Nam Theun 2 Hydropower Project (NT2)

Impact of Energy Conservation, DSM and Renewable Energy Generation on EGAT's Power Development Plan (PDP)

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DISCLAIMER

This report was prepared as an independent assessment of the economic potential for energy conservation, DSM and renewable energy generation in Thailand by the year 2011. The report examines available information on the technical, economic, and achievable potential for DSM and renewable energy resources within the study time frame. It is important to note that it is beyond the scope of this study to pass judgment on the NT2 project. The study does not analyze or assess issues related to the decision to proceed with NT2, such as the assumptions embedded in the Thai demand forecast and EGAT's priority in selection of available power plant resources.

The findings, interpretations and conclusions expressed herein are those of the author and do not necessarily reflect the views of the World Bank.

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ACRONYMS

CSE	cost of saved energy
DEDE	Department of Alternative Energy Development and Promotion
DEDP	Department of Energy Development and Promotion (former name of DEDE)
DSM	demand-side management
ECCT	Energy Conservation Center of Thailand
EE	energy efficiency
EGAT	Electricity Generating Authority of Thailand
ENCON	energy conservation (i.e. Energy Conservation Promotion Fund and Act)
EPPO	Energy Policy and Planning Office
ESCO	energy service company
GEF	Global Environment Facility
GWh	gigawatt-hour
IIEC	International Institute for Energy Conservation
IPP	Independent power producer
kWh	kilowatt-hour
M&E	monitoring and evaluation
M&V	measurement (or monitoring) and verification
MEA	Metropolitan Electricity Authority
MEPS	minimum energy performance standard
MW	megawatt
NEPO	National Energy Policy Office (former name of EPPO)
PE	primary energy purchased from NT2; considered non-firm
PEA	Provincial Electricity Authority
PDP	Power Development Plan (by EGAT)
PV	photovoltaic
RE	renewable energy
RPS	renewable portfolio standard
SE	secondary energy purchased from NT2; considered non-firm
SPP	small power producer
THB	Thai Baht
USD	U.S. dollars
VSPP	Very Small Power Producers

EXECUTIVE SUMMARY

This study assesses the achievable economic potential for energy conservation, DSM, energy efficiency (EE) and renewable energy (RE) resources by the year 2011. The World Bank commissioned this study as part of its due diligence regarding the economic merit of the Nam-Theun 2 hydropower project in Lao PDR

This study relies on published studies, review of government targets, and interviews with experts to develop an independent estimate of the achievable potential for DSM and renewable energy resources in the time frame of 2011. It concludes that there are substantial additional resources that are not accounted for in the current demand forecast (January 2004) and Power Development Plan (2004).

The table below summarizes the estimated energy and demand resources available from DSM and renewable energy resources, and compares the size and cost of these resources with the estimated output and costs of NT2.

Comparison of Commercially Viable and Achievable Resource Sizes and Commercial Costs

Resource Type	**Achievable Amount of Resource in 2011**		**Average Commercial Cost of Supplied Energy**
	Energy (GWh/yr)	**Peak (MW)**	**(THB/kWh)**
NT2 at plant	NA	995	
NT2 delivered to EGAT customers in Thailand	**5,636**	**920**	**2.3**[1]
DSM/Energy Efficiency	11,181	2,207	0.92
Firm Renewable Energy	1,943	274	1.54
Subtotal for DSM/EE and Firm RE	**13,124**	**2,481**	**< 1.88**[2]
Amount of DSM/EE included in the August 2002 demand forecast	6,314	982	NA
Amount of DSM/EE and Firm RE not included in August 2002 demand forecast and PDP, respectively.	***6,810***	***1,499***	***< 1.88***
Additional NON-Firm Renewable Energy that is commercially viable and practically achievable	3,310	1,195	2.13

A careful accounting of the realistically potential of DSM, energy efficiency, and firm renewable energy resources within Thailand indicates an achievable amount of 1,499 MW of DSM/EE and firm RE resources – beyond what is included in the existing power development plan (PDP) -- at a commercial cost less than NT2. If non-firm RE resources are included, this adds an additional 1,195 MW of non-firm RE capacity.

By comparison, the output of NT2 is rated at 920 peak MW. ***If the average demand growth assumed in the August 2002 demand forecast of approximately 1,500 MW per year is accurate, the DSM/EE and firm RE resources could delay the needed commissioning of the NT2 project for approximately one year.***

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1 Segal 2004

2 THB 1.88/kWh is the commercial cost of electricity delivered to the Thai grid from NT2. It is therefore the cut-off above which firm RE resources would not be cost-effective compared to NT2-supplied electricity. For DSM/EE resources, which are provided at the customer's facility, they could actually be cost effective up to THB 2.3/kWh, which is the commercial cost of NT2 electricity delivered to EGAT customers in Thailand.

SECTION 1. BACKGROUND

1.1 OBJECTIVE OF THE STUDY

In the course of its due diligence on the Nam-Theun 2 (NT2) Project, the World Bank ("the Bank") has been reviewing the Electricity Generating Authority of Thailand's (EGAT's) Power Development Plan (PDP) from the point of view of ascertaining whether NT2 power (about 1,000 MW, 5,500 GWh/annum) is indeed required by the Thai system by the projected commissioning date of 2010. In this regard, the Bank wanted to assess the achievable potential for Thailand's initiatives at promoting energy conservation, demand-side management (DSM) and renewable energy generation in the time period when NT2 is proposed to come on line.

EGAT's PDP takes into consideration what are currently believed to be reasonably achievable levels of savings due to DSM and generation from small power producers (SPPs). In order to assess the reasonableness of the official projections, the World Bank commissioned this review by an independent consultant of what could be achieved and how it could be realized.

The limited time frame and scope of this project (one person-month of input) has necessitated a desk review and analysis of existing materials. The consultant has reviewed available reports and materials on DSM and renewable energy policies and programs for Thailand over the past decade.

The estimates of achievable potential takes into consideration institutional, financial and other constraints. The estimates account for past experience implementing DSM at EGAT, additional experience and plans for implementation of energy efficiency at the Department of Alternative Energy Development and Efficiency (DEDE) and EPPO (Energy Policy and Planning Office).

1.2 METHODOLOGY AND COST COMPARISONS USED IN THIS STUDY

Since this study compares the cost of EE and RE resources to the cost of NT2, it is important to be clear about the benchmark used and the rationale. Economic costs exclude distorting factors and transfers such as taxes, subsidies, sunk costs, etc. Commercial costs are the essentially the selling price of the product in the market. *Since the purpose of this study is to evaluate how much EE and RE resources the market can be cost-effectively implemented by a certain date, the consultant has chosen to use the commercial cost values as benchmarks.*[3]

For the renewable energy analysis, it should be stated from the outset that – unlike DSM/EE resources, which are mostly cost-effective using either commercial or economic criteria – many of the RE resources do not pass either commercial or economic criteria. Nonetheless, in order to be thorough, this study has tried to carefully indicate the author's best estimates of the commercial and economic costs of the RE resources. *The commercial analysis for RE screens for only those RE resources that pass the commercial cost-effectiveness criteria.*

1.3 ORGANIZATION OF THE REPORT

[3] The DSM/EE cost-effectiveness estimates in this report are based on commercial costs, since estimates are based on market prices and not enough information is easily available to do economic analysis. However, since there are not significant overall subsidies in provision of power to Thai customers; since there are no major market distortions taxes or transfers involved; and since the author's assumptions include overall (i.e. societal) costs of efficiency improvements, then commercial cost effectiveness should approximate economic cost effectiveness for DSM/EE measures.

Section 2 provides a brief discussion of external costs ("externalities") of electricity generation and their relation to economic assessment of options.

Section 3 estimates the extent of the DSM/EE resource. Two approaches are used, in order to instill more confidence in the final results. In Section 3, the consultant presents a review and analysis of the potential for DSM and energy efficiency using *a sector-based analysis*.

Section 4 presents a parallel attempt to estimate an achievable level of DSM resources: by adding up the targets of the existing and planned government DSM and energy-efficiency programs, and then discounting the targets to reflect institutional and other barriers to achieving the targeted peak and energy savings.

Section 5 presents a summary and analysis of the potential for renewable energy.

Section 6 covers several issues related to, but not central to primary objective of the study. These issues include SPP regulations, cogeneration, and the variability of the demand forecast itself.

Section 7 presents the overall conclusions of the study and assesses the size of the achievable DSM and renewable energy resource.

SECTION 2. EXTERNALITY COSTS AND ECONOMIC ANALYSIS OF DSM, EE AND RE COMPARED WITH OTHER OPTIONS

Rigorous economic analysis of electricity options requires consideration of the full costs and benefits of using the resource, i.e., on the private as well as the external costs[4] and benefits of resource use. The economic value added from renewable energy and energy efficiency derives primarily from electricity produced (or saved in the case of energy efficiency), and is thus comparable across technologies, keeping in mind important distinctions between firm, non-firm power and the nature of the demand curve.

The economic costs, however, are more difficult to compare. While production costs or commercial prices can be determined within a reasonable degree of certainty (and are analyzed in the following sections), externality costs are more difficult to determine. In the case of electricity generation, external costs (or "externalities") include costs such as death and lost productivity due to illness caused by air pollution, damage to buildings from SO_2, damages from global warming, habitat loss from flooding, or damage from mining and transportation of fuels. In most cases, the affected goods are not traded in a market and their values are not directly identifiable.

In this study, the economic values do exclude taxes and subsidies to the extent identifiable. However, the available values of externalities for various renewable and energy efficiency sources used in Thailand are not sufficiently well-based to be adopted in this report. On the other hand, World Bank studies conclude that externalities associated with NT2, amount to less than 5% of the economic project cost.[5] *Therefore in the economic comparisons of various energy technologies and sources, externality costs are excluded from discussion.* Nonetheless, it is noted that externality credits should in principle be assigned to EE and RE resources.

The following sections discuss economic and/or commercial potential for energy efficiency and renewable energy.

[4] External costs "occur when the production or consumption decision of one agent affects the utility of another agent in an unintended way, and when no compensation is made by the producer of the external effect to the affected party." (Perman et al.,. 1999).

[5] Robert Mertz, World Bank. Personal communication. February 2005.

SECTION 3. DSM AND EE POTENTIAL ANALYZED BY SECTOR

3.1 INTRODUCTION

The potential for DSM and energy-efficiency resources is presented as the economic and institutionally achievable potential for savings due to energy conservation and DSM in the residential, commercial, and industrial sectors. The analysis includes best estimates of the costs for achieving the economic and achievable potential estimates. Since the power plans and much of the analysis has been carried out in the time frame of 2011, and since the NT2 project is scheduled to come on line in 2010, this analysis examines the potential for DSM and energy efficiency (EE) measures through the year 2011.

Based on the above analyses, the Consultant presents an opinion on the maximum practicably achievable and economically justifiable values of capacity and energy savings that the Bank should consider as a scenario in its analysis of EGAT's PDP.

While much progress has been made in Thailand over the past decade, the potential for increased efficiency in new homes, appliances, buildings, and factories is indisputably huge. And the economics are quite favorable -- a huge portion of the EE potential in any country is always the least cost service option. However, it is extremely difficult to make estimates of the capacity to develop the technical and financial programs to *actually deliver* the investments and actions to save energy. The estimates in this report are based on the author's experience working in Thailand and other Asian countries over the past 15 years. In order to encourage an open discussion about these "delivery barriers", the author has tried to make all assumptions about achievability as transparent as possible. It was beyond the scope of this study to provide more detailed discussion and analysis of the delivery barriers for the various energy-efficiency technologies and programs.

3.2 COST EFFECTIVENESS

Since DSM resources are delivered directly to the end user, the economic potential of DSM should be based on a cost of saved energy less than the utility's marginal cost of electricity *delivered to the customer*. In the case of this analysis, the point of comparison should be the supply resource in question, which is the NT2 project. Table 1 shows the both commercial and economic costs of electricity from NT2. *As noted earlier, the benchmark for comparison in this study will be commercial costs.*

Table 1. Commercial and Economic Costs of Electricity from NT2 Project

	Costs (THB/kWh)
COMMERCIAL COSTS	
Cost of electricity generated from NT 2 dam	1.644
Cost of NT2-designated transmission (from the border to the Thai grid)	0.24
Cost of electricity delivered to the Thai grid	1.884 [a]
Cost of T&D in Thailand to customer	0.416 [b]
Commercial Cost of electricity delivered to Thai customer	**2.30**[b]
ECONOMIC COSTS	
Levelized Economic Supply Cost to the Thai grid	1.08[a]
Cost of T&D in Thailand to customer	0.416
Economic Cost of electricity delivered to the Thai customer	**1.50**

[a] World Bank 2004; [b] Segal 2004; estimated using T&D percentage from above calculation in commercial costs.
Note: assumes THB 40.0 = USD 1

3.3 LITERATURE REVIEWED

The consultant reviewed information from previous studies concerning the potential for energy savings in the industrial and commercial sectors of Thailand. Several primary information sources were used: IIEC's extensive energy library (of more than 2,500 volumes)[6]; the Energy Policy and Planning Office (NEPO); the Department of Alternative Energy Development and Promotion (DEDP); the Electricity Generating Authority of Thailand; and the Asian Institute of Technology (AIT). In order to direct the search, we developed three critical questions for screening information.

1. Does the report describe the range of energy efficiency measures at the building/facility level in Thailand ?
2. Does the report indicate the level of energy savings expected as a result of implementing the measures ?
3. Does the report contain adequate cost information for the measures?

A complete list of references consulted for DSM and energy efficiency can be found at the end of this report.

3.4 EARLY STUDIES OF DSM POTENTIAL

The earliest document to discuss Thailand's DSM potential in detail was the DSM Master Plan, which was written in 1991, based on data market and technology data collected in 1990 and 1991 (IIEC 1991). The plan estimated the achievable and cost-effective DSM potential at that time to be in the range of 2,000 to 3,000 MW, but noted that the institutions and private sector infrastructure necessary to tap this potential did not exist cited two primary estimates of DSM potential – 2,000 MW and 3,000 MW. It also cited an earlier study that found an achievable potential of 800 MW for the residential sector (Parker 1991); and dissertation research that found a potential for energy savings in commercial buildings of approximately 800 MW (Busch 1990).

6 IIEC, the International Institute for Energy Conservation, is a U.S.-based non-profit organization with regional offices worldwide. IIEC has had an Asia Regional Office in Bangkok since 1991, and IIEC was the author of Thailand's 1991 DSM Master Plan.

3.5 APPROACH TO ESTIMATING POTENTIAL

Recently, the Thai Load Forecast has begun to include some estimates of the DSM potential in its forecasts of future electric demand. Unfortunately, however, since the early 1990s, there has been no systematic assessment of the DSM potential in Thailand. In conducting this analysis, it has been necessary to review parts of a number of studies in order to piece together an overall assessment of economic and achievable potential. The basic approach used is shown in Figure 1 below.

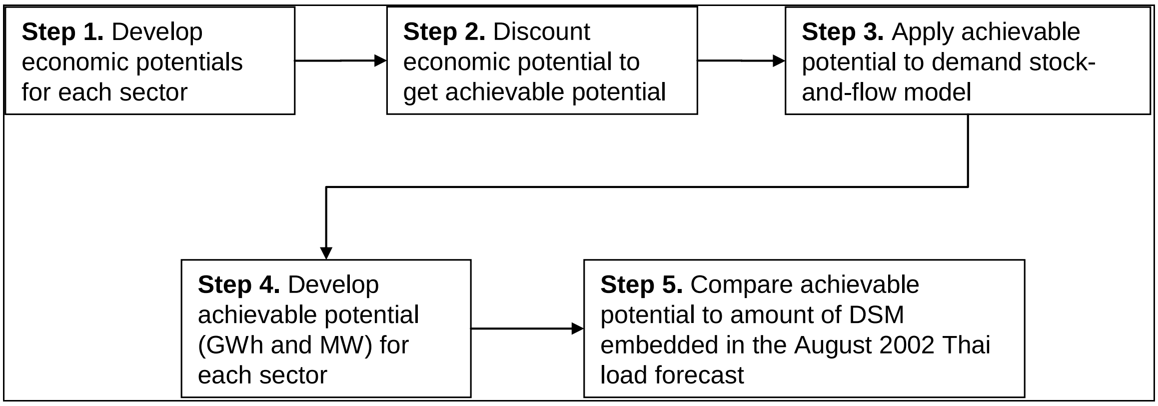

Figure 1. Flow Chart Showing Methodology for Estimating DSM Potential.

Step 1. Economic potentials for each sector. For each major end-use sector (residential, commercial, industrial), the consultant reviewed available literature in order to understand the potential for cost-effective energy-efficiency improvements. Since there has been no systematic attempt to develop sector-wide analysis, an estimate was developed of the economic potential, expressed as a percentage of energy use in existing buildings/facilities; and as a percentage of energy use in new buildings/facilities.

Step 2. Discount economic potential to get achievable potential. This discounting process is always somewhat crude, as the estimate of what is "achievable" depends on difficult-to-measure factors such as technical performance, institutional motivation and commitment, diffusion of information in the market, and a host of technical and non-technical barriers. The author tried to make reasonable judgments about measure adoption for each technology and sector and to explain the rationale. Throughout the analysis, the author tried to make conservative assumptions wherever possible – that is to underestimate the adoption of DSM and EE measures in order to be avoid overestimating DSM/EE uptake.

Step 3. Apply achievable potentials to demand stock-and-flow model. A simple stock-and-flow model was constructed based on data from August 2002 load forecast. Since the recent demand forecasts are broken down by tariff category rather than by sector, the author applied sectoral breakdowns from the 1998 demand forecast, and assumed that the relative share of electricity use and demand between the three sectors remained the same. For each sector, the savings potential was then applied to the demand forecast data, in order to develop an estimate of how much energy could be saved during the period 2004-2011. Stock and flow refers to the fact that separate estimates were made of the energy savings from the "stock" (existing facilities) and the "flow" (new facilities).

Step 4. Develop achievable potential for each sector, and overall. The achievable potential for each sector was developed using the spreadsheet model. The sector potentials were then added up to develop an overall DSM/EE potential by 2011 for Thailand.

Step 5. Compare achievable DSM potential to amount of DSM embedded in 2002 demand forecast. The achievable potentials were then compared to the amount of DSM currently embedded in the Thai Load Forecast. This process was somewhat problematic. The August 2002 demand forecast explicitly assumes 982 MW of peak demand reductions and 6,314 GWh/year of energy savings due to government DSM and EE programs. There may also be some assumptions in the forecast about market efficiency improvements over time; however, the demand forecast does not explicitly state that such assumptions were made. Accordingly, the author assumed that the total DSM/EE potential not accounted for in the demand forecast was equal to the achievable DSM/EE potentials developed in this report minus 982 MW for peak demand, and 6,314 GWh/year for energy.

3.6 INDUSTRIAL SECTOR

The most detailed and comprehensive recent assessment of technical and economic achievable potential for energy efficiency was carried out by IIEC as part of a baseline assessment for the World-Bank assisted ESCO Development Support Project in Thailand. The report reviewed a sample of 50 commercial and industrial energy audits in order to assess the potential for EE improvements and investment in Thai Designated Facilities. The report then supplemented these audit reviews with on-site interviews with managers, and review of energy audit data, at an additional 30 Designated Factories and 12 Designated Buildings.

The report used a transparent and flexible methodology for developing a range of estimates for economic and achievable potential for energy savings in large buildings and factories. The analysis began by comparing various estimates of economic efficiency improvements at the end use level[7]; applied these to the various industrial and commercial sub-sectors; and then applied these potentials to the population of large buildings and factories each sub-sector. In order to provide a reasonable range of estimates, the report developed two different scenarios that represent (based on available information) lower- and higher-end estimates of achievable energy savings and number of facilities.

The report developed estimates of achievable potential by applying two *achievability weighting factors*:

Achievable savings. This refers to the fraction of the economic measure energy saving potential that is achievable given all the various external barriers that are uncontrollable and unpredictable, such as technology performance and reliability, uncertainty in energy saving measurements, poor implementation, lack of supporting policies, etc. It also reflects the facts that not all measures will be additive and can be implemented in any given factory.

Achievable facilities. This refers to the fraction of all designated facilities in each sub-sector that will actually implement the energy-efficiency investment projects. This represents the fact that not all 100% of facilities in any sub-sector will implement energy efficiency measures, due to barriers such as lack of budget, lack of confidence, perception of risk, lack of management awareness, or poor creditworthiness.

The assumptions of the scenarios are shown in Table 2 below.

A simple example can be used to understand the table and how the weighting factors provide a conservative "downgrading" of potential EE to achievable EE. In the table, both factors (achievable savings and achievable facilities are used to "downgrade" the EE potential. Assume for example, a potential savings of 100 units. In the Conservative Scenario, this would result in an achievable savings of just 12 units; while in the Optimistic Scenario, it would result in an achievable savings of 32 units.

7 The general measures included as economic were those with a simple payback time of less than five years. For process-efficiency measures, a three-year payback cutoff was used.

Table 2. Achievability Assumptions Used in Conservative and Optimistic Scenarios for EE and Investment Potential

	Conservative Scenario	Optimistic Scenario
General Energy Efficiency		
Achievable Energy Savings	60 %	80 %
Achievable No. of Facilities	20 %	40 %
Effective Achievability Assumption as % of Economic Potential	**12%**	**32%**

Table 3 shows the estimates of end-use savings for a range of end uses and measures in the factories audited and surveyed. The figures shown are the weighted average of a review of the economic potential for each measure, from the energy audit and site visits. Only measures with a simple payback time[8] of less than 5 years were included.

Table 3. Estimates of Economic Potential for Electricity Efficiency Improvements in Thai Factories.

End-use	Energy Efficiency Measure	Simple Payback Period (years)	Average Savings (% of facility electricity use)
A/C	A/C cleaning & maintenance	0.5	0.5%
A/C	Absorption chiller	1.3	11.5%
A/C	Building insulation install.	3.5	0.9%
A/C	Electronic thermostat	0.9	0.9%
Lighting	Compact fluorescent lamps	1.3	0.7%
Lighting	Fluorescent tube lamps	4.1	0.2%
Lighting	Luminaire and reflector	2.7	2.5%
Process	Air compressor controller install.	2.2	1.1%
Process	Air pressure leak reduction	1.5	1.1%
Process	Energy-efficient air compressor	3.3	5.0%
Process	Cooling system control improve.	2.0	2.7%
Motor	High Efficiency Motors	4.4	11.1%
Motor	Motor speed controller (inverter)	1.3	1.1%
Elec. Sys.	Transformer capacity matching	0.2	0.6%
Fan	Ventilation fan efficiency	0	2.3%
Total			**42.2%**
Achievable Savings (Conservative)			**5.1%**
Achievable Savings (Optimistic)			**13.5%**
Achievable Savings (Mid-range)			**9.3%**

Note: calculations of achievable potential assume achievability factors for both technology and facility. The assumptions are described in detail in IIEC (2000).

[8] Simple payback time is a commonly used and well-known metric for financial viability of EE measures with typically short lifetimes. The simple payback time of an EE measure is the incremental up-front investment for the EE measure (compared to a standard, non-EE alternative) divided by the annual savings.

As noted earlier, this is the most comprehensive and detailed assessment of industrial EE potential. The sample was selected to cover the full range of industrial sectors, and is representative of industrial energy use in Thailand's approximately 2,000 factories considered as "Designated Facilities."[9] This assessment has been used by the Department of Alternative Energy Development and Efficiency as its benchmark study for EE potential in large industrial and commercial facilities. *In the author's view the assumptions used in this report are both conservative (i.e. tend to underestimate the potential for efficiency) because they "discount" the economic efficiency potential at both the level of the specific measures as well as at the level of the facility – arriving at achievable levels that range from one-eighth (12%) to one-third (32%) of the economic potential.*

3.6.1 Assumptions for Efficiency Improvements

Existing Factories. Based on the analysis in Table 3, *the author assumed that efficiency improvements could in existing factories achieve savings of 9.3% of electricity use during the period 2004-2011.* The rationale is that existing factories will be able to achieve the "achievable" level of savings within this period of time, since this level of savings is cost-effective and has already been discounted using the two achievability factors mentioned in the previous section.

New Factories. There is a lack of available high-quality data on the potential for efficiency improvements in the design of new factories; however, data from the buildings sector indicates that the potential for economic efficiency improvements in new buildings is significantly higher – on the order of 50-100% higher – than in existing buildings. To be conservative, the author assumed that the economic potential for efficiency improvements in new factories would be fifty percent larger than for existing factories – or 14.0% of energy use. It should be noted again that the consumptions about achievability for both existing and new factories are conservative, since they take into account the factor "achievable number of factories" and assume that only 30% of factories implement the economic energy-efficiency measures.

Table 4 below summarizes the results from incorporating these efficiency improvements into the demand stock-and-flow model.

Table 4. Achievable Potential for DSM in Thai Factories: 2004-2011

	As % of Factory Electricity Use	Savings in 2011	
		GWh/yr	MW
Savings in Stock	9.3% (over 8 years)	4,804	751
Savings in New Factories	14.0%	4,783	748
Total		**9,587**	**1,499**

Note: calculations using efficiency estimates from IIEC (2000) in stock and flow model from Thai demand forecast.

3.7 COMMERCIAL SECTOR

By nature, the commercial sector is easier to analyze than the industrial sector, since nearly all of a building's energy use is electricity, and buildings can be modeled quite accurately using building energy simulation software.

[9] Designated Facilities are regulated by the Energy Conservation Promotion Act and are required to appoint energy managers, to develop energy-saving targets, and to implement energy-saving measures.

3.7.1 Benchmarking Study of Commercial Buildings

AIT (2002) used a benchmarking approach to compare the specific energy consumption (SEC) of different building types. The review was part of a Danish-funded project to revise Thailand's building energy code.

The report analyzed available data reported by Thailand's "Designated Buildings." An indication of the vast potential for significant cost-effective and achievable energy savings can be seen by looking at the indices for total electricity consumption.

Table 5 below shows two of the primary SEC indices calculated for a sample of 94 Designated Buildings – total electricity consumption divided by total floor area. The vast differences in SEC indicate, de facto, an extremely large potential to improve the energy efficiency in the design and construction of new buildings. Using the SEC index, it can be seen that the "best building" uses 72% less energy that the "average" building; and the "worst building" uses more than 4 times as much energy as an average building.

Table 5. Benchmarking of Existing Large Commercial Buildings.

Indicator	Number of Designated Buildings	Specific Energy Consumption (kWh/sqm/yr)			% Diff. Between Min. and Ave.	% multiple of Max vs. Ave
		Min.	Ave.	Max.		
SEC of Total Electricity Consumption/ AC area	94	94.7	338.1	1455.9	72%	4.3

3.7.2 Thailand Energy Futures Study

The Thailand Energy Futures Study was an ambitious and important study that addressed the potential for significant, large-scale demand energy savings in Thailand's future based on a careful construction of scenarios for the different economic sectors. The data were based on detailed surveys and modeling of prototype commercial buildings and thus fairly represent the potential for energy-efficiency in those buildings.[10] It was carried out by the Thailand Environment Institute, and, interestingly, was funded by three organizations with a key interest in *energy supply*: EGAT, Banpu Coal Co., and Volvo.

The report analyzed data and methods used in forecasting energy use in Thailand's commercial sector under two scenarios defined for the Thailand's Energy Future Project: the reference and market scenarios. The reference scenario described the patterns of current energy use at the end-use level projected in to the future under a set of "business as usual" growth assumptions. The market scenario described an alternative path that employs cost-effective technologies that improve end-use efficiency. Prototypical building energy simulation and modeling using the DOE-2 computer software was conducted in the analysis of the reference and market scenarios. The principal advantage in using a building energy simulation model is that it can capture the interactive effects among the sub-systems within buildings, as well as seasonal variations in weather and temperature patterns.

[10] The prototype buildings for the building simulation model were based on data collected by TEI researchers and built on a foundation of research on commercial buildings dating back to the early 1990s (see IIEC 1993).

Table 6, Table 7, and Table 8 summarize the results of the market scenario analysis of this study for three commercial building types: office, retail and hotel. It can be seen that the potential for energy savings in all three sectors is substantial, and that nearly all of the measures are highly cost-effective – all of the measures are below the cost of delivered electricity for NT2, and nearly all have a cost of saved energy under THB 1.0/kWh.

Table 6. Technical Potential Energy Savings in Office Buildings

Bldg. Type	End-Use	Measure	End-Use Savings	Whole Bldg. Energy Savings	Annual Energy Savings [MWh]	Unit Cost [Baht]	Units	Cost of Conserved Energy [THB/kWh]
Office	Lighting	Efficient Lighting (elec. ballast)	59.5%	34.4%	1879		not applicable	0.74
Office	Lighting	Efficient Lighting (mag. ballast)	37.2%	21.5%	1175		not applicable	0.63
Office	Cooling	Reduced Window Area and SC	16.7%	6.7%	368		sqm of glazing area	0.88
Office	Cooling	Window Overhangs	7.6%	3.1%	168	1100	sqm of overhang	1.96
Office	Cooling	Roof Insulation	0.2%	0.1%	4	275	sqm of roof	5.61
Office	Cooling	Wall Insulation	1.6%	0.7%	36	275	sqm of opaque wall	4.33
Office	Cooling	Light-colored Roof	0.2%	0.1%	6	15	sqm of roof	0.54
Office	Cooling	Light-colored Walls	2.0%	0.8%	45	15	sqm of opaque wall	0.50
Office	Cooling	Efficient Chiller	13.9%	5.6%	306	597	kW of cool. capacity	0.55
Office	Cooling	Efficient Air Distribution	16.0%	6.5%	353	5.5	lit/sec of fan capacity	0.29
Office	Cooling	VSD Pumps	1.3%	0.5%	29	6702	kW of pump motors	0.68
Office	Cooling	Airfoil Fans	9.1%	3.7%	202	1.5	lit/sec of fan capacity	0.14
Office	Cooling	VAV System (VSD Control)	17.9%	7.2%	394	32	lit/sec of fan capacity	1.54

Source: TEI 1995

Table 7. Technical Potential Energy Savings in Retail Buildings

Bldg. Type	End-Use	Measure	End-Use Savings	Whole Bldg. Energy Savings	Annual Energy Savings [MWh]	Unit Cost [Baht]	Units	Cost of Conserved Energy [THB/kWh]
Retail	Lighting	Efficient Lighting (elec. ballast)	62.6%	49.3%	2965		not applicable	0.40
Retail	Lighting	Efficient Lighting (mag. ballast)	46.8%	36.8%	2210		not applicable	0.36
Retail	Cooling	Reduced Window Area and SC	7.3.%	2.0%	122		sqm of glazing area	0.98
Retail	Cooling	Window Overhangs	4.1%	1.1%	69	1100	sqm of overhang	1.80
Retail	Cooling	Roof Insulation	1.4%	0.4%	23	275	sqm of roof	3.38
Retail	Cooling	Wall Insulation	-0.7%	-0.2%	-11	275	sqm of opaque wall	N/A
Retail	Cooling	Light-colored Roof	1.8%	0.5%	30	15	sqm of roof	0.37
Retail	Cooling	Light-colored Walls	2.2%	0.6%	36	15	sqm of opaque wall	0.45
Retail	Cooling	Efficient Chiller	15.8%	4.4%	264	597	kW of cool. capacity	0.39
Retail	Cooling	Efficient Air Distribution	5.3%	1.5%	88	5.5	lit/sec of fan capacity	0.19
Retail	Cooling	VSD Pumps	1.8%	0.5%	31	6702	kW of pump motors	0.38
Retail	Cooling	Airfoil Fans	3.0%	0.8%	50	1.5	lit/sec of fan capacity	0.09
Retail	Cooling	VAV System (VSD Control)	4.6%	1.3%	77	32	lit/sec of fan capacity	1.24

Source: TEI 1995

Table 8. Technical Potential Energy Savings in Hotels

Bldg. Type	End-Use	Measure	End-Use Savings	Whole Bldg. Energy Savings	Annual Energy Savings [MWh]	Unit Cost [Baht]	Units	Cost of Conserved Energy [THB/kWh]
Hotel	Lighting	Efficient Lighting (elec. ballast)	70.0%	27.7%	2067		not applicable	0.45
Hotel	Cooling	Window Overhangs	1.4%	0.8%	59	1100	sqm of overhang	1.93
Hotel	Cooling	Wall Insulation	6.1%	3.6%	268	275	sqm of opaque wall	0.40
Hotel	Cooling	Light-colored Walls	1.9%	1.1%	82	15	sqm of opaque wall	0.08
Hotel	Cooling	Light-colored Roof	0.9%	0.5%	40	15	sqm of roof	0.16
Hotel	Cooling	Higher Thermostat Setpoint	24.4%	14.4%	1075	N/A	N/A	0.00
Hotel	Cooling	Efficient Chiller	16.6%	9.8%	733	597	kW of cool. capacity	0.20
Hotel	Cooling	Efficient Air Distribution	14.8%	8.7%	651	5.5	lit/sec of fan capacity	0.14
Hotel	Cooling	VSD Pumps	3.0%	1.8%	133	6702	kW of pump motors	0.14
Hotel	Cooling	Airfoil Fans	12.7%	6.8%	558	1.5	lit/sec of fan capacity	0.05
Hotel	Cooling	VAV System (VSD Control)	16.8%	9.9%	740	32	lit/sec of fan capacity	0.73

Source: TEI 1995

3.7.3 New Buildings Program Support: Demand-Side Management

The New Buildings Program Support study was commissioned by EGAT to assist in the development of a DSM program that rewards builders who improve their building's energy efficiency beyond the required Thai Building Code. The main objectives of this study were: to define the baseline energy consumption in commercial buildings in metropolitan areas; to assess the impacts of the Thai Building Code; and to encourage energy-efficient designs to be adopted in all newly constructed commercial buildings in Thailand. The engineering analysis conducted for this study include DOE-2 building energy simulations to assess the technical energy savings potential of energy-efficiency measures. Baseline and energy-efficient prototype buildings were simulated, and the energy-saving potential of different end-uses is shown in Table 9. These estimates represent the best detailed estimates of technical potential for new commercial buildings[11] that the author was able to find.

Table 9. Technical Potential Energy Savings in Different End-Uses of New Buildings

End-Use	Energy Savings Potential [% of Baseline]					
	Large Office	Small Office	Dept. Store	Large Hotel	Medium Hotel	Hospital
Interior Lighting	60.0%	48.3%	42.2%	35.7%	33.8%	54.9%
Cooling	43.7%	20.5%	12.8%	33.4%	28.3%	45.4%
Cooling Tower Fans	17.2%	N/A	-5.1%	15.0%	N/A	24.1%
Pumps & Auxiliary	6.3%	N/A	1.5%	1.5%	N/A	7.9%
Ventilation Fans	35.3%	N/A	42.8%	82.8%	17.7%	89.8%
Refrigeration	N/A	N/A	0.0%	N/A	N/A	N/A
Miscellaneous Equipment	N/A	37.8%	N/A	N/A	N/A	N/A
Combination of Efficiency Measures	**34.3%**	**27.4%**	**20.0%**	**31.7%**	**23.5%**	**41.4%**

Source: EGAT 1998

3.7.4 Thai ESCO Market Assessment

[11] The estimates represent *technical potential* for EE improvements in new building construction practice during the time frame of the study, the late 1990s.

Once again, for the commercial sector, the most detailed and comprehensive recent assessment of technical and economic achievable potential for energy efficiency is the Thai ESCO market assessment (IIEC 2000), which was described earlier in the section on the industrial sector.

Table 10 below shows the estimates of end-use savings for a range of end uses and measures in the factories audited and surveyed. The figures shown are the weighted average of a review of the economic potential for each measure, from the energy audit and site visits. Only measures with a simple payback time of less than 5 years were included.

Table 10. Estimates of Economic Potential for Electricity Efficiency Improvements in Thai Commercial Buildings.

End-use	Energy Efficiency Measure	Simple Payback Period	Average Savings (% of facility electricity use)
A/C	A/C cleaning & maintenance	0.6	1.5%
A/C	A/C package retrofit	0.9	6.7%
A/C	Building insulation	3.9	1.3%
A/C	Gypsum board and blinds install.	1.7	10.7%
Lighting	Compact fluorescent lamps	2.6	3.3%
Lighting	Luminaire and reflector	3.7	5.7%
Motor	Variable speed drive (VSD) motor	3.5	0.9%
Other	Room key switches	1.9	2.8%
Total			**30.1%**
Achievable Savings (Conservative)			**3.6%**
Achievable Savings (Optimistic)			**9.6%**
Achievable Savings (Mid-range)			**6.6%**

Note: calculations of achievable potential assume achievability factors for both technology and facility. The assumptions are described in detail in IIEC (2000).

3.7.5 Assumptions for Efficiency Improvements

Existing Buildings. Based on the analysis in Table 10, *the author assumed that efficiency improvements would be implemented in existing buildings and result in savings of 6.6% of electricity use during the period 2004-2011.*

New Buildings. In early 2004, DEDE completed a three-year project to recommend revisions to the Thai building energy code. A stakeholder process was used with technical working groups for the various building technologies; and a consensus document was developed that is currently under consideration as a mandatory building energy code that must be met by all new large buildings in Thailand. Given the fact that the building energy guidelines are a minimum and are based on economic criteria, then it seems fair to assume that the levels in this code could be achievable for all new commercial buildings. DEDE (2004C) estimates that the energy and peak power savings likely to result from the proposed code levels is 9% of a given building relative to current standard building design. *To be conservative, the author assumed that 50% of new buildings in the period 2005-2011 would achieve the levels of the proposed building code, and that thus, on average, all new buildings would use 4.5% less electricity than business as usual.*

Table 11 below summarizes the results from incorporating these efficiency improvements into the demand stock-and-flow model.

Table 11. Achievable Potential for DSM in Thai Commercial Buildings: 2004-2011

	As % of Building Electricity Use	**Savings in 2011**	
		GWh/yr	**MW**
Savings in Existing Buildings (Stock)	6.6% (over 8 years)	2,362	370
Savings in New Buildings	4.5%	1,069	167
Total		**3,431**	**537**

Note: Calculations were made using the above DSM potential estimates for existing (stock) and new buildings and applying them to commercial sector electricity use forecast in the stock and flow model described in step 3 in Section 3.5.

3.8 RESIDENTIAL SECTOR

Through 1998, the Load forecast was conducted on an end-use basis, and it was possible to carry out fairly detailed analysis of the potential for end-use efficiency improvements. The end-use data were based on household surveys that were regularly conducted on thousands of households in the PEA and MEA service areas.

After the economic crisis, when the Load Forecast had to be revised frequently, the Load Forecast Working Group reduced the frequency of the household surveys, and now the demand forecast for the residential sector is no longer based on an end-use model.[12]

It is possible, nonetheless, to make some educated guess about estimates of the potential for end-use efficiency improvements in the residential sector by using a basic end-use breakdown and then making some assumptions about future efficiency improvements based on past trends. While this type of potential estimation is not very accurate, it is the best that could be done under the limitations of this study, which relied on readily available published data.

<u>Efficiency potential for air conditioners and refrigerators.</u> As Table 12Table 12 shows, air conditioners and refrigerators have become 26-27% more efficient during the past decade. This success is due largely to the DSM labelling programs for these two products.

<u>Other end-use equipment.</u> Detailed studies of the end-use potential for other residential end-use equipment were not available. However, experience from other countries suggests that potential is quite large: a recent IEA study found an *economic EE potential* for residential end-use equipment in 2010 of 24% for OECD countries (IEA 2003). Given the relatively lower efficiency levels in Thailand, compared to developed economies, the potential savings are likely even larger. However, due to the lack of recent data for Thailand, it was conservatively assumed that the achievable potential for three products – rice cookers, ballasts, and fans[13] – would be 4% by 2011. This is half the level of efficiency improvement expected for refrigerators (8%) and one-sixth of the level of efficiency improvement expected for air conditioners over the same period.

[12] Chongpeerapien, Thienchai. 2003. Personal communication. September.

[13] These products were selected because they have significant potential and because EGAT has initiated DSM programs to promote sale and purchase of more efficient models.

Table 12. Summary of Achievable Potentials for the Residential Sector

Appliance	% of Resid. End Use for Whole Country[a]	1995-2004 improvement in EE	2004-2011 improvement in UEC	Comments	Weighted achievable EE potential for 2004-2011
Air conditioners	19%	26.0%[b]	26.0%	Assume continued shift toward high-EE units	5.0%
Refrigerator	13%	27.0%[c]	8.0%	Assume continued increase in EE, but slower rate	1.0%
Rice cooker	21%		4.0%	DSM labeling program launched in July 2004. Potential savings of > 10% through use of insulated rice cookers.	0.8%
Fluorescent Lighting	15%		4.0%[d]	EGAT has DSM labeling program for low-loss ballasts, which have losses 50% lower than standard magnetic ballasts.	0.6%
Fan	14%		4.0%[d]	DSM labeling program initiated in 2002	0.6%
Other appliances	9%		NA	Data not available	0.0%
Television	7%		NA	Data not available	0.0%
Incand & CFL lighting	1%		NA	Data not available	0.0%
Total					**8.0%**

[a] End-use breakdowns based on data from 1998 load forecast
[b] Based on EGAT 2000 and DEM 2004
[c] EGAT DSM Office, personal communication. 2004.
[d] Given absence of available data on past efficiency increases, and the presence of a DSM labeling program for each of these products, it was conservatively assumed that the average efficiency of these products would increase at half the rate of increase for refrigerators during the period 2004-2011.

3.8.1 Assumptions for Efficiency Improvements

Existing Households. We used the achievable potentials above in the stock model to estimate achievable potential for EE improvements in existing households during the period 2004-2011. The stock turnover rate (rate of replacement of existing appliances) was assumed to be 10% -- that is, on average an appliance is replaced every 10 years.[14] This is a conservative assumption given typical turn-over periods of a range of appliances, and it was made in order to simplify the analysis. *Based on the 8% potential in analysis in Table 12, and the 10% stock turnover each year, we estimate achievable potential for efficiency improvements in existing households of 0.8% per year during the period 2004-2011.*

New Households. Since there is no good data set or analysis of EE potential in new housing, we used the achievable potential for end-use equipment as the potential for savings in new households. Thus, we use *the 8% potential in analysis in Table 12, and this yields an estimated achievable potential for efficiency improvements in new households of 8%, applied to all new households constructed during the period 2004-2011.*

[14] There are no available survey data on actual Thai appliance lifetimes. This figure is based on estimates made in cost effectiveness calculations by EGAT's DSM Office.

Table 13 below summarizes the results from incorporating these efficiency improvements into the demand stock-and-flow model.

Table 13. Achievable Potential for DSM in Thai Residential Buildings: 2004-2011

	As % of Building Electricity Use	Savings in 2011	
		GWh/yr	MW
Savings in Stock	0.8% (per year)	1,583	248
Savings in New Dwellings	8.0%	1,119	175
Total		**2,702**	**423**

Note: calculations using efficiency estimates from IIEC (2000) in stock and flow model from Thai demand forecast.

3.9 Summary of DSM and Energy Efficiency Potentials

Table 14 shows an overall estimate of the achievable DSM potential based on the earlier review of available data and sector analyses. Three main points should be noted:

- First, as mentioned earlier, the DSM potential estimates are made by applying the static efficiency potentials estimated for each sector to the simplified stock-and-flow model derived from the end-use breakdown in the 1998 load forecast.[15]

- Second, the DSM measures considered are all cost effective, since they either have a cost of saved energy well below the marginal cost of delivered electricity for EGAT/MEA/PEA; or the measures have been screened to include only measures with a simple payback of less than five years.

- Third, for all three sectors, a careful and conservative approach has been taken, and the economic potentials have been discounted substantially to yield what the consultant believes are practical estimates of the achievable DSM resource during the period 2000-2011.

Table 14. Summary of DSM and Energy Efficiency Potentials by Sector

Sector	Savings Estimate Based on Analysis in …	Savings in 2011 GWh	MW
Industrial	Table 4	9,687	1,499
Commercial	Table 11	3431	537
Residential	Table 13	2,702	423
Total		**15,820**	**2,459**

3.10 Resource Cost for DSM and Energy Efficiency

It is difficult to put an overall number on the cost of saved energy (CSE) from DSM and energy efficiency measures (see Table 17). The average CSE from EGAT's DSM programs has been documented at THB 0.5/kWh (Phumarapand 2001). In the sector analysis, where data were available,

[15] It would have been preferable to have a more recent end-use breakdown for the three sectors, but the 1998 load forecast was the last forecast showing an end-use breakdown for the residential sector (Chongpeerapien 2003).

it was shown for example in commercial buildings that the CSE for almost all measures was less than THB 1.0/kWh. (see Table 6, Table 7, and Table 8). It is true that additional savings will tend to be more expensive over time, as the most cost-effective measures are exploited. But it seems reasonable to assume that for the period through 2011, the DSM resources could be captured at a total average CSE of THB 0.8/kWh. Program implementation costs were not explicitly included in the sector analyses in Section 3. Typical implementation costs for DSM programs are in the range of 10-15% of other program costs. ***Therefore, the assumed average CSE for the DSM measures assumed in this report is THB 0.92/kWh, including program implementation costs***

For the purposes of this analysis, the author assumed that all of the achievable DSM was cost-effective in a commercial sense, since the average CSE is THB 0.92, compared to a commercial cost for NT2 of THB 2.3 delivered to the Thai consumer.

Table 15. Comparison of Commercials Costs of DSM/EE and NT2 Resources

Resource Type	**Cost of Delivered Energy to Thai Consumer (THB/kWh)**
DSM/Energy Efficiency	0.92[a]
NT2 Electricity	2.3[b]

[a] Analyses in this study
[b] Segal 2004

For comparison purposes, Table 43 compares the resource size and cost of NT2 with the achievable potentials for DSM/EE and RE developed in this report. It also shows the amount of DSM/EE and RE that is not included in the 2004 Load Forecast and PDP, respectively.

SECTION 4. ACHIEVABLE DSM AND EE BASED ON GOVERNMENT PLANS

4.1 REVIEW OF EXISTING DSM AND ENERGY EFFICIENCY PLANS

This section analyzes the DSM and EE potential from a slightly different perspective. It reviews the two major government plans for DSM and Energy Efficiency: EGAT's DSM program; and the Energy Conservation Master Plan of the Department of Alternative Energy Development and Efficiency (DEDE). It provides an overall summary of the energy savings projected in the official plans. It then discounts those plans in light of institutional or other barriers which may make it difficult to achieve the program target. The two efficiency potentials – from a sector perspective, and from a plan perspective – are then compared to assess whether the assumptions and results appear robust and reasonable. In fact, the two approaches yield answers that are in a similar range, indicating that the estimates of achievable potential are reasonable.

DSM for Thailand's Electric Power System: Five-Year Master Plan

This document contains the action plans for a comprehensive set of energy conservation programs that the three state-owned electric utilities use in implementing their overall DSM program (IIEC 1991).

The plan put forward five-year DSM targets for energy savings and avoided demand of 1,080 GWh annually and 225 MW respectively. The average long-term cost of these energy savings to the utilities was estimated 0.49 Baht per kWh.

In 1991, Thailand became the first Asian country to formally approve a countrywide demand-side management (DSM) plan. Beginning in 1992, Thailand also initiated a national energy conservation law, supplemented by a ~US$80 million annual fund to finance investments in energy efficiency throughout the economy. The DSM Office was established in late 1993 and program implementation began in 1995. During the late 1990s, the DSM Office had more than 160 staff implementing residential, commercial, and industrial energy-efficiency programs. EGAT still has approximately 150 staff working in the DSM office.

In a 2000 report, the World Bank acknowledged that:

> *EGAT's DSM Office has developed a strong portfolio of DSM measures, including 19 DSM programs targeting a wide range of sub-sectors and end-uses, and substantially surpassed its original peak reduction and energy conservation targets. EGAT has created substantial public awareness of energy conservation and actively promoted private sector participation in providing such services. And, EGAT's DSM Office has been recognized internationally for its success in designing DSM programs that fit within an Asian context as well as its innovation and partnerships with other agencies.*

As Table 16 shows, EGAT exceeded its targets substantially. The five-year program began implementation in September 1995. By June 2000, after less than six years of implementation, EGAT had exceeded its five-year peak target by 138% and its energy target by 120%. By June 2001, it had exceeded its five-year peak target by 168% and its energy target by 152%.

Table 16. Targets and Savings for EGAT's DSM Programs

Program	Target		Result			
	1993-1997		As of June 30, 2000[a]		As of June 30, 2001[b]	
	Peak Demand Reduction (MW)	Energy Reduction (GWh)	Peak Demand Reduction (MW)	Energy Reduction (GWh)	Peak Demand Reduction (MW)	Energy Reduction (GWh)
1. 36 and 18 W fluorescent lamps	139	759	388	1,892	401	1,957
2. CFL	NA	NA	11	63	11	64
3. High efficiency refrigerators	27	185	83	849	109	1,106
4. High efficiency air-conditioners	22	117	84	318	117	445
5. Street lighting	0		0	17	0	17
6. Green buildings	20	140	0	0	0	0
7. Motors	30	225	0	0	0	0
Total	**238**	**1,426**	**566**	**3,139**	**638**	**3,589**

[a] Evaluated by AGRA Monenco Inc. (funded by World Bank)
[b] Updated through June 2001 by EGAT

In 2000, EGAT evaluated the cost effectiveness of its DSM programs, The results are summarized in Table 17.

Table 17. Cost Effectiveness of EGAT's DSM Programs

Metric	**Cost Effectiveness (THB)**	**Cost Effectiveness (USD)**
Estimated Total DSM Expenditures =	THB 1,815 million	$45.4 million
Cost of Peak Demand Saving =	THB 2,404/kW	$60.09/kW
Cost of Energy Saving =	THB 0.50/kWh	$0.013/kWH

Source: Phumaraphand 2000
Asssumption: 1 USD = 40 THB

EGAT's DSM Plan

As indicated earlier, the DSM programs of EGAT (which have benefited significantly through their support from GEF and the World Bank) are a widely respected example in Asia[16]; and EGAT has proven its ability to deliver cost-effective energy and peak demand savings.

Table 18 summarizes the budget and savings targets of EGAT's current five-year DSM plan, which extends through 2006. The program budget is THB 1,700 million (USD 42 million) savings targets are 632 peak MW and 2,508 GWh/year.

16 Within the next six months, for example, the governments of both Laos and Vietnam, with World Bank funding, will engage in DSM study tours to learn from the example of Thailand and build their capacity to effectively implement similar programs in their countries.

Table 18. EGAT's Demand-Side Management Plan, 2002 - 2005

											Totals		
	2002		2003		2004		2005		2006				Budget
	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	(THB million)
1. Residential													
High efficiency refrigerators	20.6	209.1	21.5	218.5	22.5	228.3	23.5	238.6	24.5	249.4	112.6	1,143.9	286
High efficiency air-conditioners	18.8	71.5	20.3	77.2	21.9	83.4	23.7	90	25.6	97.2	110.3	419.3	303
CFL	4.8	28.0	6.6	38.5	7.3	42.3	8.1	46.6	8.9	51.3	35.7	206.7	212
High efficiency ballasts	0.6	3.5	0.6	3.7	0.6	3.9	0.6	4	0.7	4.2	3.1	19.3	52
High efficiency fans	6.2	18.6	7.9	23.6	9.8	29.5	11.8	35.6	13.9	42.1	49.6	149.4	150
Total	**51.0**	**330.7**	**56.9**	**361.5**	**62.1**	**387.4**	**67.7**	**414.8**	**73.6**	**444.2**	**311.3**	**1,938.6**	**1003**
2. Business/Government													
Air-conditioning system	0.1	0.2	0.3	0.6	0.4	0.9	0.4	0.9	0.2	0.3	1.4	2.9	8
Demand management	1.1	0.4	5.3	1.6	11.6	3.5	17.9	5.4	20.9	6.4	56.8	17.3	45
Co-generation	0	0	0	0	27.9	28.5	55	56.2	53.3	54.5	136.2	139.2	30
Lighting system	3.4	5.6	14.4	24.1	21.3	35.5	20.6	34.4	9.4	15.6	69.1	115.2	105
Building envelop	0	0	0	0	0.3	0.7	0.6	1.3	0.5	1.2	1.4	3.2	13
Total	**4.6**	**6.2**	**20**	**26.3**	**61.5**	**69.1**	**94.5**	**98.2**	**84.3**	**78**	**264.9**	**277.8**	**201**
3. Industrial													
High efficiency motors	0.9	3.3	1.2	4.2	1.6	5.7	2	7.2	2.2	8	7.9	28.4	125
ESCO	5.4	40.4	13.7	118.3	0	0	0	0	0	0	19.1	158.7	30
Cost reduction for SMEs	7.3	26.2	7.3	26.2	7.3	26.2	7.3	26.2	0	0	29.2	104.8	341
Total	**13.6**	**69.9**	**22.2**	**148.7**	**8.9**	**31.9**	**9.3**	**33.4**	**2.2**	**8**	**56.2**	**291.9**	**496**
Grand total	**69.2**	**406.8**	**99.1**	**536.5**	**132.5**	**488.4**	**171.5**	**546.4**	**160.1**	**530.2**	**632.4**	**2,508.3**	**1,700.0**
Source: EGAT, May 2004													

Table 19 compares the targets for the previous DSM Plan (1995-2001) with the current DSM plan (2002-2006).

Table 19. Comparison of EGAT's Previous and Current DSM Plans.

	DSM Master Plan (1995 – 2001)			Current DSM Plan (2002 – 2006)		
		(MW)	(GWH)	Budget	(MW)	(GWH/yr)
Program Targets	USD 45.5 million	638	3,589	USD 42.5 million	632	2,508

Assumption: THB 40 = USD 1

4.1.1 Analysis of EGAT's Capability to Achieve Plan Objectives

Clearly, the budget numbers for 2002 – 2006 are comparable with the first seven years implementation of the DSM Master Plan as are the targets. The DSM Office still has 150 staff , and a wide range of active programs, most of which focus on equipment labeling – indeed half of EGAT's target savings will come from the residential sector, in contrast to the savings from DEDE's Conservation Master Plan, which will come primarily from the commercial and residential sectors.

It appears reasonable that, with continued support from EGAT management, that the DSM Office will be able attain these goals. However, there are some barriers and potential risk factors that should be addressed.

4.1.2 Barriers and Risk Factors for EGAT's DSM Effort

Since its initiation in the early 1990s, the key to the success of DSM in Thailand has been the existence of a stable funding mechanism. From the initiation of the DSM Office in late 1993, DSM funds came from a tariff adjustment mechanism. The Cabinet Resolution of 3 October 2000 approved a new tariff structure that took EGAT's DSM budget (~300 million baht/year) out of the automatic "FT" adjustment mechanism and included it in the base tariff instead. The budget for DSM activities has since been a permanent component of the electricity tariff, by being incorporated as part of EGAT's overall budget. EGAT is also still eligible to apply for additional funding from the ENCON Fund on a project-by-project basis**.**

There are two related risks to the current DSM effort. One is the lack of clear agreement on the long-term mechanism for funding DSM. The second relates to the ongoing discussions over privatization of EGAT have left the DSM Office in a kind of institutional limbo since 2000. Once EGAT is privatized, it is not clear what will happen to this unit, which does not contribute directly to the profit line of EGAT. There has been discussion of spinning it off to become an independent organization; or continuing it under EGAT. The latest government plan envisions EGAT being privatized as one single entity with no provision for major restructuring of the organization. Because the privatization has faced fierce opposition from the labor union, there are no solid plans with respect to DSM Office at present.

Given the size of the DSM operation and its successful results and profile in Thailand and throughout Asia, it is unlikely that the program will be disbanded. But the lack of agreement on a long-term funding mechanism, and the uncertainty over EGAT's corporate status are two question marks that must be addressed as the DSM effort goes forward, and also entail some risk as to whether and how much of the DSM savings will be realized.

ACHIEVABILTY OF PROGRAM TARGETS. *EGAT has shown its capacity to exceed DSM targets. The new DSM plan has a five-year target similar to what was achieved during seven years of implementation of the DSM Master Plan, and EGAT already has strong institutional capacity to* *design and implement its DSM efforts. However, given the uncertainty surrounding the status of the DSM Office as EGAT undergoes privatization, it seems reasonable to discount the DSM targets by 25% for the period through 2006. Furthermore, because the potential for DSM in all sectors will still remain large, it is assumed that a similar rate of DSM energy and peak savings will be maintained through 2011.*

4.1.3 Load Management: EGAT’s “Peak Cut” Program

EGAT in early 2004 announced a “Peak Cut” Program, with the target to reduce peak demand by 500 MW by 2006. Under the program, EGAT will provide incentives for large consumers to use their existing generators during peak hours: 10.00-11.30, 13.30-16.30 and 18.30-20.30 during the period of March through May. Based on EGAT’s load duration curve for year 2000, the highest 1010 MW of consumption occurred during only 60 hours out of the year (EGAT, 2000).

EGAT will provide three kinds of subsidies:

- payment for meter installation and electrical system improvement;
- an “availability payment” (AP), which will cover equipment and maintenance costs for generators during the target hot-weather months. The AP was announced to be THB 66.45/kW/month;and
- An “energy payment “(EP). The EP payment will be based on the number of kWh produced and will be indexed to the cost of diesel: EGAT will pay the equivalent cost of 1 liter of diesel for each three 3 units of electricity produced. The price of diesel will be calculated from PTT's average price of that month. For example, if the diesel price is THB15/liter, the EP payment will be B5/unit.

EGAT’S 500 MW peak load program is a form of load-shifting – from EGAT generating capacity to *existing* commercial and industry back-up generators. The goal of the peak cut program is to offset consumption during the highest peaks of the year. It directly assists EGAT from having to provide new capacity because without the 500 MW peak load program these backup generators would not otherwise be expected to run at these times. Without the Peak Cut contribution, EGAT would have to find 500 MW of peak resources from some other generating resource.[17]

As implemented, the Peak Cut program will provide a valuable complement in EGAT’s generation portfolio to the portion of renewable energy generation that is non-firm.

In addition to the Peak Cut program, the EGAT DSM program has Demand Management program for the commercial sector, which has a target of 57 MW peak reduction by the end of 2006.

ACHIEVABILTY OF PROGRAM TARGETS. *EGAT has the technical capacity to implement the Peak Cut program, and it is assumed that the level of 500 MW is achieved by 2006 and maintained through the period 2011.*

4.1.4 DEDE’s Five Year Energy Conservation Master Plan

The Energy Conservation Master Plan was drawn up during the second half of 2001 as part of the then-new Director General’s initiative to revamp the DEDE bureaucracy and make managers accountable on concrete results. The targets laid out in the Master Plan have eventually, if somewhat slowly, been translated into specific sets of “key performance indicators” (KPIs) for each division,

[17] See http://www.portlandgeneral.com/business/large_industrial/FAQ.asp?bhcp=1 for a description of an identical program run by Portland General Electric in the USA.

and individual DEDE managers now have their annual views tied to their performance relative to the KPIs.

The Master Plan's targets were drawn up through a bottom-up process that went through several iterations and were adopted informally in a organization-wide meeting in December 2001 and then formally when the plan was signed by the Minister of Science, Technology, and Environment in October 2002.[18]

[18] Most of these savings targets for facilities were also incorporated into the National Energy Strategy, a document that was prepared by NEPO at the direction of the then-Deputy Prime Minister overseeing the energy sector, Mr. Chaturon Chaiseng. The Master Plan was formally signed by the Minister of Science Technology and Environment (MOSTE), one month before the formation of the Ministry of Energy.

Table 20. Electricity Energy and Demand Targets for Five-Year Energy Conservation Master Plan (2002-2006)

Sector	Facility/Program	Targets	
		GWh	MW
Industrial	**Designated factories**		
	Existing factory	1,862.37	372.47
	SM/IP projects	504.66	66.13
	EE revolving fund[a]	-	-
	Sub-total	**2,367.03**	**438.60**
	Non-Designated factories		
	SM project	226.14	29.01
	IP project	53.26	6.60
	Energy audit service	27.00	3.24
	Taxes and duty exemption	174.16	20.90
	Sub-total	**480.56**	**59.75**
INDUSTRIAL SUB-TOTAL		**2,847.59**	**498.35**
Commercial	**Designated buildings**		
	Private designated buildings	182.36	39.23
	Government designated buildings	1,021.68	192.78
	SM/IP projects	252.67	55.11
	EE revolving fund	280.00	56.67
	Sub-total	**1,736.71**	**343.79**
	Non-Designated Buildings		
	SM for private non-designated bldg.	73.52	17.11
	SM for govt. non-designated bldg.	35.56	7.57
	IP project	53.27	11.53
	Government buildings	509.05	103.90
	Energy audit service	17.00	3.60
	Taxes and duty exemption	34.84	6.97
	Sub-total	**723.24**	**150.68**
COMMERCIAL SUB-TOTAL		**2,459.95**	**494.47**
Residential	Support for EE equipment production	405.00	81.00
	Energy cons. for direct target group	35.49	7.10
	Change low to high EE equipment	432.00	86.40
	Public relations campaign	54.84	10.97
RESIDENTIAL SUB-TOTAL		**927.33**	**185.47**
GRAND TOTAL		**6,234.87**	**1,178.29**

[a] For Designated Factories, the EE Revolving Fund has targets for thermal energy savings, but no specific targets for electrical energy and peak demand reductions.

The total targets are quite ambitious – approximately twice as high as the DSM Master Plan. – More than 6,200 GWh/year by 2006 and 1,100 peak MW.

Analysis of DEDE's Capability to Achieve Plan Objectives

As mentioned above, DEDE has been undergoing a management transition toward quantifiable key performance indicators, and this should in theory bode well for DEDE's capacity to achieve the Master Plan targets.

Nonetheless, there are a number of significant barriers that cast doubt on the viability of the Master Plan targets. The first is that at present it appears that, programmatically, the renewable energy plans and targets are getting a larger share of the focus and attention of DEDE management. While there has been much media publicity in late May and early June 2004 about energy conservation efforts in light of the skyrocketing price of oil, most of the policy measures have been short-term and focused on transportation energy; and the Energy Conservation Master Plan, which focuses more on long-term -- rather than immediate – measures has not been a topic of public discussion.

A second barrier is that progress in implementation of the Master Plan has been slow during the first two years of implementation (2002 and 2003), and programs have been delayed due to factors such as delays in procuring program budgets from the ENCON Fund and in some cases, approval from the Energy Ministry.

A third barrier is that the current Minister of Energy is favoring tax incentives over direct subsidies for energy efficiency. The Ministry is currently in discussions with the Revenue Department over the form of these tax incentives

ACHIEVABILTY OF PROGRAM TARGETS. *Given all of the above, it seems reasonable to discount the targets in the Energy Conservation Master Plan significantly, by 75%, in order to come to a hard-headed assessment of what is likely to be achieved through the DEDE programs during the period 2002 to 2006. At the same time, is assumed that a steady rate of energy and peak savings will be maintained by DEDE-funded and implemented programs through 2011.*

4.2 ANALYSIS OF ACHIEVABLE POTENTIAL FOR GOVERNMENT DSM AND ENERGY EFFICIENCY PROGRAMS

Table 21. Downgrading of Government EE Plans Based on Assessment of Achievability

	EGAT DSM Savings (achievability adjustment downward 25%)		DEDE Master Plan Savings (achievability adjustment downward 75%)		Total of EGAT and DEDE Savings (adjusted downward for achievability)	
Year	**Peak (MW)**	**Energy (GWh/yr)**	**Peak (MW)**	**Energy (GWh/yr)**	**Peak (MW)**	**Energy (GWh/yr)**
2004	350	1,074	98	469	448	1,543
2005	635	1,484	182	923	817	2,407
2006	849	1,881	295	1,559	1,144	3,440
2007	969	2,279	337	1,782	1,306	4,060
2008	1,089	2,676	379	2,004	1,468	4,680
2009	1,209	3,074	421	2,227	1,630	5,301
2010	1,329	3,471	463	2,450	1,792	5,921
2011	1,449	3,869	505	2,673	1,954	6,541

4.3 SUMMARY AND CONCLUSIONS ON ACHIEVABLE POTENTIAL FOR DSM AND ENERGY-EFFICIENCY

Section 2 provided a careful analysis of the potential for DSM and energy efficiency based on the achievable potential for technologies and implementation in each major sector (industrial, commercial, residential).

Section 3 was a parallel attempt to come at the problem from another angle – by estimating an achievable level of DSM resources: by adding up the targets of the existing and planned government DSM and energy-efficiency programs, and then discounting the targets to reflect institutional and other barriers to achieving the targeted peak and energy savings. A comparison of the results is shown in Table 22.

While the estimates of peak reduction are similar, the estimates for energy savings are much lower for the analysis of government programs. This likely reflects the inclusion of the 500 MW "peak cut" program of EGAT and the government focus on peak load management compared to energy efficiency.

Table 22. Summary of DSM and Energy Efficiency Potentials

	Savings in 2011	
DSM and EE Potential Methodology	**GWh**	**MW**
Sector Analysis[a]	**15,820**	**2,459**
Analysis of Government Programs[b]	**6,541**	**1,954**

[a] Source: Table 14

[b] Source: Table 21

In order to come up with a single estimate of the DSM and energy efficiency potential, it was decided to take an average from the two methods, which yields the result in Table 23.

Table 23. Best Estimate of DSM and Energy Efficiency Potential[a]

	Savings in 2011	
	GWh	**MW**
Achievable DSM and EE Potential	**11,181**	**2,207**

[a] Based on an average of results from the sector analysis in Section 2 (Table 14) and the analysis of government DSM and energy-efficiency programs in Section 3 (Table 21).

SECTION 5. RENEWABLE ENERGY POTENTIAL, COST, AND TARGETS

5.1 INTRODUCTION TO RENEWABLE ENERGY POTENTIAL

There is significant renewable energy potential in Thailand, and recent government initiatives have shown a commitment to substantial renewable energy targets. The first part of this section reviews and summarizes studies that have estimated commercially viable[19] renewable energy potential in Thailand. Next, current arrangements for sale of renewable energy to the grid are summarized and discussed. This is followed by a discussion of recent Thai renewable energy targets and policies that are under discussion that the government believes is necessary to stimulate the market sufficiently to reach a target of 8% total energy from renewable sources by the year 2011.

Based on published studies and industry interviews, *commercial* costs of renewable energy from different sources are estimated, including a discussion of the potential capacity for each fuel type to generate firm and non-firm electricity for lower cost than electricity from Nam Theun 2.

The amount of firm renewable energy potential that can generate electricity for a commercial cost than NT2 is estimated at 300 MW, while potential non-firm renewable electricity that is lower cost than NT2 is estimated at 2641 MW. The next part of this section develops a similar analysis for *economic* costs of renewable energy compared with electricity from NT2, and concludes that 300 MW of firm renewable energy is economically competitive with NT2 and 126 MW of non-firm renewable electricity has lower costs than NT2.

Finally, commercially viable potentials are adjusted to account for various technical and institutional factors that are expected reduce or increase actual investment in renewable energy compared to commercially viable potential. We estimate that 216 MW of firm renewable energy and 1252 MW of non-firm is practically achievable by year 2010.

Readers should take note that non-firm renewable energy is not directly comparable to the output from NT2. Most of the electricity from NT2 is "firm" in the sense that it is able to reliably deliver electricity during peak times. EGAT is required by the NT2 power purchase agreement to purchase 4406 GWh per year of firm power (called Primary Energy or "PE") during peak hours (6 am to 10pm) and another 948 GWh during off-peak hours, called "SE1" (referring to secondary energy) and is considered "non-firm". If sufficient water is available, another 282 GWh of SE2 may can be purchased at EGAT's option (Vernstrom, 2004, p. 19). While many non-firm generators in practice do generate electricity between 6am and 10pm (peak hours as defined by the NT2 contract), non-firm contracts do not require generators to commit to generating during these times. Thus non-firm renewable energy is not strictly comparable to PE, which accounts for the vast majority of NT2 output, but is comparable to SE1 and SE2.

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[19] All references to "commercial viability" or "commercial costs" for renewable energy assume generators are compensated according to commercial arrangements that apply to renewable energy generators *currently in operation* as of March 2005. These arrangements are described in detail in the section titled "Prices paid for grid connected for renewable energy in Thailand". For the majority of renewable energy in Thailand (in terms of number of generators, installed capacity, or contracted sales to the grid) these commercial arrangements involve no subsidies (price subsidies or non-price subsidies) and electricity is compensated at EGAT's long run avoided cost (firm) and short-run avoided energy cost (non-firm), and are the same prices per kWh and per kW capacity given to fossil fuel cogeneration.

5.2 DEFINITION OF RENEWABLE ENERGY

This report adopts the Thai Ministry of Energy definition of renewable energy used in both the current SPP and VSPP programs (EGAT, MEA and PEA 1998; NEPO 2002). Definitions for new policies under development are virtually identical:

1. **Electricity generated from renewable energy sources** such as wind, photovoltaics, mini or micro-hydroelectricity and biogas (excluding the use of oil, natural gas, coal and nuclear power).

2. **Electricity generated from the following fuels:**
   2.1 agricultural waste or residues, or residues from agricultural or industrial production processes;
   2.2 products converted from agricultural waste or residues, or residues from agricultural or industrial production processes;
   2.3 municipal waste;
   2.4 dendrothermal (wood from fuel tree plantation).

3. **Electricity generated from steam** left over from agricultural or industrial production processes that use fuels listed under items 1 or 2.

Any generator using fuels listed above may use commercial fuels such as oil, natural gas and coal as supplementary fuels. However, the accumulated thermal energy contributed from the commercial fuels in any given year must not exceed 25% of the total thermal energy used in electricity generation during that year.

The Ministry of Energy further defines renewable energy hydroelectricity to be no larger than 30 MW (Thai Ministry of Energy 2004).

5.3 PRICES PAID FOR GRID CONNECTED FOR RENEWABLE ENERGY IN THAILAND

Prior to estimating the potential for commercially or economically viable renewable energy it is necessary to first discuss the conditions that determine commercial viability – the price paid for electricity sold to the grid.

Under current policies Thai utilities pay private generators prices set by the Small Power Producer (SPP) and Very Small Power Producer (VSPP) programs. Whereas the SPP program accounts for over 99% of renewable energy capacity sold to the grid by private companies, the VSPP program currently accounts for less than 1%. On this basis, the SPP program alone serves as an accurate benchmark of prices at which renewable energy generation is commercially viable.

5.3.1 Small Power Producers (SPP)

The Small Power Producer (SPP) program applies to cogeneration (generally using natural gas or coal) and renewable energy. SPP generators[20] connect to PEA or MEA lines and sell electricity under power purchase agreements (PPAs) to EGAT. Generators in the SPP program are limited to 90 MW maximum export, and are typically 5 MW or larger. In terms of installed capacity, the vast majority of projects are non-renewable cogeneration plants using coal or natural gas, accounting for over 3,100 MW of generating capacity. While prices paid for electricity vary somewhat from contract to contract, generators whether coal, gas or renewable receive the same levelized tariff. SPP generators are broken into two categories: firm and non-firm depending on their ability to guarantee availability. Firm fossil-fuel fired SPPs must generate for at least 7008 hours per year and must generate during the months March, April, May, June, September and October. Furthermore, monthly capacity factor must exceed

[20] For list of plants, generation capacities, and contracted sales to EGAT see http://www.eppo.go.th/power/pw-spp-name-status.xls.

0.51 and not exceed 1.0. Shut-down for maintenance shall take place during off-peak months of January, February, July, August, November and December and may not exceed 35 days in a 12-month cycle. For renewable energy firm generators all requirements are the same as for fossil-fueled generator except the requirement to generate 7008 hours per year is relaxed to 4670 hours per year and must include March, April, May and June (EGAT 2001). Based on an average of actual payments to SPP generators from October 2001 to September 2002, firm SPP generators were paid 2.20 THB/kWh comprising an energy payment of 1.37 THB/kWh and a capacity payment of 479.7 baht/kW/month (FT subcommittee 2003, page 62 table 7.1.27). These payments are based on EGAT's long-run avoided capacity and energy cost (NEPC, 1995). Non-firm generators can generate for as many hours as they choose, but receive only an energy payment calculated at EGAT's short-run avoided energy cost (NEPC, 1995). Actual payments to SPP non-firm generators from October 2001 to September 2002 average 1.77 THB/kWh. While fossil fueled generators are eligible to generate as non-firm SPPs, to date none have chosen this option.

In total, as of July 20045, 41 renewable energy generators totaling 860 MW in generation capacity were in operation under the SPP program, of which 8 projects totaling 214 MW are firm and 33 totaling 624 MW were non-firm (Table 24). Another 9 renewable energy projects totaling 114 MW were under negotiation.

Table 24: Summary of Operational SPP Renewable Energy Generators as of July 2004.

Primary Fuel	Capacity (MW)	Sale to EGAT (MW)	Qty firm	Qty non-firm	Capacity (MW Firm)	Capacity (MW Non-firm)	Sale to EGAT (MW Firm)	Sale to EGAT (MW Non-firm)	Qty with subsidy	MW with subsidy (capacity)	MW with subsidy (sale to EGAT)
Bagasse	543	169	0	28	0	543	0	169	5	113	57
Black Liquor	73	35	1	1	32.9	40	25	10	1	33	25
Paddy Husk	82	50	3	2	63	19	39	11	1	9	5
Paddy husk and wood chips	53	35	3	0	53	0	35	0	1	40	25
Waste	3	1	0	1	0	3	0	1	0	0	0
Wood Chips	107	54	1	1	87	20	50	4	1	87	50
Grand Total	861	344	8	33	237	624	149	195	9	282	162

Source: http://www.eppo.go.th/power/pw-spp-name-status.xls

A significant minority of renewable energy SPPs received a subsidy from the Thai Government Energy Conservation (Encon) Fund averaging 0.17 baht per kWh sold to EGAT for the first 5 years of operation based on a single round of a bidding program evaluated in 2002. Candidate renewable SPPs were invited to submit bids for the amount of subsidy that they would be willing to accept. Bids were sorted lowest-to-highest and lowest bids were accepted. Because bids were only solicited once, prior to the bid evaluation in 2002, all projects after this cutoff date have not been eligible for the subsidy.

Nine out of 41 (22%) currently operational SPPs were awarded subsidy. In terms of MW generating capacity, 282 MW out 860 MW (33%) received subsidy. In terms of contracted sale to EGAT, 162 MW out of 344 MW (47%) received subsidy. Renewable energy SPP generators that have come on-line *without subsidy* cover all of the biomass fuel types listed above in Table 24, indicating that each of these renewable energy fuels has been, in a few cases at least, commercially viable without subsidy.

Taking into account MW of subsidized and non-subsidized produced by each fuel type, the weighted average of prices paid for firm and non-firm renewable energy is presented below in Table 25.

Table 25: Weighted Prices for firm and non-firm renewable energy. The table covers different fuel-types based on data from 41 SPP renewable energy generators in operation. Units are in THB/kWh and include subsidies (if applicable). Because project-specific subsidy amounts are not publicly available, subsidy was assumed to be equal to the program average: THB 0.17/kWh. Without subsidies, non-firm electricity is priced at THB 1.77/kWh, while firm electricity is priced at THB 2.20/kWh. Prices shown in the table were weighted by subsidized and non-subsidized contracted sales (MW) to EGAT.

Primary Fuel	Weighted price (firm)	Weighted price (non-firm)
Bagasse	n/a	1.83
Black Liquor	2.37	1.77
Paddy Husk	2.2	1.85
Paddy husk and wood chips	2.32	n/a
Waste	n/a	1.77
Wood Chips	2.37	1.77
Grand Total	2.31	1.82

5.3.2 VSPP

There are less than two dozen VSPP generators currently in operation, with total cumulative capacity around 2 MW. Though insignificant in terms of total MW installed capacity, the VSPP program is described below in order to cover all forms of commercial options for renewable energy generators that sell electricity to the grid. Generators under the VSPP program connect and sell electricity directly to MEA or PEA. Generators under the program are currently limited to 1 MW net export. VSPP generators receive the wholesale TOU rate for power generated and the average wholesale FT charge. This rate is the same rate that EGAT charges MEA and PEA for wholesale power purchased from EGAT. The wholesale TOU tariff depends on the interconnection voltage and time of day (peak or offpeak[21]). For a system connected at medium voltage (12 – 33 kV), this rate is 1.17 THB/kWh (off peak) and 2.99 THB/kWh (on peak). In addition, the VSPP generator receives average wholesale FT charge, which is adjusted quarterly.[22] In mid-2004 the average wholesale FT is 0.4332 baht per unit.[23] Averaged over a 24 hour period, the VSPP tariff is approximately 2.46 THB/kWh. There is discussion underway to increase the VSPP threshold to 5 MW from the current 1 MW net export level.

5.3.3 DEDE Grid-Connected Small Hydro

In addition to SPP and VSPP programs, there are 15 grid-connected small hydro projects with a cumulative capacity of 38.9 MW that were built and operated by the DEDE using government budgets. These receive 1.1 THB/kWh for electricity generated from PEA (Subcommittee to Develop Small and Micro-hydro Projects, Royal Thai Government, 1993). Because it is not clear that electricity from the government's small hydropower is sold on commercial terms, however, these very low tariffs are of limited relevance to this study.

5.3.4 Overview of Subsidies for Grid-Connected Renewable Energy

For grid-connected renewable energy in Thailand by far the most significant subsidy is the 0.17 THB/kWh (average) subsidy provided to SPP generators and received by 9 out of 41 SPP projects

[21] Off-peak is defined as weekends, normal public holidays, and weekdays 10PM to 9AM.
[22] See http://www.palangthai.org/en/docs/SampleTariffCalculation-new.xls
[23] See: http://www.eppo.go.th/power/FT/tariff-FT.html

currently in operation. The relaxation of the yearly generation requirement for firm renewable energy generators from 7008 to 4670 hours per year is a form of subsidy, but it is difficult to determine the value. Similarly, the VSPP program contain some hidden subsidies in the sense that even though MEA and PEA purchase electricity from VSPP at the same price as from EGAT, they incur additional costs in terms of additional paperwork arising from additional accounts. Again, however, these would be difficult to measure and are expected to be small since the changes in utility operations required to accommodate VSPP are essentially minor administrative ones.

In Thailand there are several other subsidy programs for specific renewable energy technologies but these are negligible in terms of the number of MW of installed capacity that they encourage. For example, a "50 solar roofs program" implemented by EGAT provides a 50% capital subsidy for solar roof top systems, but these account for only 0.14 MW of installed capacity and even with subsidy these are not commercially viable. With help from foreign donors, Thai utilities have installed several grid-connected renewable energy demonstration plants (solar, wind power) but these total less than 1 MW. Another government program offers a 30% capital subsidy for a particular kind of biogas digestor used in pig farms. But many pig farms have chosen competitors' unsubsidized biogas digestors. As far as we can tell, no other renewable energy fuels in this report currently receive appreciable price or non-price subsidies that are not also enjoyed by conventional (fossil fuel or large-hydro) generators.

5.4 COMMERCIAL RENEWABLE ENERGY POTENTIAL

In the context of the commercial arrangements for the sale of renewable energy described above, we now turn to a discussion of commercial potential vis-à-vis these arrangements. Fuels considered include biogas, biomass (rice husk, bagasse, wood residues, cassava residues, distillery slop, palm oil residues, and sawdust), small hydropower, solar and wind power. The analysis draws on Thai government-commissioned studies and interviews with industry experts.

To date there have been several studies on renewable energy resource potentials in Thailand. Two of these studies: Black & Veatch (2000), and NEPO/DANCED (1998) were commissioned by the Thai government and focus on biomass potential. A third was conducted by the Thai Royal Irrigation Department to assess small hydropower potential from Thailand's existing irrigation weirs and dams. Finally, interviews with industry insiders provide additional estimates of commercially viable power generation potential from biogas and from bagasse under existing policies.

5.4.1 Black & Veatch (2000)

Black & Veatch (2000), *Thailand Biomass-Based Power Generation and Cogeneration Within Small Rural Industries*, commissioned by the National Energy Policy Office (NEPO) is a review of biomass resources of appropriate scale for Thailand's Small Power Producer (SPP) program. The review covers rice husk, palm oil residues, bagasse, wood residues, corncob, cassava residues, distillery slop, coconut residues, and sawdust. Black & Veatch determines commercially viability of electricity generation from each biomass fuel type with respect to *non-subsidized prices* for electricity sold to the grid.

Included is an investigation of availability, distribution, production rates and forecasts, involved industries, prices, and general suitability of the fuels for power production. The review concludes that 779 to 1,043 MW is commercially viable from these fuels. A summary of the findings is shown below in Table 26.

Table 26: Summary of Commercially Viable Biomass Potentials in Black & Veatch (2000)

	Power (MW)	Average (MW)	Capacity factor	Energy (GWh/yr)	Average (GWh/yr)
Rice Husk	234-375	304.5	0.85	1,742-2,792	2,267
Bagasse	160-248	204	0.85	1,191-1,847	1,519
Wood residues	118	118	0.85	879	879
Cassava residues	75-84	79.5	0.85	558-625	592
Corncob	54	54	0.85	402	402
Distillery slop	46-52	49	0.85	343-387	365
Coconuts	43	43	0.85	320	320
Palm oil residues	33-53	43	0.85	246-395	320
Sawdust	16	16	0.85	119	119
Total	**779-1,043**	**911**		**5,800-7,766**	**6,783**

The general methodology employed by Black & Veatch for each fuel type is to identify the amount of total output of the agricultural residue fuel, subtract the amount currently used in industrial processes, and multiply by a “biomass collectivity” coefficient reflecting the dispersed nature of the resource that estimates the viable percentage of the resource that could commercially be collected for power generation. Data on heating values for the fuel is then used to calculate the aggregate power generation potential. Black & Veatch assumes a uniform capacity factor of 85% , based on the assumption that properly sized stoker boilers will be installed to burn available fuel. The Black & Veatch study also identifies supply growth forecasts for each fuel type, but does not incorporate these into the power potential model. Supply forecasts vary from fuel to fuel, and range from “stable” to 15% expected annual increase.

The Black & Veatch assessments are likely to underestimate potential energy generation for several reasons. The study assumes that all biomass will be burned in stoker boilers, rather than in more efficient bubbling fluidized bed or gasification systems. The study assumes that new biomass generation will *not* be done in a cogeneration mode. Instead, the study assumes that facilities that need steam will continue to burn biomass separately for steam production. Investing in cogeneration is cost effective in many cases, yet Black & Veatch observe that many plant owners are reluctant to invest, and therefore the study assumes that no plant owners will. Another source of likely underestimation of potential is that the Black & Veatch study predates the ENCON renewable SPP subsidy bidding program in which some SPP generators receive subsidies for electricity sales to the grid.

Consider, for example, that the Black & Veatch study determined that 160 MW to 248 MW of electricity generation from bagasse are viable in Thailand. Yet, as of December 2003, contracts for 657 MW of bagasse have been signed, and of this 508 MW are on-line. 334 MW of new bagasse generation had signed contracts under the SPP program after the published November 2000 date of the Black & Veatch study.

Much of the data used in the study is already a decade old. Since the study was completed, agricultural production of key agricultural products with energy residues have increased from amounts upon which the Black & Veatch study was based (Table 27). These include: rice paddy (up 30%), bagasse (up 49%), and palm fruit (up 220%). Cassava has decreased about 9%.

Table 27. Updated Agricultural Production Data for Black & Veatch Study

Base agricultural product	Year of B&V data	Million tones	Year of most recent data	Million tones	Source of updated information
Rice paddy	1995	20.0	2002	25.9	(FAO, 2003:1)
Bagasse	1985-1996	40	2000-1	59.49	(Kansai Environmental Engineering 2004)
Palm fruit	1995	2.17	2003	4.8	(Univanich, 2004)
Cassava	1987-1995	20	2000-2003	18.2	(FAO, 2003:2)

At the same time, considerable quantities of some of these biomass resources have been exploited for power generation since the writing of the Black & Veatch study. For example, about 130 MW of generators now burn rice husk and/or wood chips in Thailand (sometimes mixing the fuel or using one or the other in times of scarcity), suggesting that for these fuels Black & Veatch should be used with caution in estimating available biomass resources.

5.4.2 NEPO (1998)

A study of biomass energy potential was included in a June 1998 study by NEPO, with support from DANCED, entitled, *Investigation of Pricing Incentives in a Renewable Energy Strategy, Thailand*. The study was completed by a consortium of consultants including Ramboll, EC COGEN, the Asian Institute for Technology (AIT), and the Risoe National Laboratory in Denmark. The methodology of the study is not explicitly described, but appears to be similar to Black & Veatch. The study identifies “structural” potential for each resource, a category which apparently has similar meaning to the Black & Veatch category “viable potential”. The findings are summarized below inTable 28.

Table 28. Summary of Biomass Structural Potentials in NEPO (1998)

	Power (MW)	Capacity factor	Energy (GWh/yr)
Sugar industry	1,900	0.29	4,750
Rice mills	66	0.68	396
Palm oil mills	69	0.57	345
Wood industry	950	0.68	5,700
Total	2,985		11,191

Note that the sugar and wood industry power generation (MW) estimates are considerably higher in the NEPO/DANCED study than in Black & Veatch. These higher estimates are explained in part by lower capacity factors for generation. For example, the considerably higher MW figures for bagasse follow from the NEPO/DANCED study assumption that much of the sugar industry would convert (as some major industry leaders have) to efficient cogeneration. The Black & Veatch study, on the other hand, assumes that bagasse would be used in dedicated (non-cogeneration) plants used alongside existing mill systems.

Table 29. Structural Potential from Logging and Sugar Cane Trash Identified by NEPO (1998).

	Power (MW)	Capacity factor	Energy (GWh/yr)
Logging trash	920	0.68	5,500
Sugar Cane trash	2,550	0.69	15,400
Total	3,470		20,900

In addition to wastes available at the mill site itself, NEPO/DANCED identifies more than 3,000 MW of additional biomass potential if 50% of trash is collected from sugar cane fields and rubber plantations (Table 29). The study notes that "although there is little experience using these types of waste in Thailand these fuels are being exploited in other countries of the world and there is reason to believe that it could be done in Thailand too..." (NEPO/DANCED 1998, Main Report page 9)

Since the commercial viability of this type of residue collection is uncertain, these residues are not given further consideration in this report.

5.4.3 Interviews with Industry Experts: Biogas and Bagasse

Power project developers in the biogas and bagasse industries were contacted for their assessment of potential in their respective industries. David Donnelley is general manager of Clean Energy Development Co. Ltd. (Clean THAI), a firm that develops and finances biogas systems fueled by waste products from cassava processing facilities and pig farms. Donnelley calculates that commercial potential for biogas at SPP prices exceeds 1200 MW. These comprise: 300 MW from cassava waste-water, 900 MW from cassava wet cake (a fibrous waste byproduct of tapioca production), 50 MW from pig farms and 15 MW from palm oil factories. One of Clean THAI's projects, owned and operated by the Korat Waste-to-Energy Co. Ltd. (KWTE) was completed in 2004, in Korat Province. The plant generates 3 MW of electricity and produces sufficient biogas to offset 7.5 to 8 million liters per year of heavy fuel oil at the tapioca factory. Plant availability has been 95% since commissioning (Plevin and Donnelley 2004). Donnelley is planning to add another 10 MW to accommodate wet cake.

The technology is very replicable. Clean THAI alone has signed contracts for 70 MW (electricity) of projects in cassava processing plants to be commissioned over the next five years. Of this 70 MW, 6.4 MW will come on line in 2005, with six to eight more projects totaling 12 to 15 MW coming online in 2006, and further increases in subsequent years (Donnelley 2003; Donnelley 2004). The cassava industry has seasonal variations, with processing plants operating between 275 and 350 days per year depending on size and location. However, both waste water and wet cake can be stored to later produce biogas, providing the basis for firm generation capacity. Once permits are secured (a simplified process with no EIA required for plants under 10 MW), construction and commissioning is fast: small plants take 10-12 months to commission (to 5 MW); medium size plants (5-10 MW) take 12-14 months to commission; and large plants (10 MW +) will take 14-16 months to commission.

Jeffery Dickinson is the SE Asian representative of E + Co., a global clean energy finance company. Dickenson expects over US$100 million from foreign investment funds to be invested in the Thai cassava biogas projects within the next 10 years. Dickinson plays a management role in a US$20 million fund already set up specifically to invest in biogas in Thailand. Regarding commercial viability, he said, "in our contracts with our cassava factory customers we sell electricity at 80% of PEA's retail rate[24], and biogas to fuel factory boilers at 80% of fuel oil costs. After a period of time – typically10 years -- ownership and responsibility for the entire biogas project will be granted to the cassava processing factory. Under these conditions we earn market-level returns for our investors."[25] These high performing Thai biogas projects and the projected 1200 MW of economically viable potential recently attracted the formation of a new EURO $50 million fund, dedicated to renewable energy and energy efficiency projects in Asia, expected to open in early 2005, with a target annual return of 15-20%.

Dickinson also provided figures useful in assessing production costs of electricity from cassava waste-water. First, the potential 300 MW of cassava *waste-water* biogas projects are commercially viable without

[24] This is about the same as the wholesale bulk supply tariff (generation + transmission), equal to price that EGAT sells electricity to PEA and MEA.

[25] Mr. Jeffery Dickinson's contact info for verification: jeff@energyhouse.com. Mobile phone: (+66) (7)-8004275.

generating any electricity. For example, in the KWTE project the profits made from selling biogas to the factory to offset heavy fuel oil consumption are higher than those for generating electricity, and allow the project to make market-level returns. This is a consequence of the high heating demand of cassava processing factories, the relatively low cost of providing biogas, and the high biogas yields from cassava waste-water. For operational reasons, as well as to maximize methane emissions reduction (explained below), the KWTE project is designed for the factory's full peak waste water load, and has a large flare installed to burn biogas in excess of consumption. The cost of electricity generation, then, is limited to the capital cost to install and interconnect engine-generators to burn excess gas that would otherwise be flared, plus the cost of O&M on the generators, and administration and finance costs associated with electricity production. Based on current performance, the electricity generated at the 3 MW KWTE plant is projected to total 24 million kWh in 2004 (Plevin and Donnelley 2004), equivalent to a capacity factor of 91.3%

Regarding the *economic* viability of biogas project, cassava waste-water digestors have a large additional economic value-added: offsetting methane emissions. Methane is a greenhouse gas 21 times more potent than carbon dioxide. In tapioca factories the conventional waste treatment approach is to drain waste water to ponds where it decomposes aerobically to form carbon dioxide or anaerobically to form methane. Carbon emission reduction credits are currently valued at EURO 3 to EURO 5 per tonne. The Dutch INCaF fund, managed by the World Bank's IFC, has agreed to purchase KWTE's Certified Emission Reduction (CER) credits, expected to total 380,000 tonnes of CO2 equivalent per year (Plevin & Donnelley, 2004; Dickinson 2004). This suggests additional revenues of $1.1 million to $1.9 million per year, comparable with expected revenues of $900,000 from biogas sales and $1 million from the sale of electricity (Plevin & Donnelley 2004). CER revenues will start flowing if or when Thailand agrees to allow Clean Development Mechanism (CDM) carbon trading under the Kyoto Protocol, a decision on which is expected within a year. Regardless of whether Thailand signs, however, these carbon offsets have an established value and are an *economic* benefit, even if not yet a *commercial* one captured by the company.

A third source, responsible for the power generation division at one of Thailand's largest sugar companies, estimated 2500 MW of electricity generation is commercially viable using bagasse (Tatong 2004). Of the 2500 MW total potential, 24 projects totaling 508 MW are already on-line with export of 149 MW to the grid. As of December 2003, contracts have been signed with an additional seven plants for an additional 142 MW of generation, of which 76 MW will be exported to the grid.[26] An estimated 1990 MW of potential remains undeveloped.

Table 30. Potentials from Biogas and Bagasse Based on Interviews with Industry Insiders. Cassava biogas capacity factor is estimated to be 80% (actual capacity factor to date at KWTE has exceeded 90%). Although CleanTHAI and their financers are already investing in developing over 10 MW of wet cake digestion as well, the estimated 900 MW of commercial firm generation potential from this resource is not included in the table below because the resource has yet to be exploited in Thailand at commercial scale. Bagasse potential and capacity factor are based on use of cogeneration operation dictated by factory steam requirements.

	Commercially viable power (MW)	**Capacity factor**	**Commercially viable energy (GWh/yr)**
Biogas cassava	300	0.80	2102
Biogas pigfarm, etc	65	0.5	285
Bagasse	1990	0.30	5230
Total	3255		7617

Source: Thai Royal Irrigation Department, 2004

[26] http://www.eppo.go.th/power/pw-spp-name-status.xls

In November 2004, the Royal Irrigation Department issued results for studies of production cost of electricity from small hydro projects in Thailand planned by DEDE, by PEA, and by the Royal Irrigation Department (Table 31) in some of Thailand's estimated 6,000 irrigation dams. Off these 728 projects totaling 369 MW, electricity production costs have been estimated for 100 projects totaling 271.3 MW. The weighted average production cost of these 100 projects is 1.74 THB/kWh suggesting that most of these 100 best projects could be commercially viable operating as non-subsidized, non-firm SPPs.

Table 31: Breakdown of planned small hydro development by DEDE, RID, and PEA by 2010. Source: (Thai Royal Irrigation Department, 2004)

	Number of Projects	Power (MW)	Range of production costs (THB/kWh)	Average electricity production cost (THB/kWh)
DEDE (feasibilty study completed)	23	70.2	0.78 – 3.12	1.91
DEDE (pre-feasibility study completed)	26	44.8	1.06 - 4.15	1.69
Royal Irrigation Dept (medium size)	51	156.3	0.87 – 3.67	1.67
Sub total / average	100	271.3		1.74
DEDE (other)	72	19.29		n/a
Royal Irrigation Dept (small size)	550	20		n/a
PEA	6	38.67		n/a
Total	**728**	**369**		**n/a**

5.5 Commercial and Economic Costs of renewable energy in Thailand

The discussion above has focused on estimates of potential for renewable energy at tariffs paid under the unsubsidized SPP program. Below we consider commercial and economic costs for renewable energy sources, together with an accounting of the MW of firm and non-firm potential that are economically or commercially below the cost of generating power from NT2 and transmitting the power to Thailand (Table 32 and

Table 33). This is followed by a technology-by-technology discussion of the basis for these cost estimates.

5.5.1 Commercial costs

In cases in which private renewable energy producers were willing to divulge sufficient information, commercial costs were directly calculated. This was only possible in the case of electricity generation from biogas. In most cases, however, it was not possible to access cost information as private producers are reluctant to release cost data to competitors. In these cases, the prices in Table 25 (weighted average price paid to actual SPP generators, including subsidies if any) are used as an upper bound proxy for commercial cost. This approach assumes that generators are not selling below cost in the long run. Commercial-self interest provides sufficient evidence that this assumption is correct.

In determining the amount of capacity that is below the 1.88 THB/kWh commercial cost of NT2 electricity, two steps were required. First, potential for each renewable fuel is divided into firm and non-firm potential based on actual firm/non-firm ratios of existing operational power plants using the same fuel (columns 6 and 7 of Table 24). Second, each price is compared with the 1.88 THB/kWh threshold. If electricity is lower cost than NT2 it is added to the appropriate firm/non-firm column.

For biomass fuel sources for which actual SPP tariffs are not available (corncob, distillery slop, palm oil residues, and sawdust), it is assumed that these generate non-firm electricity at a commercial cost equal to 1.82 THB/kWh, derived as the weighted average non-firm SPP tariff (including subsidies) for all actual operating non-firm biomass sources.

Commercial production costs for small hydro are 1.74 THB/kWh as described above, and expected to be non-firm because water flows in these irrigation projects are in many cases tied to existing obligations for seasonal/hourly water flows. For renewable energy technologies that are expected to not to be commercially viable without subsidies (wind and solar), commercial costs estimates are drawn from a government commissioned study to determine renewable energy subsidies (Energy for Environment 2004). Solar capacity is assumed to be non-firm even though solar electricity is an excellent match with Thailand's daily load profile and always provides the most electricity during sunny peak hours when Thailand's load is highest.[27] Wind power is assumed to be non-firm.

Table 32. Commercial production costs and MW of firm/unfirm potential competitive with NT2.

	Commercial cost (firm) (THB/kWh)	**Commercial cost (non-firm) (THB/kWh)**	**MW of firm potential under 1.88 THB/kWh**	**MW of non-firm potential under 1.88 THB/kWh**
Biogas				
Cassava waste-water	1.54		300	-
Pig farms, etc	1.8		-	65
Biomass				
Rice Husk	<2.20	<1.85	-	35
Bagasse		<1.83	-	1990
Corncob		<1.82	-	54
Distillery slop		<1.82	-	49
Wood residues	<2.37	<1.77	-	118
Palm oil residues		<1.82	-	43
Sawdust		<1.82	-	16
Small & micro- hydro		1.74	-	271
Wind		5.2	-	-
Solar		10.1	-	-
Total			**300**	**2641**

Biogas commercial production costs / quantity of firm capacity competitive with NT2

As discussed in the section on the KWTE Cassava waste-water biogas plant, 300 MW of electricity from biogas are expected to be commercial as an add-on to utilize gas that would otherwise be flared from biogas plants that are commercially viable selling biogas to offset in-factory heavy fuel oil consumption. In calculating commercial costs, the author assumed a 10% discount rate[28], 16% interest on capital[29], capital costs of US$1 million per MW installed capacity, 80% capacity factor, and annual O&M + administration equal to 8% of equipment procurement costs. Electricity is produced under a build-own-transfer (BOT) for 10 years, after which time ownership and control are granted at no cost to the factory owner. Under these conditions[30], commercial production costs for this firm electricity

[27] Assumed Thailand's peak consumption occurs in the early afternoon of the sunniest days of the hot/dry season. This peak is driven by air conditioning loads.

[28] Commercial discount rate used by EPPO for energy projectrs ranges from 8-12%.

[29] Based on expected investor returns of 15% to 17% per annum (Plevin and Donnelley, 2004)

[30] These assumptions compare with KWTE actual figures of less than $US 1 million equipment procurement cost per MW, capacity factor of over 90%.

are 1.541 THB/kWh, or US$0.0385 per kWh. These commercial costs are lower than projected NT2 commercial costs cost of 1.88 THB/kWh (US$0.047/kWh) for the price of NT2 electricity not including transmission and distribution in Thailand[31] or 2.30 THB/kWh including T&D costs[32] within Thailand. Biogas from cassava is considered firm power based on year-round availability of fuel and high capacity factor.

Commercial production costs of electricity from biogas from other sources (livestock farms, distilleries, palm oil) have been calculated at 1.8 THB/kWh (Amatayakul and Greacen, 2002) based on internal EPPO studies. Biogas is already commercially viable at unsubsidized prices under the VSPP or (for larger installations) the SPP programs, as evidenced by a 5 MW biogas-fired generator currently negotiating a contract to connect as a non-firm, unsubsidized SPP[33]. This tariff for this electricity is expected to be close to the average of 1.77 THB/kWh for non-firm SPP.

Biomass commercial production costs / quantity of non-firm capacity competitive with NT2

Biomass estimates of commercial costs use average actual (Table 25) prices as an upper-bound proxy.

Rice husk

Three firm SPP generators burn rice husk and generate over 80 MW of electricity. Long-run commercial costs for these plants are expected to be below the average non-subsidized SPP firm tariff of 2.20 THB/kWh as none of the existing plants received subsidy. This is consistent with economic costs (not including externalities) for rice husk generation in an 18 MW plant calculated (see details in economics section below) to be 1.57 to 1.80 THB/kWh.

Rice husk prices are an important determinant in rice husk fired power plants, accounting for 25% to 30% of electricity production cost. Rice husk prices vary from province to province, and also vary seasonally. Prices as high as 550 baht per tonne have been reported (Ranjana Wangvipula 2004). High prices of rice husk have been problematic for rice husk power plants, and it appears that there remains limited scope for new large power plants that rely on rice husk for fuel.

Two non-firm SPPs use rice husk as a fuel, with total capacity of 19 MW. Using the weighted mix of operational project's subsidized and non-subsidized non-firm SPP tariffs as a proxy, non-firm rice husk plants are expected to have commercial costs of production under 1.85 THB/kWh.

Bagasse

Commercial potential for bagasse is based estimates from interviews sugar industry professionals. Bagasse projects account for the bulk of existing non-firm biomass installed capacity, as well as potential. Currently 23 SPP bagasse projects totaling 486 MW are in operation as unsubsidized, non-firm SPP generators. These would be expected to have commercial costs below the average 1.77 THB/kWh paid under the SPP program.

Other biomass fuels

Following the existing ratio of 8 firm to 33 non-firm SPPs in operation, we expect other biomass fuels are also likely to operate as non-firm generators. Unlike rice husk, the majority of these fuels are residues from agro-industry used to generate electricity by factory owners, and thus have limited exposure to biofuel market price volatility.

As most non-firm SPP generators are built primarily to offset on-site electricity consumption (at retail rates of 1 to 3.5 THB/kWh depending on time of use), the commercial benefits can be considerably

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[31] Nam Theun 2 Project Economics Interim Summary Report, 21 August 2004.

[32] For distributed small scale generators (5 MW and under) sited relatively near loads the appropriate comparable NT2 cost is arguably 2.3 baht/kWh. For larger generators that make use of the Thai transmission and distribution network, the 1.88 baht/kWh figure is more appropriate.

[33] http://www.eppo.go.th/power/pw-spp-name-status.xls.

higher than the 1.77 THB/kWh non-firm tariff suggests. Interconnection itself provides valuable backup power, and the ability (but not obligation) to sell non-firm electricity when agricultural surpluses are available and/or factory load is low may mean that actual commercial costs are quite low.

Estimates on MW of commercial viable potential from non-bagasse fuels are based on Black & Veatch which, as discussed above, is predicated on non-subsidized SPP prices.

Small- hydro commercial production costs / non-firm capacity competitive with NT2

Small and micro-hydro production costs are calculated to be the same as economic costs (discussed below in economic cost section) because these projects are to be built by government agencies using government budgets. These costs are based on feasibility studies of 100 projects planned by the DEDE and the Royal Irrigation Department. The weighted average cost of 100 projects totaling 271.3 MW is available is 1.74 THB/kWh, with variation from 0.78 THB/kWh to over 4 THB/kWh. Though some hydro SPPs provide firm power, this study assumes the hydro sites in question can only provide non-firm power.

Wind commercial production costs

Wind power unit costs in Thailand are calculated to be 5.2 THB/kWh, based on Thailand's wind regime powering a 1000 kW turbine installed at 80 meters costing EU$1000 per kW with a lifetime of 20 years, O&M expenses equal to 2% of capital cost, financing through a 70:30 debt to equity ratio with debt serviced at 10% over 7 years, a financial internal rate of return FIRR of 10%, a discount rate of 6.5%, income tax of 30% after an 8 year tax holiday, and an exchange rate of 40 baht to $US (Energy for Environment, 2004; annex volume, annex of seminar presentations, wind presentation, page 17)

These commercial costs exceed conventional costs of NT2.

Solar commercial production costs

Solar electricity commercial costs is calculated to be 10.1 THB/kWh, based on a solar module cost of US$2.381 per peak watt producing 3.45 kWh/kWp/day, with a lifetime of 25 years, O&M expenses equal to 0.1% of capital cost, an IRR of 10%, a discount rate of 5.75%, and an exchange rate of 40 baht to $US (Energy for Environment, 2004; annex volume, annex of seminar presentations, solar presentation, page 12)

These levels are consistent with typical international estimates (Navigant Consulting 2003), and far exceed conventional costs of NT2.

5.5.2 Economic costs

The economic cost of electricity production from cassava biogas is based on capital cost and discounted O&M and administration costs provided by project developers. Economic costs of rice husk are derived in Energy for Environment (2004) based on data from a variety of projects. Other biomass economic cost estimates are derived from commercial costs, subtracting finance costs, taxes, and profits.

Economic costs of small hydro are based on feasibility and prefeasibilty studies of 100 projects. Solar and wind costs are derived in Energy for Environment (2004) based on Thai-specific data.

Table 33. Economic production costs and MW of firm/unfirm potential competitive with NT2.

	Production cost (THB/kWh)	**MW of firm potential under 1.08 THB/kWh**	**MW of non-firm potential under 1.08 THB/kWh**
Biogas			
Cassava waste-water	1.02	300	-
Pig farms, etc	1	-	65
Biomass			
Rice Husk	1.57 to 1.8	-	-
Bagasse	1.2 to 1.5	-	-
Corncob	1.3 to 1.6	-	-
Distillery slop	1.3 to 1.6	-	-
Wood residues	1.2 to 1.5	-	-
Palm oil residues	1.2 to 1.5	-	-
Sawdust	1.2 to 1.5	-	-
Small & micro- hydro	1.02	-	61.4
Wind	4.0 to 4.6	-	-
Solar	10 to 15	-	-
Total		**300**	**126.4**

Biogas economic production costs / quantity of firm capacity competitive with NT2

As described in the commercial costs section, biogas electricity generation is calculated as an complementary investment to utilize gas that would otherwise be flared from biogas plants that are commercially viable selling biogas to offset in-factory heavy fuel oil consumption for processing cassava. In calculating economic costs, a 10% discount rate was assumed, US$1 million per MW installed capacity, 80% capacity factor, and annual O&M equal to 8% of equipment procurement costs over a projected equipment life of 20 years. Based on these assumptions[34], economic cost of electricity production is 1.025 THB/kWh, or $0.0256/kWh assuming an exchange rate of 40 baht per $US. This economic cost is lower than NT2's projected levelized economic costs of $0.027/kWh.

This calculation does not include the externalities. Because electricity production is an adjunct using excess gas from already profitable biogas for heat installations, however, externalities (positive or negative) are negligible.

If economic cost of the entire project including biogas digester is considered, then total economic costs will be substantially lower. The current value of emissions reductions is roughly equivalent to total revenues from energy sales (Dickinson 2004), suggesting that total economic cost of the system as a whole is slightly less than zero. But because the system could achieve methane reductions without generating electricity (by flaring gas), it is questionable to attribute these benefits to electricity generation as such.

Not including externality benefits, economic costs of biogas from other sources (pig farms, etc.) are expected to be higher than cassava based on the need to build digestors, and smaller economies of scale. Economic cost ignoring externalities is roughly estimated to be 1.5 THB/kWh, 15% lower than commercial cost, taking into account deletion of financing and taxes. Including externality benefits from methane emissions reductions (not to mention extensive water pollution and odor problems associated with Thai livestock industry) produces the same situation in which electricity generation economic cost is the marginal cost of adding a generator and interconnecting to the grid. Total economic costs in this case are expected to be approximately 1 THB/kWh.

[34] These assumptions compare with KWTE actual figures of less than $US 1 million equipment procurement cost per MW, capacity factor of over 90%.

Biomass economic production costs / quantity of non-firm capacity competitive with NT2
An EPPO-commissioned report conducted by the Energy for Environment calculated that economic production costs for an 18 MW firm rice husk generation plant are 1.5697 baht per kWh (for a project life of 25 years) to 1.8027 baht per kWh (for a project life of 15 years), assuming interest rate of 5.75%, 80% load factor, rice husk at 350 baht/tonne, a capital cost of 54,639 baht/kW, O&M costs of 0.3817 THB/kWh, and a heat rate of 13,400 kJ/kg (Energy for Environment 2004, page 2-87, table 2-43).

Economic costs for non-firm power, and for non-market residue fuels are expected to be lower. Subtracting the economic cost contribution of rice husk fuel (0.4734 THB/kWh) but adding the economic value of rice husk ash[35] (0.1082) from the above estimates suggests costs (for firm power, given "free" fuel) of 1.2045 to 1.4375. Fuel may be considered "free" if it has no resale value, has disposal costs, and if it must be transported anyway as part of the factory operations. If combined with steam generation for factory processes, it is probable economic costs could be below 1.08 THB/kWh for some projects. For the purposes of this study, however, it is assumed that this is not the case. Economic costs for non-market biomass fuels are estimated to range from 1.2 to 1.6 baht, depending on economies of scale, fuel handling properties, and seasonal availability.

Externality costs could be positive or negative, depending on the current uses of the fuel, and the pollution control schemes employed. Carbon emissions reductions are a positive externality currently equal to about 0.048 baht to 0.08 THB/kWh at current carbon prices.[36]

Small- hydro economic costs / non-firm capacity competitive with NT2
Small and micro-hydro economic production costs are based on feasibility studies of 100 projects planned by the DEDE and the Royal Irrigation Department. The cost range of these projects is significant, with some having production costs significantly as low as 0.78 THB/kWh, and others in excess of 4 THB/kWh. Sorting projects from lowest cost to highest, 10 projects totaling 61.4 MW have a combined economic cost of 1.02 THB/kWh.

Externality costs for these projects are expected to be low as all projects under consideration are to be constructed in existing dams and irrigation projects. Though some hydro SPPs provide firm power, this study assumes the hydro sites in question can only provide non-firm power.

Wind economic production costs
Energy for Environment calculates economic cost of wind power in Thailand at 4.0 to 4.6 THB/kWh based on assumptions of a capital cost of US$1416 per kW for a 1 MW turbine, producing power at 16% capacity factor, with O&M expenses equal to 2% of capital costs, a discount rate of 5.75% over a 20 year equipment lifetime (Energy for Environment 2004, page 2-89). These costs are substantially above NT2 economic costs.

Solar economic production costs
Energy for Environment calculates economic cost of solar power in Thailand at 9.06 to 10.7 THB/kWh based on assumptions of a capital cost of US$3016 per peak kW, producing power at 13.7% capacity factor, with O&M expenses equal to 0.1% of capital costs, a discount rate of 5.75% over a 20 year equipment lifetime (Energy for Environment 2004, page 2-89). Amatayakul and Greacen (2002) cite 10 THB/kWh. These levels are consistent with typical international estimates (Navigant Consulting 2003), and far exceed conventional costs of NT2.

35 Rice husk ash is a valuable additive to high quality cement if produced under proper conditions.

36 Two Thai biomass projects totaling over 40 MW, one using rubber wood waste and another using rice husk have already sold certified carbon credits to international buyers.

5.6 THAI GOVERNMENT RENEWABLE ENERGY TARGETS

The discussion above has focused on estimates of commercial arrangements for electricity sales, on commercially viable renewable energy potential, and on commercial and economic costs of renewable energy for projects that are *currently online*. We now turn to a discussion of Thai government targets and subsidy programs for future projects, based on an overarching goal of having 8% of the country's commercial *energy* needs be met by renewable energy by 2011. These programs, when in place, are expected to considerably further enhance the commercial viability of all renewable energy fuels, even those such as wind and solar power that are currently commercially unfeasible. The discussion of Thai government targets and pending policies, in turn, informs the final portion of this section concerning practically achievable potential.

5.6.1 Renewable Energy and Energy Conservation Plan 2002-2011 (NEPO, 2002)

In 2002, under the direction of then Energy Minister Chaturon Chaiseng, NEPO developed a set of renewable energy targets as part of a comprehensive 10-year "Renewable energy and energy conservation plan 2002-2011", published in Thai language. The plan's targets for the year 2011 are shown below in Table 34.

Table 34. Renewable Energy Targets Published by NEPO (2002).

	Power (MW)	Capacity factor	Energy (GWh/y)
Solar electricity (grid connected)	148	0.14	181
Wind	20	0.15	26
Biogas[37]	30.2	--	--
Biomass (bagasse, rice husk, black liquor, wood chips, palm)	983	0.93	8038
Hydro (micro, mini- and small -- 14 MW or smaller)	78	0.44	--
Geothermal[38]	6	0.71	36
Total	1,254		8,556

5.6.2 Energy Strategy for Competitiveness Workshop (28 August 2003)

In a strong enhancement to targets released in by NEPO in 2002, at the *Energy Strategy for Competitiveness Workshop* (August 28, 2003) chaired by Prime Minister Thaksin Shinawatra, the current Minister of Energy Promin Lertsuriyadej released new expanded renewable energy targets.
The overarching target announced at the meeting was to increase renewable energy use from a year 2003 level of 0.5% of total commercial energy to 8% of total commercial energy consumption by the year 2011. The Thai government has reaffirmed this target in a number of domestic energy policy forums, as well as the 2004 International Conference for Renewable Energies in Bonn Germany, and most recently included the 8% target in Thailand's UN Millennium Development Goals.[39]

The most recent plans (Thai Ministry of Energy, 2004) call for the 8% obligation to be met through the combination of ongoing VSPP and SPP programs, a Renewable Portfolio Standard (RPS), a variety of incentive programs, and increased funding for research and development of renewable

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[37] Given the high potential of economically viable biogas in the cassava industry, it is surprising that biogas projections are so small in government figures. Cassava biogas has been a largely overlooked resource, only recently realized by government energy bureaucracy. Initial government studies in laboratories proved favorable, but the institutional arrangements for transition from government laboratory scale to commercial application never materialized.

[38] Geothermal electricity so far has only been produced by EGAT. Because the geothermal resource is fairly small it is omitted from further inclusion in this analysis.

[39] http://www.undp.or.th/mdgr.htm

energy technologies. Renewable energy's electricity contribution is targeted at 2,400 total MW. Of the 2,400 MW target, the plan notes that 560 MW are already installed. As shown below in Table 35, the remaining 1840 MW comprises 400 MW from an RPS set at 5% of new fossil generation capacity, and 1440 MW to be developed through a variety of programs including specified electricity tariffs for different renewable energy, tax breaks, direct capital subsidies, and R&D. The EGAT 2003 PDP accounts for 223 MW of renewable energy SPP between 2003 and 2006, leaving 1617 MW of new renewable energy targeted by the government but not in the 2003 PDP.

Table 35. Policy to Produce Electricity Using Renewable Energy Equal to 6% of All Installed Generating Capacity by 2011.

Target		**MW**
Renewable Portfolio Standard (RPS) of 5% of new generation capacity	Solar	200
	Wind	100
	Biomass	100
Incentive & support:	Biomass	740
• Specify electricity purchase price	Small hydro	350
• Capital subsidy	SPP (mostly biomass)	300
• Tax reductions, R&D	Solar	50
Total		1,840

Source: Presentation by Minister of Energy Promin Lertsuriyadej at "Energy Strategy for Competitiveness Workshop" chaired by Prime Minister Thaksin Shinawatra, August 28, 2003.

Non-electricity renewable energy contributions to the 8% target comprise 3,910 KTOE in the form of heat (to be encouraged through incentive programs), and 1,570 KTOE for biofuels for the transport sector, including 3.0 million liters per day of ethanol and 2.4 million liters per day of biodiesel (also supported through incentive programs).

At the same workshop, the government announced a new assessment of renewable energy potential (Table 36). It was not specified whether these are seen to be "technical" or "economic" potential, though the numbers suggest technical potential. Capacity factor and annual energy production figures were not provided.

Table 36. Thai Renewable Energy Potentials.

	Power (MW)
Small hydro	700
Wind	1600
Solar	>5000
Biomass	7,000
Total	>14,300

Source: Presented at Energy Strategy for Competitiveness Workshop, August 2003.

5.6.3 Government Budget Allocations for Renewables and Energy Efficiency

Details of the RPS, incentive programs, and tax breaks are currently[40] under consideration by the Ministry of Energy. However, new funds totaling 1.3 billion baht per year (US $32.5 million per year) have been allocated by Cabinet to meet the government's year 2011 energy efficiency and renewable energy target (Table 35). These funds, totaling 9.1 billion baht over 7 years, are in addition to 7.397 billion baht of funds earmarked for renewable SPP subsidies and other pre-existing programs. All told, 16.497 billion baht (US$412 million) will be spent in the next 7 years. The new 9.1 billion baht will be allocated as follows:

[40] As of December 2004

50% for renewable energy, 35% for energy efficiency, and 15% for administration costs (ENCON Committee 2004).

5.7 PRACTICALLY ACHIEVABLE POTENTIALS

In Thailand, as elsewhere, non-subsidized commercial viability is not the sole determinant of which technologies are built. On the one hand, government support in Thailand will likely lead to some installations of renewable wind and solar electricity that would not happen without subsidy. On the other hand, in many cases businesses with biomass residue streams are too busy with their primary business, are unaware of opportunities, and are reluctant to invest in technologies they know little about. Though new support agencies such as the Biomass One-stop Clearing House (BOSCH) provide valuable information, lack of awareness of opportunities and constraints hinder higher levels of deployment. In other cases, a key barrier is lack of adequate sources of finance at interest rates that reflect true project risk. Because renewable energy technologies and markets are new and undergoing rapid development, and because of lack of familiarity, financial institutions may overestimate risk and are unwilling to provide financing on terms that allow development of otherwise viable opportunities.

Still other barriers arise from utility planning processes that fail to take into consideration sufficiently broad options when conducting least-cost planning, or which consider planning from utility's commercial perspective rather than from a society-wide economic perspective. Inadequate treatment of risk (especially fuel price volatility risk), combined with the ability of utilities to pass costs directly to consumers leads to both inadequate valuation of portfolio diversity in power generation and to utility overinvestment in generation. Both of these situations provide disincentives for utilities to engage with the private sector to find innovative solutions. Policy plays a large role. Tariff design with time of day pricing that rewards electricity generators for producing electricity when it is needed most sends more appropriate price signals to renewable energy generators than tariff designs that are based on solely on firm/non-firm distinctions . Much can be accomplished if an empowered, competent, and truly independent regulatory authority (which Thailand lacks) is active in protecting the interests of ordinary citizens vis-à-vis the power sector.

Considering these and other technology-specific barriers, this section provides a qualitative discussion of the likely deployment of each renewable energy technology by 2011 as the basis for discounting commercially viable quantities to "practically achievable" levels. In Table 37 below, "commercially viable" estimates are multiplied by both "technology factor" and "institutional factor" coefficients. The technology factor reflects the fact that in some cases, technology arrangements at plants preclude investment in equipment to harness the full commercially viable potential use of renewable energy. The institutional factor reflects the fact that businesses with renewable energy resources may decide, because of insufficient knowledge, perception of high risk, or other factors, not to invest in renewable energy generation even if it is commercially viable. Structural and institutional factors appear to be the greatest barriers to renewable energy development in Thailand. It should be noted, however, that recently a number of institutional barriers have improved. For example for VSPP generators, significant steps have been taken to remove stumbling blocks regarding assessment of VAT tax and questions regarding the requirement for concessions that had blocked or slowed processing of VSPP applications. Similarly for renewable energy SPPs, the requirement of generating no more than 65% of capacity during off-peak periods has been rescinded by Cabinet decree.

Table 37. "Commercially Viable" And "Practically Achievable" Estimates of Power From Renewable Energy Technologies in Thailand.

	Commercially viable power (MW)	Tech factor	Inst factor	Practically achievable Firm (MW)	Practically achievable non firm (MW)	Capacity factor
Biogas						
Cassava	300	0.90	0.80	**216**		0.80
Pig farm, etc.	65	0.75	0.60		**29**	0.50
Biomass						
Rice Husk	150	0.75	0.25	**22**	**7**	0.85
Bagasse	1990	0.75	0.50	-	**746**	0.30
Coconuts	43	0.75	0.50	-	**16**	0.85
Corncob	54	0.75	0.50	-	**20**	0.85
Distillery slop	49	0.75	0.50	-	**18**	0.85
Wood residues	118	0.75	0.50	**36**	**8**	0.85
Palm oil residues	43	0.75	0.50	-	**16**	0.85
Sawdust	16	0.75	0.50	-	**6**	0.85
Small hydro	271	0.75	0.75	-	**152**	0.44
Solar*	n/a	n/a	n/a		**100**	0.14
Wind*	n/a	n/a	n/a		**75**	0.15
Total	**3099**			**274**	**1195**	

* Not commercially viable without subsidy. The levels reflect government targets.

5.7.1 Practically Achievable Biogas

The bulk of commercial biogas potential is in the cassava processing industry. Here the key constraint on development of the estimated 300 MW of commercially viable potential is financing. Within the next 10 years, US$100 million will be invested in Thai biogas. However, over US$300 million is required for full development of the sector, which considering that capital costs are around $1 million per MW. CleanTHAI has a head-start in terms of signing contracts with cassava producers, half a dozen other companies (CST Environment, Jiamphatana, several contractors for Biogas Advisory Unit of Chiang Mai University, and the Energy for Environment Foundation) are actively involved in project development. Given the lucrative returns, competition is expected, but expertise in the field is limited, and much of CleanTHAI's success is attributable to technology innovations that it currently holds the rights to. It is uncertain whether expansion of the industry can take place in ways that maintain the high quality performance that early entrants have achieved.

Several outside factors could have significant influence. One is that all cassava processing facilities in Thailand export their tapioca or modified starch to developed countries (primarily Australia, Europe, Japan and S. Korea). These markets are all ISO 9000 certified, which means that all of their suppliers must also be ISO 9000 certified (which they are). In many of these markets, there is an international push to have ISO 14000 as the norm. If this happens, all Thai cassava processing facilities will then have to treat their wastewater flows in a different manner; different from the current methods utilized (i.e. open lagoon network), thus biogas production under controlled environment is the answer. In this case, biogas for electricity becomes a byproduct of a mandatory waste-treatment measure – expect more than 300 MW.

Another strong possibility is that the Thailand government agrees to carbon trading under the Clean Development Mechanism. As discussed above, this new revenue stream would be the same order of magnitude of the existing revenue stream for these already commercially viable projects. Again, the 300 MW of commercially viable potential would have to be revised upwards (300 MW covers about half of Thai cassava processing facilities), and even higher investor returns could be met.

A third possibility is that the currently unsubsidized biogas plants may be eligible for renewable energy subsidies currently under development. This could include a production subsidy (feed-in tariff), premiums for biogas under the RPS, or inclusion of biogas in a “green power” program under discussion. More likely in the short term is the expansion of VSPP to include streamlined interconnection and wholesale TOU tariffs for projects that export up to 5 MW, up from the current maximum threshold of 1 MW. All increase the commercial viability of biogas.

A fourth possibility is that digestion of cassava wet cake waste is a commercial success, following in the footsteps of cassava wastewater. Industry insiders estimate that wet cake has a commercial potential of 900 MW (not included in tables above because commercial scale pilot has not yet happened).

On the other hand, it is possible that the cassava industry declines because of market competition (Thailand is the world’s second largest producer, second to Brazil), widespread disease, or the discovery of some as-yet unknown use of cassava residues with higher commercial value than electricity production.

The potential range of build-out in biogas industry by 2011 ranges from a low of 100 MW (unlikely given that CleanTHAI alone has 70 MW of projects in the pipeline for 3-5 years) to more than 300 MW assuming availability of finance and growth of competent project developers. The most likely scenario is that considerable growth will occur, with 220 MW of firm biogas developed and 30 MW of non-firm biogas by 2011. The “technology factor” in the case of biogas is high at 0.9, as the technology provides significant space savings over the use of holding ponds, improves environmental quality, has negligible negative environmental impacts, is quickly installed, and commercial level projects have already performed beyond expectations. The “institutional factor” of 0.8 reflects the challenges yet fundamental competency in rapid expansion of the industry to meet commercial potential.

5.7.2 Practically Achievable Biomass

Biomass development is also constrained by insufficient low-interest finance. In all likelihood, however, it will receive a boost as 1140 MW of biomass electricity are slated for subsidies under the government program to reach its 8% renewable energy target. These include 100 MW under the RPS program, and 1040 MW under a variety of other incentives including a new round of SPP subsidy bidding.

CDM could also play a significant role. Two 20 MW scale biomass projects have already been approved for carbon trading, and buyer found for the CERs. Thailand’s decision to adopt CDM, if it comes, will further boost commercial returns.

With commercial viability exceeding 2000 MW without subsidy, and with significant targets and subsidies to push them, it is likely that Thailand will see at least 900 new MW of biomass capacity online by 2011. For all biomass cases technologies, “technology” derating factor is set at 0.75, reflecting general ease of accommodating changes in residue flows, modest space requirements, acceptable water requirements, and commercially developed technology. The institutional factor is set at 0.5 for all resources except rice husk, reflecting remaining lack of awareness of opportunities to develop biomass residue resources, hurtles in obtaining necessary permits and permissions, and also reflecting community opposition in the case of some larger projects. In the case of rice husk, the institutional factor is set at 0.25 reflecting challenges with price volatility and lack of power plant bargaining power in purchasing sufficient fuel supplies.

5.7.3 Practically Achievable Small Hydro

The government has made development of small hydro a priority, with incentives planned for 350 MW. Though the incentives have yet to be determined, the agency charged with designing the incentive program, the DEDE, also has extensive small hydro experience and is taking a lead role in developing plans for new installations. While this represents a possible conflict of interest, the arrangement suggests that coordination between subsidies and project developer will likely go smoothly and support levels may be high. In addition, small hydro projects would likely be eligible to receive revenues for carbon emissions reductions, if CDM is approved by the Thai government.

These small hydro projects should have limited impacts on the environment as they are all planned for existing dams and irrigation structures. Although community opposition has been strong to larger hydro projects in Thailand (such as the 50 MW Pak Mun dam) the diversions to natural water flow in this case are already mostly in place. For this reason, both technology factor and institutional factor are set at 0.75.

5.7.4 Practically Achievable Solar and Wind Power

Even though neither solar nor wind power are commercially viable without subsidies, they will be deployed to a certain extent in Thailand to meet RPS requirements and in response other incentives. Solar electricity and wind power figure strongly in government vision of renewable energy development in the country, and significant investment is already underway to build both solar cells and wind turbines in Thailand to meet demand expected to be spurred by domestic programs. This includes a 20 MW/year amorphous solar module facility, and a factory to build various plans for wind turbine manufacture to be begin production within 18 months.

EGAT, working together with PEA and DEDE are reportedly developing plans for three small wind farms of 50 MW, 30 MW and 20 MW in three southern province to fulfill EGAT wind obligations under the RPS. Because the technologies are not viable without subsidies, and because the subsidy levels have not yet been determined, the concept of “technology factor” or “institutional factor” are not appropriate here.

5.8 Estimate of Practically Achievable Annual Renewable Energy Production by 2010

Energy produced (GWh/yr) from this practically achievable basket of renewable energy producers is shown below in Table 38 below. In the table, GWh/yr figures for each fuel are calculated from practically achievable MW and capacity factors shown above in Table 37:

- An estimated 1,943 GWh/yr of firm electricity is practically achievable at a commercial cost of 1.71 THB/kWh.
- An additional 3310 GWh/yr of non-firm electricity is achievable at 2.18 THB/kWh. The higher cost of non-firm electricity is as a result of high cost of solar and wind contributions. Without solar and windpower, the total mix is 1.77 THB/kWh, but rises to 2.01 with solar and wind included.

Table 38. Estimate of Practically Achievable Annual Renewable Energy Production by 2010.

	GWh/yr firm	GWh/yr non-firm	Commercial cost firm (baht/kWh)	Commercial cost non-firm (baht/kWh)
Biogas				
Cassava	1514	0	1.54	
Pig farm etc	0	128		1.80
Biomass				
Rice Husk	161	49	2.2	1.85
Bagasse	0	1961		1.83
Distillery slop	0	137		1.82
Wood residues	268	62	2.37	1.77
Palm oil residues	0	120		1.82
Sawdust	0	45		1.82
Small & micro hydro	0	588		1.74
Wind*	0	123		5.20
Solar*	0	99		10.10
Firm total	1943		**1.71**	
Non-firm total		3310		**2.18**
TOTAL	5252			**2.01**
Non-firm total excl. wind & solar		3088		**1.81**
TOTAL excl. wind & solar	5031			**1.77**

* Not commercially viable but still likely to be built since these sources are emphasized in government plans for subsidies.

5.9 SUMMARY AND CONCLUSIONS ON RENEWABLE ENERGY POTENTIAL

5.9.1 Potential for Firm and Non-Firm Renewable Energy

Table 39 summarizes the overall conclusions for RE potential. In terms of commercial viability, the author estimates -- based on government commissioned studies and interviews with industry professionals – that 300 MW of firm renewable electricity and 2651 MW of non-firm renewable electricity is has commercial costs below the projected 1.88 THB/kWh for electricity delivered to Thailand from the NT2 project in Laos (see Table 32).

Table 39 Summary of Renewable Energy Potentials

		RE Potential in 2011	
Sector	**Estimate Based on Analysis in …**	**Firm**	**Non-Firm**
Commercial and Economic RE Potential			
Commercially viable power	Table 32	300 MW	2,641 MW
Economically viable power	Table 33	300 MW	126.4 MW
Practically Achievable Potential			
Commercially viable power	Table 37	274 MW	1,195 MW
Commercially viable energy	Table 38	1,943 GWh/yr	3,310 GWh/yr

Inexpensive firm renewable electricity potential derives from particularly cost-effective biogas using waste water from Thailand's large cassava processing industry, with commercial costs of 1.54 THB/kWh based on existing commercial-level operations, a 10 year project life, and returns to investors at 16% per annum. Non-firm capacity is dominated by biomass, in particular bagasse (1,990 MW), with commercial costs for biomass of different fuel types estimated using actual average SPP prices for each fuel type as an upper bound proxy for costs. Non-firm hydropower in existing dams and irrigation systems provides another 271 MW of potential at average cost of 1.74 THB/kWh.

In terms of economic viability, 300 MW of firm RE potential (cassava wastewater biogas) is found to have economic costs lower than NT2's projected economic costs of 1.08 THB/kWh; and 126.4 MW of non-firm potential is also less economically costly than NT2 (comprising 65 MW of non-firm biogas and 61.4 MW of small hydropower).

Because of a variety of institutional and technical factors, not all of the low-cost renewable energy potential is expected to be developed by 2011. At the same time, a certain amount of non-commercially or non-economically viable renewable energy sources are expected to be installed in response to government programs. As indicated in Table 37 (and summarized in Table 39), there is a practically achievable potential of an estimated 274 MW of firm RE generation, and 1,195 MW of non-firm generation.

In terms of energy produced, expected energy production of practical potential is equal to 1943 GWh/yr (firm) and 3310 GWh/yr (non-firm) at average commercial cost of 1.71 and 2.18 THB/kWh respectively. The higher cost of non-firm electricity is a consequence of expected solar and wind contributions which require significant subsidies to be commercially viable. The firm/non-firm aggregate price is 2.01 THB/kWh. Without wind or solar, aggregate price is reduced to 1.77 THB/kWh..

5.9.2 Policy Context

Commercially and economically viable potential should be considered in the context of Thai government priorities to develop renewable energy. The overarching target calls for increasing renewable energy use from a year 2003 level of 0.5% of total commercial energy to 8% of total commercial energy consumption by the year 2011. The Thai government has reaffirmed this target in a number of domestic energy policy forums, as well as the 2004 International Conference for Renewable Energies in Bonn Germany, and most recently included the 8% target in Thailand's UN Millennium Development Goals.

The most recent plans call for the 8% obligation to be met through the combination of a renewable portfolio standard (RPS), a variety of incentive programs, and increased funding for research and development of renewable energy technologies. Renewable energy's electricity contribution is targeted at 1,840 MW new capacity, comprising 400 MW from an RPS set at 5% of new fossil generation capacity, and 1,440 MW to be developed through a variety of programs including specified electricity tariffs for different renewable energy, tax breaks, direct capital subsidies, and R&D.

The EGAT 2003 PDP accounts for 223 MW of renewable energy SPP between 2003 and 2006, leaving 1,617 MW of new renewable energy targeted by the government but not in the 2003 PDP. To meet the targets, new funds totaling over baht 4.5 billion (US$112.5) are allocated to support renewable energy by the year 2011. These funds are in addition to 7.397 billion baht ($185 million) funds earmarked for renewable SPP subsidies and other pre-existing programs.

SECTION 6. ISSUES RELATED TO THIS ANALYSIS

While the scope of this study is limited to an assessment of the achievable potential for cost-effective DSM/energy efficiency and renewable energy resources, this short section looks at several related "macro" issues and how they may affect the analysis of power and energy resources needed at the end of this decade. The purpose is to provide an underlying context to the discussion of DSM and renewable resources.

6.1 SMALL POWER PRODUCER RESOURCES

A brief review of recent PDPs and power purchase policies suggests a larger potential for renewable SPPs than indicated in the official power plans. Citing oversupply after the 1997 financial crisis, EGAT announced that it would indefinitely postpone accepting applications from new SPP generators. Renewable-energy SPPs[41], however, are exempted from this restriction, and EGAT is required to purchase power from renewable SPPs up to an offered purchase price. The offered purchase prices are published in the SPP regulation, which divide SPPs into two categories: firm and non-firm, depending on their ability to guarantee availability. The actual weighted average price of power delivered by biomass SPPs, both firm and non-firm, was around 2.06 THB/kWh in October 2002.

For the purpose of planning generation requirements, EGAT's Power Development Plan (PDP) considers only firm SPPs. The latest PDP (2004) includes 211.1 MW of SPPs, which have either signed contracts with EGAT or been approved to receive subsidy from the ENCON Fund, for the entire planning period of 2004-2015. There are however additional potential SPPs that intend to sell power, as evidenced by the large number of applications that have been submitted to EGAT but not yet received acceptance. As can be seen in Table 40, the proposals submitted but not accepted by EGAT amount to more than 2,000 MW of firm power.[42] These non-contracted potential SPPs are not included in the PDP.

6.2 COGENERATION RESOURCES

This study has also not considered energy savings from cogeneration — although this may be a considerable omission. Cogeneration is a large source of potential energy efficiency savings because the combined production and utilization of heat and power for industrial processes can raise the efficiency of the power plant output by as much as two-fold and reduce the need for electricity supply. The SPPs noted in Table 40 that have been submitted but not contracted by EGAT represent more than 4,000 MW of power, approximately half of which would be consumed on site and half sold to the grid. Since most of these projects were submitted prior to the economic crisis, it is likely that there is significant additional cogeneration potential for on-site generation as well as sale to the grid. While this report did not investigate the cogeneration potential in detail, it is noted that the number of submitted projects represents a large, as yet untapped, resource.

[41] Renewable-energy SPPs are defined as power producers with net power sale to EGAT of no greater than 90 MW and at least 75% of the plant heat value derived from renewable energy sources.
[42] http://www.eppo.go.th/power/pw-spp-purch-Total.xls

Table 40. EGAT Power Purchases from Small Power Producers (as of January 2004)

	Firm	Non-Firm	Total
1. Proposals submitted			
at 1.1 Number of Projects	79	50	129
1.2 Generating Capacity (MW)	7,845.11	893.71	8,738.82
1.3 Sale to EGAT (MW)	4,624.80	292.28	4,917.08
2. Received Notification of Acceptance*			
2.1 Number of Projects	42	43	85
2.2 Generating Capacity (MW)	3,655.21	820.70	4,475.91
2.3 Sale to EGAT (MW)	2,123.30	281.10	2,404.40
2.4 Type of Fuels			
- Natural Gas	20	-	20
- Hydro Power	-	1	1
- Coal	5	2	7
- Oil	1	-	1
- Bagasse	2	30	32
- Paddy Husk	5		
- Paddy Husk, Wood Chips	2	1	3
- Municipal Waste	-	1	1
- Bagasse, Wood bark, Paddy Husk	2	-	2
- Rubber Wood Chips, Palm Residue	1	-	1
- Paddy Husk, Bagasse, Eucalyptus	1	1	3
- Black Liquor	1	-	1
- Waste gas from production process	-	2	2
- Wood bark, Wood Chips, Black Liquor	1	-	1
- Rubber Wood Chips	1		
3. Contract Signed			
3.1 Number of Projects	35	38	73
3.2 Generating Capacity (MW)	3,492.51	766.20	4,258.71
3.3 Sale to EGAT (MW)	2,019.60	256.60	2,276.20
4. Supplying Power to The Grid			
4.1 Number of Projects	32	30	62
4.2 Generating Capacity (MW)	3,166.51	687.50	3,854.01
4.3 Sale to EGAT (MW)	1,937.20	222.40	2,159.60

* Excludes Small Power Producers that did not present Proposal Securities and withdrew

6.3 Load Forecast

It may also be helpful to put EGAT's projected need for power from NT2 into perspective. While the planned contribution from NT2 is 920 MW, the variability in the January 2004 demand forecast (upon which the most recent PDP 2004 is based) is considerably larger. The difference between the low and high scenario forecasts for year 2010 is about 8,200 MW—almost nine times the capacity of the NT2 project. Furthermore, a review of Thai electricity load forecasts over the past 12 years shows that the forecasts have historically tended to be high compared to actual demand experienced by the electricity system (see Figure 2). Compared to the forecasts, actual demand tends to be lower and only in rare cases has even exceeded the low-forecast scenario. However, since the 1998 crisis, the more recent load forecasts appear to be more accurate.

The assumed average GDP growth rate of 6.5% for the next 13 years in the MEG scenario also appears high, especially considering the current situation in which oil prices are high, a circumstance that was unforeseen at the time the forecast was made. Moreover, the actual average annual GDP growth rates over the past 10 and 15 years were only 3.9% and 5.6% respectively, and the size of the economy was much smaller then.

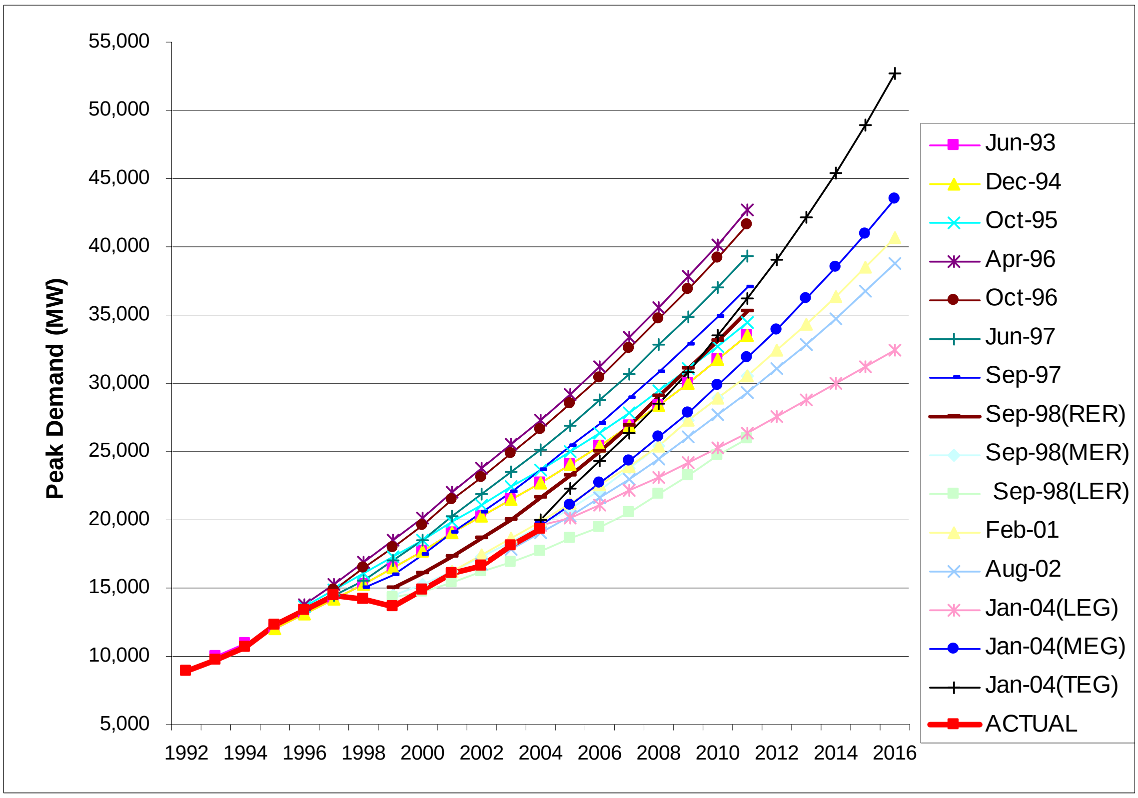

Figure 2. Comparison of Thai Load Forecasts to Actual Demand from 1992 to Present.

SECTION 7. OVERALL CONCLUSIONS ON ACHIEVABLE POTENTIALS

This section pulls together the data presented previously to review the amount of DSM and renewable energy that has been included in recent load forecasts and PDPs, respectively and to compare these to the more detailed estimates that have been developed of the achievable potential for DSM and renewable energy resources potential through 2011.

Table 41 compares various estimates of the MW potential; and Table 42 compares the potential for energy savings (or delivered energy in the case of renewable energy).

In the August 2002 load forecast, the estimated peak demand savings in the year 2011 was 982 MW; and in the January 2004 forecast, it is 1,649 MW. Based on the assessment in this study, the achievable commercial DSM potential for 2011 is significant higher, at 2,207 MW.

In terms of renewable energy, this study estimates that there is a practically achievable commercial potential of 274 MW of renewable energy in 2011.

In sum, this study identifies 1,499 MW of additional, achievable and cost-effective DSM and renewable energy resources that are not accounted for in the August 2002 load forecast (see Table 43).

Table 42 shows estimates of the potential for reductions in energy requirements. *The overall avoided energy in this analysis is 11,468 GWh/year from DSM/EE and 5,400 GWh/year from renewable energy, for a total of 16,868 GWh/year. This is 6,264 GWh per year more than is included in the January 2004 load forecast.*

Table 41. Comparison of Estimates of the Commercial DSM and RE Resource for Thailand – PEAK DEMAND RESOURCES.

	2002 LOAD FORECAST		**WB VIEW ON 2002 LOAD FORECAST**	**THIS STUDY**		
	EE Plans reported in Aug. 02 Load Forecast	**EE in Aug. 02 Load Forecast**	**EE in World Bank Alt. View (Mar 04)**	**DSM/EE Potential: Average from Sector and Govt. Analyses**	**FIRM RE Potential Based on Technology and Cost Analysis**	**Overall Avoided Peak from DSM/EE and FIRM RE**
Year	**(Peak MW)**	**(Peak MW)**	**(Peak MW)**	**(Peak MW)**	**(Peak MW)**	**(Peak MW)**
2004	638	247	94	**154**		
2005	787	396	170	**427**		
2006	912	520	251	**708**		
2007	1,017	626	331	**996**		
2008	1,104	713	410	**1,286**		
2009	1,195	803	504	**1,583**		
2010	1,287	896	582	**1,891**		
2011	1,373	982	662	**2,207**	**274**	**2,481**

Table 42. Comparison of Estimates of the Commercial DSM and RE Resource for Thailand – ENERGY RESOURCES.

	2002 LOAD FORECAST		WB VIEW	THIS STUDY		
	EE Plans reported in Aug. 02 Load Forecast	EE in Aug. 02 Load Forecast	EE in World Bank Alt. View (Mar 04)	DSM/EE Potential: Average from Sector and Govt. Analyses	Firm RE Potential Based on Technology and Cost Analysis	Overall Avoided Energy from DSM/EE and Firm RE
Year	(GWh/yr)	(GWh/yr)	(GWh/yr)	(GWh/yr)	(GWh/yr)	(GWh/yr)
2004	4,105	1,589	606	**778**		
2005	5,061	2,545	1,095	**2,163**		
2006	5,862	3,346	1,617	**3,587**		
2007	6,540	4,024	2,129	**5,048**		
2008	7,101	4,585	2,635	**6,517**		
2009	7,682	5,166	3,238	**8,021**		
2010	8,277	5,761	3,742	**9,581**		
2011	8,830	6,314	4,259	**11,181**	**1,943**	**13,124**

Table 43. Comparison of Commercially Viable and Achievable Resource Sizes and Commercial Costs

Resource Type	Achievable Amount of Resource in 2011		Average Commercial Cost of Supplied Energy
	Energy (GWh/yr)	Peak (MW)	(THB/kWh)
NT2 at plant	NA	995	
NT2 delivered to EGAT customers in Thailand	**5,636**	**920**	**2.3**[43]
DSM/Energy Efficiency	11,181	2,207	0.92
Firm Renewable Energy	1,943	274	1.54
Subtotal for DSM/EE and Firm RE	**13,124**	**2,481**	**< 1.88**[44]
Amount of DSM/EE included in the August 2002 demand forecast	6,314	982	NA
Amount of DSM/EE and Firm RE not included in August 2002 demand forecast and PDP, respectively.	**6,810**	**1,499**	**< 1.88**
Additional NON-Firm Renewable Energy that is commerciall viable and practically achievable	3,310	1,195	2.13

43 Segal 2004

44 THB 1.88/kWh is the commercial cost of electricity delivered to the Thai grid from NT2. It is therefore the cut-off above which firm RE resources would not be cost-effective compared to NT2-supplied electricity. For DSM/EE resources, which are provided at the customer's facility, they could actually be cost effective up to THB 2.3/kWh, which is the commercial cost of NT2 electricity delivered to EGAT customers in Thailand.

8. REFERENCES

Agra-Monenco. 2000. *DSM Program Evaluation. Conservation Program*. Final evaluation for GEF-funded DSM program. Bangkok, Thailand. March.

AIT (Asian Institute of Technology). 2002. *Review of State of the Art Building Design in Hot and Humid Climate*. Prepared for Thailand Department of Alternative Energy Development and Efficiency (DEDE) and Danish International Development Agency (Danida). Bangkok, Thailand. November.

Amatayakul, W. and C. Greacen. 2002. *Thailand Experience with Clean Energy Technologies: Power Purchase Programs*. UNDP International Seminar on Energy for Sustainable Development and Regional Cooperation, Beijing, China.

Black & Veatch. 2000. *Final Report: Thailand Biomass-Based Power Generation and Cogeneration within Small Rural Industries*. Thailand National Energy Policy Office. Bangkok, Thailand.

Busch, J. 1990. From Comfort to Kilowatts: An Integrated Assessment of Electricity Conservation in Thailand's Commercial Sector. Ph.D. Thesis, Energy and Resources Group, University of California, Berkeley.

Chulalongkorn University. 2004. Summary of Results from Energy Efficiency Revolving Fund and Annex 4.4-4.11. Energy Research Institute of Chulalongkorn University. Bangkok, Thailand. April.

Daily News, Minister of Energy believes that if small hydro projects happen electricity will be cheaper (in Thai), in Daily News. 12 December, 2003: Bangkok.

DEDE (Department of Alternative Energy Development and Efficiency) 2004C. Energy audit reports and Targets and Plans prepared for Designated Facilities for DEDE's Planning Division. Bangkok, Thailand. Reviewed in May.

DEDE (Department of Alternative Energy Development and Efficiency) 2004B. Brochure with energy savings results of 30% Subsidy Program. Bangkok, Thailand. May.

DEDE (Department of Alternative Energy Development and Efficiency) 2004C. Macroeconomic analysis of the impact of the proposed revision to the Thailand building energy code. Bangkok, Thailand. January.

DEDE (Department of Alternative Energy Development and Efficiency). 2002. Energy Conservation Master Plan 2002-2006, Department of Alternative Energy Development and Efficiency. Bangkok, Thailand. October.

DEDP (Department of Energy Development and Promotion). 1998. *Micro-Mini Hydropower Development*. Bangkok, Thailand.

DEM (Danish Energy Management A/S). 2004. Benchmarking of Air Conditioner Efficiency Levels in Five Asian Countries. Final Draft Report. Prepared for the Australian Greenhouse Office. June.

Dickinson, J. 2004. Personal communication. Bangkok, Thailand.

Donneley, D. 2003. Personal communication. Bangkok, Thailand.

Donneley, D. 2003. Personal communication. Bangkok, Thailand.

DOE/EIA. 1995. Electricity Generation and Environmental Externalities: Case Studies. http://www.eia.doe.gov/cneaf/electricity/external/external.pdf

EGAT. 2003. Management of the Energy/Electricity Industry for the People. Bangkok, Thailand. 17 April.

EGAT. 2000. Load duration curve. Bangkok.

EGAT. 2001. *Power Purchase Agreement for SPPs*. Bangkok, Thailand.

EGAT (Electricity Generating Authority of Thailand). 1998. *New Buildings Program Support: Demand-Side Management (Draft Final Report)*. Prepared for EGAT DSM Office by NEOS Corporation. Bangkok, Thailand. September 4.

EGAT, MEA, and PEA. 1998. Regulations for the Purchase of Power from Small Power Producers. Bangkok (English Translation). January.

ENCON Committee. 2004. Resolution of the Energy Conservation and Promotion Committee. (in Thai) 7 Dec 2004. Bangkok.

Energy for Environment. 2004. *Study to determine methods to support electricity generation from wind and solar energy*. Bangkok, E for E Foundation. Commissioned by Thailand Energy Policy and Planning Office (EPPO).Bangkok, Thailand.

Energy for Environment. 2003. "Study to Determine Appropriate Solar, Wind and Microhydro Tariffs." E for E Foundation. Commissioned by Thailand Energy Policy and Planning Office (EPPO).Bangkok, Thailand.

EPPO. 2004. Policy and Program on Promotion of Renewable Energy (in Thai). EEDA Renewable Energy Forum,Thursday, 28 October, BITEC Bangna, Bangkok.

FAO. 2003. *Current Production and Crop Prospects*. http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/005/y9141e/y9141e05.htm

FAO. 2003. *June 2003 cassava market assessment*. http://www.fao.org/es/esc/en/20953/21029/highlight_28829en.html

FT Subcommittee. 2003. *Report on calculations of automatic adjustment tariff (FT) for the month of September*, 2002. Bangkok, Thailand.

IIEC (International Institute for Energy Conservation). 2000. Thailand ESCO Development Project: Industrial/Commercial Energy Efficiency Market Assessment. Prepared for: Thai-German Energy Efficiency Promotion Project (ENEP) and Department of Energy Development and Promotion (DEDP). Bangkok, Thailand. 21 December.

IIEC (International Institute for Energy Conservation). 1993. *Thailand: Promotion of Electricity Energy Efficiency, Pre-Investment Appraisal (Final Report)*. Prepared for world Bank/Global Environment Facility, United Nations Development Program. Bangkok, Thailand. February.

IIEC (International Institute for Energy Conservation). 1991. *Demand Side Management for Thailand's Electric Power System: Five-Year Master Plan*. Submitted to Electricity Generating Authority of Thailand, Metropolitan Electricity Authority and Provincial Electricity Authority, Bangkok, Thailand. Bangkok, Thailand. November.

IEA (International Energy Agency). 2003. "470 Mtons CO2 at Negative Cost: Opportunities in Appliances Energy Efficiency Programmes." Presented by Benoit Lebot, Energy Efficiency Policy Analysis Division, IEA, at the conference, Climate Change and Energy: A Focus on Technologies. Bonn, Germany. 11 June.

Jiandong, T. 2003. "Small hydro on a large scale: challenges and opportunities in China." Renewable Energy World **6**(1): 97-102.

Kansai Environmental Engineering. 2004. *Feasibility Study on Cogeneration Business in Thailand Utilizing the Bagasse and Rice Husk*. Bangkok, Kansai Environmental Engineering Center, Co., Ltd. http://gec.jp/gec/en/Activities/cdm/FS200309SE.pdf

LFWG (Load Forecast Working Group). 2003. Thailand Electricity Demand Load Forecast. 2003.

Navigant Consulting (2003). The Changing Face of Renewable Energy.

NEPO (2002). Regulations for Purchase of Power from Very Small Renewable Energy Power Producers (English Translation), NEPO. http://netmeter.org/en/regs/commercial

NEPO (National Energy Policy Office). 2002. *Renewable energy and energy conservation plan 2002-2011* (in Thai). Bangkok, NEPO.

NEPO (National Energy Policy Office). 2001. *Strategic Plan for Thailand's Energy Development*. NEPO.

NEPO (National Energy Policy Office). 1998. *Investigation of Pricing Incentive in a Renewable Energy Strategy*. Bangkok, Thailand. Report produced for NEPO with support from Danish Cooperation for Environment and Development (DANCED).

Parker, D. 1991. Residential Demand Side Management in Thailand. International Institute for Energy Conservation, Bangkok, Thailand.

Perman, R., Y. Ma, et al. (1999). *Natural Resource & Environmental Economics*. London, Longman.

Phumaraphand, N. 2001. "Evaluation Methods and Results of EGAT's Labeling Programs." Presentation at the conference, *Lessons Learned in Asia: Regional Conference on Energy Efficiency Standards and Labeling.* Organized by Collaborative Labeling and Appliance

Standards Program (CLASP) and the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). Bangkok, Thailand. Bangkok, Thailand. 29-31 May.

Richard Plevin and D. Donnelley. 2004. "Converting waste to energy and profit." Renewable Energy World **7**(5): 74-81.

Ranjana Wangvipula. 2004. Rice husk demand seen as too high. Bangkok Post.28 August

Ryder, G., Thailand's Flawed Electricity Privatization: The Case for Citizen-Oriented Reform, in Power Sector Reform. 1999, Probe International: Toronto.

Segal, Mark. 2004. Consultant. Personal communication. December.

Shrestha, S. and T. Lefevre. 2000. Estimation of external cost associated with electricity generating options in Thailand using simplified methodologies. Eighth APEC Clean Fossil Energy Technical Seminar. Bangkok. http://www.apec-egcfe.org/ThaiSeminar_2000/3-2%20S_Shrestha.pdf

Sundqvist, T. 2000. *Electricity Externality Studies: Do the Numbers Make Sense?* Instituitionen for Industriell ekonomi och samhallsvetenskap Avdelningen for Nationalekonomi. Lulea Tekniska Universitet.

Tatong, S. 2004. Personal communication. Bangkok, Thailand.

TEI (Thailand Environment Institute). 1995. *Thailand Energy Futures, Appendix E: Energy Efficiency Potential in the Industrial Sector.* Prepared for the Thailand Environment Institute by the Stockholm Environment Institute - Tellus Institute. Bangkok, Thailand. May 15.

TEI (Thailand Environment Institute). *Consultant Report on the Residential and Commercial Sectors for Thailand's Energy Future Project*. Prepared for the Thailand Environment Institute by Dr. John Busch, Lawrence Berkeley National Laboratory. Bangkok, Thailand. April 1995.

Thanh, B. and T. Lefevre. 2001. "Assessing health benefits of controlling air pollution from power generation: the case of a lignite-fired power plant in Thailand." *Environ Manage* **2**: 303-17.

Thai Ministry of Energy. 2004. Progress in developing regulations to purchase electricity under RPS policy (in Thai). Powerpoint presentation. Undated, November. Bangkok, DEDE.

Thai Royal Irrigation Department. 2004. *Project to develop master plan and to implement small hydro projects in dams and irrigation systems* (in Thai). November. Bangkok, Ministry of Agriculture.

Thammasat University. 2004. "Monitoring and Evaluation of Energy Conservation in Buildings and Industries. Draft Final Report." Thammasat University Research and Consultancy Institute, April.

Thammasat University. 2004. "Evaluation Study of Energy Conservation in Implemented Government Buildings." Thammasat University Research and Consultancy Institute. Bangkok, Thailand. March.

Univanich. 2004. Univanich Palm Oil forecasts strong growth in Thailand's oil palm industry.http://univanich.com/news.htm

Vongsoasup, S. and P. du Pont. 2004. "Energy Efficiency Promotion Strategy For Energy And Buildings In Thailand." Presented at WEC Regional Energy Forum – FOREN 2004. Neptun, Romania. 13-17 June.

World Bank. 2004. "Nam Theun 2 Project Economics: Interim Summary Report." Prepared by Mark Segal for The World Bank. 21 August.

World Bank. 2000. *DSM in Thailand: A Case Study*. Report produced for UNDP and World Bank Energy Sector Management Assistance Programme (ESMAP). Washington, DC. October.