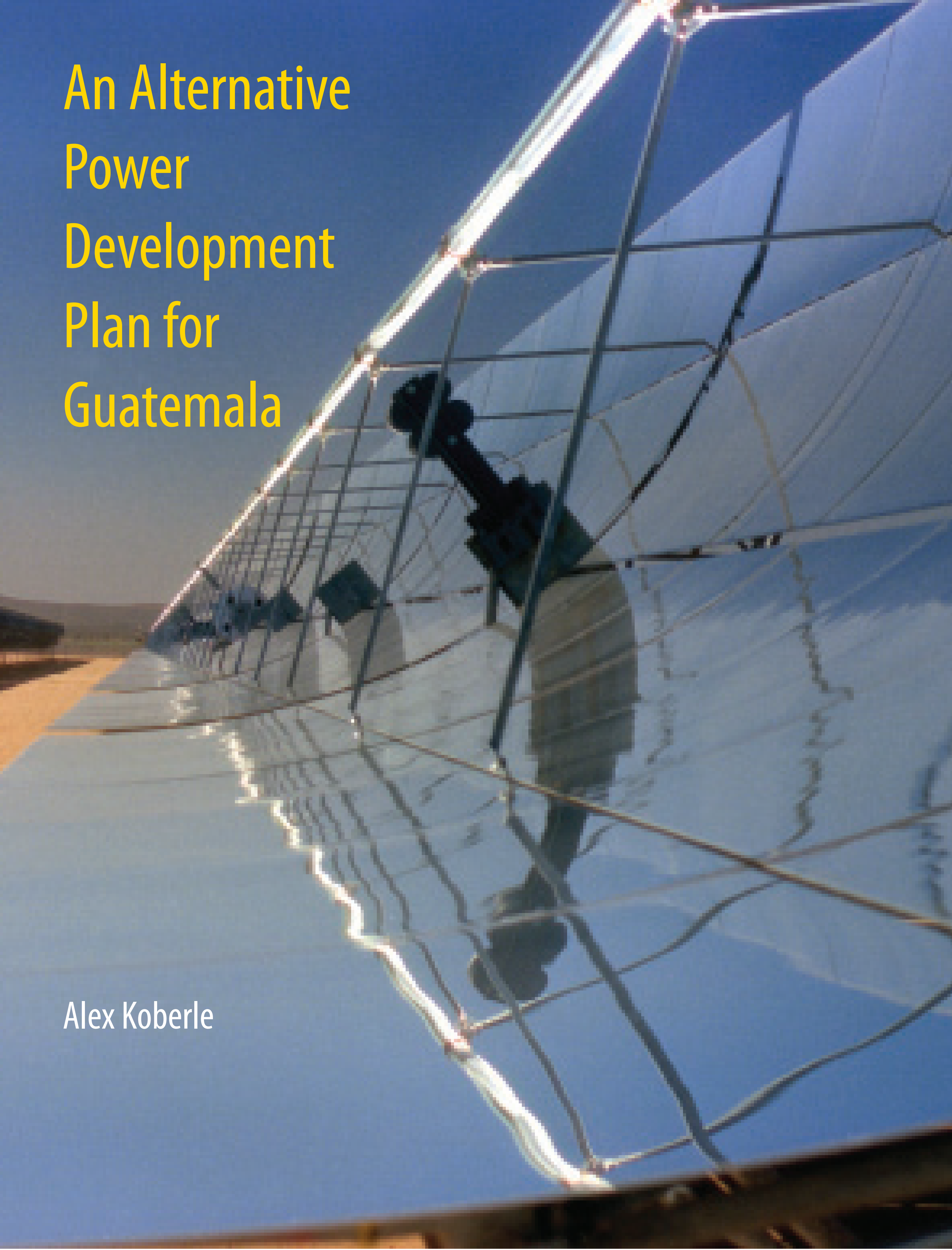
An Alternative Power Development Plan for Guatemala

Alex Koberle



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Berkeley, California

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Guatemala Executive Summary

In 2008, the government of former President Alvaro Colom announced plans to overhaul the country's electricity sector and to diversify its power supply away from petroleum derivatives towards hydropower and coal. The plans[1] to do this, produced by the Comisión Nacional de Energia Elétrica (CNEE), rely mostly on building new hydro and coal capacity to meet future demand growth and to replace petroleum-based power plants. The plans make no mention of energy efficiency improvements to reduce future demand, and the development of true renewables is limited to a 50-MW biomass sugar mill already under construction, and a possible 40-MW geothermal power plant. The plans also aim to modernize the aging transmission grid and reduce losses so as to deliver electricity more reliably and efficiently, as well as to expand the grid to rural areas currently without electricity.

The plans have raised concern from community groups and NGOs for their reliance on large coal and hydropower projects with high potential to cause social conflict and environmental degradation. The proposed projects have revived the memories of violence over the relocation of Mayan communities caused by the construction of the Chixoy hydroelectric dam in the 1980s.

The purpose of this study was to critically examine the government's electricity development plans and to determine if there is a more sustainable and economically efficient solution to meet the country's future electricity needs. We found that Guatemala's energy needs until 2022 can be met with a combination of energy efficiency measures and renewable energy, eliminating the need for new coal or hydro capacity. Such an approach would guarantee Guatemala's future energy supply at lower cost than what is being currently proposed, with the final result being cheaper electricity for the Guatemalan consumer.

In order to create our alternative plan, we first looked at the government's projections for future electricity demand. In the government's plans, future electricity demand projections were based largely on estimated GDP growth, which was advancing at a fast rate at the time the plans were elaborated. In part because of the global recession, those projections turned out to be overestimates. However, further analysis revealed that the government has consistently overestimated electricity demand growth every year since 2001. This suggests a flaw in the methodology used in forecasting peak capacity demand. For example, an update released in 2010 still managed to overestimate peak capacity demand for that year by 20 MW. Another update released in January 2012 also overestimated peak capacity demand for 2011 by around 60 MW.

In order to come up with a more realistic demand projection, in Part 1 of this report we analyzed actual peak capacity demand values for the period 2001-2009, which revealed an average historical growth of 50 MW per year. In contrast, CNEE's plans estimated annual growth of 70 to 90 MW. As a result, in our alternative power development plan we use a projected growth rate of 50 MW per year to forecast future demand. In the report, we also recommend that using GDP growth to determine future electricity demand growth is unreliable and should be replaced by a bottom-up approach that takes concrete per-sector growth figures and energy efficiency savings into account to create a forecast that is more in-line with the recent growth figures actually observed.

Our next step was to evaluate the potential for energy efficiency improvements to reduce the need for additional generation investment. It is well-known that energy efficiency measures are cheaper and faster to come online than building new power plants. The government's plans do not include energy efficiency improvements as a potential approach to meeting and/or reducing future demand. Energy efficiency gains are not included in demand forecasting despite the fact that CNEE claims on its website that there is potential for 250 MW of savings in Guatemala, an amount comparable to the capacity of the

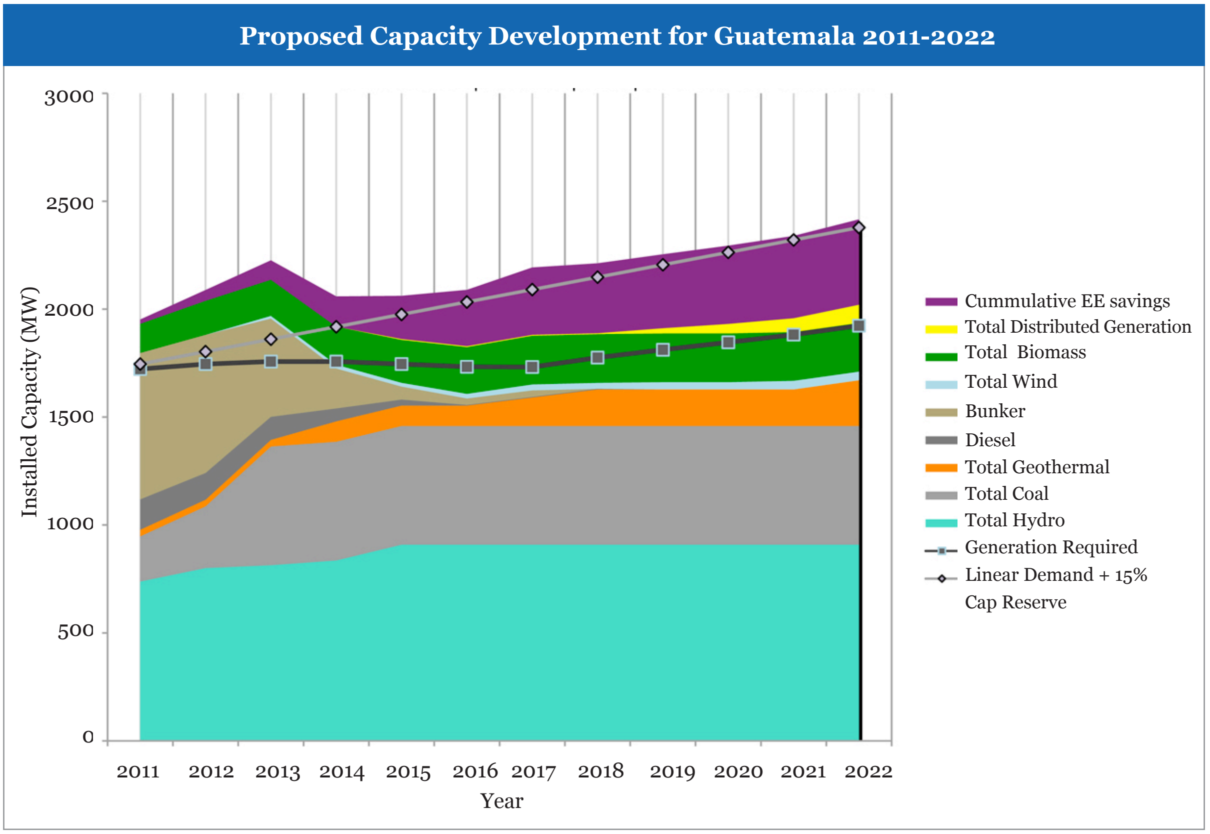
1 The generation and transmission expansion plans were released in 2008 as a single document titled *Planes de Expansión - Sistema Eléctrico Guatemalteco*. The generation expansion plan is called *Plan de Expansión Indicativo del Sitema de Generación 2008-2022* and the transmission expansion plan is called *Plan de Expansión Sistema de Transportes 2008-2022*. Updates to the plans were released in 2010 and 2012.

country's largest hydroelectric plant. Part 2 of this report explores energy efficiency in Guatemala and finds ample potential savings to be gained from investments that amount to a fraction of the costs for the proposed electricity-generation infrastructure projects. Both technical and regulatory efficiency measures are explored. In addition to the potential 250 MW claimed by CNEE, we found another 145.5 MW of realistic potential energy efficiency savings. Our alternative power development plan includes both figures, yielding potential savings of 395.5 MW through 2022.

Part 3 explores Guatemala's potential for renewable energy other than large hydro. Although the original version of CNEE's expansion plans included only small amounts of non-hydro renewable energy sources, the most recent 2012 version (*PEG2 2012*) does include up to 300 MW of new geothermal capacity to come online by 2017. Wind power is also a promising new technology. The first utility-scale wind farm is currently under construction and should deliver up to 50 MW by 2015. Several other projects are in various stages of development. We include three wind projects already under development in the alternative PDP, and conservatively project another 75 MW to come online by 2022.

Biomass from sugar mills has been used in Guatemala to generate electricity for decades and our research found plans for new private sector investments aiming to boost biomass capacity. We believe that an additional 152 MW of biomass capacity is realistic for the period until 2022. We also propose that small local sources of distributed wind, solar and biomass generation could reduce transmission losses and the need to build new transmission and distribution infrastructure. Guatemala receives large amounts of sunlight and there is good potential for electricity generation from solar photovoltaic rooftop installations. Starting from 2017, we propose adding 20 MW per year of solar photovoltaic capacity to the grid. Our analysis of the economic viability of each renewable energy technology shows that these are clear cost-competitive alternatives to more hydropower, coal or gas to meet a realistic projection of future needs for electricity in Guatemala in the next ten to fifteen years.

This report combines realistic demand projections, energy efficiency gains and potential renewable energy sources, to create an alternative Power Development Plan (PDP) for Guatemala requiring no new hydro or coal capacity to be built beyond those facilities already under construction. The Revised PDP is explored in detail in Part 4 of this report and is illustrated in the graph below. The analysis indicates that there are viable alternatives to CNEE's plans that could accomplish the same goals with less economic, social and environmental costs. Results suggest that if energy efficiency measures are given priority, and some of the non-hydro renewable potential were developed, then the electricity infrastructure projects currently under construction would add enough to Guatemala's installed capacity to meet future demand growth through 2022. This report therefore recommends that a freeze on new fossil fuel and hydropower projects be enacted while an aggressive energy efficiency deployment program is launched and completed.



Proposed Capacity and Demand Projections for Guatemala 2011-2022

Introduction

In 2008, Guatemala's electricity regulator *Comisión Nacional de Energia Eléctrica - CNEE* introduced plans to overhaul the country's generation and transmission systems called the *Planes de Expansión - Sistema Eléctrico Guatemalteco*. The first part of the plan deals with the electricity generation system and is called *Plan de Expansión Indicativo del Sistema de Generación 2008-2022 (PEISG)*[1]. The second part is named *Plan de Expansión de Transportes (PET)* and deals with the upgrading of the aging transmission system[2]. The plans rely on econometric models based on GDP growth to make projections of future electricity demand from which to chart generation infrastructure technology should be developed to guarantee the supply of electricity.

To account for the reduced GDP growth caused by the global recession, in 2010 CNEE released the *Perspectivas de Mediano Plazo (2010-2015) para el Suministro de Electricidad del Sistema Eléctrico Nacional* (*Perspectivas 2010* from here on). This publication revised demand projections downward to reflect the slow economic growth of 2008-2010. It nevertheless still predicted a low case demand scenario for 2010 that was 18 MW above the actual observed peak demand. It also provided an update on several projects under construction due to come online by 2015. Article 15bis of the *Reglamento del Administrador del Mercado Mayorista* determines that a Generation Expansion Plan be released every two years with a 10-year minimum time horizon. In January 2012 a new version of the plan titled *PEG2 2012*[3] was released that changed little in the projections of future capacity demand. The numbers provided are similar to the low-case scenario of the *Perspectivas 2010* but extends the time horizon to 2026. The *PEISG* is the main plan authorized by Congress, with the *Perspectivas 2010* being simply an update using reduced GDP figures resulting from the global recession. The *PEG2 2012* expands on the *Perspectivas 2010* and updates some of the generation infrastructure plans to reflect new market conditions. Therefore, all documents are treated as the same expansion plan, except that where they differ we shall use the updated *Perspectivas 2010* or *PEG2 2012*.

The *PEISG* has two main objectives: 1) to replace aging baseload thermal plants powered by diesel and bunker fuel oil, thereby reducing the country's vulnerability to oil-price volatility in its electricity generation; and 2) to meet Guatemala's projected future capacity demand. The plan also aims at energy matrix diversification, efficient generation, cost reduction, regional energy integration, and reducing the carbon footprint of the electricity sector[4]. The plan uses GDP growth as the main determinant for forecasting future demand. It aims to reduce CO_2 emissions in 2022 from a projected 32 tCO_2/capita to 25 tCO_2/capita by relying on hydropower to generate over half of the country's electricity. It also aims to reduce electricity production costs by eliminating the need to import 114 million barrels of bunker a year[5]. The *PEISG 2008* relies exclusively on large hydropower and fossil-fueled thermal generation to meet future demand, but the *Perspectivas 2010* proposes some "distributed renewable generation" in one of its five future scenarios to "eliminate price volatility during the transition (May-June) from the wet to the dry season"[6].

The *Plan de Expansión de Transportes (PET)* proposes the construction of 1394 kilometers of new high-voltage transmission lines, and the upgrading of aging transformer stations. The goals are to connect the country in a series of five transmission sub-grids that would link generating sites (hydropower mostly) and load centers, and reduce transmission losses[7]. All proposed generating sites are hydropower projects without any non-hydro renewable source sites taken into account.

1 CNEE 2008
2 CNEE 2008a
3 MEM 2012
4 CNEE 2008, p.3
5 CNEE 2008, p. iii
6 CNEE 2010a, p 73
7 CNEE 2008

This report proposes that GDP-based demand forecasting is unreliable and should be replaced by a bottom-up approach that takes concrete per-sector growth figures and energy efficiency savings into account to create a forecast that is more in-line with the recent growth figures actually observed. It also explores energy efficiency potential and shows that there are clear cost-competitive alternatives to more hydropower, coal and gas to comfortably meet a realistic projection of future needs for electricity in Guatemala in the next ten to fifteen years.

Part 1 of this report examines the methods and assumptions of the *PEISG* and offers a critique of its GDP-based projection methods, and discusses the transmission grid overhaul plans in light of renewable energy potential. Part 2 examines the potential for energy efficiency measures in Guatemala, which, if deployed, constitute an alternative to building new generation capacity. Part 3 will examine the potential for renewable sources other than hydropower. In Part 4 of this report we will propose an Alternative Power Development Plan (PDP) for the country that incorporates existing capacity, projects currently under construction, energy efficiency potential, and renewable sources other than hydropower.

1

An Evaluation of Guatemala's Current Demand Projections

1

An Evaluation of Guatemala's Current Demand Projections

Background:
Guatemala's Electricity Market

Guatemala's state-owned utility, the *Instituto Nacional de Electrificación - INDE* was founded in 1959 and became responsible for all aspects of electricity generation, transmission and distribution[8]. By the 1980s it became unable to finance the capital expenditures required for the electricity sector's growth and development. Congress attempted to generate interest in private investments through the *Renewable Energy Law* of 1986 but by 1990 92% of electricity in Guatemala was still generated by state-owned facilities. By the early 1990s, the system's installed capacity was unable to keep up with demand and daily blackouts were common. INDE began to offer very generous power purchase agreements to spur private investment and between 1993 and 1996 thirteen private Power Purchase Agreements (PPAs) were signed opening the market to private investments[9].

In the wave of privatizations of public infrastructure that swept through the developing world in the 1990s, Guatemala's Congress passed the *Ley General de Electricidad* in 1996. That legislation broke up and privatized parts of the state's electricity infrastructure and created an open market for electricity (the *mercado mayorista*) and a market administrator *Administrador del Mercado Mayorista (AMM)*. The AMM is charged with overseeing contracts and transactions as well as matching supply and demand throughout the national grid (called *Sistema Nacional Interconectado* or *SNI*).

INDE remained a state-owned enterprise and continued to operate generation plants, transmission lines and distribution of electricity through its three subsidiaries. INDE's generation falls under the auspices of its subsidiary *Empresa de Generación de Energia Eléctrica (EGEE)*, which owns several hydroelectric plants (including Chixoy, Jurun Marinalá and Aguacapa) and thermal plants, and sells its electricity directly on the open market. It has by far the largest installed generation capacity in the country and in 2010 supplied over 2,655 GWh of electricity[10]. The other two INDE subsidiaries are ETCEE dealing with transmission of electricity and ECOE with commercialization and distribution. These are all still owned by the state.

8 deGaute.com 2008
9 Study by the Lawrence Berkeley National Laboratory - Murtishaw et al 2008
10 Administrador del Mercado Mayorista. *Informe Estadístico 2010* - AMM 2011b, p.3.

Today, electricity regulation is the realm of the *Comisión Nacional de Energia Eléctrica (CNEE)*, which sets rates and promotes development of new capacity and energy efficiency. CNEE also coordinates auctions and open bidding sessions between the country's distributors and the generation sector. Guatemala has three main utilities that cover the bulk of Guatemala's consumers: EEGSA, DEOCSA and DEORSA. All three have transmission and distribution lines. EEGSA is the largest, serving the capital and surroundings in the departments of Guatemala, Sacatepequez and Escuintla; it provides over 50% of the country's electricity and distributes 593 MW of capacity through its network. On the other hand, DEOCSA serves about 862,000 consumers and DEORSA 504,000. Together they supply a stable demand of 532 MW[11]. The remaining demand is supplied by municipal power companies and large consumers with direct Power Purchase Agreements (PPA) with generators.

Guatemala suffered from very high electricity prices in the early 1990s, which drove the construction of new capacity infrastructure. Bunker and diesel-fired thermal plants were built in the 1990s and a few new bunker plants were built in the past 10 years, one as recently as 2008. Sugar mills built 381 MW of capacity that burn sugarcane biomass and bagasse and locked in 20-year contracts at very high prices. These contracts are also partly to blame for Guatemala's high electricity costs along with generation from petroleum derivatives. Many of these contracts are due to expire starting 2011 and should be renegotiated at lower prices. The current plans to phase out petroleum-based generation should also contribute to lower electricity prices in Guatemala.

Private generators represent a growing part of the installed capacity in the country and all projects currently under construction are private enterprises of single entities or consortia made up of both domestic and foreign investors. All new capacity in the pipeline is privately funded and therefore the adoption of renewable energy other than hydropower in Guatemala will depend on the private sector's confidence in attractive returns on investment.

Guatemala's Installed Capacity

Through most of the 20th century, Guatemala relied mostly on hydropower to meet its electricity demand and some hydroelectric plants have been operational for over 70 years: Santa Maria (5 MW) started operations in 1927, and El Salto (2 MW) in 1938[12]. Some were built in the 1960s and 70s, and the most notorious and biggest dam in the country, Chixoy (300 MW), went online in 1983 following a bloody massacre of Mayan villagers who refused to be relocated to make way for the reservoir. The rifts caused by that history still linger and were evident in the fierce public opposition that derailed the construction of the Xalalá dam in 2009. No large hydro megaprojects were built in Guatemala for 20 years since Chixoy, although a handful of medium-sized dams were built in the 1990s and 2000s. In 2003-2004 El Canada (48 MW) and Renace (68 MW) went online and Xacbal (94 MW), the latest hydroelectric dam to be introduced, began operations in August 2010[13] amid

11 EEGSA 2010
12 AMM 2011a
13 AMM 2011a

Table 1.1. Guatemala's Installed Capacity in 2011				
Fuel Type	**Technology**	**Installed Capacity (MW)**	**Installed Capacity (MW)**	**Observations**
Coal	Steam Turbine	159.00	6.8%	San Jose Plant
Diesel	Gas Turbine	260.90	11.1%	
Fuel Oil #6 (Bunker)	Int. Combustion Engine	736.70	31.3%	
Bagasse	Steam Turbine	371.50	15.8%	Harvest Time
Geothermal	Steam Turbine	49.20	2.1%	
Water	Hydroelectric	774.10	32.9%	
	Total Installed Capacity:	**2351.40**	**(Harvest Time)**	
Fuel Oil #6 (Bunker)	Steam Turbine	206.70	8.7%	Non-Harvest Time

Source: AMM 2011a Prepared by A. Koberle

public controversy. There are currently at least five hydroelectric projects under construction slated to become operational between 2011-2015 totaling 152MW[14].

The first coal plant went online in 2000, the 130-MW San Jose plant owned by TECO Energy. Three new coal plants are now under construction: Duke Energy (80 MW), ESI (80 MW) and Jaguar Energy (275 MW), all of which are expected to come online by 2013[15]. The country has two plants totaling 49 MW of geothermal capacity in operation[16], 75 MW slated for 2014 and another 88 MW by 2018[17]. So far Guatemala has no utility-scale wind or solar power but several wind farms have been approved. Feasibility studies are underway for the Viento Blanco wind farm (21-MW)[18], and the 48-MW Santo Antonio El Sitio is under construction and should be operational by May 2014[19].

Table 1.1 shows the current distribution of Guatemala's installed capacity by fuel type and technology.

GDP Projections and Electricity Demand Forecasts

The *PEISG 2008* expansion plan relies on future capacity demand projections based largely on GDP growth forecasts that assume a business-as-usual relationship between electricity demand and economic growth. In addition

14 *Perspectivas 2010*. CNEE 2010a, p.51.
15 *Perspectivas 2010*. CNEE 2010a, p.51.
16 AMM 2011a
17 CNEE engineer Oscar Arriaga, personal email communication on June 1, 2011.
18 Álvarez 2011
19 Álvarez 2012

Table 1.2. Historic and Projected Real GDP Growth rate						
Annual Real % GDP Growth - Guatemala						
Data Source	CNEE % GDP Growth (Low)	CNEE % GDP Growth (Medium)	CNEE % GDP Growth (High)	IMF Real % GDP Growth Historic (p) = projected	Banco de Guatemala % GDP Growth Historic	ANG Real % GDP Growth Historic
	Projected (in 2007)	Projected (in 2007)	Projected (in 2007)			
Year						
2001	n/a	n/a	n/a	2.4	2.3	n/a
2002	n/a	n/a	n/a	3.9	2.25	3.87
2003	n/a	n/a	n/a	2.5	2.13	2.53
2004	n/a	n/a	n/a	3.2	2.75	3.15
2005	3.3	3.3	3.3	3.3	3.16	3.26
2006	5.3	5.3	5.3	5.4	4.57	5.37
2007	5.7	5.7	5.7	6.3	n/a	6.27
2008	4.3	5.3	6.3	4.0	n/a	3.29
2009	4.4	5.4	6.4	0.4	n/a	0.58
2010	4.0	5.0	6.0	1.3 (p)	n/a	n/a
2011	4.0	5.0	6.0	3.5 (p)	n/a	n/a
2012	3.8	4.8	5.8	3.5 (p)	n/a	n/a
2013	3.6	4.6	5.6	3.5 (p)	n/a	n/a
2014	3.4	4.4	5.4	3.5 (p)	n/a	n/a
2015	3.2	4.2	5.2	n/a	n/a	n/a

Source: Prepared by A. Koberle
Data Source: CNEE – PESG 2008, IMF website, Banco de Guatemala, ANG website

to GDP and the number of connected users being taken as independent variables, the demand from some undisclosed short-term industrial projects was also taken into consideration. The figures provided include 50 MW for a cement factory in 2010, and 117 MW for the mining industry coming gradually online between 2011 and 2014. A lowest scenario called *vegetativo* was also calculated without the inclusion of these specific (though undisclosed) projects[20].

There are several problems with relying on GDP growth to predict future electricity demand growth. In general, GDP can be difficult to pin down. It depends on how it is calculated and, therefore, its value is subject to interpretation. Table 1 shows CNEE's GDP projections along with past and projected GDP figures from the IMF, the Guatemalan Central Bank and from Guatemala's *Asociación Nacional de Generadores (ANG)*. The fact that CNEE, Banco de Guatemala, and ANG provide different numbers is evidence of the subjectivity of GDP. It is even more difficult to make long-term projections of GDP growth. Although energy demand projections are often tied to GDP growth, there are other factors involved that are independent of GDP, such as

20 *PEISG 2008*. CNEE 2008, p.14

Table 1.3. CNEE's Projections for Capacity and Generation Demand Growth in Guatemala

Year	Capacity Demand MW				Energy Demand GWh			
	Vegetativo	Bajo	Medio	Alto	Vegetativo	Bajo	Medio	Alto
2008	1,505	1,505	1,505	1,505	8,172	8,172	8,172	8,172
2009	1,575	1,575	1,591	1,606	8,568	8,568	8,652	8,735
2010	1,649	1,699	1,732	1,763	8,984	9,422	9,601	9,774
2011	1,726	1,846	1,898	1,949	9,419	10,107	10,390	10,667
2012	1,807	1,958	2,031	2,103	9,876	11,147	11,545	11,937
2013	1,891	2,054	2,150	2,245	10,355	11,777	12,302	12,823
2014	1,969	2,137	2,251	2,363	10,800	12,267	12,891	13,509
2015	2,047	2,215	2,347	2,478	11,244	12,712	13,438	14,157
2016	2,125	2,292	2,444	2,593	11,689	13,157	13,989	14,813
2017	2,206	2,374	2,540	2,709	12,151	13,618	14,560	15,493
2018	2,287	2,454	2,644	2,833	12,630	14,097	15,154	16,199
2019	2,371	2,539	2,751	2,961	13,127	14,594	15,770	16,932
2020	2,461	2,628	2,862	3,094	13,644	15,111	16,411	17,694
2021	2,553	2,721	2,978	3,232	14,182	15,649	17,077	18,488
2022	2,650	2,818	3,099	3,376	14,741	16,209	17,772	19,315

Prepared by A. Koberle
Data Source: CNEE – PESG 2008, IMF website, Banco de Guatemala, ANG website

energy efficiency improvements and primary-fuel prices. CNEE's GDP-based model assumes that electricity demand will continue to grow at a 1:1.1 ratio compared to GDP. Energy efficiency can decouple that relationship and help reduce the ratio to levels below 1:1, so that GDP growth does not imply increased electricity demand.

Another shortcoming of using GDP to predict electricity demand is that predicting economic trends is an uncertain and inexact endeavor. As a case in point, CNEE's projections were made before 2007 and did not foresee the global economic crisis of the last few years. As a result, its already optimistic growth forecast proved to be an exaggeration in hindsight, as can be seen for years 2009-2010 when compared to the historic values reported by the IMF (Table 1.2).

Table 1.3 is taken directly from *PEISG* and shows the projected peak capacity and annual generation demand resulting from CNEE's analysis. All entries are projected values created before the global economic crisis hit. Even the *vegetativo* case of 2008 was already an overestimate. According to the Guatemalan electricity market administrator *Administrador del Mercado Mayorista (AMM)*, peak demand was 1472 MW in 2009, and 1468 MW in 2010[21]. CNEE's projected low-case growth scenario for 2010 is a full 231 MW above the actual observed value. Even the so-called *vegetativo* growth scenario is 181 MW above observed values. AMM has reported actual peak capacity demand numbers consistently below CNEE's projections for years 2008, 2009 and 2010.

21 Weekly Post-Operative Reports. AMM 2011

The *Perspectivas 2010* document released in 2010 was meant to provide an update to the *PEISG 2008*, and includes two demand projection scenarios based on the post-recession downward-revised GDP figures now available. Although the new demand projections seem to be more realistic, *Perspectivas 2010* projected the peak capacity demand for 2010 to be 1488 MW as a low-case and 1528 MW as a high-case scenario[22]. The AMM-reported value of 1468 MW means *Perspectivas 2010* missed the target for the year of its release, overstating peak capacity demand for 2010 by at least 20 MW. In keeping with the mandate to release an updated plan every two years, the government released the *PEG2 2012*. Although released in 2012, this new version still showed peak capacity demand for 2011 to be 1534 MW[23]. This number is the lower demand scenario in the *PEG2 2012*. Another, higher scenario is offered as well that includes demand from rural electrification and industrial projects that push capacity demand growth to rates averaging 124 MW per year over the period 2012-2026[24]. The transmission expansion plan update (named the *PET2 2012*) states a directive to raise the rural electrification rate from 82.7% today to 90.0% by 2021 and 95.0% by 2025[25]. No details are included to explain how rural electrification and/or industrial projects would raise demand to such high rates.

Preliminary research of AMM's weekly dispatch reports indicate that peak capacity demand for 2011 will be 1475 MW, an increase of only 7 MW over 2010, and well below any of CNEE's projections. This points to problems with the methodology and suggests that any future projections based on this model may prove to be inflated within a year. It's understandable that models will miss the mark when dealing with the complexities of electricity demand and GDP, but to consistently overstate the actual amounts means that something is wrong with the underlying model and it should be revised before it is used to approve multibillion-dollar projects that will be operational for decades to come.

There are several possible reasons why the projections have been inaccurate. First, it is not uncommon for government agencies to overstate projected needs[26]. Also, the economic crisis had a profound effect on electricity use worldwide and Guatemala was no exception. The country's peak capacity demand fell by 1% in 2008 as compared to 2007, even though the economy grew by 3.29%[27]. This disconnect between economic growth and capacity demand may be explained by economic growth through consumption of industrial supply overstock, which would lead to reduced manufacturing demand, while stocked goods are absorbed. A third reason for the demand reduction may be energy efficiency gains driven in part by high energy costs in 2005-2007 and public conservation campaigns. Using projected GDP growth to forecast capacity demand is a top-down approach that has not been effective. In other countries, predictions based on GDP routinely fail to materialize and are often overblown[28].

22 CNEE 2010a, p.47
23 MEM 2012, p.1
24 Calculated from Table 1 of MEM 2012, p1
25 MEM 2012a, p.1
26 See Thailand's case, for example, in Greacen 2004
27 ANG 2010
28 See for example Greacen 2004

The reduction in peak capacity demand from 2009 to 2010 is made even more significant by the fact that electricity consumption went up by 3.16% from 8014 to 8276 GWh[29] even as capacity demand fell. This means that more electricity was consumed during off-peak hours suggesting successful demand side management. Shifting electricity consumption away from peak hours whenever possible reduces peak capacity demand, the main driver for construction of new generation infrastructure. It means the current installed capacity is being used more efficiently and that the same economic output was generated with less installed capacity.

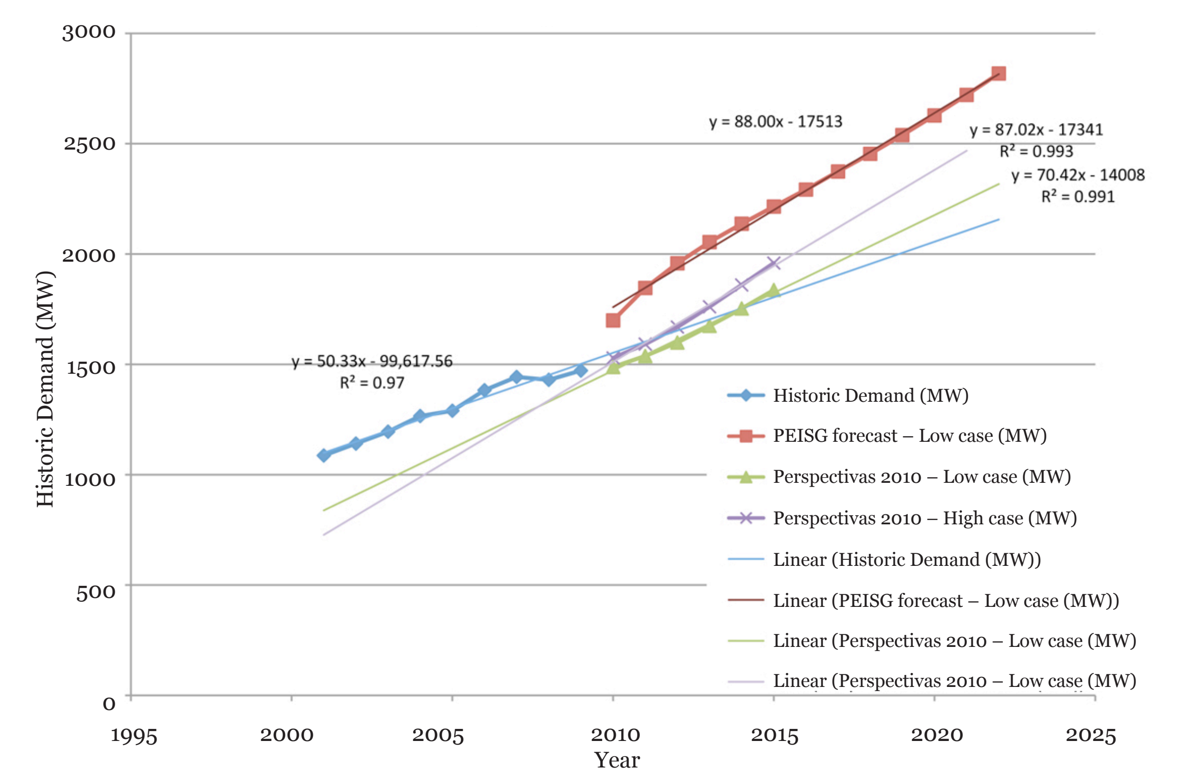
Figure 1.2 shows a linear regression for the observed historic capacity demand in Guatemala between 2001 and 2009 (blue), for the low-case demand forecast by CNEE from 2010 to 2022 as reported in *PEISG* (red), and for the low- and high-case scenarios proposed by CNEE in the *Perspectivas 2010* (green and purple respectively). Between 2001 and 2010, capacity demand grew at an average 50 MW per year (R^2=0.97, a very good fit) but in 2008 CNEE projected it would grow much faster: around 90 MW per year in the period 2010-2022. As the two lines for the *Perspectivas 2010* scenarios show, the revised projections are much closer to the historic trends. However, even though they begin around the same point as the observed 2010 capacity peak, both the low- and the high-case scenarios show demand growing much faster than one would expect if it were to continue growing at 50 MW per year. In fact, the high-case scenario in the *Perspectivas 2010* projects an annual increase of 87 MW, comparable to the low-case growth scenario of the *PEISG*. The low-case *Perspectivas* scenario shows demand growing at a more modest 70 MW per year, which is still 40% faster than the historic trend.

CNEE's plans do not offer much in the way of explanation for the reasons behind such dramatic increases except in generic and vague allusions to GDP growth and undisclosed industrial and mining projects. Nor do they take into consideration any potential savings from energy efficiency gains. If a sustained capacity demand growth of such magnitude is real, then considerable investments will be required and CNEE should clearly delineate what is causing this increase and provide some options on how to meet the demand growth.

In this paper we present the elements of a new approach to electricity sector planning in Guatemala; one in which 1) new demand is clearly identified and supply met in the most efficient way possible with the least socio-environmental impacts; 2) potential energy efficiency gains are realized through concrete regulatory measures that diminish the need for new infrastructure; and 3) potential renewable sources other than large hydropower are given serious consideration. While it is beyond the scope of this paper to be able to conduct detailed analyses of future demand projections based on real data for each sector, we will use Guatemala's historical demand growth rates as the basis for predicting future demand growth. In the chapters to follow we explore the other elements of this new approach.

29 AMM 2011

Figure 1.2. Regression Analysis of Guatemala's Historic and Projected Capacity Demand



Transmission Expansion

CNEE's *Plan de Expansión de Transportes - PET*[30] released in 2008 delineates the proposed construction of new high-voltage transmission lines needed to reduce the pressure on the already overwhelmed national power grid and to connect the regions with generating capacity to the load centers. Hydropower projects are specifically mentioned but other renewable sources are conspicuously absent. In December 2009 the Colombian utility Empresa de Energia de Bogotá was awarded the contract to start construction of 1394 km of new power lines and substations[31]. The project will cost an estimated US$422m, with an additional US$82m for the interconnection with Mexico and the SIEPAC grid, a large Central American interconnected power network in development now[32]. It is unclear if any new transmission lines are to be built connecting renewable energy sites to the grid. In a recent interview, former MEM minister Luis Ortiz said

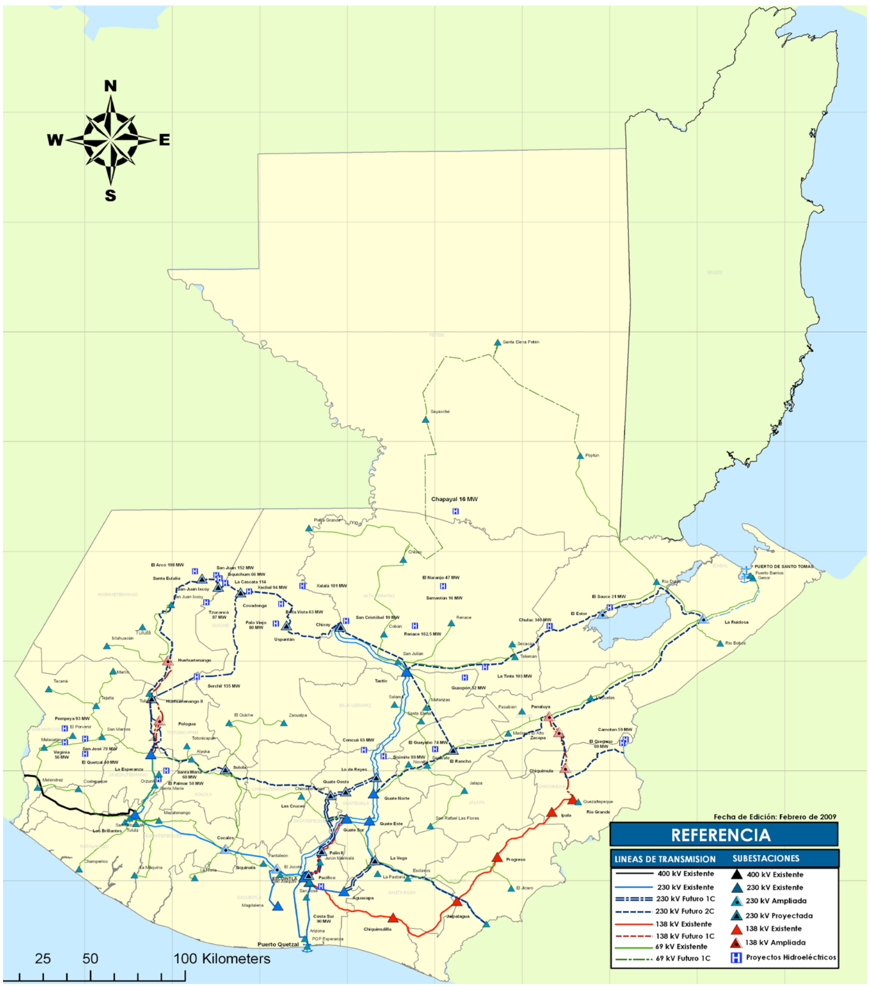
> The *PET* would facilitate the construction of generating plants, especially hydroelectric dams, whose resources are in the North, West and Central Guatemala, as it would facilitate the transport of the energy from these areas to the national system.
>
> *Prensa Libre* 2010

30 CNEE 2008a
31 Alvarez 2009. *El Periodico*. December 12, 2009.
32 *Business News Americas*, June 2009

There were several projects under construction in 2007 at the time the *PET* was released, some of which have since been completed. The 400 kV, US$55 million interconnection with Mexico was officially inaugurated in October 2009 and upon approval of regulations in March 2010, Guatemala could increase its purchase to 200 MW of electricity from Mexico over the next two years. Of this amount, 120 MW is already being distributed by INDE[33] and the remaining 80 MW is to become available in August 2013[34]. In January 2012 the *Ministerio de Energia y Minas (MEM)* released an update to the *PET* titled *Plan de Exapnsión de Transportes 2012-2026*[35]. This document determines that the original transmission expansion plan of 2008 is being carried out on time and sets rural electrification goals of 90% by 2015 and 95% by 2021, up from 82.7% today.

Below is a map of existing and projected transmission lines as of February 2009:

Figure 1.2. Existing and Projected Transmission Lines and Substations as of February 2009



Source: CNEE – *PET 2008*

33 *Prensa Libre*, Feb 12, 2010
34 Perspectivas 2010 - CNEE 2010a, p.51
35 MEM 2012a

Guatemala plans on relying partly on power imports from Mexico through 2022 to make up for reduced hydroelectric output during the dry season[36]. This is surprising given that the generation expansion plans seem to be proposing new infrastructure well in excess of what's needed to cover projected demand. Some[37] claim that the excess power is to be used for exports to other Latin American grids through SIEPAC. However, CNEE explains that although more expensive than domestic electricity produced from hydropower or coal, Mexican electricity is still cheaper than diesel- or bunker-fueled Guatemalan electricity[38].

The *PET* aims to connect the whole country in a continuous, modern grid that *can* be used to bring electricity efficiently to the various regions of the country, several of which are still living off the grid. However, there is growing recognition that for more remote places it might be better both environmentally and cost-wise to invest in renewable energy-powered isolated mini-grids or other stand-alone generation such as solar home systems rather than connecting everyone to the main grid.

The grid would also provide electricity to regions rich in current and untapped mining potential, which require a lot of electricity. These regions are rich in natural resources, including hydropower potential as well as mining and oil deposits[39]. Many hydro projects in these regions (including Xalalá) have met with serious resistance from local populations.

The siting of transmission lines can have profound impacts on which energy resources get developed. By proposing new transmission lines close to planned hydropower generation sites but leaving other renewable energy locations without transmission capability, the plan would result in a *de facto* subsidy to the large hydropower projects proposed in the separate Generation Expansion Plan (*PEISG*). This is because in order to sell its electricity to the grid, renewable projects would also have to include the cost of transmission lines or would have to wait for additional lines to be built. The transmission plan as it stands effectively reduces the apparent cost of the proposed hydropower projects, but leaves other renewables such as wind, solar and geothermal sources isolated, further increasing the apparent costs of developing them. Although renewable energy sites are generally close to load centers and transmission lines in Guatemala, the need for even a short (<50 km for example) transmission line can be a serious financial and/or bureaucratic obstacle.

Generation Capacity Expansion

The generation expansion plan outlined in *PEISG 2008* is well underway. The goal of eliminating diesel generation will become a reality by 2015, and

36 CNEE 2008, p.31
37 e.g. *El Observador* 2010
38 Perspectivas 2010 - CNEE 2010a, p.51
39 *Invest in Guatemala* 2010

bunker generation will also be reduced significantly[40]. CNEE's expansion plans involve mostly large hydroelectric projects, large coal, and imports from Mexico. Table 1.4 is from *Perspectivas 2010* and shows 769.6 MW of new capacity under construction due to come online by 2013. In addition, there are other hydroelectric projects currently under construction and some others that have begun to get the required permits and approvals[41]. In May 2010, MEM official Carlos Meany informed that the following projects were already under construction: Panam (6.9 MW), La Helvetia/SDMM (6.8 MW), the two *Renace* projects (130 MW), Sulin (19 MW), Finca Lorena (23 MW), Las Animas (10 MW), Cueva Maria (9.3 MW), and El Volcán (26 MW)[42].

There are also references to liquefied natural gas (LNG) as a potential fuel source but no specifics[43]. (**Table 1.4**).

As for other renewable sources, geothermal and unspecified "Renewable Distributed Generation" are featured in only one of five future generation scenarios included in *Perspectivas 2010[44]*, but *PEG2 2012* includes a possible 300 MW from geothermal power plants to come online starting in 2017[45].. Energy efficiency remains unmentioned in any expansion plans and continues to take a back seat to building capacity infrastructure to meet demand. In the discussions to follow we will examine the potential for energy efficiency (Part 2) and for renewable sources other than large hydro (Part 3). We then

Table 1.4. Projects Under Construction in Guatemala in 2010

Start of Operations	Project	Capacity (MW)
June – 10	Duke Fase 1	40
July – 10	Hidroeléctrica Xacbal	94
August – 10	Hidroeléctrica Santa Teresa	19.6
January – 11	Duke Fase 2	40
June – 11	Hidroeléctrica El Manantial	35
Dec – 11	Hidroeléctrica El Cóbano	7
June – 12	Hidroeléctrica Palo Viejo	80
Nov – 12	ESI	80
May – 13	Jaguar	275
June – 13	Hidroeléctrica San Cristóbal	10
August - 13	Interconexión México	80 3
	Total	**769.6**

Source: Perspectivas 2010 (CNEE 2010a, p.51)

40 CNEE 2010a - A tender of 800 MW worth of power supply contracts will happen by the end of 2011, and all bids were due in by October 28, 2011 (*El Periódico* 2011). The deadline has since been changed to January 06, 2012 (Bolaños 2011). Of these 800 MW, 60% will have to come from renewable sources (including hydro) with 15-year contracts and up to 40% may come from non-renewable sources limited to coal, bunker and liquefied natural gas (LNG). Winning bids are expected to become operational on May 1, 2015 (EEGSA 2010). At least one proposal for a 50-MW wind farm is expected (El Periódico 2011). In March 2012, the first round of concessions awarded contracts totaling 210 MW to several hydroelectric projects, most of which were still under construction at the time.

41 For example, in April 2011 *El Periódico* reported that the hydroelectric project *El Oregano* (120 MW) was approved by MEM and *El Renace* 2 (162.5 MW) was already under construction (Alvarez 2011).

42 Quiñoes, F. Usarán Menos Bunker en Generar Luz. Siglo XXI. May 15, 2010. Accessed online at http://www.s21.com.gt/node/10972

43 EEGSA 2011

44 CNEE 2010a, p.71

45 MEM 2012, p. 2

combine these analyses into a Revised Power Development Plan (PDP) for Guatemala, which we present in Part 4. In the Revised PDP, we will include the current installed capacity, plus new hydro and coal projects only if they are currently under construction. Those projects that have been approved but have not broken ground yet will not be included.

2 Energy Efficiency Potential in Guatemala

2

Energy Efficiency Potential in Guatemala

> "Demand management and electricity conservation can improve profitability of energy providers, create new energy efficiency services industries, and, most importantly, help to *decouple* economic development from electricity demand growth."
>
> (Limaye *et al*, 2008)

The Power of Negawatts[46]

Power sector planners and utility officials in Europe, North America and parts of Asia increasingly rely on incentivizing energy efficiency as a central tool in meeting electricity growth at low cost. As will be explored in this chapter, the potential for efficiency gains in Guatemala is significant. Unfortunately, CNEE's expansion plans (*PEISG 2008* and *Perspectivas 2010*) do not mention energy efficiency at all and propose to meet future electricity demand through new capacity infrastructure only[47]. Electricity demand projections based on GDP assume that the economic output per unit of electricity consumed remains constant and is therefore an incomplete approach that neglects the gains from both technological and regulatory energy efficiency measures.

Many developed nations have enjoyed healthy economic growth while their per capita electricity use has remained flat. As a good example of this, between 1990 and 2007, Germany's GDP grew by 20% while its primary energy consumption decreased by 7%[48]. California, Denmark, and the Netherlands are also good examples of flat per capita electricity demand despite rising GDP in the last few decades[49].

Although a comprehensive energy efficiency program in Guatemala has not been undertaken, some domestic and regional plans have been launched to varying levels of success. In response to the oil shocks of the 1970s, USAID helped Guatemala, Costa Rica, El Salvador, Honduras and Nicaragua establish the Regional Industrial Energy Efficiency Program (PEEIR) in 1982. It targeted large users such as manufacturers and provided training in energy

46 Negawatts represent the megawatts created by energy savings, that is the capacity made available by energy efficiency measures which can be used for other purposes.

47 Instead, a separate energy efficiency plan was submitted to the Guatemalan Congress where it awaits approval. See following paragraphs.

48 Piedrahita 2009

49 See for example Kandel et al 2008, World Bank 2011

management and audits, held seminars and demonstrations and produced technical manuals. It emphasized simple conservation measures such as fixing leaks and insulation. By 1989 some 2,000 companies had estimated savings of about US$7 million a year throughout the region[50]. However, the plan lacked continuity and once the original push wore off, the gains were lost to inactivity. According to USAID, "as fuel prices returned to more stable levels, incentives for energy conservation also declined"[51].

The *Organización Latina-Americana de Energia* (OLADE) reports that more recent energy efficiency programs in Brazil, Mexico, Costa Rica, Peru and Cuba have yielded notable results avoiding the need for expensive new power plants. In 2005 alone, Brazil invested US$52.7 million in energy efficiency initiatives that generated savings of 2158 GWh[52] in electricity and US$960 million in postponed new capacity construction. In the same year, Mexico saved 1301 GWh, equivalent to the consumption of either the state of Baja California Sur or Colima[53]. In Mexico, the cost to conserve 1 kW through energy efficiency measures was found to be 75% less than the cost of adding 1 kW of capacity by building new infrastructure[54]. Efficiency measures also resulted in a reduction of 347 MW in capacity and 1,962 GWh in energy demand[55,56].

It is noteworthy that two of the most successful energy efficiency programs in Latin America – those of Mexico and Costa Rica – have treated the savings resulting from energy efficiency programs as tantamount to new capacity and have included them in their future energy plans and forecasts[57]. In February 2011 CNEE submitted a comprehensive energy efficiency plan - the *Plan Integral de Eficiencia Energética (PIEE)* - but as of this writing it remains stalled in the Guatemalan Congress waiting for approval and funding along with the *Ley de Eficiencia Energética*. CNEE's *Perspectivas 2010* does not include energy efficiency and continues to rely on new generation infrastructure to meet projected demand. The *PEG2 2012* does include one scenario in which energy efficiency gains are considered. In this scenario the total new capacity includes 300 MW of geothermal capacity while new hydroelectric capacity added is reduced to 650 MW from the 1110 MW projected in another scenario that differs only in the lack of energy efficiency gains[58]. This represents over 450 MW of potential energy efficiency gains through 2026. One of the central recommendations of this report is that a temporary freeze on new infrastructure projects be enacted between 2015-2022 and that an aggressive energy efficiency deployment schedule be made top priority.

---

50 USAID 1996

51 USAID 1996

52 Because we are mostly interested in reducing capacity demand, we try to express efficiency savings in MW or kW whenever possible, but generation savings are just as desirable. Some reports only provide generation savings expressed in MWh or GWh and we will report these when capacity savings are not reported.

53 Poveda 2007, p.10

54 Dufour 2006

55 Poveda 2007, p.11

56 The Mexican standards program was implemented in 1995 starting with only four main products – refrigerators, air conditioners, washing machines and electric motors. By 2005, standards for just these four products resulted in a 9.6% decrease in national electricity demand, and reduced the need for generating capacity by 6.4%. The rapid success of the Mexican program depended on a clear legislative authority to set standards and strong enforcement. Mexican manufacturers exceeded the requirements of the standards, partially from a desire to become more competitive in international markets (MacNeil et al 2007).

57 Poveda 2007, p.13

58 MEM 2012, p.12

The Daily Load Curve

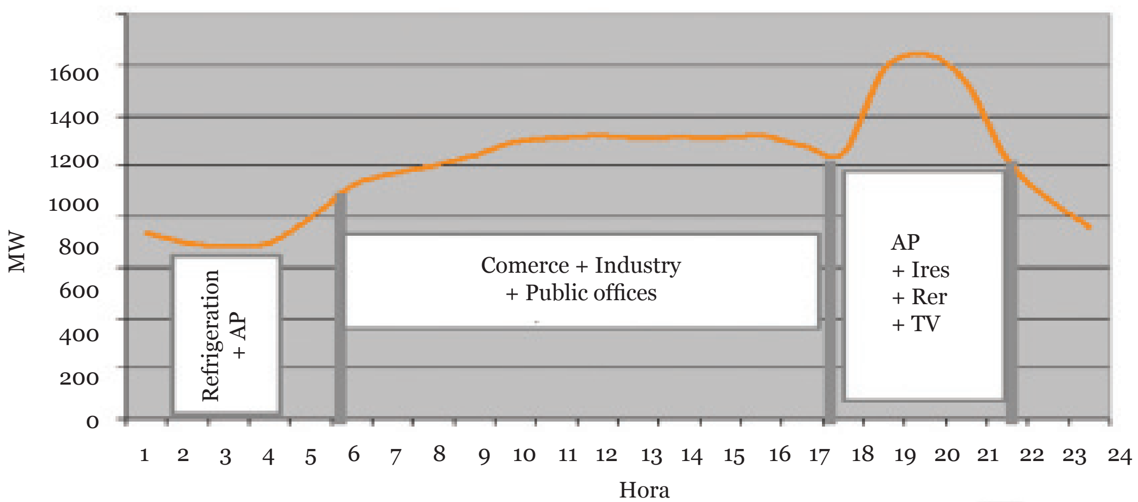
The driving force behind the need for new capacity infrastructure in Guatemala and elsewhere lies in the daily peak capacity demand. A country's generation infrastructure must supply enough capacity to meet its highest demand, even if only for a few hours a day, a few days a year. So whatever consumption is driving the annual peak will determine what the installed capacity must be in order to adequately provide the needed electricity.

Figure 2.1 shows Guatemala's typical load curve. Although the load curve changes everyday, its shape remains fairly constant *with an evening peak throughout the year*[59]. Therefore, any approach that reduces the evening peak will also reduce the need for new generation infrastructure. The evening peak is driven mainly by commercial, residential and public lighting, plus residential refrigeration[60]. Energy efficiency measures tackling these elements will therefore reduce peak capacity demand and eliminate the need for extra power plants.

In addition, demand side management (DSM) tools such as *interruptible demand* can also help reduce the underlying industrial capacity demand during peak hours. Electricity-intensive industries such as cement, mining and refrigeration can be sent price signals during peak hours that would entice them to temporarily reduce their loads to minimal requirements thereby lowering system-wide demand. As we shall see next, Guatemala's new efficiency plan takes aim at some of the drivers of the capacity peak.

Figure 2.1. Guatemala's Typical Daily Load Curve

March 23, 2011



La demanda de energía en Guatemala oscila entre 650 MW a las 3:00 de la mañana, hasta 1435 a las 20:00 horas. El pico se inicia a las 18:00 horas y finaliza a las 22:00 horas.
Source: Velásquez 2011

CNEE Comisión Nacional de Energía Eléctrica

Curva de la carga diaria de Guatemala.
Traducción de las claves: AP = Alumbrado público; Ires = Iluminación residencial; Ref = Refrigeración; TV = Aparatos de televisión

59 AMM 2011
60 Velazquez 2011

A New Plan for Energy Efficiency in Guatemala

In 2008, CNEE and MEM developed an energy efficiency plan named the *Plan Integral de Eficiéncia Energética – PIEE*. Financing of US$600,000 was approved by the IDB and complemented by US$150,000 from CNEE to develop the institutions necessary to administer the plan. In March 2009 the (mostly bureaucratic) objectives were given a period of 15 months to be completed. These were[61]:

- Establishment of a national energy efficiency department (*Organo Técnico Nacional de Eficiéncia Energética*), responsible for elaborating plans and monitoring the execution of the energy efficiency programs to be implemented in the country.
- Elaboration of a proposal to establish a financing fund (*Fondo Nacional para Eficiéncia Energética – FONAEE*) for specific energy efficiency projects. The loans would be repaid in a reasonable time by the energy savings generated. These projects will be in effect for all sectors of the economy: residential, commercial and industrial; public and private.
- Elaboration of specific proposals for energy efficiency incentives.
- The development of a program to train Guatemalan technicians on energy efficiency.

The funds from IDB were for drafting a plan and creating the necessary institutions to oversee it, and did not include direct funding for FONAEE (or FODEE as it has been called more recently). Resources for the fund will come from elsewhere, but not until the plan gets Congressional approval[62]. According to its website, IDB financed a second project starting in February 2010 to continue administrative and training procedures. Several meetings with sectors of society took place, resolutions were signed and a timeline for initial implementation of efficiency measures was released in August 2009. However, as of this writing, the energy efficiency legislation that would formalize the plans formulated by CNEE - the *Ley de Eficiencia Energética* - is awaiting approval by the Guatemalan Congress[63]. As a result the proposed measures in Table 2.1 have yet to be implemented.

Once the plan is approved by Congress, the funding for the actual implementation will need to be secured. A US$100-million line of credit is being prepared by IDB, and is scheduled to be made available to the government of Guatemala in 2012[64]. According to Velazquez (2011), once the plan is approved, the following measures will be implemented:

61 CNEE 2009a – p. 109
62 However, some projects have already been financed through the BID funds. See for example Bolaños 2012
63 Velazquez 2011
64 IDB 2011

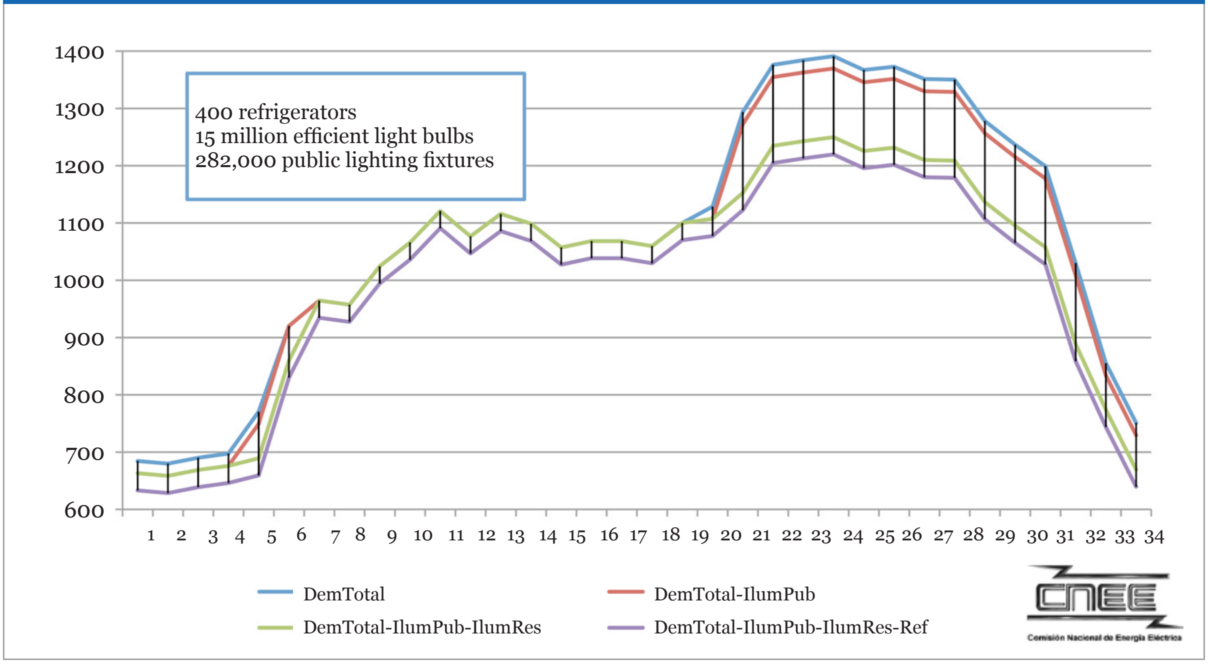
Table 2.1. Planned Energy Efficiency Programs				
Measure	**Objective**	**Expected Effect**	**Agent**	**Start Date**
Replace Mercury Vapor with Sodium Vapor fixtures in public lighting	Replace 282,000 fixtures	- 34% savings - 20MW lower peak demand	CNEE/MEM Pilot project	Mar 2010
Time Change Daylight Savings Program	Energy Savings Lower capacity	- 50 GWh savings - 60MW lower peak demand	Legislative bill	Abr 2010
Change old Refrigerators	Replace 80% of old refrigerators	- Save 25% in residential refrigeration	Financing Through FONAEE	Jan 2011
Substitute industrial Electric motors	Replace 50% of Inefficient Motors	Reduce 10% Use in industrial Sector	Financing Through FONAEE	Jan 2011
Better stoves	Build 100,000 Stoves	10% reduction in use of wood	Financing Through FONAEE	Jan 2011

Source: CNEE 2009.

- Distribution of 15 million CFLs (20 Watts) to residences nationwide at a projected cost of US$22 million.
- Replacement of 282,000 mercury vapor lamps (175 Watts) in public lighting with 100-Watt sodium vapor fixtures at a cost of US$28 million. This would mean a reduction in peak capacity demand of 21.15 MW (=282,000 * 75). However, because public lighting falls under jurisdiction of the municipalities, the time frame for deployment will be years instead of months, despite the fact that the national government plans to provide financial assistance to help municipalities meet the upfront costs[65].
- Replacement of 50,000 refrigerators older than 10 years at a cost of US$15 million.
- Daylight savings implementation. In 2006 an experimental daylight savings program was enacted that reduced peak demand by 41 MW. Moreover, peak demand started an hour later but subsided at the usual time so electricity consumption fell by 28.8 GWh[66]. However, daylight savings will not adopted permanently because of public opposition due to increased crime faced by people on their way to work in the dark. In addition, the projected results were seen as marginal, so the idea has been abandoned[67].
- Training of energy efficiency professionals through seminars and lectures.

65 CNEE engineer Oscar Arriaga in personal email communication on June 16, 2011.
66 Carpio 2010
67 CNEE engineer Sergio Velazquez, personal email communication on July 20, 2011.

Figure 2.2. Impact of 3 energy efficiency projects on the daily load curve in Guatemala.



Source: Velázquez 2011

Figure 2.2 shows the projected results of some of the energy efficiency measures in the proposed energy efficiency plan *PIEE*. An approximate 190-MW reduction in peak capacity demand at a cost of US$65 million[68] implies a cost of US$342/kW. This is much less than the construction cost of new electricity generation plants of any technology.

CNEE's website states that a reduction of 250 MW in capacity demand could be attained, equivalent to the capacity of Chixoy, the largest hydroelectric plant in Guatemala, representing 20% of total generation in the country[69]. According to CNEE engineer Sergio Velazquez[70], these savings would be realized through the complete execution of the projects proposed in the *PIEE*, namely replacement of residential and public lighting and of inefficient refrigerators, as well as the transmission and distribution upgrades that will reduce losses and other inefficiencies of the current grid. Mr. Velazquez states that these are conservative estimates and that once the projects are operational, the observed savings may be even larger.

Mr. Velazquez also states that the majority of peak demand comes from public and residential lighting, and to a lesser extent from residential appliances. Commercial demand is low as most establishments close at 6 PM, and the amount of industrial activity during the evening is not considerable[71].

We will use CNEE's 250-MW figure in our Alternative PDP for Guatemala in Part 4. We will estimate that these measures can be deployed by 2017, and

68 Velazquez 2011
69 http://www.cnee.gob.gt/xhtml/usuario/ahorro.html - Accessed on July 28, 2011.
70 Personal email communication on July 21, 2011.
71 Personal email communication on July 20, 2011.

will spread the 250 MW savings over the years 2011-2017. Next, we explore the potential for further energy efficiency measures beyond the proposed by CNEE.

Potential for Further Energy Efficiency Gains

As noted in the previous section, the need for new capacity infrastructure is driven by an evening peak in demand, so now we will explore measures that would help reduce that peak beyond what's proposed by the current plan.

Public Lighting

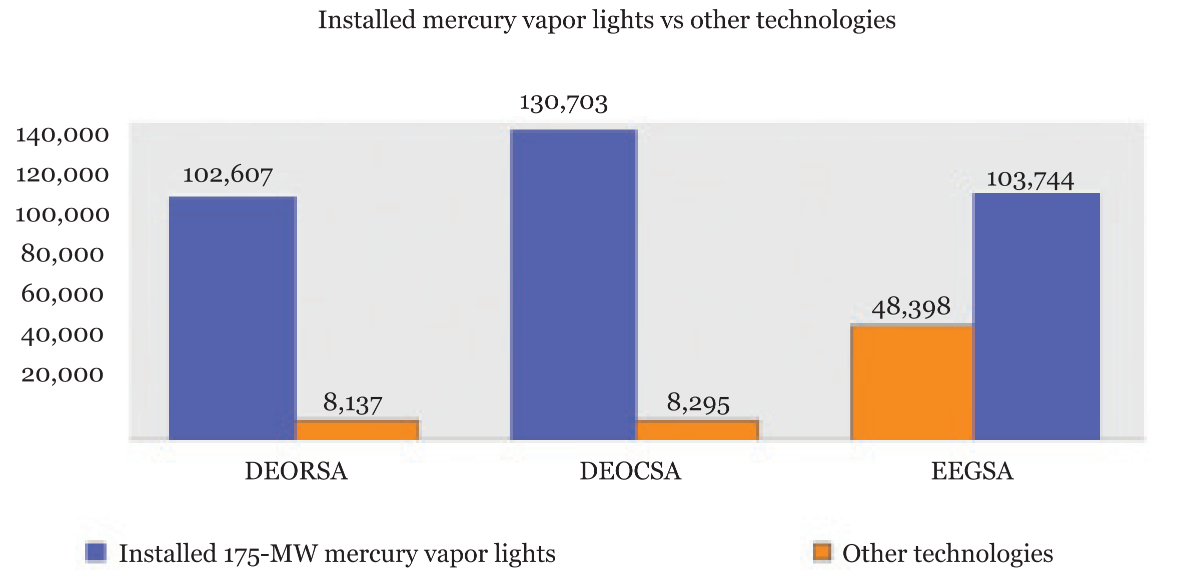
Public Lighting is an ideal candidate for energy efficiency upgrades. It is controlled by government, and the initial replacement cost can be recouped from the electricity savings. The energy efficiency plan calls for replacing mercury vapor with sodium vapor lamps, but currently available LED technology is an even more efficient solution. However, the investment needed will ultimately have to be paid for by consumers, and the payback time was deemed too long due to the current prices of LED lighting. Therefore, in the first stage, CNEE recommended the use of 282,000 sodium vapor lamps, which require a smaller upfront investment. The introduction of LEDs was left for a later stage, when prices are lower and the technology more advanced[72]. Figure 2.3 shows the current distribution of public lighting fixtures in Guatemala showing that 282,000 mercury lamps remain in operation out of a total of 428,884 lamps. Assuming all of them would be 100-Watt sodium vapor fixtures by 2016, replacing them with 58-Watt LEDs would generate an additional 18 MW of peak demand savings[73].

The added benefits of using LEDs include not only reduced electricity bills and peak capacity demand, but also a space that is more evenly lit providing increased security for streets and parking lots[74].

Although LEDs are still expensive, prices are coming down and the savings generated are significant, often cutting in half the kWh consumed. A 2008 study in the city of San Francisco by US Department of Energy and Pacific Gas & Electric[75] in which LEDs from four different manufacturers were compared side by side in street tests for quality of lighting and energy savings found that all LEDs fared better than the control High Pressure Sodium (HPS) luminaire in both categories. The tested LEDs reduced capacity demand by between 69.1% and 97% and provided between 283 kWh and 398 kWh annual savings in generation assuming 4100 hours of operation per year. These savings offset the high initial costs, and the two fixtures with better illuminance turned out

72 CNEE engineer Sergio Velazquez. Personal email communication on July 20, 2011.
73 18 MW = 428,884 fixtures x 42 Watts savings/fixture
74 Walmart reports that a single parking lot upgrade from 400-Watt Metal Halide (MH) fixtures to GE's 205-Watt LED reduced its capacity demand from 16.8 kW to 5.6 kW (a 66.6% reduction). It also provided a more uniformly lit parking lot.
75 PG&E 2008

Figure 2.3. Distribution of Public Lighting Fixtures in Guatemala



Source: Eng Sergio Velazquez CNEE

to be the better economic performers as well, with simple payback periods of 3.7 to 6.3 years for new construction and 7.4 to 10.8 years for retrofits. Another advantage of LEDs is their extended lifespans, typically five times longer than HPS[76], which reduces the O&M costs. The study concluded that at PG&E's LS-2 rate schedule of US$0.12/KWh, *annual energy savings per fixture* ranged from US$25 to US$39 depending on the brand.

Because in Guatemala public lighting is added to electricity ratepayers' bills, the efficiency gains would translate to lower electricity bills for the country's population. An IDB (2009) study also found that a significant number of streetlights were burned out, providing no illumination but still drawing electricity because the ballasts are not disabled when the lamps burn out. This means that consumers were paying for lighting that wasn't there. The extra benefit of a more efficient public lighting system is that it would put money in the pockets of consumers instead of utilities.

For the Revised PDP in Part 4, we include the replacement of 282,000 175-Watt mercury vapor lamps with 100-Watt sodium vapor lamps already lumped in with the 250-MW savings planned for by CNEE. We then add 18 MW between 2018 and 2022 representing the replacement of the sodium vapor fixtures with LEDs.

76 Lifespan of HPS lamps is usually less than 10,000 hours. Lifespan of LED lamps is 50,000 hours. Source: LED Lighting Watch. http://www.ledlightsorient.com/watch/why-led-street-lights-are-better-than-hps-street-lights.html. Accessed 7/1/11

Residential Lighting Efficiency

CNEE's plan[77] calls for the replacement of 15 million incandescent bulbs with CFLs. The savings generated contribute to the 250-MW total estimated potential. However, LEDs for residential use are also coming down in cost so we propose eventual replacement of the CFLs with LEDs. The lighting output of a 9-Watt LED is comparable to a 14-Watt CFL.

A study by the Lawrence Berkeley Laboratory on Mexico's Ilumex program[78] used a formula to estimate the reduction in capacity demand from replacing incandescent bulbs with CFLs, as follows:

Avoided Capacity = [# CFLs * W saved per CFL * 0.8]/(1-T&D loss).

The 0.8 coeficient is the *peak coincidence factor* representing the percentage of lights expected to be on at peak hours (0.8=80%); and T&D loss represents capacity losses due to transmission and distribution. Without loss of generality we can use this formula to calculate the savings resulting from the replacement of CFLs with LEDs in Guatemala by using T&D losses for the country. We will use CNEE's most recent report of 4.0% for T&D losses[79], and a saving of 5 Watts per lamp. Then the formula becomes:

Avoided Capacity = # CFLs * 5 W saved per CFL * 0.8 (peak coincidence factor) * 1/.96

Thus replacing 15 million CFLs with LEDs would yield 62.5 MW in additional peak demand reduction. This would also translate to lower electricity bills for consumers so a program to replace residential CFLs with LEDs would not only contribute to a flattening of the evening demand peak, but it would also benefit the bottom line of all Guatemalan households.

It is important to note that these savings are made more significant by the fact that Guatemala's 10% poorest households spend about 42% of their income on electricity bills and, for the next poorest 10% that value is 13%[80]. Therefore, a program that donates or subsidizes CFLs and/or LEDs effectively increases the income of the most disadvantaged Guatemalans in addition to significantly reducing demand for electricity.

In our revised PDP we include the 62.5 MW savings resulting from the replacement of 15 million residential CFLs with LEDs between 2018-2022. The replacement of incandescents with CFLs is included in the 250-MW savings already planned by CNEE.

77 *The Plan Integral de Eficiencia Energetica* - CNEE 2009
78 Sathaye et al 1993, p.16
79 CNEE 2010a, p.37
80 CEPAL 2008, p.70

Electric Showers

Laine (2008) states that electric showerheads widely used in Guatemala have a range of 3400 to 5000 Watts. A quick calculation for a typical 10-minute shower gives 0.700 kWh of electricity consumption[81]. With several people in a household, this demand for energy can add up when calculated across the country. The sum of thousands of these showerheads coming on at the same time most likely contribute to the evening peak as people return from work. Without formal behavioral studies and a survey of shower use in households in Guatemala it is impossible to calculate the contribution of electric showers accurately. However, using household data from Perez (2006), suppose that right at peak time one showerhead is on in 5% of the 238,907 households consuming more than 300 kWh a month[82]. That means 11,945 showerheads are demanding a minimum of 3 kW of capacity. This would create about 35.8 MW in capacity demand. More efficient showerheads, solar water heaters or gas-heated showers could be used to reduce the capacity demand caused by electric showers.

Because data on electric shower distribution and usage is not available, we will not include any estimates of savings in the Revised PDP. Therefore, any measures to reduce electricity demand from electric showers represent potential savings beyond those included in the final model.

Institutional Efficiency

Institutions such as universities tend to consume large amounts of electricity throughout the day. Night classes in particular mean lights and air conditioning are on. Although there are few formal reports of energy efficiency upgrades in Guatemala, institutions throughout Central America have been making energy efficiency investments with great results. Costa Rican NGO BUN-CA (www.bun-ca.org) has several efficiency case studies of universities, government buildings and hotels in multiple countries. These can be used as examples of what could happen in Guatemala if a concerted effort were applied.

Take for example the case of Universidad Tecnológica de Panama (UTP). BUN-CA reports that in 2002, the UTP administration outlined an energy-efficiency plan to manage growing electricity consumption and appointed an Energy Saving Supervisor (*Supervisor de Ahorro Energetico*). By using sensors that determined if a room was in use or not, the university was able to automate light and air conditioning control as needed. There are classes from 7 AM to 11 PM. A pilot project in 20 rooms determined that the University could save 1609 hours of electricity use and reduce AC use by 20%. This implied about US$4000 (at US$0.12¢/kWh) in annual savings for the 20 rooms and a load reduction of 17,280 Watts. The measure cost $4100 so the payback period was a little over a year. For the next 20 rooms, less expensive sensors were used so it took only 7 months to recover the US$2600 spent[83].

81 For a showerhead with an average of 4200 Watts.

82 One showerhead on in 5% of high-electricity-use households is a conservative estimate. For example, these households probably have at least 3 people taking 10-minute showers, meaning 30 minutes per household. If this shower time is spread out between, on average, 6pm and 9pm (3 hours) then the chance of a shower in operation during peak time is 0.5/3 = 17%.

83 BUN-CA 2008

Similarly, the Nicaraguan Chamber of Industry replaced incandescent bulbs with CFLs and upgraded its air conditioning units to more efficient models. The US$223 investment in lighting resulted in US$711 per year in savings and a 1.87 kW capacity demand reduction due to lighting. The US$4697 investment in air conditioning cut capacity demand by 5.60 kW[84].

Because data on institutional electricity usage is not available, we will not include any estimates of savings in the Revised PDP. Therefore, any measures to reduce electricity demand from institutions represent potential savings beyond those included in the final model.

Commercial Efficiency

Commercial establishments that remain open after dark include shopping malls, supermarkets, and stores in commercial districts. There is ample potential for energy efficiency improvements starting with changing the lighting to more efficient technology as discussed above. Other areas for improvement include air conditioning, refrigeration, heating etc.

BUN-CA's case studies describe several small hotels that have adopted simple energy efficiency measures. The Hotel del Mar in Costa Rica invested US$2,136 in replacing old air conditioning units with newer, more efficient ones, saving 15.8 MWh a year in energy use, so the investment cost was recouped in about 10 months. The energy savings represented an 18.4% reduction in total energy consumption for the year and a 22.6% drop in peak capacity demand by the hotel.

These are high percentage numbers that, if spread throughout the economy could reduce energy consumption and capacity demand significantly. The immediate savings should be enough of an incentive for business owners to make the investment, but they would need to be educated and shown convincing data to support the case. Financial tools to help managers and owners overcome the upfront costs of implementing energy efficiency measures would also help increase the adoption of efficiency policies.

Because data on commercial electricity usage is not available, we will not include any estimates of savings in the Revised PDP. Therefore, any measures to reduce electricity demand from commercial establishments represent potential savings beyond those included in the final model.

Industrial Efficiency

Although the evening demand peak is driven mostly by residential, public and commercial lighting and air conditioning, some industrial activity also continues during this time and efficiency measures would help address capacity demand. Moreover, industrial electricity consumption accounts for about a quarter of total consumption[85] in Guatemala so measures to improve industrial efficiency would contribute to an overall reduction in energy use.

84 BUN-CA 2009
85 Irungaray 2006

Because the peak demand occurs between 6 and 10 PM and utilities charge a higher fee for electricity consumed at this time[86], industries have an incentive to turn off any equipment that is not essential for operations. However, in boom times when demand for manufactured products is high, companies may run their production lines 24 hours a day to fulfill orders. In that case, any efficiency measures will help to keep peak demand low. In addition, more efficient equipment means a lower energy (kWh) consumption, which translates to lower electricity bills and greater global competitiveness.

Electric motors, air compressors and refrigeration are the main drivers of demand capacity in industry. According to the Rocky Mountain Institute[87], the practice of installing more powerful motors than is required to perform jobs adequately is common but the cost to replace them prevents their replacement by more appropriately-sized equipment. Electric motors also require a lot of electricity when they are first engaged, translating into a transient peak in capacity demand lasting less than a second. But these peaks force companies to purchase large capacity plans from utilities. High-efficiency motors with capacitors or variable frequency drives to reduce start-up current spikes have the potential to reduce both capacity (kW) and energy (kWh) demand.

Cajas (2004) reports potential savings at *Jumbo Sack de Polyproductos de Guatemala S.A.*, a packaging manufacturer in Guatemala. By replacing a 50-hp electric motor with a high-efficiency 40-hp motor with a frequency drive, the company could save 168.5 kW per motor. The cost of the new motor and drive was reported at US$7,785. These are significant savings at a very low cost (US$46/kW). It would allow the company to renegotiate its contract with the utility for a lower capacity demand tier. This in turn sends a signal to the utility that the total capacity they must supply has gone down, reducing the need for more generation infrastructure.

Amory Lovins of the Rocky Mountain Institute reports on a typical design flaw of pumping systems that do not appropriately size electric motors and pipe diameter, resulting in oversized pumps, which leads to excessive electricity use[88]. System-wide redesigns that are mindful of electricity-use efficiency can dramatically reduce capacity demand in industry at very low cost. For example, reorganizing the location of equipment so that cooling pipes run in straight lines reduces friction from 90-degree elbows and allows for the use of much smaller pumps.
Waste heat from industrial processes can also be used to power steam turbines to generate electricity. Cementos Progreso is one of the largest consumers of electricity in Guatemala[89] and is partnering with Swiss multinational company Holcim Cement Ltd to build a new plant capable of producing 2.2 million tons of cement per year. Holcim will own 20% and Progreso 80% of the plant[90].

86 Cajas 2004
87 See for example Lizardo et al 2011, p. 2 for a description of inefficient engineering practices.
88 In a presentation at Stanford University titled Advanced Energy Efficiency: Industry. Available as a video asset through http://www.itunes.stanford.edu
89 AMM 2010
90 CAD 2010

In Vietnam, Holcim Vietnam Cement Ltd will use waste heat from its kilns to generate electricity at its Hon Chong cement plant in the Mekong delta. The 6.3-MW facility will cost about US$28 million to build and maintain[91]. Although Cemento Progreso's website claims the plant will use the latest environmental safety practices, it makes no mention of using its waste heat to generate electricity. The plant is scheduled to be fully operational in 2012.

Assessing the potential for industrial efficiency is unfortunately beyond the scope of this report. It would take surveys of the actual plants to assess the efficiency of existing equipment and designs before making an estimate of the potential. We therefore only include 10 MW of cogeneration from the Cementos Progreso cement plant in our Revised PDP. Because the cement plant being built in Guatemala is comparable in size to the retrofitted Vietnamese plant, we estimate that a comparable amount of electricity could be generated at the new plant. The remaining 3.7 MW would come from similar retrofits at existing plants owned by Cementos Progreso and others.

Policy Reforms and Incentives to Encourage Energy Efficiency

One of the main obstacles to the adoption of energy efficiency measures is finding the upfront capital to finance the initial investment. In some US states, an efficiency fee is added to the electric bill and the funds are then used to promote energy efficiency measures. For example, Oregon's *Oregon Energy Trust* is funded by a 3% fee on all electric bills within the state and uses it to subsidize energy efficiency measures and renewable energy in all sectors of the economy (www.energytrust.org). Although the markets of Guatemala and the US are different, this method could be deployed to help fund energy efficiency in Guatemala.

Other regulatory mechanisms that encourage utilities to improve their customers' energy efficiency are limited by the way utilities make money and remain in business. It is therefore vital to address the way rates are designed in order to encourage energy efficiency. US regulators have been reforming the way utilities are rewarded for their services since the 1980s and 1990s with the express purpose of encouraging energy efficiency programs through demand-side management on the part of the utilities. Once an appropriate rate structure is adopted that rewards utilities for implementing efficiency measures, then it becomes in the interest of the utility to encourage and even finance efficiency measures for its customers[92].

One of the most successful tools deployed to incentivize demand-side management is what is known as *Decoupling* or *Performance-Based Revenue*. It works by decoupling a utility's revenue from the amount of electricity it sells to consumers. Under conventional regulation if actual electricity sales fall below the forecast, the utility will have less profits or even a loss, so promoting energy efficiency, green buildings or efficient appliances goes against their interests. Through a rate-adjustment mechanism, decoupling separates the utility's profits and revenue from the actual volume of electricity sold, and utilities are rewarded for promoting energy efficiency measures.

91 VBEN 2011
92 Raphals 2005

Decoupling works by allowing for a slight increase (2-3%) in the electricity rates if efficiency measures reduce total usage by more than a specified target. It also penalizes utilities by reducing its rates if usage increases beyond a threshold[93]. Since CNEE is responsible for setting electric rates, this is a viable scenario in Guatemala.

From the regulatory standpoint, demand side management has been recently introduced into the Guatemalan electricity market. In 2009, CNEE introduced the practice of *interruptible demand*, in which large users agree to reduce their load in case of excessive demand or supply problems. Large users agree to reduce demand in 1 MW blocks upon request from the utility or in response to a price signal[94].

US utilities can be used as case studies for their Guatemalan counterparts. Southern California Edison, for example, has several different programs for participating customers, particularly large industrial and agricultural users. Some of these involve measures already planned or adopted in Guatemala like temporary power interruption events at the request of the utility. But other successful approaches should be considered such as reductions in load to agreed-upon values, load shifting to off-peak hours and long-term efficiency improvements[95].

Efficiency Measures at the Generation Stage

Globally, generating losses have historically been much higher than they needed to be. Plant design techniques have increased plant efficiency in the last decades so that less primary fuel is needed to generate a kWh of electricity. For the case of Guatemala, existing facilities need to be assessed for their efficiency and upgraded wherever possible before new facilities are built from scratch. A repowering of old plants could improve their efficiency dramatically by replacing old generators with modern, combined-cycle gas turbines housed in the same facilities as the old equipment. However, the potential for this repowering needs to be assessed by a study of specific power plants. As of 2008, Guatemala had proven natural gas reserves of 2.96 billion m^3, and none of it had been tapped[96].

Cogeneration (discussed above in the case of the cement industry) can strongly increase overall efficiencies by making productive use of waste heat and steam for industrial processes, or even for powering cooling systems for large commercial buildings with cooling needs.

Efficiency Measures at the Distribution Stage

There are several ways to control demand at the distribution stage through demand response mechanisms that reduce demand during peak hours. Currently, a significant percentage of Guatemala's electricity generating capacity is reserved for peak consumption. If peak demand can be reduced, it would result in a lower need for additional capacity.

93 PSN 2010
94 CNEE 2009a
95 SEC 2010
96 CIA 2010

One way to reduce peak demand is to charge for electricity according to the time it is used, something called Time of Use (TOU) or Real-Time Pricing (RTP). RTP has only recently been introduced in Guatemala[97]. Real-time pricing allows utilities to actually flatten out the peaks in demand during the course of the day by charging a premium rate during peak hours, and thereby encouraging facility managers to reduce their load during those hours and shift their loads to low-demand times, typically 10 pm to 6 am.

Although demand response will come of age as smart meters are brought to scale in the market it is already a very useful tool in controlling peak demand. Smart meters are being widely deployed in the US right now and they are the first step in creating the "smart grid", a distribution network with embedded automated controls that allow flow of information in both directions and is supposed to help match demand and supply more closely. So as the Guatemalan government starts its grid expansion, one question to keep in mind and a factor to watch out for is *how much smarter is the grid becoming?* If the current expansion is being carried out by deploying state-of-the-art transmission technology it might be a good thing, as it may lay the foundation for a future smart grid to be operational in Guatemala. But if all the investment is being done using legacy technology that is out of date, maybe it should be rethought.

Leveraging demand response allows for the introduction of renewable sources of energy like solar and wind - which don't consistently generate power. "Today, when the sun doesn't shine, the utility may ramp up a fossil fuel plant — not a very green strategy. But, with a smart grid, if renewable power isn't available because it is overcast, the utility can call upon demand response rather than firing up a fossil fuel plant"[98]. Although this does not negate the need for dispatchable power plants, it may well reduce their usage, bringing about a reduction in fuel use and pollution.

Conclusions

The analysis shows that the potential for energy efficiency savings is significant in all sectors of the economy. Moreover, several measures with short payback periods remain unused. A comprehensive approach that educates managers and owners of the potential improvements to their bottom line brought about by energy efficiency measures, and financing mechanisms to help overcome the upfront costs would go a long way to promote adoption. The efficiency plan currently awaiting approval in Congress is but a beginning, laying out some initial goals along with the bureaucratic blueprint for carrying out the actual measures that will eventually bring about a flattening out of electricity demand. The IDB is preparing a loan package worth US$100 million for Guatemala to be used in funding efficiency measures. CNEE has begun a public awareness campaign to bring about some of the behavioral changes

97 CNEE 2008a
98 Lorenz 2009

that entail significant savings such as adoption of CFLs, proper placement of refrigerators in homes and turning off of lights in unused rooms. However, a comprehensive plan with guaranteed funding and long-term goals can ensure Guatemala's energy security at a much smaller economic, social and environmental cost than building new generating infrastructure.

In public lighting, serious consideration should be given to switching the whole system to LED fixtures. Cash-strapped municipalities should be assisted in securing the funds needed to finance the high initial capital cost of LED fixtures. Likewise, incentives should be given to the deployment of LED lighting in households, commercial buildings, stores, and hotels along with their parking lots.

Retrofitting refrigeration and HVAC systems in both commercial and industrial applications can also provide ample and inexpensive savings. Lines of credit along with efficiency label programs and education campaigns would help bring about the deployment of more efficient appliances. Updates in industrial design that would diminish friction in cooling pipes, reduce the size of required electric pumps and motors, and utilize natural or cogenerated cooling and heating all have immense potential to be inexpensive solutions.

All of the above most likely add up to a significant percentage of Guatemala's current installed capacity but a formal survey of buildings, equipment and practices is needed to assess the actual savings potential. The *Ley de Eficiencia Energetica* and the *PIEE* currently awaiting approval from Congress could create the environment that would in turn make such surveys, studies and assessments possible and in the interest of individuals and businesses. It is of fundamental importance that the plans be approved and the funding be made available that is needed to conduct such assessments and implement efficiency measures that would reduce the need for more capacity infrastructure.

Table 2.2 summarizes the potential energy efficiency savings identified in the analysis. These are the conservative values included in the Revised Power Development Plan (PDP) proposed in Part 4 of this report, and *do not* represent the total energy efficiency potential for the country. The first line represents the 250-MW CNEE estimates of potential efficiency savings[99].

99 http://www.cnee.gob.gt/xhtml/usuario/ahorro.html

Table 2.2. Proposed Deployment Schedule of Energy Efficiency Measures for Guatemala

Proposed Energy Efficiency Deployment Schedule for Revised PDP												
Energy Efficiency												
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
CNEE Plan (250 MW)	20	30	40	50	50	60	50					
Streetlight Sodium to LED								3	5	5	5	
Residential CFL to LED								8	12.5	14	14	14
Solar Water Heaters						1	1	1	1	1		
Cogeneration (Cement)					10							
Cumulative EE Savings	20	**50**	90	140	200	261	312	324	342.5	362.5	381.5	395.5

Source: See text for references. (These values do not represent total efficiency potential for Guatemala)

3 Renewable Energy Potential

3 Renewable Energy Potential

Guatemala has significant untapped renewable energy potential in the form of wind, solar, geothermal, biomass and small hydro sources. In addition, a few studies have been conducted on methane from landfills as a potential source for electricity generation that could also help alleviate the chronic garbage problem. Worldwide, one of the main barriers to renewable energy deployment is that optimal sites for wind, solar and geothermal tend to be far from the load centers, meaning new transmission lines must be built which raises the total cost of the electricity produced. Guatemala's case is special in that the sites of sources of renewable energy lie relatively close to the main load centers in the southwest portion of the country. For example, Solar and Wind Energy Resource Assessment (SWERA) wind maps show the highest quality sites to be located within 100 miles of the capital.

Each source of renewable power has its advantages and disadvantages. The intermittent nature of wind and solar means they must be part of an electricity supply system that includes dispatchable power (generally hydropower, gas turbines, or other thermal energy sources) for those times when the wind doesn't blow and the sun doesn't shine. Geothermal and biomass on the other hand are dispatchable sources that can be relied on for baseload power.

Guatemala does have in place an incentive for renewable energy projects: Law Decree 52-2003. It provides incentives in the form of tax breaks, including exemption from import tax on equipment and services during the implementation phase, and a tax-exemption for project income on the first ten years of operation. The Decree also provides for 10 years of tax exemption on renewable energy investments for commercial and agricultural enterprises[100]. In November 2010, CNEE enacted Resolution 268-2010 allowing small generators to obtain long-term contracts beyond the spot market[101]. This allows small generators to enter into Power Purchase Agreements (PPAs) with distributors and/or large consumers on terms that guarantee a steady long-term return on investment.

In this part we will first assess the levelized cost of renewable energy in general, and then explore the country's renewable potential in the form of wind, solar, biomass, geothermal, small hydro and garbage.

100 Guatemala 2003
101 Prensa Libre 2010

Levelized Costs of Renewable Energy

Although renewable technology has higher up-front capital costs in the construction of the generation infrastructure, over the life of the plant, renewables can be competitive with the most cost-effective fossil fuels including coal and natural gas. The **levelized cost of energy (LCOE)** is calculated by dividing total costs over the lifespan of the plant by total electricity generated, yielding a $/MWh ratio. Renewables offer the additional advantage of financial stability in the face of fluctuating fossil fuel costs because fuel costs are generally zero or very close to zero. Biomass does have some fuel costs attached but they don't exactly correlate with fossil fuel and still represent a hedge against fossil fuel price volatility. Once the infrastructure is built, the long-term costs amount to fixed and variable O&M plus return on capital, and these are predictable[102].

The actual price that coal electricity sells for in Guatemala is private information negotiated between the parties to each PPA, but the average price of coal electricity is reported to be US$0.09435/kWh[103]. This is an average of the baseload long-term contracts and the peak-time running reserve sales. We offer it here as a basis for comparison with the prices of renewable sources with potential in Guatemala described in the following sections.

Because field research is beyond the scope of this study and not much data is available for Guatemala, we will use examples from other countries wherever possible, including Costa Rica and the US, adapting costs where possible to the Guatemalan context. We will now turn to an analysis of each renewable source of energy as it applies to Guatemala. This analysis will then be used when we present a Revised Power Development Plan in Section 4.

Capital (Overnight) Costs

The overnight capital costs represent the cost of building a new plant from scratch to be fully operational, including all necessary accessories and catalysts loaded. The US National Renewable Energy Laboratory and National Energy Technology Laboratory have published reports on the costs of energy production. Table 3.1 lists some of the reported capital costs for different technologies.

Distributed Generation

Distributed generation is defined as electricity produced locally where it is consumed. It may be small or large, connected to the grid or not. For example, a large sugar producer that uses its biomass waste to generate electricity to power its facilities may sell its excess electricity to the grid when it produces

102 See for example NREL 2011
103 CNEE engineer Oscar Arriaga in personal email communication on June 27, 2011.

Table 3.1. Overnight Capital Costs for some Electricity Generation Technologies (in US$/kW). (NGCC = Natural Gas Combined Cycle)						
Overnight Capital COsts (2007$/kW)						
Source	**Coal**	**NGCC**	**Biomass**	**Wind**	**Hídrica**	**Geotérmica**
NREL[1]						
Low Estimate	$1,700	$800	$2,100	$1,500	n/a	$2,000
High Estimate	$2,100	$1,000	$3,600	$2,250	n/a	$5,000
NETL[2]						
Average Costs	$2,010	$718	n/a	n/a	n/a	n/a
ETSAP-IEA[3]	**Hídrica**					
Low Estimate	$1,750					
High Estimate	$6,250					

Sources: 1) NREL 2010, pp 24-32. 2) NETL 2010, p.9. 3) ETSAP 2010

more than it uses or buy from the grid when it needs more than its generating capacity can supply. Also, an isolated community may invest in a small hydro or solar PV system and build its own mini-grid completely disconnected from the national grid.

Distributed generation is one of the fastest growing segments of the electricity generation industry. Distributed generation makes economic sense by locating generation near distributed fuel sources (for example, biomass residues from agro-industry) or near places where steam, heating (or steam-driven cooling) are needed. Grid-connected distributed generation can help reduce transmission costs by producing electricity at sites nearby where it is used. And off-grid distributed generation can often be cost-effective compared to extending transmission and distribution lines to remote areas.

González (2008) reports that in the past, the radial (centralized) distribution network was desirable because there was increased efficiency with large electric generators. But technological advances of the past decades have improved efficiency of small generators to the point that there is little difference in efficiency between large and small generators. Thus, distributed generation is today a feasible alternative to centralized grids, saving money and energy by eliminating capital investments in transmission lines and reducing distribution losses.

The *Norma Técnica para la Generación Distribuida Renovable – NTGDR* was enacted into law in 2008 with the specific aim of enabling Guatemalan small energy producers, up to 5 MW, to sell their excess electricity to the grid. The rule does not specify a price for the electricity sold and there are no mentions of any type of a Feed-in-Tariff. Any person or business may generate and sell electricity to INDE, from a single-family grid-connected home PV system to a 5-MW sugar cane boiler turbine. Since the law's passing, 7.61 MW of distributed generation capacity has been connected to the grid[104].

104 CNEE 2010, p. 27

Wind

Wind power consumes no fuel, has no emissions, and the energy required for construction is usually recouped within a few months. Windpower is a nice match for existing hydropower. Hydropower's dispatchability complements windpower's intermittency. Conversely, when the wind blows, electricity generated in wind farms substitutes for hydropower, keeping valuable water behind the dam. In Guatemala, this is especially the case during the transition between the dry and wet seasons in May and June[105] when hydropower reservoirs are at their lowest levels and winds are most reliable[106].

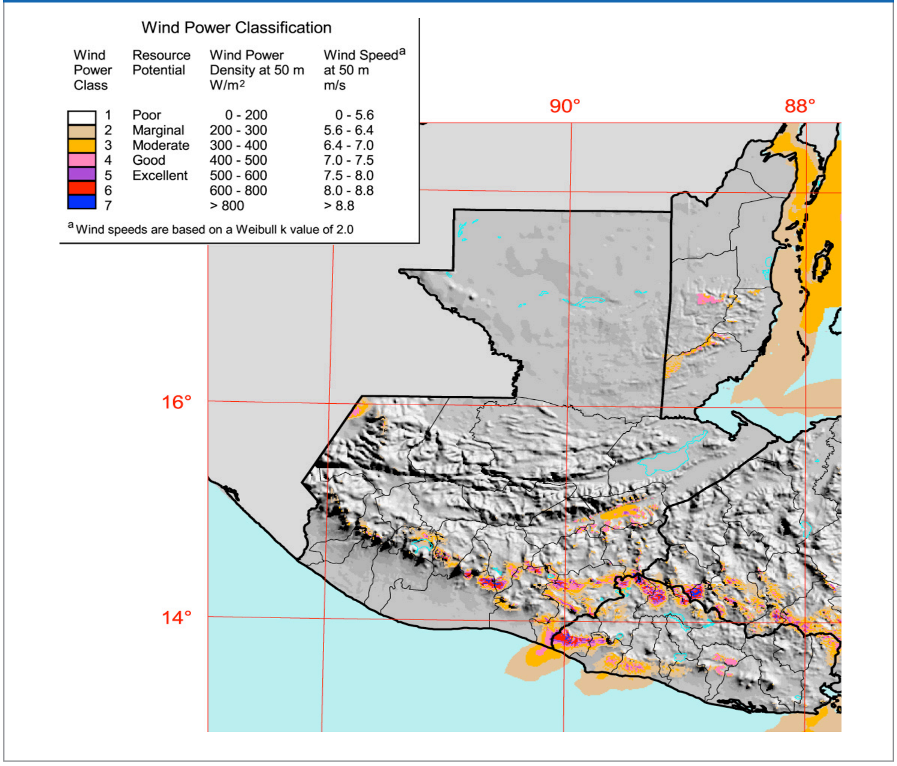
The country's Ministry of Energy and Mines (MEM) estimates wind energy potential of up to 7,000 MW[107], but more conservative estimates of the economically viable potential have placed it at between 400 and 700 MW[108]. As of this writing there are no utility-scale wind farms in operation in Guatemala. However, a few projects are under development and may be operational in the short-term. The first project likely to be completed is Santo Antonio El Sitio (50 MW) in Santa Elena Barrillas, Huehuetenango expected to go online in May 2014[109]. This wind farm consists of 16 turbines and its operator - Centrans Eneergy - that the proposed facility could be built for US$125 million should it be awarded a contract during from PEG1-2010[110]. This implies a cost of wind energy in Guatemalan of US$2250/KW.

Another project recently granted approval is **Viento Blanco** (21 MW), a utility scale project located in Escuintla also near the major load centers, which includes a substation and a 1.2-km transmission line that will link it to the grid at the La Palin sub-station[111]. CNEE approved resolution 194-2010 granting rights-of-way and permits for the project, setting April 2011 as the start of operations. The project is currently in feasibility studies and is one of the bidders in the 2012 tender PEG1-2010. There are no easily available cost estimates for this project.

Another project under consideration is **Buenos Aires**, a 15-MW wind farm located about 35 km southwest of Guatemala City. Test wind towers have been installed since 2005 to measure wind speed at various locations with promising potential for wind generation according to the Solar and Wind Energy Resource Assessment (SWERA) maps[112]. The SWERA wind maps (Figure 4.2) indicate that most of the "excellent" wind generation potential is located in the Southwestern foothills between Escuintla and Jutiapa. This is close to the capital city, not only the largest concentration of consumers of electricity in the country, but also a region crossed by transmission lines and dotted with transforming sub-stations. Much of the new proposed transmission lines of the *PET 2008* would go through this territory thus facilitating transmission of wind energy generated here.

105 CNEE 2010a, p.73
106 Gallegos and York 2010
107 MEM 2007
108 See for example Gallegos and York 2010; or Jacobs 2011
109 Alavarez 2012
110 *El Periodico* 2011
111 CNEE 2010, resolution 194-2010
112 MEM 2008

Figure 3.1. Wind Map from SWERA for Guatemala.



Source: SWERA (2010)

Another area of ample generation potential according to SWERA wind maps is the Eastern region of Zacapa. The government has proposed several infrastructure projects in this region, namely port expansions in Puerto Barrios and a transportation corridor linking the eastern seaboard with the Pacific coast ports, aiming to compete with the Panama Canal for transport of goods between the Atlantic and Pacific Oceans. This corridor would include a railroad, a 4-lane highway, a multipurpose pipeline[113], and is expected to also bring in industrial parks, mining operations and cement factories. As a whole, these are expected to provide synergies in transmission capacity, supporting infrastructure, and electricity demand that will lower costs of windpower there.

Capital costs of wind farms have come down significantly in the last few years, and given zero fuel costs and relatively low O&M costs, utility-scale wind is a viable option to meet growing demand. Brenes (2010) reports on two of Costa Rica's wind farms: *Tejona* (20 MW) had capital costs of $1250/kW and *PE Guanacaste* generates electricity at about US$0.09/kWh cost.

These values compare well with the US estimates of costs provided by the National Renewable Energy Laboratory (NREL). According to NREL, the capital cost for onshore wind in the US ranges from $1200 to $2300 per kW, with the mean at $1630 per kW[114]. Financing tends to be expensive in Guatemala so it is likely that the capital costs for building utility scale wind farms there

113 Alvarez 2009
114 2006$, NREL 2011

are comparable to the US, with financing costs offsetting potential lower construction labor costs and government incentives. Thus, in the absence of any working wind farms, in order to estimate a levelized cost of wind energy in Guatemala, we will use the conservative value of $2000/kW for the capital costs of wind power.

NREL (2011) reports that in the US the capacity factor for onshore wind averages 39% (with a range of 22% to 47%). Costa Rican and Honduran wind farms have capacity factors between 40-50%[115]. Because the best sites are still available for use in Guatemala with SWERA maps showing several sites with wind speeds well above 7.0 m/s at 50m, we conservatively assume a 40% capacity factor for wind power in Guatemala for the foreseeable future. NREL reports average US windpower fixed O&M costs at $35/kW/yr. Given that labor rates in Guatemala are considerably lower than in the US, we will use $30/kW/yr as a conservative estimate of average O&M costs for wind farms in Guatemala. Again, these values correlate well with those observed in Costa Rica.

With these values, NREL's *Levelized Cost of Energy Calculator* gives a levelized cost of wind power at US$0.075/kWh[116]. This assumes a 10% discount rate and a project amortization period of 20 years. Although these assumptions may not be perfect fits for Guatemala, it does show wind energy costs are down to a level that makes wind a competitive alternative[117].

At the household and village scale, wind power can be used for distributed generation in isolated areas such as mountain villages or the regions of Petén, Alta and Baja Verapaz, Huehuetenango and San Marcos. Several small villages that are currently off the grid could benefit from small wind turbines, as the technology can be quickly and cost-effectively deployed, bypassing the need to build long-distance transmission and distribution lines. In China, for example, over 200,000 small wind turbines provide electricity for remote households[118]. In Guatemala, Engineers Without Borders and San Francisco-based Catapult Designs have teamed up with Quetzaltenango-based Appropriate Infrastructure Development Group to develop low-cost, pico wind turbines that can be built entirely in Guatemala[119].

The Revised PDP will include the projects Santo Antonio (50 MW by 2013), Viento Blanco (20 MW by 2014) and Buenos Aires (15 MW by 2016). It will also include 75 MW of other wind power, including utility scale and distributed resources that we believe should come online as 25 MW by 2017, 25 MW by 2019 and 25 MW by 2021. However, because of the low capacity factor of wind farms, the total available wind power at peak times is much smaller than the nameplate capacity. Therefore, wind projects will be derated to 25% of their nominal nameplate capacity. This reduces the 130-MW projected total nameplate capacity to an effective 32.5 MW *at peak demand time*. However, deployment of wind farms should not be hindered by their low capacity factor. Costa Rican and Honduran wind farms operate at a range of 40-50%

115 See for example Borchgrevink 2004 or REVE 2009.

116 NREL 2011a

117 CNEE engineer Oscar Arriaga (personal email communication) reports that the average cost of electricity from coal in Guatemala is US$94.35/MWh. This is an average cost and includes baseload and peak rates paid to coal-based generators.

118 Zhang and Qi 2011

119 http://catapultdesign.org/projects/wind-turbine

Table 3.2. Proposed Deployment Schedule of Wind Capacity in Guatemala

Wind Capacity Deployment Schedule													
Wind	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	0	0	0	50	70	70	85	110	110	135	135	160
Location													
Buenos Aires							15						
Viento Blanco					20								
Santo Antonio				50									
Alternativas Eólicas								25		25		25	
	Installed Nameplate Capacity	0	0	50	70	70	85	110	110	135	135	160	160
Capacity Factor	25%												
Total Effective Wind Capacity		0	0	12.5	17.5	17.5	21.25	27.5	27.5	33.75	33.75	40	40

Prepared by A. Koberle

Wind Capacity Deployment Schedule													
Wind	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	0	0	3.75	3.75	8.75	13.75	13.75	20	20	26.25	26.25	32.5
Location													
Buenos Aires			15										
Viento Blanco					20								
Santo Antonio						20							
Alternativas Eólicas								25		25		25	
Capacity Factor	25%												
Total Effective Wind Capacity		0	3.75	3.75	8.75	137.5	137.5	20	20	26.25	26.25	32.5	32.5

Prepared by A. Koberle

capacity factor and a 20-MW project can generate close to 100 GWh of electricity per year[120].

The table 3.2 shows the deployment schedule used in the Revised PDP.

Biomass

The potential for electricity production from agricultural biomass in Guatemala is large as the country has a strong agro-industrial sector with considerable biomass waste products. Sugar mills already use their biomass waste to generate electricity in Guatemala with an effective installed capacity of about 300 MW[121].

120 See for example Borchgrevink 2004 or REVE 2009.

121 AMM 2011

During the harvest season (Nov-May) they can generate up to 25% of Guatemala's electricity by burning sugarcane bagasse and other residues[122]. These biomass generators in sugar mills were built in the 1980s and 1990s when the price of electricity in the country was much higher than it is today. Several of the long-term contracts signed at the time will be expiring in the next 2-5 years and will most likely be renegotiated at much lower rates. A 2009 CEPAL study reports that ACI[123] set a goal to reach 500 MW of bagasse generation capacity by installing more efficient boilers, the use of quoted condensation turbines and improvements to the sugar refining process[124]. A December 2010 Quiñones report (2010a) states that two mills (Pantaleón and Magdalena) placed orders for the new equipment and that the 500 MW target will be met by 2016.

Sugar mills can only use bagasse during the harvest season from November through May. Several have been using bunker oil to keep generating electricity in the remainder of the year. However, Quiñones (2010) reports that the upgrades listed in CEPAL (2009) will also allow the sector to shift to coal generation in the off-season. On a cautionary note, there are reports of sugar mills also cutting down trees to burn in their boilers especially during the off-season, causing widespread deforestation, and river and wetland degradation[125].

Besides sugarcane biomass, corn makes up a large percentage of the agricultural production and is concentrated in the northern departments of Petén, Alta Verapaz, Quiché, Huehuetenango and San Marcos[126]. These areas can benefit from distributed generation of electricity, as they are largely poor, rural areas disconnected from the grid. Coffee plantations cover the largest area in agricultural Guatemala with 273,000 ha[127]. However, most of its residue is used as fuel to dry the coffee beans after harvest, so the potential there is likely small. Further studies are needed to assess the electricity generating potential of these biomass resources.

There is also significant potential for small-scale distributed biomass generation. By using small-scale biodigesters in an experimental Costa Rican dairy and pig farm, Lansing et al (2008) found that 27.5 m^3/day of methane can be produced from the manure of 5 cows and about 6 m^3/day from 40 pigs. This amount of biogas was used to meet 82% of the farm's morning electricity peak demand of 12.9 kW. The complete system cost under US$40,000 and reduced organic matter discharges by about 90%. Such systems could add up to a significant capacity if deployed in distributed generation programs throughout Guatemala. An accurate study of the distribution of dairy and pig farms would be needed to determine their actual electricity-generating potential.

For the biomass potential in the Revised PDP we will use the initial target of 400 MW by 2014 reported by ACI[128], rising to 500 MW by 2016 as reported by Quiñones (2010a). AMM (2011) reports both nameplate (371.5 MW)

122 AMM 2010, CEPAL 2009
123 ACI = Asociación de Cogeneradores Independientes (Independent Cogenerator's Association)
124 CEPAL 2009, p. 44
125 Casasola 2010
126 Fuentes Lopez et al 2005
127 Garcia 2004
128 in Ortiz 2008

and effective (300.17 MW) installed capacity of sugar mills. Thermal biomass generating plants function much the same way as coal plants do, so when there is enough fuel available during the harvest season, they operate continuously. However, because of the lack of feedstock in the non-harvest season, the Revised PDP assumes a 45% capacity factor for sugar mills. The effective capacity for existing and future sugar mill plants will be derated by that amount, reducing the 500 MW to an effective 226 MW. It is important to note that this aggressive derating neglects the contributions of the sugar mills to generate capacity by running on coal during the non-harvest season. Therefore, the Revised PDP is not including about 200 MW of coal-fired electricity that will be available once sugar mills complete the coal retrofit explained above. This derating also obscures the fact that for six months out of the year, sugar mills will provide up to 500 MW of renewable energy.

Table 3.3. Proposed Deployment Schedule of Biomass Capacity in Guatemala

Sugarmill Biomass Capacity Deployment Schedule													
Biomass	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	300	300	350	372	392	442	482	502	502	502	502	502
Location													
Ing Costa Sur			50										
Other Mills				22	20	50	40	20					
	Nominal Installed Capacity		350	372	392	442	482	502	502	502	502	502	502
Capacity Factor	45%												
	Effective Biomass Capacity	135	158	167	176	199	217	226	226	226	226	226	226

Prepared by A. Koberle

Sugarmill Biomass Capacity Deployment Schedule (MW)													
Biomass	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	300											
Location													
Ing Costa Sur			50										
Other Mills				22	20	50	40	20					
	New Biomass Subtotal		50	22	20	50	40	20	0	0	0	0	0
Capacity Factor	45%	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
	Effective Biomass Capacity	135	158	167	176	199	217	226	226	226	226	226	226

Prepared by A. Koberle

Because of the lack of available data on dairy and pig farms it is difficult to estimate the potential for distributed small-scale biogas generation. Therefore, we do not include the development of distributed biogas projects in dairy and pig farms throughout the country. Distributed biogas projects can be quickly deployed but require the education of farmers to reap the potential benefits.

The Table 3.3 summarizes potential for utility scale sugar mill capacity.

Garbage

Electricity from landfills can be generated by collecting biogas emitted from the decomposition of garbage and/or through incineration. When collected, Guatemala's garbage ends up in landfills. A 2003 study on solid waste management in Guatemala quoted the 2002 census stating that the country produces 8,203,123 metric tons of solid waste per year (equivalent to 22,474 metric tons per day). Of this total, about 72% of residential trash is collected in the capital city while only 23% is collected elsewhere in the country[129]. Of the garbage that is NOT collected, 36% is burned, 17.5% is buried, almost 44% is thrown anywhere and the remainder has "other" fates[130].

The landfills produce a large amount of methane that can be used for electricity generation. The Villa Nueva landfill receives 300 metric tons of garbage per day, the decomposition of which creates enough methane gas to generate an estimated 1 MW of electricity. The larger Zona 3 landfill in Guatemala City is seven times larger and receives some 3,500 metric tons of garbage everyday. The methane produced there is enough to generate an estimated 4 MW of electricity[131]. There is so much methane being produced at the landfill that clouds of methane gas above the landfill catch fire several times a year causing damage and casualties[132]. Capturing the gas to produce electricity would help reduce these dangers.

There are a few municipal landfills receiving large amounts of trash daily that would be prime candidates for landfill gas projects: Quetzaltenango (80 tons/day), Huehuetenango (15 tons/day) and Puerto Barrios (13 tons/day)[133]. A landfill gas thermal plant dispatched as a "peaker" plant could command high prices for its electricity, providing revenue for cash-strapped municipalities.

The National Renewable Energy Laboratory (NREL) estimates that landfill gas plants in the US have capital costs averaging $2300/kW, a capacity factor of about 83%, and Fixed O&M costs of about US$111/kWh/yr[134]. Assuming Guatemala O&M is a bit less than the US, say $100/kWh/yr, plugging the US values into NREL's *Levelized Cost of Energy Calculator* yields a levelized cost of energy of $0.045/kWh, a very competitive rate particularly if used to produce electricity during peak hours.

In the Revised PDP, we will include 4 MW by 2017 from a landfill-gas project in the capital city's dumps.

129 IIA 2003, p.4
130 IAA 2003, p.19
131 Benavante 2008
132 USAID 2011
133 IIA 2003, p. 20
134 2006$, NREL 2011

Small and Micro-Hydro Power

Much of the damage from hydropower is caused by large dams and reservoirs that impede the passage of fish, and flood habitat and people's lands. Micro-hydro projects can generate electricity with less environmental destruction. Opportunities exist in Guatemala for environmentally-friendly hydropower at a variety of scales, from household-scale turbines (hundreds of watts), to community-scale systems of tens of kilowatts, to grid-connected projects that generate megawatts.

Fundación Solar reports the construction of a 165 kW micro-hydro project that serves the 2,500 people of Chel, Xesayi and Las Flores, located about 300 km northwest of Guatemala City. The project was community built, with each family providing 80 days of labor between 2003 and 2007 in exchange for a connection to the system. The availability of this power turned Chel into a regional hub with flourishing small businesses including butchers, ice factories, blacksmiths and a library. Chel is now a center of social and economic services to adjacent villages[135].

XelaTeco installed a 16-kW micro-hydroelectric system for the remote Comunidad Nueva Alianza. The finished system provides 40 families (approx. 200 people) with clean and renewable electricity. The same group helped build a 75-kW hydroelectric system at La Fe y Chantel that powers agricultural machinery, with plans to extend their mini-grid to the homes of the community's 100 families.

Because it is hard to estimate micro-hydro potential and any projects installed in remote areas would not substitute for grid-connected electricity, the Revised PDP does not include any micro-hydro capacity. However, the technology remains a relatively low-impact solution to both remote and grid-connected areas.

Geothermal Power

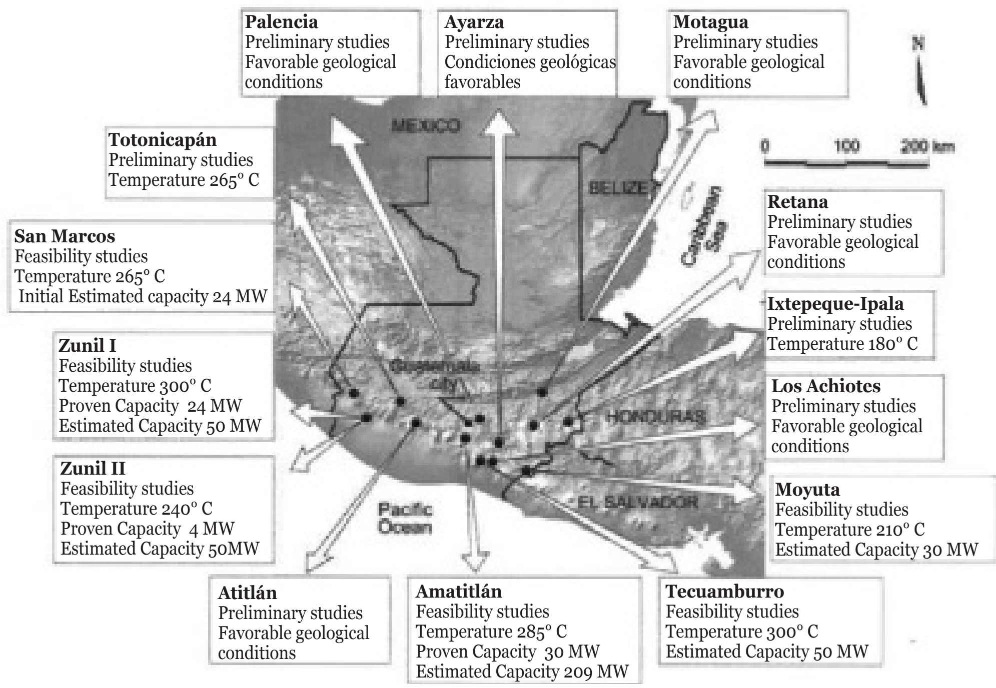
Estimates of geothermal power potential in Guatemala vary from 400 MW[136] to 4,000 MW[137]. The Ministry of Energy and Mines claims the country's economically-viable potential to be 1,000 MW[138]. Nearly all of this potential remains untapped[139].

The illustration in Figure 3.8 has been reproduced in several publications, websites and presentations and seems to be accepted as a reliable indication of the country's geothermal potential.

The interest in developing Guatemalan geothermal potential has been

135 Fundación Solar Energy Program - http://www.fundacionsolar.org.gt
136 Jimenez 2010; INDE 2007
137 Geothermal Energy Association
138 MEM 2010
139 Meisen and Krumpel 2009, MEM 2007

Figure 3.2. Geothermal sites in Guatemala



growing. In April 2010, US Geothermal Inc was awarded concession to build the *El Ceibillo* plant in Amatitlán. The plant will have a nominal capacity of 25 MW and cost an estimated US$50 million[140]. CNEE reports in its *Perspectivas 2010*[141] that a 50 MW geothermal project should come online by 2014. *PEG2 2012* foresees a total of 300 MW of geothermal capacity coming online between 2017 and 2026[142].

Table 3.1, showing planned geothermal projects by the private sector, was provided by CNEE engineer Oscar Arriaga[143].

Proyecto	Potencia MW
ZUNIL	24
Ortitlan	25.2

As a renewable source of energy, geothermal power plants have the advantage of having baseload capability and thus can provide reliable firm capacity. As opposed to wind and solar which are intermittent in nature geothermal plants are one of the most reliable sources of electricity, with capacity factors typically between 80% and 90%[144]. This is better than hydropower, which

140 El Periódico 2010
141 CNEE 2010, p. 73
142 MEM 2012, p.2
143 Personal email communication
144 NREL 2011

Table 3.4. Existing (top) and planned geothermal projects in Guatemala.		
Proyecto	**Potencia MW**	**Fecha de entrada en operación**
Geotérmica El Ceibillo	25	01/07/2014
Geotérmica Moyuta	44	31/12/2018
Tecuamburro-Ortemala 1	50	01/09/2014
Geotérmico Tecuamburro	44	30/06/2017

Source: Provided by CNEE Eng. Oscar Arriaga in personal email communication

Table 3.5. Geothermal Capacity Deployment Schedule

Proposed Deployment Schedule of Geothermal Capacity in Guatemala

Geothermal	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	36	36	36	36	111	111	111	155	199	199	199	199
Proyect Name													
Tecuamburro-Ortemala 1					50								
El Ceibillo					25								
Tecuamburro								44					
Moyuta									44				
Other alternatives													50
	Nominal Installed Capacity	36	36	36	111	111	111	155	199	199	199	199	249
Capacity Factor	85%												
Total Effective Geothermal Capacity		30.6	30.6	30.6	94.35	94.35	94.35	131.75	169.15	169.15	169.15	169.15	212

Source: Ing. Óscar Arriaga/CNEE en un e-mail de comunicación personal Preparado por A. Koberle - Vea texto para las fuentes

is subject to seasonal flow regimes. Geothermal plants do have social and environmental impacts, and therefore need to be sited appropriately, with comprehensive evaluations of their impacts, consultations with potentially affected communities, and plans in place to ensure that all impacts are managed appropriately.

The main issue with developing geothermal potential is the high upfront capital costs of developing the resource. High costs of drilling plus the risk premiums of drilling "dry" wells make upfront costs of developing geothermal resources hard to finance. However, once an appropriate well is found, then the levelized cost of geothermal electricity is comparable to hydropower, with low O&M costs and no fuel costs. Other potential obstacles to geothermal development include availability of transmission lines close to geothermal sites, and the relative unfamiliarity with the technology compared to thermal or hydropower.

In our Revised PDP, we will include the four planned projects listed by Eng. Arriaga, plus an additional 50 MW to come online between 2018 and 2022.

Geothermal plants operate with an average capacity factor of 85% so we derate all new geothermal nameplate capacity by that amount. The table below shows the deployment schedule of geothermal capacity used in the Revised PDP.

Solar Power

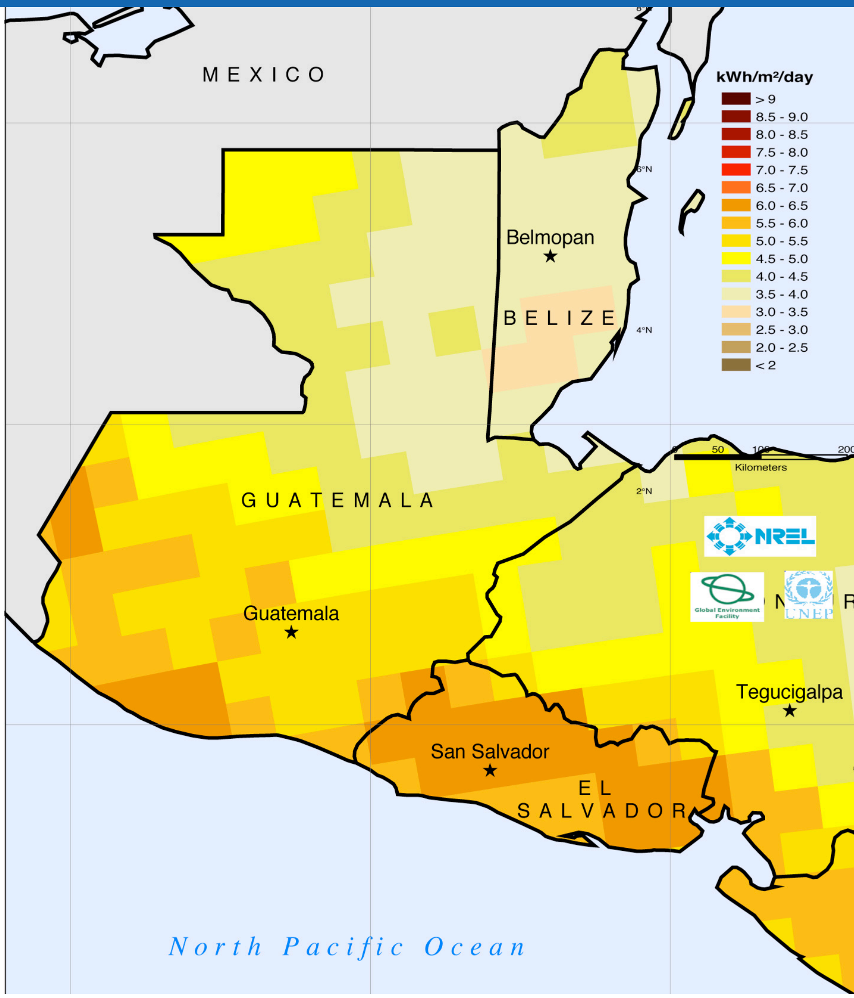
According to the Solar and Wind Energy Resource Assessment (SWERA) solar maps, Guatemala's average irradiation is 5.3 kWh/m^2/day[145] (Figure 3.6). Solar is currently more expensive than other renewable energy sources discussed in this chapter. Increasing efficiencies and lower processing costs are leading to declining costs, however. Solar module costs have decreased from $6.07 per watt in 1990 to $1.85 per watt in 2010[146]. In 2011, modules are available for as low as $1 per watt[147].

Small photovoltaic (PV) systems have been successfully deployed in remote areas in Guatemala that have no access to grid electricity. Fundación Solar and its partners (notably ADIM) have successfully provided electricity to several small remote villages using PV technology. In 2004, USAID partnered with Fundación Solar and several other local NGOs to launch 180 photovoltaic systems in six rural communities in Guatemala's northern Quiche region, for household, commercial and community use[148].

For the Revised PDP, we estimate the deployment of distributed solar PV at a rate of 20 MW per year between 2019 and 2022. These numbers are aggressive by today's standards, but as the cost of solar PV continues to drop it will become increasingly attractive to leverage the high levels of solar irradiation in Guatemala. This is particularly the case if the government launches incentive programs for individuals and businesses to install rooftop solar panels. The solar energy generated during the day translates to less water being released for hydropower generation that would in turn be available to meet the evening peak for more days out of the year.

145 MEM 2008a
146 http://www.exposolar.org/2011/eng/center/contents.asp?idx=94&page=4&search=&searchstring=&exposolar=C
147 At these rates of decline, parity with marginal grid power costs in Guatemala is not unlikely by 2020.
148 USAID website: http://www.usaid.gov

Figure 3.3. Solar Irradiation Map for Guatemala



Source: SWERA 2010a

Conclusions

The foregoing analysis shows that the potential for renewable sources of electricity generation other than large hydro is abundant in Guatemala and a comprehensive energy plan should take into account and seek to develop that potential. The benefits include both economic and environmental gains, and further guarantee the country's energy security.

Table 4.1 summarizes the potential for each category of renewable energy to be included in the Revised PDP presented in the next section. The listed totals include current installed capacity already in operation.

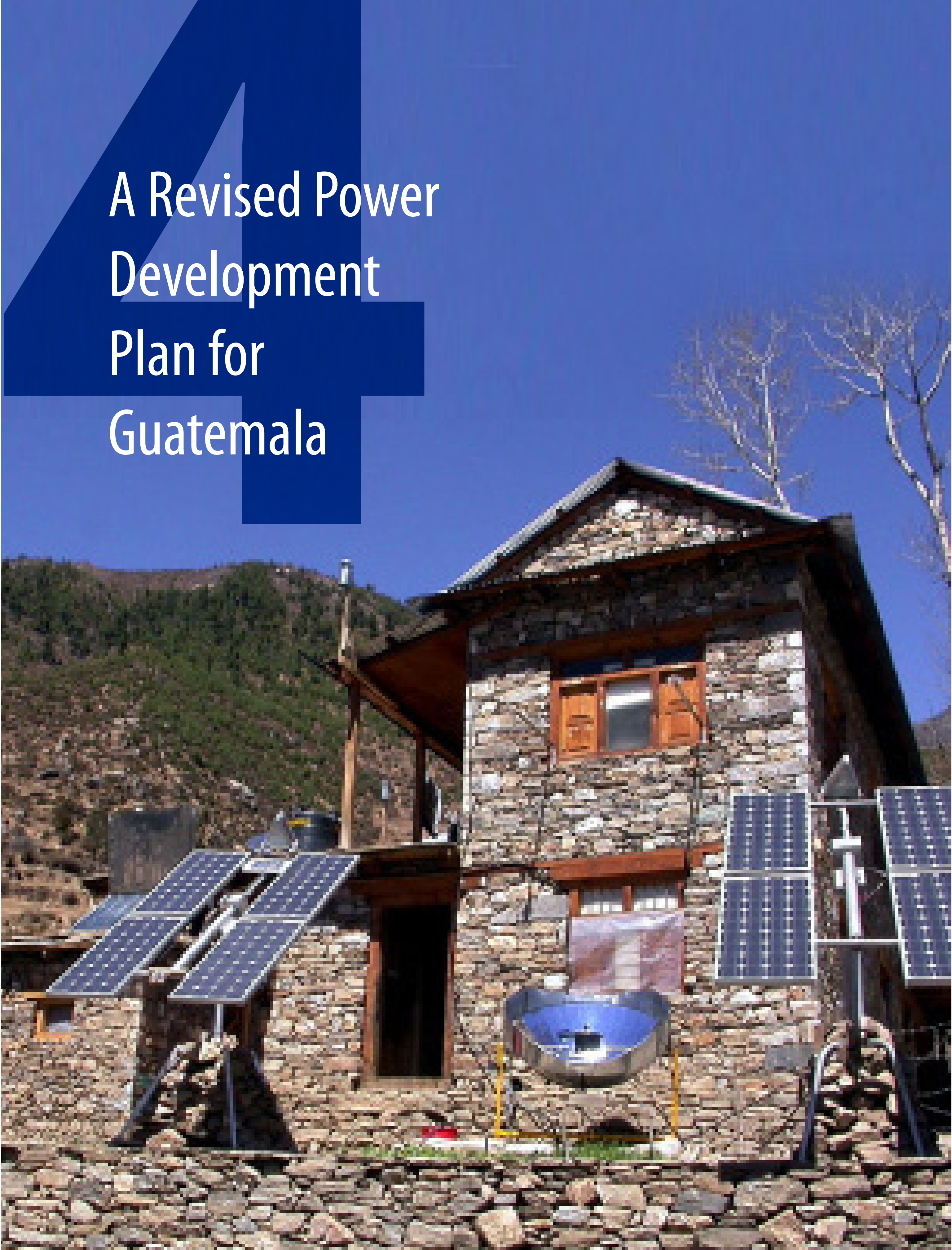
Table 3.6. Proposed Renewable Energy Deployment Schedule for Revised PDP

Geothermal	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	36	36	36	36	111	111	111	155	199	199	199	199
Proyect Name													
Tecuamburro-Ortemala 1					50								
El Ceibillo					25								
Tecuamburro								44					
Moyuta									44				
Otras alternativas													50
	Installed Nominal Capacity	36	36	36	111	111	111	155	199	199	199	199	249
Capacity Factor	85%												
Total Effective Geothermal Capacity		30.6	30.6	30.6	94.35	94.35	94.35	131.75	169.15	169.15	169.15	169.15	212
Wind	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	0	0	0	50	70	70	85	110	110	135	135	160
Location													
Buenos Aires							15						
Viento Blanco					20								
Santo Antonio				50									
Alternativas Eólicas								25		25		25	
	Installed Nominal Capacity	0	0	50	70	70	85	110	110	135	135	160	160
Capacity Factor	25%												
Total Effective Wind Capacity		0	0	12.5	17.5	17.5	21.25	27.5	27.5	33.75	33.75	40	40
Biomass	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	300	300	350	372	392	442	482	502	502	502	502	502
Location													
Ing Costa Sur			50										
Otros Ingenios				22	20	50	40	20					
	Installed Nominal Capacity		350	372	392	442	482	502	502	502	502	502	502
Capacity Factor	45%												
	Total Effective Biomass Capacity	135	158	167	176	199	217	226	226	226	226	226	226

Table 3.6. Proposed Renewable Energy Deployment Schedule for Revised PDP

Distributed Generation	**Year**	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	0	0	0	0	0	4	4	4	4	24	44	64
Type	**Location**												
Rellenos Sanitarios	Ciudad de Guatemala					4							
Solar Fotovoltaico	Distributed									20	20	20	20
Total Effective Distributed Capacity		0	0	0	0	4	4	4	4	24	44	64	84
Total Renewable Energy (MW Effective to the Grid)		**166**	**188**	**211**	**288**	**315**	**337**	**389**	**427**	**453**	**473**	**499**	**562**

4 A Revised Power Development Plan for Guatemala



4

A Revised Power Development Plan for Guatemala

Part 1 of this report addressed the pitfalls of relying on GDP growth forecasts to make future electricity demand projections while downplaying the importance of energy efficiency measures in curbing the need for new power infrastructure. Part 2 addressed the potential for energy efficiency gains in Guatemala from technical, regulatory and policy measures, as well as from supply and demand side measures. Part 3 examined the existing potential for renewable sources other than large hydroelectric dams. We now combine the results into a revised Power Development Plan (PDP) for Guatemala.

As explained in Part 1, Guatemala's electricity capacity demand grew by an average of 50 MW per year between 2001 and 2010. The analysis in Part 1 also showed that CNEE's projections consistently overestimate electricity demand growth. The GDP-based capacity demand projections in the *PEISG 2008* were so inflated that even the lowest-case scenario proved to be 11% higher than observed values by 2010. Even the revised projections offered in the *Perspectivas 2010* publication proved overstated by the end of the year they were published. For our alternative PDP we use the growth figure of 50 MW per year as the business as usual scenario. We then subtract potential energy efficiency savings and add a 15% reserve margin to arrive at a *generation required* figure for each year between 2011-2022.

To generate a revised power development plan we used the following premises:

- Capacity Demand in Guatemala has grown linearly at a steady 50 MW per year since 2001 and we used this number as a projected business-as-usual growth estimate for the period 2011-2022 from which we subtracted potential energy efficiency savings.
- Potential for Energy Efficiency savings has just started to be tapped and remains high, particularly with measures that address the daily evening peak driven in large part by residential, commercial and public lighting. Such measures include deployment of efficient lighting fixtures (CFLs, LEDs) and regulatory instruments like *interruptible demand*. CNEE estimates the potential for energy efficiency savings at 250 MW. This value is attainable through various measures and our model assumes they will be deployed over the period 2011-2016 as described in Part 2. Savings from these measures plus other additional potential will be treated as tantamount to new capacity.
- Any generating plants currently under construction were included as available capacity from the date they are to come online[149].

149 As listed in CNEE 2010a and Alvarez 2011

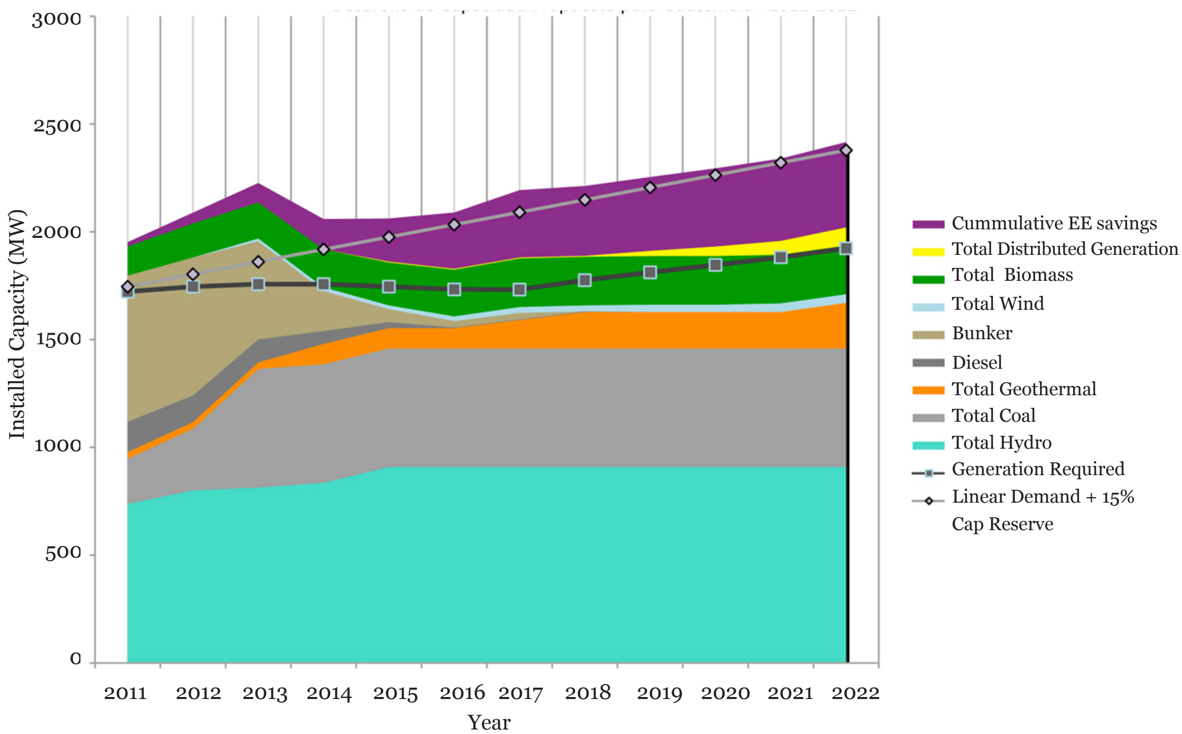
- Phasing-in of renewable sources other than hydropower was included conservatively, reflecting investment interests currently circulating in the country.
- Other Distributed Renewable Generation (DRG) includes landfill gas, dairy- and pig-farm bio-gas, and distributed Solar PV. Solar PV capacity will not be included until 2019, when PV prices are expected to become competitive. We suggest the introduction of 20 MW per year of distributed Solar PV between 2019-2022, but the likelihood of such deployment will depend largely on the introduction of financial and/or regulatory incentives such as Feed-in-Tariffs, tax credits etc, to help overcome investment barriers.
- A 50-MW Geothermal project to come online by 2014 was used in one of the generation scenarios in CNEE's *Perspectivas de Mediano Plazo*[150] and was included here, along with four other projects listed by CNEE engineer Oscar Arriaga planned to become operational between 2014 and 2018. These are Tecuamburro-Ortemala 1 (50 MW by 2014), El Ceibillo (25 MW by 2014), Tecuamburro (44 MW by 2017) and Moyuta (44 MW by 2018).
- Nameplate capacity of all energy projects (renewable and fossil-fueled) were derated by their estimated capacity factors so that the resulting PDP reflects effective capacity to the grid. Capacity factors were estimated for large hydro (45%), coal (96%), geothermal (85%), wind (25%) and biomass (45%)[151].
- Capacity for solar PV and landfill gas were not derated. It is assumed that the nominal nameplate value required will be deployed to meet the effective megawatts included here. This makes our estimates for these technologies more aggressive but given the small quantities involved and the long deployment schedule suggested, we feel these are attainable with the proper incentives from public administrators.
- The 200 MW available for import from Mexico is not included in the model but its availability can be used to balance loads and meet peaks whenever necessary.

Figure 4.2 shows the graphed results of the Revised PDP. The grey line is the business-as-usual scenario of linear growth at the rate of 50 MW per year. The black line is the generation required to meet the 50-MW capacity demand growth minus energy efficiency gains, *and* adding a 15% reserve margin. The purple area represents cumulative energy efficiency savings as described in Part 2. Therefore, for each year, the black line is equal to the grey line minus the purple area plus 15%.

150 CNEE 2010a, p.73

151 Derating biomass installed capacity by 45%, reduces the 2015 nameplate capacity of 500 MW to an effective 226 MW. It is important to note that this aggressive derating neglects the contributions of the sugar mills to generate capacity by running on coal during the non-harvest season, as well as the fact that they operate on biomass at about 85% capacity factor during the harvest season. Therefore, the Revised PDP is not including about 200 MW of biomass/coal-fired electricity that will be available once sugar mills complete the coal retrofit as explained in Part 3. Regardless, the results show that even without considering this available capacity, peak demand in Guatemala can be met by existing and under-construction generation plants with implementation of the 250-MW potential for energy efficiency stated by CNEE.

Figure 4.1. Proposed Capacity and Demand Projections for Guatemala 2011-2022



Proposed Capacity and Demand Projections for Guatemala 2011-2022

The graph shows that with a concerted effort to deploy energy efficiency measures and renewable sources other than large hydropower, Guatemala will have enough installed capacity to meet demand plus a 15% reserve margin. The hydro and coal generation projects already under construction and slated for completion by 2015 should provide ample low-cost firm capacity to allow for more reliable generation, lower-cost electricity, and for the phasing out of diesel and bunker plants. With the amount of baseload capacity thus increased, the development of other renewable sources such as geothermal, wind, and distributed PV should follow. The availability of the 200 MW of derated biomass/coal and the 200 MW available for import from Mexico means there is even more capacity available than suggested by the graph and further contributes to the strength of the argument for a freeze on new infrastructure projects.

The proposed energy efficiency savings and renewable source deployment suggested here are conservative estimates of the total potential. Energy efficiency programs in particular could reduce electricity in all sectors of the economy at much lower costs than building new generation infrastructure, whether renewable or fossil-fueled. Comprehensive industrial efficiency programs that design factories with a systemic approach that minimizes the size of electric motors and pumps can reduce peak capacity demand at a fraction of the price needed to construct new generation plants. Public, residential and commercial lighting retrofits and refrigerator replacement can also produce significant savings. Regulatory measures and financing mechanisms should be made available to assist businesses and individuals overcome the high upfront capital costs that may otherwise prevent them from making investments in energy efficiency.

Before any new generation projects are approved for construction, the most obvious and realistically priced energy efficiency measures should be given serious attention. There should be a call for bids aiming to fulfill building upgrades, streetlight conversion to LEDs, and refrigerator replacement programs, just to name a few possibilities. As the new coal and large hydropower projects come online, the government and CNEE can start phasing out the expensive diesel- and bunker-fired thermal plants and feel confident that cheaper, more reliable electricity will be available to meet medium term demand. Immediate attention should then be given to aggressive energy efficiency programs, along with ways to finance them and see them through. We suggest a freeze in approvals of new generation infrastructure projects for five years while energy efficiency programs are pursued in earnest. Only after aggressive energy efficiency programs have been implemented should new generation projects be given consideration. By that time, new generation and storage technologies may become available and costs will be lower for renewables, meaning a different playing field that is more likely to be better aligned with the realities of electricity generation in the 21st century.

Appendix

Alternative Power Development Plan for Guatemala using energy efficiency and renewable energy sources that are not large hydropower.
Every time that a list of capacity factors is given, the values reflect the actual capacity that goes to the grid.

Guatemala - New Capacity Pipeline+Energy Efficiency=Reduced demand and excess capacity													
Hydroelectric	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Capacity Factor = 45%	Existing	701	738	801	814	836	909	909	909	909	909	909	909
	Location												
Santa Teresa	Alta Verapaz	19.6											
Palo Viejo	Quiché		80										
La Helvetia/ SDMM			6.8										
Sulin	Alta Verapaz		3										
Panam			6.9										
El Cobano			7										
El Manantial			35										
Finca Lorena					23								
El Renace 2						162.5							
Las Ánimas				10									
Cuevamaría				9.3									
El Volcan					26								
San Cristóbal				10									
Bellavista 2		63											
Total Hydro		738	801	814	836	909	909	909	909	909	909	909	909

Guatemala - New Capacity Pipeline+Energy Efficiency=Reduced demand and excess capacity												
Coal	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Capacity factor = 96%		133	218	298	573	573	573	573	573	573	573	573	573
	Location												
Las Palmas 2		85											
Jaguar Energy				275									
ESI			80										
	Nominal Capacity	218	298	573	573	573	573	573	573	573	573	573	573
Total Coal	Effective Capacity	209.3	286.1	550.1	550.1	550.1	550.1	550.1	550.1	550.1	550.1	550.1	550.1
Geothermal	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Capacity Factor = 85%	Existing	36	36	36	36	111	111	111	155	199	199	199	199
	Location												
Tecuamburro-Ortemala 1					50								
El Ceibillo					25								
Tecuamburro								44					
Moyuta									44				
Alternativas Geotérmicas													50
	Nominal Capacity	36	36	36	111	111	111	155	199	199	199	199	249
Total Geothermal	Effective Capacity	30.6	30.6	30.6	94.4	94.4	94.4	131.8	169.2	169.2	169.2	169.2	211.7
Wind	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Factor de Potencia = 25%	Existing	0	0	0	12.5	17.5	17.5	21.25	27.5	27.5	33.75	33.75	40
	Location												
Buenos Aires							15						
Viento Blanco					20								
Santo Antonio				50									

Guatemala - New Capacity Pipeline+Energy Efficiency=Reduced demand and excess capacity													
Wind	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Alternativas Eólicas								25		25		25	
Capacity Factor	= 25%												
TotalWind		0	0	12.5	17.5	17.5	21.25	27.5	27.5	33.75	33.75	40	40
Biomass	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Capacity Factor = 45%	Existing	300											
	Location												
Ing Costa Sur			50										
Otros Ingenios				22	20	50	40	20					
Factor de Potencia	45%												
Total Biomass		135	158	167	176	199	217	226	226	226	226	226	226
Distributed Generation	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
	Existing	0	0	0	0	0	4	4	4	4	24	44	64
	Location												
Rellenos Sanitarios						4							
Solar PV										20	20	20	20
Total Distributed Generation		0	0	0	0	4	4	4	4	24	44	64	84
Total Diesel	181	141	124	107	60	28	3	3	3	0	0	0	0
Total Bunker	700	678	640	455	185	60	30	30	0	0	0	0	0
Total Installed Capacity		1932.05	2038.765	2136.35	1919.15	1861.775	1828.525	1881.175	1888.575	1911.825	1931.825	1958.075	2020.575
Demanda Lineal	1468	1518	1568	1618	1668	1718	1768	1818	1868	1918	1968	2018	2068
Energy Efficiency													
Año	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Plan PIEE/CNEE (250 MW)		20	30	40	50	50	60	50					

Guatemala - New Capacity Pipeline+Energy Efficiency=Reduced demand and excess capacity													
Energy Efficiency													
Alumbrado Público Sodio a LED									3	5	5	5	
Residencial CFL a LED									8	12.5	14	14	14
Calentadores de Agua Solar							1	1	1	1	1		
Cogeneración (Cemento)						10							
Cumulative Energy Efficiency Savings		20	50	90	140	200	261	312	324	342.5	362.5	381.5	395.5
	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Linear Demand - EE		1498	1518	1528	1528	1518	1507	1506	1544	1575.5	1605.5	1636.5	1672.5
Linear Demand + 15% Cap Reserve		1746	1803	1861	1918	1976	2033	2091	2148	2206	2263	2321	2378
Needed Generation		**1723**	**1746**	**1757**	**1757**	**1746**	**1733**	**1732**	**1776**	**1812**	**1846**	**1882**	**1923**
Year		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Excess Capacity		209	293	379	162	116	95	149	113	100	86	76	97

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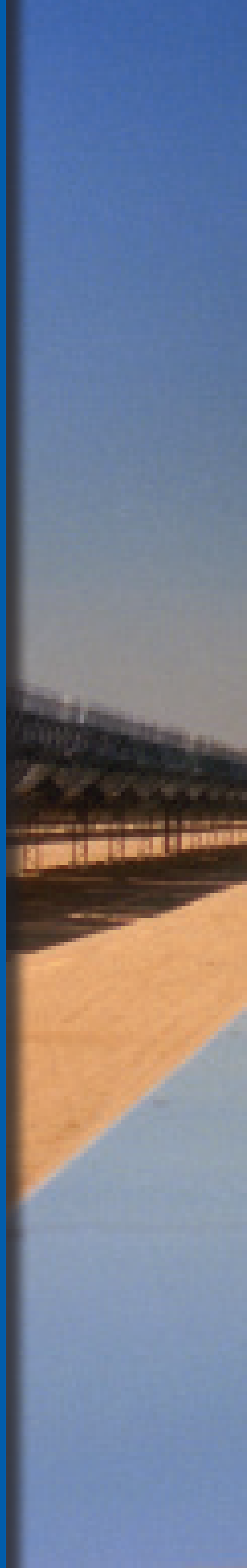

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