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SUSTAINABLE ENERGY IN CAMBODIA: STATUS AND ASSESSMENT OF THE POTENTIAL FOR CLEAN DEVELOPMENT MECHANISM PROJECTS

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Front cover illustrations (from left to right, top-down): opening ceremony of the IGES/MoE Workshop on the Clean Development Mechanism by So Puthea; solar panels at the NEDO-funded hybrid PV and biogas project near Sihanoukville, CRCD team testing wind turbine by Tin Ponlok; a group of REEs visiting the JICA-funded diesel power plant in Siem Reap Province by Thanakvaro De Lopez; cooking in Angkor times at Bayon Temple's bas-relief by Tin Ponlok; power grid in Phnom Penh by Noelle O'Brien; used truck engine converted to a rice mill motor drive in Battambang by Tin Ponlok; charcoal transported to Phnom Penh by Noelle O'Brien; power house of the NEDO-funded solar PV-mini hydro project in Kampong Cham Province, locally reassembled truck by Tin Ponlok; smoke from a Phnom Penh power station by Sao Phan; a pile of rubber tree fuelwood at a brick kiln by Tin Ponlok.

Back Cover Illustrations (from left to right, top-down): workers uploading finished bricks from a kiln in Kandal Province, preparation before wind turbine testing, wind turbine for water pumping in Kampong Cham, motorbike transport in Kandal Province, a stack of rice husk in Battambang Province, children collecting rice husk for cooking in Battambang Province, diesel water pumping in Kandal Province by Tin Ponlok; workers chopping fuelwood by Noelle O'Brien; cattle farm providing manure for biogas production near Sihanoukville, diesel engine drive for a mini rice mill, fuelwood collected from the Mekong River during the flooding season, a mini rice mill in Kampong Speu Province, skylights in front of the Cambodian Climate Change Office children collecting fuelwood in Kandal Province by Tin Ponlok.

FOREWORD

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Credits: Picture 1 by Noelle O'Brien; Picture 2 by Thanak De Lopez; Picture 3 by So Puthea; Pictures 4 and 5 by Tin Ponlok.

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AIT	Asian Institute of Technology
CFSP	Cambodia Fuelwood Saving Project
COGEN3	EC-ASEAN COGEN Programme
CO_2equiv.	CO_2 equivalent
CRDT	Cambodian Research and Development Team
EAC	Electricity Authority of Cambodia
EDC	Electricité du Cambodge
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organisation
GTZ	German Development Co-operation
IPP	Independent Power Producer
JAFTA	Japan Forest Technical Association
JICA	Japan International Co-operation Agency
JWRF	Japan Waste Research Foundation
KCEC	Khmer Consultant Engineering Corporation Limited
kTOE	Kilo-tonnes of Oil Equivalent (unit of energy)
MAFF	Ministry of Agriculture, Forestry and Fisheries
MEF	Ministry of Economy and Finance
MIME	Ministry of Industry, Mines and Energy
MoE	Ministry of Environment
MoP	Ministry of Planning
NEDO	New Energy and Industrial Development Organisation
NGO	Non-Governmental Organisation
NIS	National Institute of Statistics
PV	Photovoltaic
RE	Rural Electrification
RE&T	Rural Electrification Transmission Project
REAP	Renewable Electricity Action Plan
REE	Rural Electricity Enterprise
REF	Rural Electrification Fund
RGC	Royal Government of Cambodia
SME	Small and Medium Enterprise Cambodia
SMEC	Snowy Mountains Electricity Corporation
TA	Technical Assistance
ToR	Terms of Reference
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

UNITS OF MEASUREMENT

Abbreviation	**Unit**	**Equivalent**
V	volt	Unit of voltage
kV	kilovolt	1,000 volts
W	watt	Unit of power
kW	kilowatt	1,000 watts
MW	megawatt	1,000 kW
J	joule	Unit of energy
Wh	watt-hour	3.6 kJ
kWh	kilowatt-hour	1,000 Wh
MWh	megawatt-hour	1,000 kWh
GWh	gigawatt-hour	1,000 MWh
stere	stere	1 m^3 of stacked fuelwood [1]

[1] The conventional definition of a stere is $1m^3$, which is used in this report. In some areas of Cambodia, such as Phnom Penh markets, 1 stere is equal to a stack of fuelwood 1m by 1m by approximately 0.5m (FAO 1998).

ABSTRACT AND POLICY BRIEF

Cambodia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December 1995. Since then, it has made significant progress in preparing to participate in the Clean Development Mechanism (CDM). An interim Designated National Authority (DNA) has been established at the Ministry of Environment, draft sustainable development criteria have been prepared, and a program of capacity building is well under way with concerned stakeholders.

Current energy use in Cambodia is not environmentally, socially or economically sustainable. Most of the energy consumed is in the form of fuelwood or charcoal and almost all electricity is generated from imported fossil fuels. Consequently the CDM has much to offer Cambodia by facilitating the development of sustainable energy projects.

This study provides a broad overview of Cambodia's energy sector in the context of the country's geography and recent history. It then provides an initial assessment of the potential for sustainable energy projects in Cambodia. This section contains both a coarse, theoretical estimate of the potential for each type of renewable energy, and also a discussion of the current status of projects. This approach finds almost 47 million tonnes per year of potential greenhouse gas (GHG) abatement. Existing projects account for just under 60,000 tonnes of annual GHG abatement.

Most of the projects identified in this study are small, for example 21 mini and micro-hydro projects all less than 5 MW in capacity. This presents a challenge for project investors to ensure that fixed management and certification costs of each project do not make the projects unfeasible. Therefore the simplified methodology for small CDM projects, designed to reduce reporting costs, will be especially important in Cambodia.

This study finds that proposed CDM projects in Cambodia may satisfy the eligibility and administrative requirements, but two issues need to be addressed. The first is the issue of foreign aid funding being used for project development, which is expected in Cambodia; the second is how project developers and potential investors will manage the risk that is inevitable in Cambodia's present economic and political situation. The report describes a variety of government and other initiatives currently being implemented which should contribute to the feasibility of Cambodia's sustainable energy projects.

The need for an ongoing and effective program of data collection and management is continually raised throughout this report. Recommendations for such a program are made in the conclusion.

Acknowledgements

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SECTION ONE: INTRODUCTION

1.1 BACKGROUND

The Institute for Global Environmental Strategies (IGES) of Japan has established an Integrated Capacity Strengthening for the Clean Development Mechanism (ICS-CDM). ICS-CDM has an overarching objective of enabling potential CDM host countries and Japanese investors to participate in CDM projects that contribute to sustainable development.

ICS aims at strengthening the institutional and human capacities in host countries to implement CDM projects through: (i) information dissemination and awareness raising about CDM, (ii) network building among entities interested in CDM in host countries and Japan, (iii) training of personnel to implement CDM, and (iv) support of the finding, development and implementation of CDM projects.

Cambodia has been selected as one of the three participating countries in the region to implement the ICS-CDM project. Phase 1 of the project started from 1 January 2004 and was completed on 31 March 2004 and focused on CDM awareness raising through workshops and a CDM booklet, and assessment of sustainable energy status in Cambodia.

1.2 SCOPE AND OBJECTIVES

The objective of this report is to provide an independent, unbiased stock taking of the status and opportunities for stationary (non-transport related) sustainable energy projects in Cambodia, and a realistic assessment of the potential for developing CDM projects based on these opportunities. The intended audience for this report is all stakeholders in potential CDM projects in Cambodia, and in particular potential project developers, financiers, foreign investors, equipment suppliers, donors and organisations interested in facilitating CDM.

For the purposes of this study a sustainable energy project refers to any project which reduces the emissions of greenhouse gases through the use of renewable energy, energy efficiency or switching to cleaner (i.e.: less greenhouse gas intensive) fuels. Projects in the transport sector are not considered in this study.

This report also includes recommendations for the design of Phase 2 of the ICS-CDM project. Two activities in particular are detailed in the draft terms of reference provided in the Appendix for development of a CDM Investor's Guide for Cambodia and CDM project pipeline.

1.3 AVAILABLE DATA AND INFORMATION

There is very little recent data available on any aspect of Cambodia's energy sector. In particular there has been no comprehensive renewable energy resource assessment for Cambodia, and there is very little energy use data for specific industry sectors and applications.

Official government figures are generally old, incomplete and unreliable. And there is no program established for regular survey and analysis of energy sector data. Foreign donors fund most of the studies and reports on Cambodia's energy sector, and they are generally isolated one-off studies, rather than a regular program of data gathering.

Many existing reports on various aspects of the energy sector are not based on original data, and often data sources are not referenced thoroughly. Consequently it is difficult to reconcile conflicting data or analyse trends (Hundley 2003, NEDO 2002).

SECTION TWO: COUNTRY BACKGROUND

This section provides a brief background to relevant aspects of Cambodia's geography, recent history, politics and economy. A short description of Cambodia's power sector follows, including institutional structure, supply and distribution, future projections and government plans.

2.1 GEOGRAPHY

Cambodia covers an area of 181,035 km^2 in continental South East Asia, bordered on the East by Vietnam, on the North by Laos and Thailand, on the West by Thailand, and to the South by the Gulf of Thailand (MoE 1994). The country is approximately half the size of Japan and a third the size of Thailand.

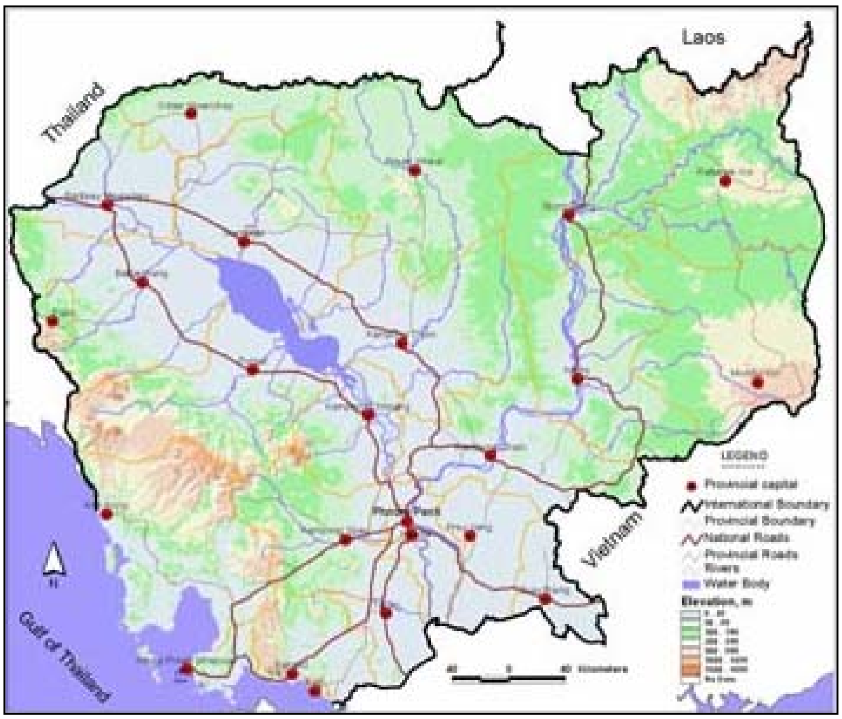


Figure 1: Map of Cambodia

Cambodia has a population of approximately 13.8 million people, of which just over half are under 18 years old (NIS 2003)[2]. Around 84% of the population live in rural areas while most of the rest live in Phnom Penh, the capital city, and other urban areas.

[2] These figures are a projection by the National Institute of Statistics of Cambodia's population in 2003, based on the 1998 census.

2.2 RECENT HISTORY AND POLITICS

Most of the last 30 years in Cambodia was marred by war and violent destruction. Most of the country's infrastructure and technical capacity were systematically destroyed during the Khmer Rouge period, from 1975 to 1979. This was one of the worst periods of human destruction ever seen and in many respects the country is still recovering from the damage to society and the economy (Chandler 1991, Kiernan 1998, Vickery 1986). In some ways the economy is less developed today than it was in the 1960s before the conflicts started (Hundley 2003).

Cambodia is a Constitutional Monarchy with King Norodom Sihanouk as the Head of State. The first post-war democratic elections were held in 1993 which resulted in a period of relative peace and stability. Cambodia's most recent democratic elections held in July 2003 was won by the ruling Cambodian People's Party (CPP). However, CPP failed to achieve the necessary majority in parliament and to reach an agreement with other major parties to form a new government. Consequently there is still no official government formed at the time of the writing of this report, some nine months after the elections.

2.3 ECONOMY

With a GDP per capita of just US $290, Cambodia belongs to the group of twenty poorest nations and is classified as a Least Developed Country (LDC) (Council for Social Development 2002, World Bank 1999). More than a third of the population are living under the poverty line, which is equivalent to a spending capacity of US$0.50/day, and in rural areas this figure rises to 40% (World Bank 2000).

The economy is based on agriculture, which contributes 39.6% of GDP. Garment and tourism sectors are playing an increasing role in the national economy. However, the country is also still highly dependent on foreign aid that contributes 14% of GDP (NIS, 2002). This foreign aid contribution is one of the aspects threatened by the current political situation with no new government formed in the nine months since the July 2003 elections. Some significant loans and assistance packages have been halted until the government is in a position to execute a binding loan agreement (Ten Kate 2004).

2.4 ENERGY SECTOR

Aside from biomass, Cambodia has few conventional energy sources available within the country, and even fewer currently exploitable. Wood accounts for more than 80% of total national energy consumption (MIME 1996). Fuelwood is by far the main source of energy available to the general population, but plays an even greater role for the poor and rural people. Yet, the main source of fuelwood in Cambodia, that is, natural forests, have been severely degraded due to widespread logging and forest land conversion for various purposes over the past twenty years (ADB 2000, Global Witness 2000).

Picture 1: Charcoal Transported to Phnom Penh

The country relies almost entirely on the importation of fossil fuels, mainly diesel and heavy oil, for electricity production. There is no in-depth comprehensive geological survey data available to assess the extent of Cambodia's fossil fuel deposits. Offshore surveys of oil and natural gas have been conducted for the past ten years with various successes and failures. Test drills have revealed the potential existence of presumably large, but yet undetermined, offshore natural gas fields in Cambodia's portion of the Gulf of Thailand. Since neighbouring Thailand has confirmed gas deposits, and has been commercially exploiting them, the probability is high that Cambodia will be able in the longer term to undertake likewise exploitation. This would, however, require substantial investments in infrastructures. Commercially viable offshore gas extraction will probably not be achievable for at least another five years. Two US and one Japanese oil companies have signed concessionary agreements with the Royal Government of Cambodia (RGC) and were scheduled to begin extensive exploration in early 2003 (Carmichael 2003).

Coal deposits are thought to exist in Stung Treng, Preah Vihear and Kampong Thom provinces. In the offshore of southern Kampot and Kaoh Kong there is an availability of reserves of bituminous coal[3]. However there has not been a comprehensive national survey of either (NEDO 2002).

2.5 ELECTRICITY SUPPLY

Electricity was introduced into Cambodia at the beginning of last century under the French colonial administration. Today electricity is provided by a number of different organisations using many different systems, standards and levels of quality. The various types of electricity suppliers in Cambodia can be summarised as follows:

[3] The NEDO study's claim of coal deposits could not be verified.

Table 1: Electricity Suppliers in Cambodia

Supplier	Areas Supplied	Installed Capacity, MW (Estimated for 2001)
Electricit du Cambodge (EDC)	6 Major towns, including Phnom Penh (MIME 2002)	32
Independent Power Producers (IPP) selling to EDC	Phnom Penh and Kompong Cham (MIME 2002)	127
Provincial Electricity Operators (provincial offices of MIME)	10 Provincial towns	14
Rural Electricity Enterprises (REE) operating mini-grids	4 Provincial towns and hundreds of smaller towns and villages (estimated 600 REEs)	60
Battery Charging Services (REEs which do not also operate a mini-grid)	1500 battery charging services (REEs) in hundreds of towns (Hundley 2003)[4]	38
Imported Power from Thailand and Vietnam (22kV lines)	7 Border towns (Hundley 2003)	15
Private stand-by diesel generation (large scale only)	All areas, but mainly Phnom Penh and Siem Reap (Hundley 2003)	116
Total		**402**

Electricity costs in Cambodia range from US$0.09/kWh to US$0.53/kWh for government services, and can be much higher for small private services or battery charging services (De Lopez, Praing & Toch 2003, Hundley 2003). Cambodia has the highest electricity costs of any ASEAN country, as shown here in Table 2. It is important to note that the tariff ranges quoted here for Cambodia must be for government serviced urban areas because they are much lower than the figures reported elsewhere for rural areas.

Table 2: Official Electricity Tariffs in ASEAN Countries, US Cents/kWh (Source: ACE 2004)

Country	Residential	Commercial	Industrial
Brunei Darussalam	2.88-14.42	2.88-11.54	2.88-11.54
Cambodia	9.17-17.03	15.72-17.03	12.58-15.72
Indonesia	1.69-4.60	2.77-5.65	1.71-4.38
Lao PDR	0.55-3.8	4.18-5.22	3.51
Malaysia	5.53-8.94	2.63-10.52	2.63-10.52
Myanmar	8.14	8.14	8.14
Philippines	3.15-10.71	3.68-9.85	3.35-10.84
Singapore	9.23	4.42-7.18	4.16-6.69
Thailand	3.41-7.47	2.94-7.47	2.94-7.13
Vietnam	2.92-8.17	4.24-13.96	2.83-13.96

2.6 RURAL ELECTRICITY ENTERPRISES

An estimated 600 Rural Electricity Enterprises (REE) operate small diesel-powered mini-grids to sell power to an estimated 60,000 customers (Meritec Ltd 2001b). The

[4] Estimated total installed capacity of the estimated 15,000 battery charging services, assuming an average generator size of 25kW.

REEs are usually small locally-owned businesses which consist of a diesel engine and generator with low voltage distribution lines which service anywhere from 30 to 2,000 local households and businesses. The average tariff charged by REEs is estimated at US$0.53/kWh (Hundley 2003). An estimated 8,000 battery charging businesses provide services to households and businesses, and the effective tariff is often over US$1.00/kWh (Meritec Ltd 2001b).

Some REEs have expressed interest in using renewable energy technologies in their businesses. A large group of REEs, mainly from provinces in the northwest of the country, attended a workshop in April 2004 to discuss the potential for biomass gasification technologies in Cambodia. At least one of the businessmen subsequently held discussions with regards to plans for a trial project.

Picture 2: A Group of REEs Visiting the JICA-Funded, 8-MW Diesel Power Plant in Siem Reap

The government's plans for rural electrification promote an important role for REEs, which echoes the World Bank's mantra of greater private sector participation. However in practice there has been friction between public and private industry in some areas where the government's electricity utility, EDC, has allegedly established operations in the business area of existing REEs, thus threatening the REEs' business viability. REEs are currently seeking longer licence periods from the Electricity Authority of Cambodia (EAC) to allow them to plan further in advance and achieve investment returns over a longer period. They claim this would allow them to reduce their electricity tariffs (SME 2001).

2.7 Other Relevant Sustainable Energy Activities

This section describes current government policies and multilateral projects that are relevant to the development of sustainable energy projects in Cambodia.

2.7.1 Rural Electrification and Transmission Project

The World Bank has facilitated a Rural Electrification and Transmission (RE&T) project with loan funding from the World Bank and Asian Development Bank (ADB), and a grant from the Global Environment Facility (GEF). The stated objectives of the project are to improve power sector efficiency and reliability, reduce electricity supply costs, improve standards of living and economic growth in rural areas, to strengthen electricity institutions and regulatory framework and to encourage sector commercialisation and privatisation (Hundley 2003).

The project will consist of four major sections:

a) Construction of a 220kV transmission line to Vietnam plus strengthening of the 115kV grid around Phnom Penh;

b) Extension of rural grids to connect 50,000 new households, plus forming partnerships with some REEs;

c) Establish a pilot Rural Electrification Fund (REF) to provide subsidies for eligible projects which propose to provide reliable power generation to rural areas, and especially encouraging solar and hydro systems; and

d) Institutional development and sector reform including technical assistance for renewable energy business development, awareness raising and project development for the REF pilot.

Commencement of the RE&T is already overdue, and execution of the loan agreement is currently suspended due to the government hiatus.

2.7.2 Rural Electrification Fund

As described above, the REF will subsidise rural electrification projects, including mini hydro and PV. This may provide a good additional source of funding for potential CDM projects. Mini hydro and PV projects would have to be bundled in order to be feasible due to the transaction costs.

The Rural Electrification Fund (REF) will be administered by a secretariat, established with autonomy from the government, and a board with members from the government as well as the donors and industry.

The secretariat will call for proposals from private developers to implement rural electrification solutions in particular areas, consisting of either:

New mini-grid based on generation from diesel, solar or hydropower generation;

Extension of an existing small grid system to connect new households;

Solar Home Systems (SHS); or

Mini or Micro hydropower system.

Proposals will be selected according to eligibility criteria and successful proposals will receive an REF grant. The grant is expected to subsidise about a quarter of the total project costs, private equity of the owner is expected to provide another 25%, and a bank loan the final 50%. The difficulty in obtaining an appropriate bank loan is a significant barrier to the success of the REF. The proposed subsidy rates are shown in Table 3.

Table 3: Proposed REF Subsidy Rates

Project Type	Total Cost	REF Grant
New household connected to existing diesel mini-grid	US$150	US$45
Mini hydro (0.75-5 MW)	US$1744/kW installed	US$400/kW installed
Micro hydro (average 50 kW)	US$2700/kW installed	US$400/kW installed
Solar home system	US$400 per set of 40 Wp	US$100 per set of 40 Wp

2.7.3 Five-Year Renewable Energy Action Plan

MIME is currently drafting a document, based on the World Bank's Renewable Energy Action Plan (REAP) of 2003, which aims to propose a plan of action to develop renewable energy over the period 2005 to 2010. Once completed, the document will be proposed to the Council of Ministers for approval. No funding or implementing bodies have yet been identified for the activities in the plan.

2.7.4 ASEAN Energy Policy and Systems Analysis Project

The energy planning and analysis capabilities of ASEAN countries is being addressed in a capacity building project which started in 2002 in Malaysia, Indonesia, Phillipines, Thailand and Vietnam. Cambodia, Myanmar and Laos joined the project in 2003. Training is provided to relevant government departments in each country in the use of the MARKAL software tool. MARKAL was developed by the International Energy Agency in the 1980's to simplify the analysis of energy systems and has been used widely across the world (SMEC 2002).

Cambodia has now established a model of the country's energy systems, based on all available data, that allows analysis of the long-term effects of various energy scenarios. For example it could be used to estimate the effect on greenhouse gas emissions of a change in the price of oil, or a change in the price of renewable energy technology. The last stage of the project, in late 2004, will involve technical assistance to model a particular set of scenarios identified as relevant by the Cambodian participants.

2.7.5 Technical Standards for Electricity

Technical standards for the generation, distribution and transmission of electrical power were produced in 2003 by a team of Japanese engineers funded by JICA. The engineers collaborated with counterparts from MIME, EAC and EDC and also presented their progress at a series of stakeholder workshops. The documents include a section on renewable energy but this consists of just a few paragraphs which relate to hydropower. The documents are currently being translated and then EAC plans to begin a two-year grace period for compliance with the standards.

Many operators are likely to face significant investment costs in order to upgrade equipment to comply with the standards. However the first problem may be that most rural electricity business operators are not highly trained and would not be able to understand the requirements of the standards, or have the equipment necessary to assess the compliance of their generators and distribution system.

2.7.6 Planning Strategy for Energy Cropping

The Ministry of Land Management, Urban Planning and Construction is currently considering strategies for introducing economic concessions for land dedicated to growing energy crops (Zimmerman, W., 2004, pers. comm., 12 April). The energy crops may be used for fuel wood, charcoal, to fuel gasifiers or to produce liquid fuels such as biodiesel or ethanol. Representatives of relevant ministries, including the Ministry of Land Management, Urban Planning and Construction, MIME and the Council for the Development of Cambodia (CDC) participated in a three-day study tour to Thailand in March 2004. The tour was funded by GTZ and involved tours of biofuel and energy cropping developments there.

SECTION THREE: STATUS AND POTENTIAL OF SUSTAINABLE ENERGY IN CAMBODIA

The following sub-sections will assess the technical potential for, and current status of, sustainable energy projects in Cambodia. Each major renewable energy technology type is discussed separately, starting with a broad estimate of Cambodia's available resources. Details of existing and possible future projects are then provided. Energy efficiency projects are discussed in two broad categories: residential energy efficiency and industrial energy efficiency, according to the end-use applications. The calculations proposed here are necessarily rough due to the lack of data and the brief nature of this study. Consequently care should be taken with the use of the estimates made here. All assumptions, data sources and calculation methods are provided in the tables in Appendix A.

The results from this section, summarised below in Table 4, estimate potential greenhouse gas emission savings in Cambodia of almost 47 million tonnes of CO_2 equivalent per year. A summary of the individual projects, which either installed or only identified, is provided in Table 31 in Appendix B.

Table 4: Summary of Potential Sustainable Energy Generation and Savings (Note: for calculation methods see this section and tables in Appendix A)

Energy Sources	Technical Potential (GWh/year)	Currently Installed Projects (GWh/year)	Theoretical Remaining Potential (GWh/year)	Potential Annual GHG Abatement (kton CO_2 equiv.)
Hydro-power	37,668	55	37,613	26,228
Biomass [5]	18,852	-	18,852	13,146
Solar	65	1	64	44
Wind	3,665	-	3,665	2,556
Industrial Energy Efficiency	547	-	547	381
Residential Energy Efficiency	6,591	29	6,562	4,576
Total	**10,868**	**30**	**10,838**	**46,931**

A summary of the sustainable energy projects either currently installed or just identified is provided in Table 5. This shows 57 projects with a total installed capacity of 1,825 MW, most of which are hydro projects. The table shows that there are very few projects identified in the biomass, wind, solar or energy efficiency sectors. This is despite the significant resource potential, and the need for decentralised renewable energy systems to supply power in rural areas. This highlights the current need for effective activities to identify and develop feasible sustainable energy projects. More details on the installed and identified projects are provided in Table 31 in Appendix B.

[5] In this table, 'biomass' refers to projects based on modern efficient technology, rather than conventional uses of biomass, such as residential cooking with traditional fuelwood stoves, or wood-fired brick kilns.

Table 5: Sustainable Energy Projects Currently Installed or Identified

Project Type, Status	Number of Projects	Total Installed Capacity (MW)	Annual Generating Potential (GWh/year)	Potential Annual GHG Abatement (ton CO_2 equiv.)
Hydro-power	**42**	**1,825.07**	**9,005.90**	**6,300,035**
Operational	3	13.04	55.64	39,317
Identified	39	1,812.03	8,950.26	6,260,717
Biomass [6]	**9**	**2.36**	**16.60**	**13,347**
Operational	3	0.07	0.56	504
Identified	6	2.29	16.04	12,843
Solar (PV)	**3**	**0.42**	**0.77**	**692**
Operational	3	0.42	0.77	692
Identified	0	0	0	0
Wind	**2**	**0.66**	**1.73**	**1,561**
Operational	0	0	0	0
Identified	1	0.66	1.73	1,561
Energy Efficiency	**2**	**18**	**128.66**	**181.959**
Operational[7]	1	0	28.66	6,959
Identified[8]	1	18	100	175,000
All Projects	**57**	**1,847**	**9,154**	**6,475,231**
Operational	10	14	86	46,685
Identified	47	1,833	9,068	6,428,545

3.1 HYDROPOWER

The findings of this section, and relevant hydropower projects, are summarised in Table 6, and more detail can be found in Table 31 in Appendix B.

Table 6: Summary of Hydropower Projects

Hydropower Project Type	Number of Projects	Total Installed Capacity (MW)	Annual Generating Potential (GWh/year)	Potential Annual GHG Abatement (ton CO_2 equiv.)
Installed Projects				
Large (5 MW to 465 MW)	1	12.00	53.00	36,941
Mini-hydro (500 kW to 5 MW)	1	1.00	2.50	2,250
Micro-hydro (10 kW to 500 kW)	1	0.04	0.14	126
Identified Projects				
Large (5 MW to 465 MW)	20	1,788.30	8,839.97	6,161,462
Mini-hydro (500 kW to 5 MW)	9	23.05	108.50	97,650
Micro-hydro (10 kW to 500 kW)	10	0.68	1.78	1,605.60
Total	**42**	**1,825.07**	**9,005.90**	**6,300,035**

[6] In this table, 'biomass' refers to projects based on modern efficient technology, rather than conventional uses of biomass, such as residential cooking with traditional fuelwood stoves, or wood-fired brick kilns.

[7] This project involves the saving of charcoal, and so does not have an installed capacity. Also, for the purpose of this table the energy content of the amount of charcoal saved has been converted to units of GWh. However the GHG abatement figure has been calculated from the quantity of the saved charcoal, rather than from the GWh saved as is done for the other electrical projects.

[8] This project involves replacing a diesel generator with a more efficient unit, and so the calculation of GHG abatement also takes into account other factors such as likely changes in EDC's load allocation (De Lopez, Praing & Toch, 2003b).

3.1.1 Technical Potential for Hydropower

The Asian Development Bank (ADB) has estimated that Cambodia has the potential for an installed capacity of 8,600 MW of hydropower generation, while MIME has estimated it at 10,000 MW (Hundley 2003)[9]. Taking ADB's estimate, and assuming a conservative average capacity factor[10] of 50%, then this suggests a potential generation from hydro of 37,668 GWh per year. This is about 70 times the current annual output from EDC.

Approximately 50% of this potential capacity is located on the Mekong River, 40% on tributaries to the Mekong, and 10% is from the South-Western coastal areas. These rivers play an essential part in the country's economy and culture. Consequently any potentially adverse impacts of proposed projects must be assessed.

The first assessment of Cambodia's hydropower resources, rarely quoted but often plagiarised, was performed by the Mekong River Secretariat in the early 1970s. This study estimated that Cambodia's potential for hydropower power was at least 2,376 MW in the lower Mekong Basin and 988 MW outside the lower Mekong basin (Mekong Secretariat 1971, 1973). A total of 24 and 11 projects were identified by the study for each watershed. To date, a total of 70 potential hydro sites have been identified (Meritec Ltd 2001a).

3.1.2 Current Status of Hydropower Projects

There are two commercial-size hydropower projects in Cambodia with a total installed capacity of 13 MW. Kirirom 1 power plant was built in 1968 with support from Yugoslavia but operation ceased under the Khmer Rouge regime in 1975. In 1999 a private Chinese firm, China Electric Power Technology Import & Export Corporation (CETIC), obtained permission to re-build the project, which was re-commissioned in May 2002 with a capacity of 12 MW and an upgraded 115kV transmission line to Phnom Penh (De Lopez, Praing & Toch 2003a). The project generated about 53 GWh in 2003 (Hundley 2003).

Picture 3: Kirirom 1 Hydroelectricity Power House

[9] This section and the studies mentioned are concerned with projects which generate electricity using hydropower. Applications using hydropower for mechanical applications such as rice milling or wood processing are not specifically considered here.

[10] The capacity factor of a power generation system is the ratio of its maximum potential annual output to its actual expected annual output. The difference between the two figures is due to factors such as maintenance outages, fuel availability and losses.

O Chum power station is a 1 MW hydro plant near Banlung, the capital of Ratanakiri province. It is government owned and operated, and was commissioned in 1993 with an estimated annual generation output of 2.2 GWh to 2.5 GWh (Hundley 2003).

New Energy and Industrial Technology Development Organisation (NEDO) of Japan built a hybrid PV and mini-hydropower project in Kompong Cham province. The project was commissioned in January 2004 and consists of two 20 kW hydro turbines, on the outlet of an existing irrigation reservoir, plus a total of 88 kWp of PV capacity which is dispersed in a number of sites throughout the nearby village (MIME 2003).

There is anecdotal evidence to suggest that some villagers in Pailin municipality and Mondulkiri and Ratanakiri provinces near the border of Vietnam in North East Cambodia are operating pico-hydro[11] units in basic run-of-river installations. These units were most likely bought from China or Vietnam, but no data exists on their prevalence or performance (Hundley 2003).

3.1.3 Identified Potential Hydropower Projects

Two separate pre-investment studies have been conducted on small and micro-scale hydropower opportunities in Cambodia. The study of small-scale hydro first identified 68 potential projects based on a desk study with basic feasibility criteria. Six of these projects, which ranged in size from 0.65 MW to 4.2 MW, were selected and studied in more detail (Meritec Ltd 2001a). The study of community-scale hydro projects identified an initial 45 projects, and then conducted a feasibility analysis of 6 of them that ranged in size from 32 kW to 246 kW (Meritec Ltd, 2003). The map in Figure 2 indicates the location and potential size of some of the hydro projects identified in various studies. More details on some of these projects are provided in the project summary in Appendix B.

JICA is planning to build three mini hydropower projects in Mondulkiri province with a capacity of 200 kW each (The Commercial News, April 26, 2004). It is not known whether these projects were identified in the study of community-scale hydro projects.

The government's Power Sector Strategy 1999-2016 indicates plans to build the Kamchay hydropower project in 2008 with a capacity of either 47 MW or 125 MW (MIME 1999). In March 2004 MIME published an invitation to pre-qualification for firms interested in development of the project with an installed capacity of 180 MW (MIME 2004). The increase in capacity from previous MIME plans was the result of a feasibility study produced in 2002 by Experco of Canada (MIME 2003). The Kamchay project site is located on the Prek Tuuk Chhu river in Kampot Province within the Bokor National Park.

[11] Pico-hydro refers to hydropower systems with a capacity smaller than 10kW which are usually operated in a run-of-river configuration.

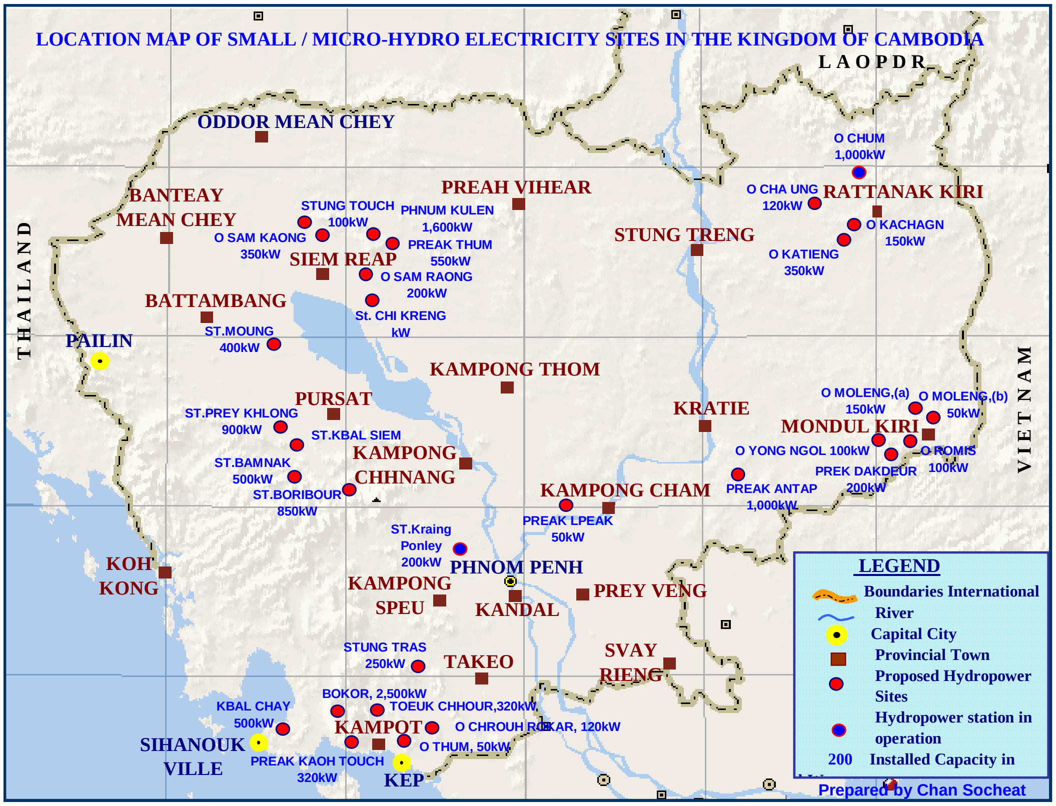


Figure 2: Map of Potential Micro-hydro and Mini-hydro Sites in Cambodia (Source: MIME 2003)

3.2 BIOMASS

The findings of this section, including relevant biomass projects, are summarised in Table 7, and more detail can be found in Table 31 in Appendix B.

Table 7: Summary of Biomass Projects

Biomass Project Type	Number of Projects	Total Installed Capacity (MW)	Annual Generating Potential (GWh/year)	Potential Annual GHG Abatement (ton CO_2 equiv.)
Installed Projects				
Hybrid Bioreactor and PV	1	0.07	0.56	504
Domestic Biodigesters [12]	112	n/a	0.52	48
Identified Projects				
Biomass Gasifiers (wood, rice husk)	3	0.285	1	1,123
Biomass-fired Cogeneration (rice husk, cashew nut shell)	2	2	14	11,719
Landfill Gas Capture or Flaring [13]	1	*	*	*
Total	**119**	**2**	**17**	**13,395**

[12] The annual generating potential is estimated by assuming that one biodigester provides a household with all its annual energy requirements for cooking and heating, which is assumed equal to the annual average consumption of charcoal per household (CFSP 2003)

[13] Details on the potential landfill gas project are not available as the study is currently underway.

3.2.1 Technical Potential for Biomass Energy

Cambodia has significant biomass energy resources including plantation forests such as rubber, many types of agricultural crop and livestock residues such as rice husk, cattle manure, municipal waste and sewerage (Verwoerd 2001, De Lopez, 2004). For this study we have considered all the sources of biomass that are likely to be available for commercial energy generation and assuming an average conversion efficiency of 34%[14] we estimate a potential generation of 18,852 GWh per year. This is actually less than the total biomass energy consumption proposed by the 1995 Energy Balance. We assume this discrepancy is at least partly because our study does not consider the potential contribution from natural forests used for firewood and charcoal, and also because the energy balance does not account for conversion losses (MIME 1996).

This estimate considers the bioenergy potential for the whole country from residues from all major agricultural crops plus livestock, sewerage and municipal waste, as shown in Table 17 in Appendix A. It is important to note that this calculation assumes that only *waste* products from forestry operations are used for energy, such as waste timber from wood processing operations and rubber trees harvested at the end of their 30 year productive life (Verwoerd 2001). The study does not consider the potential for energy cropping, where areas of land are dedicated to growing and harvesting plant species for use as a fuel source.

Many of the bioenergy resources considered here are already being utilised for various applications, such as cooking energy and cattle feed. These existing uses, and the availability of alternative sources, are an important consideration for any potential bioenergy project. For example a project which uses the rice husk output of a rice mill in order to provide the mill's power requirements may inadvertently deprive the surrounding community of its main cooking fuel (De Lopez 2004). This study does not consider these potential social impacts, but they are an important factor in the feasibility of any commercial energy project.

NEDO has also made an assessment of Cambodia's biomass resources but this considers only rice, sugar cane, maize, sugar palm and cattle manure as possible sources of biomass. The study restricted calculations to the provinces of Kampong Cham, Kampot and Battambang. This approach estimated a total available energy across these four provinces of 1,203 GWh per year (NEDO 2002). Another study estimated that 327 GWh of energy could be generated from biogas recoverable from Cambodia's animal wastes (Bhattaracharya, Thomas & Salam 1997).

Energy from biomass can be used by direct combustion, or can be converted into a more convenient fuel such as biogas or a range of liquid biofuels. The production and use of biofuels in Cambodia is an interesting prospect because some biofuels, such as

[14] The average conversion efficiency of biomass technologies is estimated by assuming an average conversion efficiency of 40% for biomass heating, and 15% for electrical or shaft power generation (UNDP, 2000). Then it is assumed that 75% of biomass applications are for heating or cooking, and 25% are for electrical or shaft power generation.

biodiesel[15], can be used directly in standard petrol or diesel engines with only minor modifications (NBB 2004). Biodiesel is considered to have zero net greenhouse gas emissions, for the purposes of CDM accounting, if the biomass fuel is from a source which is managed sustainably.

There may also be long-term economic and social benefits of establishing biofuel production in Cambodia. These include reducing the reliance on imported fuel, which reduces the drain on foreign exchange reserves and exposure to oil price volatility. However the production of significant quantities of biofuel would require large areas of land for suitable energy crops.

For example to produce enough biodiesel to replace the amount of diesel fuel used in Cambodia for the generation of electricity would require approximately 8,000km^2 of soy bean crops, which is approximately equal to the size of Kompong Cham province[16]. According to 1996 figures Cambodia has about 350km^2 of soy bean crops (MIME 1996). This degree of land use change and the necessary irrigation would have significant social and environmental impacts. The required crop area may be reduced by producing the required quantity of biodiesel from a variety of vegetable and animal oils and also waste oils.

3.2.2 Current Status of Biomass Energy Projects

Biomass is the source of over 80% of Cambodia's energy consumption, as explained earlier in this report. However this mainly involves combustion of fuelwood or charcoal in domestic cooking stoves. Wood and rice husk are also used in some commercial applications such as brick kilns, bakeries, distilleries and noodle factories. NEDO commissioned a biogas-fired electricity generation project in February 2004 near Sihanoukville. The project combines biogas and PV technologies to supply a peak 120 kW of power to a number of local villages. The biogas is generated from cattle manure from a feedlot and is used to fire two 35 kW gas engines driving a generator (NEDO 2004).

An entrepreneur in Battambang province built a small biomass gasifier to supplement the diesel fuel used in his generators that supply electricity to the local town. It is designed to run on charcoal and seems to have been built more for demonstration purposes than commercial operation (Site visit by the lead author, February 2004).

At least two small residential biodigester projects have been implemented in Cambodia, with varying success, to supply biogas for domestic cooking. Each of the projects employ a similar basic biodigester design using plastic sheeting to form a sludge chamber in an open trench, and PVC piping to distribute the generated biogas to a large plastic storage bladder inside the house, from where it is piped to a low pressure gas burner in the kitchen. A project by the United Nations Food and

[15] The term biodiesel is defined as a substitute for diesel fuel that consists of either (i) pure vegetable oils; (ii) 'methyl esters' refined from vegetable oils or animal fats through a chemical process; or blends of conventional diesel fuel with vegetable oils or methyl esters (Knothe, Dunn and Bagby, 2002).

[16] This estimate is based on Cambodia's soy crop yield in 1995, and assumptions are noted in Table 13 of Appendix A.

Agriculture Organisation (FAO) involved construction of biodigesters in around 98 households in Takeo province. Apparently there is strong demand from FAO to install more but they lack the funding (Kean, S. 2004, pers. comm., 9 March). Two projects implemented by the Cambodian Rural Development Team (CRDT) organisation have seen up to 14 biodigesters installed in villages in Kompong Cham and Takeo provinces since 2002 (CRDT 2003).

A team from the Japan Waste Research Foundation (JWRF), funded by JICA has established a project to investigate the feasibility of reducing methane emissions from the Stung Mean Chey landfill waste site in Phnom Penh. The landfill covers a maximum area of 11.6Ha and contains 1.3 million cubic metres of municipal waste. The team has installed a system of pipes inside a section of the site with equipment to measure and flare the gas. Part of the project will involve assessing the feasibility of various uses for the vented landfill gas, including charcoal production and electricity production (JWRF 2003).

3.2.3 Identified Potential Biomass Projects

Three small biomass-fired generation projects are being planned and coordinated by the Small and Medium Enterprise (SME) non-governmental organisation. Two wood fired gasifiers are planned for Battambang province, to be fuelled by a fast-growing tropical tree (Glyricidia spp.) planted specifically for the purpose. One 10 kW gasifier will power a small grid operated by a village community cooperative, while another gasifier will be between 75 kW and 100 kW and operated commercially as part of an REE's mini-grid. The third project will involve a 200 kW rice husk gasifier in Siem Reap province, operated in a rice mill by an REE (SME 2004).

The COGEN3 program[17] has conducted a pre-investment study for a potential biomass-fired cogeneration project at the Angkor Kasekam Roongroeung rice mill just outside of Phnom Penh. The project involves installation of a rice husk furnace, steam turbine and generator with a rated electrical capacity of 1.5 MW. The mill's production of rice husk is expected to generate enough electricity to supply the factory's total load, thus replacing the existing diesel generators. Excess steam from the boiler will be passed through a heat exchanger and used to dry rice paddy before processing. The study suggests a total project cost of 3.34 million Euros and an Internal Rate of Return (IRR) of 26.9%. The project proponents are currently seeking equity financing of about 0.85 million Euro before proceeding with the project (COGEN3 2004).

A potential biomass-fired cogeneration project is also being considered at a cashew nut processing factory on National Highway 7 between Phnom Penh and Kompong Cham city. The factory uses a small steam boiler, which is fired with waste cashew nut shells, to supply low-grade steam for treating the cashew nuts. The project would involve replacing it with a larger capacity boiler that would provide sufficient process

[17] COGEN3 is a program funded by the European Commission that promotes the use of cogeneration in ASEAN countries. The program employs international technical experts to implement a range of activities in host countries such as workshops, study tours and feasibility studies. The program offers a grant to cover 15% of the capital cost of cogeneration projects that use European cogeneration equipment.

steam for the factory, and would also drive a generator to supply electricity to two local towns. This would require a generator of about 500 kW capacity, and initial calculations have suggested the factory would need to expand existing storage and production capacity of the factory so as to increase the daily volume of waste shells from 3 tonnes to 20 tonnes. The owner of the factory is at an early stage of considering the project's feasibility (site visit by the lead author, September 2003).

The Cambodia Fuelwood Saving Project (CFSP) is investigating the feasibility of producing char biomass briquettes to substitute for fuelwood or charcoal in household cooking. The idea is to source waste biomass such as crushed sugar cane, heat this in a special kiln to produce charcoal, which is ground, mixed with some binding material and extruded into a convenient briquette. Tests on these briquettes show that they are comparable with wood charcoal in terms of cooking energy, but have some drawbacks such as higher ash content (CFSP 2004b).

3.3 SOLAR POWER

The findings of this section are summarised in Table 8, and more detail can be found in Table 31 in Appendix B.

Table 8: Summary of Solar Projects

Solar Project Type	Number of Projects	Total Installed Capacity (kW)	Annual Generating Potential (MWh/year)	Potential Annual GHG Abatement (ton CO_2 equiv.)
Installed Projects [18]				
Communications Towers	200	251.0	606	546
Community Buildings	20	26.0	63	57
Bridge Lighting	10	17.4	42	38
NGO Facilities	5	3.8	9	8
Battery Charging Stations	5	2.2	5	5
NEDO PV/Hydro Demo	1	68.0	130	113
NEDO PV/Biogas Demo	1	50.0	90	83
Identified Projects				
none				
Total	**242**	**418.7**	**947**	**850**

3.3.1 Technical Potential for Solar Power

Cambodia receives a relatively high level of solar radiation throughout the year. NASA's global solar radiation model estimates the daily average to be about 5.10 kWh/m^2 with a monthly average deviation of 11% (Meritec Ltd 2001b). To put this in perspective, NEDO calculated that the average daily insolation in Phnom Penh is 5.0 kWh/m^2, while in Tokyo it is 3.5 kWh/m^2. NEDO also used the NASA model to generate a low-resolution solar map for Cambodia by plotting the model's predictions approximately every 40km and interpolating between the points as shown in Figure 3 (NEDO 2002).

[18] Except for NEDO figures, the estimates for project numbers and installed capacities here are based on the figures for 2002 in Table 9 and are extrapolated for a current installed capacity of 300kW.

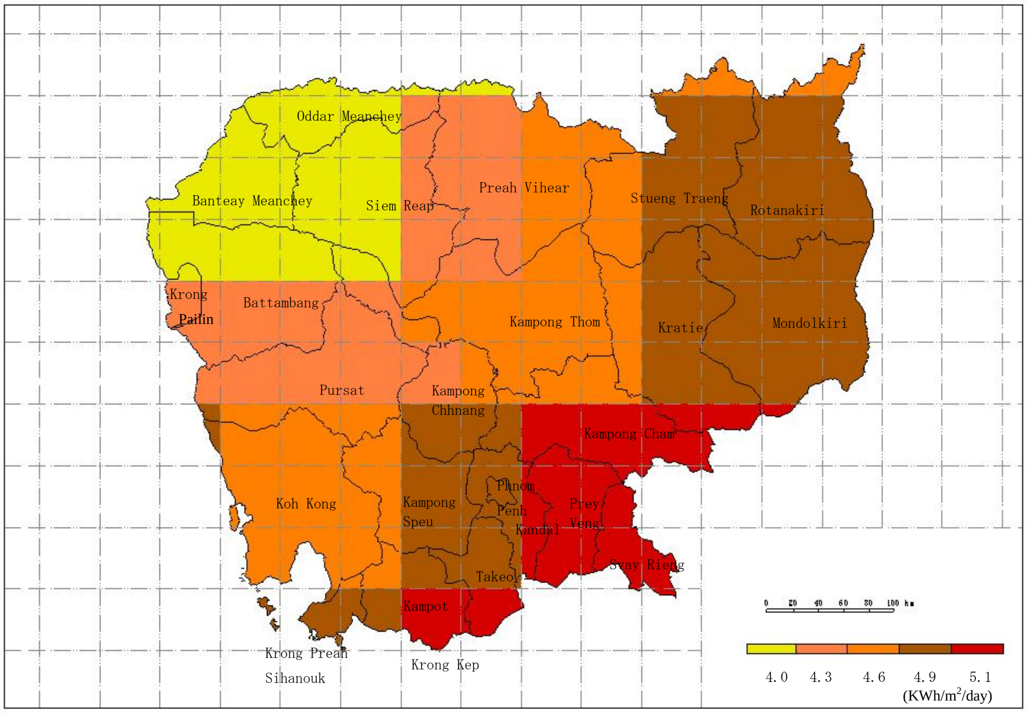


Figure 3: Solar Insolation Map for Cambodia (Source: NEDO 2002)

The theoretical maximum potential for harnessing solar energy can be calculated by first estimating the total maximum surface area of the country that is available for mounting collectors (either photovoltaic or solar thermal) and then calculating the potential installed peak capacity and generation assuming a conversion efficiency for particular technologies.

This approach suggests that there is 0.02% of Cambodia's land area suitable for installing PV modules. With current technology this would provide a peak capacity of 4,189 MW and generate approximately 21 GWh/day of electricity[19]. To put this in perspective, over a year this would be roughly 13 times the total annual power currently generated by EDC[20]. Or alternatively, if this land area was used to install domestic solar hot water heaters then 49.3 GWh/day of energy, in the form of hot water, could be generated and thus significantly reduce the need for other fuels such as fuelwood or charcoal to heat water.

The estimated technical potential for solar power is an interesting figure, however it is not as relevant as for other technologies. The reason is that the availability of suitable land area is not the most significant barrier to the wider use of solar energy. The feasibility of projects in the short term is driven by relative energy costs, affordability and awareness. A study of the PV market in Cambodia which did consider these

[19] This calculation assumes that 0.02% of Cambodia's land area is available for installing PV modules, i.e.: it is not used for any type of agriculture and is not under water. And it assumes that this land has an average daily irradiation of 5.10 kWh/sq.m, and that the modules have an average conversion efficiency of 13%. See Table 19 in Appendix A for more detail and data sources.

[20] Calculated assuming installed PV capacity of 4189MWp, generating for 350 days of the year, and compared to EDC's generation output for 2002 (EDC 2002).

factors estimated a potential demand of 440,000 households which would be willing and able to purchase an 80WPV system if provided with appropriate information and opportunities (Burgeap and Kosan Engineering 2001). This study identified the main barriers to the PV market as the high initial investment cost and the low awareness of the technology within Cambodia.

3.3.2 Current Status of Solar Power Projects

Table 9 indicates that over 200 kW of PV systems had been installed in Cambodia between 1997 and 2002 for a variety of applications including remote communication systems, water pumping, community lighting, village supply, battery charging and individual home systems (MIME 2002).

Table 9: Photovoltaic Systems Installed in Cambodia between 1997 and 2002 (MIME 2002)

Type of Infrastructure	Capacity (Wp)	Percent of Total Installed Capacity
Telecommunications (MobiTel company)	127,000	62.1
Telecommunications (SAMART company)	38,000	18.6
Training Centre	19,691	9.6
Bridge	7,280	3.6
NGO office	3,825	1.9
School	3,279	1.6
Battery Charging Station	2,196	1.1
Household & Pagoda	1,720	0.8
Health Centre	1,595	0.8
Total	**204,586**	**100.0**

There are no accurate figures of the current installed capacity of PV, however we can estimate it to be well over 300 kW by early 2004, which assumes that the rate of new project installations has remained consistent. Cambodia's three communications companies have continued to expand their networks of remote PV-equipped towers used for housing mobile phone transponders and microwave repeater equipment. Two NEDO demonstration projects commissioned in early 2004 near Kompong Cham city and Sihanoukville, have added 117.5 kW of peak PV capacity (NEDO 2004). There is also a small but increasing number of PV systems being sold to private householders by a small number of renewable energy retail companies.

At least one company is supplying solar water heaters (SWH) to private customers in Cambodia (Khmer Solar 2003). The traditional market for SWH in Cambodia is limited because only a small proportion of households, mainly wealthy Cambodians or expatriates, use domestic hot water systems. The potential SWH market therefore is mainly in commercial hotels, guesthouses, hospitals and health clinics.

3.4 WIND POWER

The findings of this section are summarised in Table 10, and more detail can be found in Table 31 in Appendix B.

Table 10: Summary of Wind Power Projects

Wind Power Projects	Number of Projects	Total Installed Capacity (kW)	Annual Generating Potential (MWh/year)	Potential Annual GHG Abatement (ton CO_2 equiv.)
Installed Projects NEDO Village Demonstration	1	2.8	0	0
Identified Projects Sihanoukville Port Wind Turbine	1	660.0	1,700	1,561
Total	**2**	**662.8**	**1,700**	**1,561**

3.4.1 Technical Potential for Wind Power

Appropriate wind monitoring data does not exist in Cambodia to thoroughly assess the country's wind energy resources. However the World Bank published a *Wind Energy Resource Atlas of Southeast Asia* (Figure 4) that provides valuable predictions of the country's wind energy potential.

Figure 4: Wind Resources of Southeast Asia

The Atlas was commissioned as part of the World Bank's Asia Alternative Energy program and provides a prediction of a variety of detailed wind energy statistics with a spatial resolution of 1km for the entire area covering Thailand, Laos, Vietnam and Cambodia. The statistics are calculated at both 30m and 65m above ground level and include average annual wind speeds and frequency distributions. The atlas was generated using a proprietary finite element model based on a number of meteorological and topographical data inputs, but no actual wind data from ground-based monitoring systems. Therefore the data should be used with caution, and appropriate on-site monitoring is needed prior to establishing the feasibility of particular projects (Truewind Solutions LLC 2001).

This atlas indicates that Cambodia in general has relatively low wind energy resources compared to its neighbouring countries. However some of Cambodia's elevated plateaus and mountain ranges are highlighted in the atlas as having areas with high potential wind energy. The atlas estimates that a total area of 345 km^2, or 0.2% of Cambodia's land area, has a predicted annual average wind speed above 7m/s and this corresponds to approximately 1,380 MW of potential wind turbine capacity with an annual generation of 3,627 GWh[21].

This figure only considers the potential for large commercial wind turbines, while in Cambodia there should also be good potential for smaller village-scale wind energy projects. The atlas estimates that 6% of the rural population live in areas with an annual average wind speed of 5m/s to 7m/s at 30m above ground level, which should be sufficient for village-scale wind energy. So if 50% of rural households in these windy areas were to install a 400W wind generator, then the total installed capacity would be approximately 22 MW which would generate about 39 GWh per year.

The above predictions of potential installed capacity and generation do not consider some other important factors that determine project feasibility, such as project development costs or relative value of the power generated. The atlas does not specify the accuracy of the predictions, but suggests that similar exercises in the Philippines had error margins of about 8% with respect to the predicted annual average wind speeds. This error is significant considering that the energy production of a turbine is related to the cube of the wind speed, so that an 8% error in wind speed would mean about a 24% error in the calculated energy production.

Also, the model used for the atlas does not consider topographic features smaller than 1km. This may be significant in the plains of Cambodia which often feature small hills which are typically around 50m to 100m elevation above the plains. An example of such a feature is Phnom Chiso, a hill in Takeo province which is a tourist attraction for its Angkor era ruins. This site does have a small wind turbine installed, but it is not operational as explained later in this section.

The Government of Flanders[22] established a wind monitoring site near Sihanoukville in January 2003. The site consists of a 30m high mast with an anemometer and wind vane mounted at the top and another at approximately 20m above the ground. Data monitoring commenced in early February 2003 and is currently the only high quality wind energy data available in the country. Consultants are currently producing a report on the feasibility of a potential wind power project as discussed later in this section (Dezeure, J 2004, pers. comm., 18 April).

NEDO also produced a simulated wind map for Cambodia, however it used a coarse resolution of 25km and a much less sophisticated modelling tool compared to the World Bank atlas. The NEDO map does not indicate at what height the predicted wind speeds are made, and so accurate comparisons are impossible.

NEDO also installed a meteorological monitoring station in year 2000 as part of a project to install small hybrid wind and PV battery charging systems in houses in a

[21] The predicted wind speeds are for 65m above ground level, corresponding to the hub height of large modern wind turbines, and the potential generating capacity has been calculated by assuming that each square km can accommodate wind turbines with a total combined rated capacity of 4MW (Truewind Solutions LLC 2001).
[22] Flanders is the largest province in Belgium.

village in Takeo Province (described in next section). The monitoring station included an anemometer and wind vane, but unfortunately it was installed only about 3m above ground in an area surrounded by trees and houses. Consequently the data is not representative and cannot be used for accurate wind modelling. This monitoring station has now been relocated to a site on a hill above Sihanoukville, mounted on the roof of a building, but the quality of the data has not been determined.

3.4.2 Current Status of Wind Power Projects

The only wind turbines installed in Cambodia are small scale turbines, generally around 400W capacity, which have either been donated as part of a multi-lateral demonstration project, or else purchased by private households to charge batteries for rural houses with no grid access[23]. There is also a small turbine installed on Bokor mountain in Kampot Province to power equipment on a communications tower owned by the Mobitel cellular telephone company.

NEDO installed 6 wind and PV hybrid systems, in a village in Takeo Province in 2001 as part of a demonstration project (NEDO 2003). Each of the houses was equipped with a 400W wind turbine and 150W PV system plus battery charging equipment. A similar system was also installed nearby in a pagoda on top of Phnom Chiso, a hill which attracts tourists to visit some Angkor era ruins near the pagoda. Unfortunately it appears that none of the wind turbines are operating at the time of writing this report. The turbines in the village had been disconnected from the battery charging system because the regulators were thought to be malfunctioning. The wind turbine installed on the hill of Phnom Chiso is inoperable, having lost a blade and hanging from its mounting after a suspected lightning strike. It is thought to have been in this condition for at least 12 months (site visits by the lead author, April 2003 and February 2004).

3.4.3 Identified Potential Wind Power Projects

A team of consultants are currently studying the feasibility of installing at least one commercial scale (600 kW with 65m hub height) wind turbine at the site monitored by the Government of Flanders in Sihanoukville, discussed earlier in this section. Initial results of the study recommends the need for further wind monitoring, identification of a more suitable site close to the existing one, and connecting the turbine to the planned new distribution grid at the Sihanoukville Port (Dezeure, J 2004, pers. comm., 18 April).

3.5 GEOTHERMAL

No comprehensive study has been conducted on sources of geothermal energy in Cambodia, or the potential feasibility of harnessing it.

[23] This study will only consider wind turbine technology for electricity generation and not windmills used directly for water pumping or other mechanical work.

There is one obvious source of geothermal energy in Cambodia in the form of a thermal spring in the province of Kompong Speu at the foothills of the Cardamom mountains. The spring is a tourist attraction and some local people believe that the water has some spiritual and medicinal significance, probably due to its distinctive chemical composition.

It is an area of marshy land covering approximately one hectare which features shallow pools, approximately 30cm deep and a few metres wide, with very clear water at approximately 70 degrees Celsius[24]. From this cursory description the site would appear to be a source of low grade heat only, however high grade steam may be feasibly accessible by drilling into the earth below the marsh. There is currently no local energy load, apart from a few small food stalls, so the potential for an energy project seems low.

There are no existing projects or plans for harnessing geothermal energy in Cambodia. A detailed study is needed to confirm commercial development potential.

3.6 WAVE OR TIDAL

There has been no assessment of potential wave or tidal energy resources in Cambodia. However the authors assume the resources are relatively poor considering that Cambodia's short coast is sheltered by a large number of small islands in the Gulf of Thailand, and only occasionally experiences large waves or high tides. Considering that the wave and tidal technology is at an early stage of commercialisation elsewhere in the world, even at sites with significant wave and tidal energy, the authors assume there is no potential for feasible wave or tidal projects in the near future. There are no existing projects or plans for harnessing wave or tidal energy in Cambodia.

3.7 ENERGY EFFICIENCY

3.7.1 Technical Potential for Energy Efficiency Improvements

A thorough analysis of the potential for energy efficiency improvements among Cambodia's various energy using sectors requires detailed data on the types of operations being conducted by firms in these sectors, the types of equipment and systems they use, and their energy use profiles. Unfortunately no such data is available for Cambodia.

For the purposes of this study, a national energy balance from 1995 was used to estimate energy consumption patterns across the following broad industry categories:

Power Sector – electricity generators and suppliers including government utilities, IPPs, REEs, and also companies that own and operate their own generators (these companies may also belong to the commercial or industrial sectors, depending on their prime business);

[24] Observations made by the author during a visit in March 2003.

Industrial Sector – all companies involved in manufacturing activities such as brick kilns, garment factories, tobacco processing, etc.;

Commercial Sector – hotels, office buildings, restaurants, shopping centres and hospitals; and

Residential – all private households.

The most relevant and feasible energy efficiency project types were selected for each industry sector, and the average potential saving from each project was estimated based on relevant studies and industry benchmarks, as summarised in Table 11. The total potential energy saving was then calculated by estimating the proportion of the sector's energy which was consumed by the particular application or technology. This process estimates that a 29% energy saving could be achieved, equivalent to about 467 GWh per year (MIME 1996). These estimates are necessarily coarse, due to the lack of appropriate data, but they provide a basis for discussion. The calculation tables and assumptions are provided in the appendix.

Table 11: Identified Potential Energy Efficiency Projects and Potential Savings

Project Type	Project Description	Potential Energy Saving
Power Sector		
Generation	Upgrade equipment to more efficient modern designs, optimise engine sizing and control strategies, install monitoring sensors and improve maintenance programs and energy management.	15%
Distribution	Optimise network design to balance loads, upgrade conductor sizes and quality to reduce losses, install power factor correction.	10%
Cogeneration	Harness waste heat for on-site heat or cooling load (or sell to neighbouring factory, building etc).	30%
Industrial Sector		
Steam System	Upgrade boiler design, insulate ducting, clean and maintain steam traps, pre-heat feed water with waste process heat, fix leaks, install monitoring sensors and improve maintenance programs and energy management.	15%
Lighting	Optimise design to minimise energy use by using skylights, windows, task lighting; upgrade technology with high efficiency fittings, reflectors, lamps, ballasts and voltage controllers; improve automatic and manual control using occupancy sensors, brightness sensors, dimmers and timers.	15%
Brick Kilns	Build high efficiency design (eg: Vertical Shaft Kiln) to minimise heat loss, use waste heat, and make continuous process; use organic additives in clay such as rice husk; install monitoring sensors to optimise process flow and energy use.	50%
Cogeneration	Harness waste heat from generator and use for on-site heat or cooling load (or sell to neighbouring factory, building etc).	30%
Commercial Sector		
Lighting	Optimise design to minimise energy use by using skylights, windows, task lighting and zoning; upgrade technology with high efficiency fittings, reflectors, lamps, ballasts and voltage controllers; improve automatic and manual control using occupancy sensors, brightness sensors, dimmers and timers.	15%

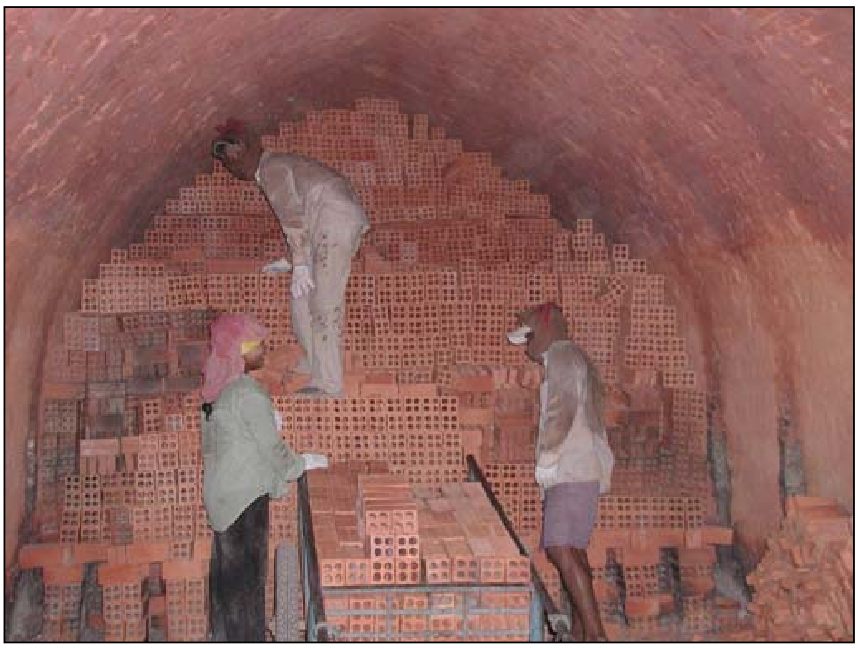
Project Type	Project Description	Potential Energy Saving
Air Conditioning	Optimise building design to maximise insulation, minimise direct solar gain (e.g.: plant trees and shading), zoning to avoid cooling unused areas and ceiling fans where possible; upgrade technology using improved refrigerants + lubricants, heat pumps, exhaust air heat capture; and improve system control by using comfort and occupancy sensors, timers, and possibly night-purge function.	40%
Water Heating	Optimise system design using centralised or small individual units, reduce distance from source to use, minimise water temperature for application, and harness waste heat where available (from nearby industry or air conditioning); upgrade technology to solar where possible, avoid electric storage systems, insulate ducting; reduce water use by fixing leaks and using efficient nozzles, taps and showers.	95%
Cogeneration	Harness waste heat from generator and use for on-site heating or cooling load, such as water heating or air conditioning and refrigeration (or sell to neighbouring factory, building etc).	30%
Residential Sector		
Improved Cook Stoves	Disseminate improved cookstove design, with improved insulation and air flow, to provide greater combustion and thermal efficiency.	30%
Energy Saving Fluorescent Lamps	Replace incandescent lamps with energy saving lamps, which use less power to provide the same amount of light, and also have a longer life (e.g.: replace 25W incandescent with 7W fluorescent).	72%

Cogeneration or Combined Heat and Power (CHP) refers to a system which simultaneously provides electrical or mechanical power, plus heat energy. This is achieved by capturing the heat which is usually wasted by power systems, and therefore can provide energy savings of around 30% (COGEN3 2003). The waste heat can be used for refrigeration or air conditioning applications by using absorption chiller technology. Cogeneration projects are only successful in situations where power and heat are required at the same site, or at least in close proximity. The most likely applications in Cambodia are therefore in garment factories, large rice mills and hotels.

Cooking is the obvious focus of any residential energy efficiency program in Cambodia because over 95% of total household energy use is in the form of fuelwood or charcoal for cooking in a traditional cookstove (MIME 1996 as cited in NEDO, 2002). Consequently an important energy efficiency project in the residential sector is to improve the efficiency of the cookstoves. The potential energy savings of such a project are far greater than the potential savings in all the other sectors combined.

A report from 1997 estimated that there were 446 brick kilns in Cambodia (Burgess 2002). Most of these use wood as fuel, and an increasing number are using rice husk, especially in areas where wood is becoming scarce such as in Battambang Province (Tin, De Lopez, Sau, Hing & Jude 2003, Verwoerd 2001). A study of fuel wood flows in Phnom Penh in 1998 found 71 brick kilns which each used an average of about 4.5TJ of wood energy per year (FAO 1998). Assuming this consumption is representative of other kilns in the country, then the total biomass energy consumption from brick kilns in 1997 was just under 1,987TJ per year. This figure does not agree with the 1995 Energy Balance which claims that the total wood energy consumed in Cambodia’s industrial sector was just under 370TJ (MIME 1996). It is unlikely that the output of the brick industry grew by over 22 times in just two years, which suggests that there is an anomaly in the Energy Balance figures. We have used the larger figure for the purposes of estimating potential energy savings in the brick kiln industry.

By far the most common design of brick kiln in Cambodia is basically a long rectangle which is inherently inefficient because, among other things, it uses a batch process so that the heat energy used for each batch must be completely expelled before the finished bricks can be removed and the next batch started. In addition the method of firing the kilns by positioning burning wood in open fireboxes is not ideal. Vertical shaft brick kilns are a radically different design developed in China in the 1960s that can achieve up to 50% fuel savings compared to conventional designs due to reuse of heat and a more continuous process (Jones 1995). Small design changes to conventional brick kilns can also achieve significant savings. Experience in Sri Lanka with low cost projects such as fitting ash grates and steel doors to the fireboxes saved up to 15% of the wood consumed.



Picture 4: Workers Unloading Finished Bricks from a Kiln in Kandal Province

3.7.2 Current Status of Energy Efficiency Projects

The Cambodia Fuelwood Saving Project (CFSP) was established in 1997 by the GERES organisation with funding from the European Commission (CFSP 2002). The project aims to move towards sustainable charcoal use by improving the fuel efficiency of household cookstoves. This is achieved mainly by disseminating and encouraging the use of an improved cookstove design which saves around 30% of fuel (charcoal or fuelwood). The CFSP had disseminated 36,000 improved cookstoves by the end of 2003 which is saving an estimated 10,841 ton of charcoal per year (CFSP 2004a).

The PREGA program[25] completed a pre-feasibility study in 2003 regarding the rehabilitation of one of EDCs main power plants in Phnom Penh. The 18 MW "C2" power plant was commissioned in 1967 and consists of three heavy fuel oil steam turbines of 6 MW capacity per unit. The plant has low energy efficiency and currently uses 410 grams of fuel per kWh of electricity generated. The proposed project would install a new 18 MW oil-fired power plant that is expected to consume 210 grams of fuel per kWh of electricity generated (De Lopez, Praing & Toch 2003b). While the proposed project does represent significant energy efficiency improvements, greater savings of greenhouse gas and sulphur oxide emissions could be achieved by also switching to a cleaner fuel such as diesel or natural gas. This project is currently being considered by EDC.

[25] The Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement (PREGA) program is funded by the Dutch Government.

SECTION FOUR: POTENTIAL FOR CDM INVESTMENT IN SUSTAINABLE ENERGY PROJECTS

The previous section outlines the technical potential for sustainable energy projects in Cambodia, and Appendix B lists a pipeline of existing and identified projects. This section summarises the potential sustainable energy projects that could be eligible for CDM funding. It also describes the eligibility and administrative requirements for CDM projects, and investigates the resulting issues or benefits for potential CDM projects in Cambodia.

4.1 CDM ELIGIBILITY REQUIREMENTS AND BARRIERS

4.1.1 Host Country Institutional Arrangements

Cambodia ratified the UNFCCC in December 1995 and the Ministry of Environment (MoE) has coordinated preparations for participation in CDM (MoE, 2002). An initial national communication under the UNFCCC was published in August 2002 that provided a national greenhouse gas inventory for 1994 and described Cambodia's ability to respond to the effects of climate change. In mid 2003 the MoE was appointed as the interim Designated National Authority (DNA) for CDM in Cambodia. Capacity building activities are being conducted with a range of stakeholders, including relevant government ministries, private developers, non-government organisations, foreign investors and donor organisations.

The following potential CDM projects have been discussed with the DNA in Cambodia:

107.5 kW hybrid PV and mini hydropower project in Kompong Cham Province, built by NEDO and commissioned in January 2004;

120 kW hybrid PV and biogas project near Sihanoukville, also built by NEDO and commissioned in January 2004 (Picture 5);

Picture 5: The 120kW Hybrid PV and Biogas Project near Sihanoukville: a) Cattle Manure Is Used to Produce Biogas, and b) Solar Energy Component

Proposed landfill gas flaring project at Stung Mean Chey landfill site in Phnom Penh which is currently undergoing preparatory testing by the Japan Waste Foundation; and

Proposed afforestation project involving 10,000ha rubber plantation in Mondulkiri Province, which is currently being assessed for feasibility by Marubeni Corporation of Japan (Marubeni 2003).

4.1.2 Additionality

Eligible CDM projects deliver “real, measurable and long term” benefits. CDM projects must produce additional emission reductions, and would not otherwise happen. This involves an assessment of the baseline scenario, or the scenario that would have happened in the absence of the project. To prove additionality, project proponents need to prove that the project is not part of the baseline scenario, that is not business as usual. The CDM Executive Board at it’s tenth meeting provided guidance for testing additionality, such as the barrier test; or the common practice test. As there are many institutional, technical and financial barriers for investment in small-scale sustainable energy projects in Cambodia, proving additionality for projects would not be difficult. Large-scale hydro projects remain controversial, and are particularly difficult to prove additionality (Point Carbon 2003).

4.1.3 Sustainable Development Criteria

Any project proposed for CDM accreditation in Cambodia must first be assessed by the DNA for compliance with Cambodia’s own criteria for sustainable development (UNEP 2002). The integrity of this process is important to ensure that Cambodia establishes credibility as a host of effective CDM projects. While a less stringent process may initially attract project developers looking to reduce project transaction costs, in the long run it could deter investors and developers because of the increased risk of the CDM Executive Board refusing to issue Certified Emission Reductions (CER) to projects from Cambodia. Even if CERs are issued, they could be devalued in the CER trading market if liable entities voluntarily decide to boycott certain unsustainable projects or host countries.

In response to the four projects described above, the DNA has prepared draft sustainability criteria for Cambodia plus a baseline assessment for Phnom Penh. These criteria are based on Cambodia’s existing government development plans, policies, regulations and laws.

4.1.4 Transfer of Technology and Know-how

Proposed CDM projects must demonstrate that one of their outcomes will be a transfer of new technology and skills to the host country. Over the last 10 years, Cambodia has hosted many projects involving the implementation of foreign technology and techniques. However it is difficult to find examples of such projects that have achieved successful long-term technology transfer. Evidence from sustainable energy projects in Cambodia suggests that some foreign donor organisations insist on employing their own nationals, and rarely provide detailed project design, testing or performance data to their Cambodian counterparts.

4.1.5 Transaction Costs and Administration Fees

A significant number of potential sustainable energy projects in Cambodia will meet the CDM small-scale methodology criteria (renewable energy projects with maximum output of 15 MW; reduction of energy consumption equivalent of less than 15 GWh or a reduction of anthropogenic emissions for projects that emit less than 15 kilotonnes of CO_2 equiv. per year). This methodology reduces transaction costs, particularly as it defines the baseline methodology and additionality tests.

Cambodia is classified as a Least Developed Country (LDC) and so CDM projects here are exempt from the standard 2% administration fee charged by the Executive Board.

No decision has yet been made on the level or structure of administration fees that may be charged by the DNA for processing project proposals.

Some factors that may raise project costs are the limited local technical capacity, the need to import most equipment which will attract up to 50% tax, and the established system of “unofficial fees” charged for many government services or approvals. Some of the capacity development activities in Cambodia that have been funded by donors and ODA may help reduce transaction costs for project developers, such as the calculation of emissions baselines.

Cambodia’s Law on Investment establishes legal, financial and institutional incentives to attract foreign investment that should assist developers of potential CDM projects. However arranging local finance for projects will be very difficult due to the immature state of the finance industry.

4.1.6 Diversion of Overseas Development Assistance

Under the Marakesh Accords, Overseas Development Assistance (ODA) must not be diverted to CDM projects, which has been interpreted to mean it must not be used to directly purchase CERs during the implementation of CDM projects (Pembina Institute, 2002). The precise interpretation of this rule is not yet determined, and there are widely differing views on how it applies. It is likely that a ruling or guidance will be required by the CDM Executive Board. This is an important issue for Cambodia because most the investor climate remains weak and much of the investment in the energy sector to date has been through ODA. Other sources of project funding are hard to find in Cambodia due to the high perceived risk for private investors, and the difficulty in obtaining loan finance from banks and other institutions.

4.1.7 Project Claim Period

Project proponents must indicate on their project submissions whether they wish to claim CERs for a maximum 10 year period, based on the initial emissions baseline calculation, or whether they will claim CER's for three 7 year periods with the baseline re-assessed at the end of each period. This will be an important consideration for energy projects in Cambodia due to the significant proposed developments in the industry over the next 12 years (MIME 1999). For example all electricity in Phnom Penh today is supplied by diesel and heavy fuel oil generators and some hydropower, but once the planned transmission line from Vietnam is commissioned the emissions baseline for Phnom Penh should be significantly less "carbon-intensive". Consequently for a given energy project, its potential greenhouse gas abatement will be reduced and the project proponent may prefer to use the initial baseline for as long as possible. This may affect larger projects more as these will likely require a dynamic baseline (such as the approved methodology (AM0004) for grid connected biomass projects). The small scale baseline methodology applies a static baseline and hence will give more certainty for the volume of CERs generated.

4.1.8 Risk Management

The allocation of risk in CDM projects must be agreed between project developers and investors. There are three main risks for these parties to consider in Cambodia. Firstly there is the risk that a proposed CDM project does not achieve accreditation, either by the DNA or the Executive Board. Secondly there is the risk that once an eligible project is operating it fails to generate the projected quantity of CERs. And thirdly there is the risk that the value of the CERs on the trading market is reduced as a result of an adverse ethical reaction in the market to an aspect of either a specific project or the host country.

Risk management is project-specific, but there are some common influences in Cambodia. Firstly investors will generally perceive a high risk of any project in Cambodia due to a variety of factors including high sovereign risk (it is only seven years since a political coup, and the current government is in a hiatus), unreliable legal system, and high levels of corruption which could inflate projected costs. Consequently investors will prefer to minimise their risk by securing an agreement to purchase the CERs at the time they are created. However the project developer will also want to minimise their exposure to these risks, and also has the difficulty of raising finance in Cambodia, so they will generally prefer that the investor makes an up-front payment for CERs delivered later. The high perceived risks for investors in Cambodia should reduce over time assuming that the country remains at peace and the number of successful foreign investments increases.

Conclusions and Recommendations

This preliminary desk study indicates good potential for sustainable energy projects in Cambodia, especially in the area of hydropower, biomass and energy efficiency. These opportunities mainly involve small projects that are relatively more expensive to develop and manage than larger ones. However small scale projects do benefit from simplified CDM methodology and also have less CDM approval risk, in terms of both the CDM Executive Board and host government approval.

Section three of this report highlights that very little resource assessment or project identification work has been undertaken except for hydropower projects. This makes it difficult to develop a CDM project pipeline and promote projects to investors. An assessment of the resource potential and identification of specific projects and partners is essential for attracting CDM investment. It is also essential for providing a sustainable alternative to the country's energy policy makers, government officials and investors.

The authors recommend that the following activities should be implemented in order to facilitate development of a pipeline of sustainable energy projects in Cambodia that are ready for potential CDM investment:

A comprehensive assessment of biomass energy resources including agricultural residues, potential energy crops, industrial wastes and municipal wastes;

An assessment of energy efficiency opportunities in Cambodia, with the aim of identifying generic projects that are replicable across industries;

Identification of potential sustainable energy projects by experienced experts using available resource assessments, regional and industry workshops, and site visits;

Feasibility studies of the projects identified which include the potential impact of CDM financing and also discussion of possible business models and partner organisations within Cambodia; and

Production of a guide for potential investors in sustainable energy projects in Cambodia that would include a detailed project pipeline, financial analyses and relevant background information on investing in Cambodia.

The development of Cambodia's energy sector may be critical if the country is to achieve its targets for poverty reduction. Sustainable energy can play an important role in this development by enhancing energy security and providing local economic benefits through job creation and reducing imports of fossil fuels. The benefits of distributed generation from renewable sources are especially valuable in Cambodia where there is the challenge of providing energy services to a rural population with minimal existing infrastructure. The CDM presents a clear opportunity for Cambodia to develop sustainable energy solutions, rather than only those with the lowest initial capital cost.

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Statistical Tables

Appendix A: Assumptions and Calculations for Energy Estimates

Table 12: Hydropower Resources and Existing Projects

Average capacity factor	50%	
Theoretical hydro resource	8,600	MW
Theoretical annual generation	37,668	GWh/year
Kirirom generation (approx)	53	GWh/year
O Chum II generation (approx)	2.3	GWh/year
NEDO PV/Hydro hybrid (hydro only)	0.2	GWh/year
Total	55.5	GWh/year

Source: World Bank 2003, NEDO 2002

Table 13: Estimate of Biofuel Crop Area Required to Replace Diesel for Electricity Generation

Soy Bean Oil			
Soy bean crop yield	1	t/ha	Source: MAFF 1999
Soy bean oil yield	19%		Source: Hammond, Johnson and Murphy 1993
=	171	L/Ha	
Heating value	39,623	kJ/kg	Source: Knothe, Dunn and Bagby 2002
Specific density	0.9	g/ml	
Cambodia's Biofuel Requirements			
Fuel used for power gen	4,803	TJ/year	Source: MIME 1996
Equivalent biofuel quantity	134,690,002	L/year	
Crop area needed	787,661	Ha	
=	7,877	sq.km	
Cambodia's existing soy crop area	349.5	sq.km	Source: MAFF 1999

Table 14: Animal Husbandry Data for Cambodia

Animal Type [1]	Animal Population			Average Population	Daily Excreta (kg/animal/day) [2]	Annual Excreta ton/year
	1993	1994	1995			
Non-dairy cattle	2,527	2,622	2,778	2,642	12	11,573
Buffalo	828	814	765	802	12	3,514
Horse*	20	21	21	21	12	91
Swine	1,992	2,002	2,039	2,011	4	2,936
Poultry	9,465	10,094	10,067	9,875	0.02	72
					Total	**18,186**

Sources:
1. Animal populations from MAFF 1999, except for horses: FAO 1995.
2. Animal excreta data from MAFF 2000, except for Buffalo and Horse which is assumed same as cattle.

Table 15: Estimate of Biomass Conversion Efficiency

Electrical Shaft Power			
Av. biomass heating value	17.5	MJ/kg	
Biomass conversion rate	1.4	kg/kWh	Source: UNDP 2000
=	24.5	MJ/kWh	
Input energy per unit output:	6.81		
Conversion efficiency	15%		
Heat and Cooking			
Biomass conversion rate	0.6	kg/Mcal	Source: UNDP 2000
=	10.5	MJ/Mcal	
Input energy per unit output:	2.51		
Conversion efficiency	40%		
Proposed Efficiency Factor			
Heating/cooking applications	75%		
Electricity/power applications	25%		
Average efficiency factor	34%		

Table 16: Land Use in Cambodia

Total land area in Cambodia	18,903,106	Hectares	100.00%
Forest	14,514,916	Hectares	76.79%
Rice fields	1,825,319	Hectares	9.66%
Water	1,340,858	Hectares	7.09%
Flooded area	1,066,613	Hectares	5.64%
Orchards	108,630	Hectares	0.57%
Rubber plantation	39,977	Hectares	0.21%
Slash and burn (Swidden Ag)	3,571	Hectares	0.02%
Available for PV or SHW:			
Town	2,024	Hectares	0.01%
Other surfaces	1,198	Hectares	0.01%
Total Available for Solar	**3,222**	**Hectares**	**0.02%**

Source: JAFTA, 1995

Table 17: Calculation of Potential Biomass Energy Resources

Crop or Biomass Source	Annual Production in Tons [1]	Residue Types	Residue Production Ration (tons) [2]	Biomass Fuel Available (Ton/year)	Lower Heating Value of Fuel (GJ/Ton) [3]	Energy Available in Fuel (GJ/year)	Source of Heating Value Data
Rice	4,041,000	Straw	1.76	7,112,160	16.02	113,936,803	Verwoerd 2001
		Husk	0.27	1,091,070	12.58	13,725,661	" "
		Bran	0.08	323,280	13.97	4,516,222	" "
Sugarcane	160,000	Tops	0.3	48,000	15.81	758,880	" "
		Bagasse	0.29	46,400	18.1	839,840	" "
Maize	95,000	Stalks	2	190,000	16.8	3,192,000	" "
		Cob	0.27	25,650	16.28	417,582	" "
		Husks	0.2	19,000	12.38	235,220	" "
Cassave	229,000	Stalks	0.06	13,740	17.5	240,450	" "
Soy beans	35,000	Straw+Pods	3.5	122,500	12.38	1,516,550	" "
Jute	250	Stalks	3	750	12.38	9,285	" "
Rubber tree wood	563,000	Waste Wood	0.54	304,020	17	5,168,340	" "
Sugar palm	10,000		0.2	2,000	11	22,000	" "
Wood processing residues [9]	106,175.4		0.395	41,939	20	838,786	Kartha, Larson, 2000
Cashew nuts [5]	1,397		40	55,880	20	1,117,600	SEDA 2002
Coconuts [6]	300,000		0.1	30,000	20.56	616,800	Kartha, Larson, 2001
Animal manure [7]	18,186		0.7	12,730	35.967	457,875	Kartha, Larson, 2002

Crop or Biomass Source	Annual Production in Tons [1]	Residue Types	Residue Production Ration (tons) [2]	Biomass Fuel Available (Ton/year)	Lower Heating Value of Fuel (GJ/Ton) [3]	Energy Available in Fuel (GJ/year)	Source of Heating Value Data
Municipal waste	316,761		0.75	237,570	15.12	3,591,836	www.ecosolutions.com
Human sewerage [8]	4,718,493		0.3	1,415,548	35.967	50,913,015	Jenkins 1999
					Total	**202,114,744**	GJ/year
					=	**56,143**	GWh/year
			Available Converted Energy [10]			**18,852**	GWh/year

[1] Source: NIS 2000, except for sugar palm (a new crop with plans for 10,000t/year - NEDO 2002); and Municipal Waste (MOE 2001).

[2] Figures for crops are suggested by NEDO 2002. Ratio for manure is an estimate.

[3] Calorific values are given as Lower Heating Values on a wet basis as reported in NEDO 2002.

[4] This study considers palm fibres only as reported in NEDO 2002, rather than fruit stems and shells.

[5] Cashew nut production information from The Cambodian Scene Magazine 2003.

[6] 150 million coconuts harvested annually (MAFF), estimated 2.5kg per coconut.

[7] See calculations for manure from Animal Husbandry Data for Cambodia, below.

[8] Source: Jenkins, 1999.

[9] Source of production data: MAFF 1999 as cited in MOE 2002; source of residue ratio: FAO 1998.

[10] See Estimate for Biomass Conversion Efficiency in Table 15.

Table 18: Cambodia's Daily Insolation (kWh/sq.m/day)

Jan	Feb	Mar	Apr	May	Jun
5.41	6	6.34	6.04	5.17	4.36

Jul	Aug	Sep	Oct	Nov	Dec
4.66	4.24	4.49	4.47	4.86	5.11

Avg daily insolation is a 10 year avg for location with Lat.10, Long 104
Note: "Insolation" = Solar irradiation, measured here on a horizontal surface
Source: http://eosweb.larc.nasa.gov cited in "Final Report on RE Strategy & Program", Meritec and KCEC, March 2001

Table 19: Calculation of Technical Potential for PV

Avg. daily insolation	5.10	kWh/sq.m/day	See Table 18
Total land area available for PV	32,220,000	sq.metres	See Table 16
Conversion efficiency of PV modules	13%		Source: IEA PVPS 2003
Peak installed capacity of PV modules	4189	MW	Note: Assuming peak insolation of 1000 kW/sq.m
Potential daily generating capacity	21.34	GWh/day	
Potential annual generating capacity of PV	7,470.54	GWh/year	Note: Assumes 15 days/year with no output due to system maintenance or failure
Annual generation output of EDC utility	535.70	GWh/year	Note: Output includes purchases from IPPs (EDC 2002)
Comparison of PV potential and EDC output	13.95	times	

Table 20: Market Potential for Photovoltaics in Cambodia

Potential market	440,000	Households
Average system size	0.08	kW per household
Total market capacity	35.20	MW
Potential generation	65	GWh per year

Table 21: Calculation of Potential for Solar Water Heating

Daily avg. insolation	5.10	kWh/sq.m/day	
Total land area available for SWH Collectors	32,220,000	sq.metres	
Conversion efficiency of SHW system	30%		Source: ITDG Technical Brief, website 2004
Potential generating capacity	49.26	GWh/day	Note: This would be more than 24 times the total amount of energy required to boil 10 litres each day for every household in Cambodia

Table 22: Calculation for Potential Commercial Wind Turbine Output

Potential installed capacity	1,280	MW	Source: Truewind Solutions, 2001 for areas with wind speed >7m/s
Assumed capacity factor	30%		Note: Estimate based on wind speed and performance of modern turbines
Potential annual generation	3,364	GWh/year	

Table 23: Calculation for potential small wind turbine output

Rural Households (HH)	1,846,744		Source: NIS General Census 1998
Proportion of rural HH in windy areas	6%		Source: World Bank Wind Atlas, 2001
Penetration rate of wind turbines	50%		Note: Estimate
Average capacity of rural wind turbine	400	W	Note: Estimate
Total potential installed wind turbine capacity	22.16	MW	
Assumed capacity factor	20%		Note: Estimate based on wind speed and small turbine performance and maintenance
Potential annual generation	39	GWh/year	

Table 24: Energy Consumption of Brick Kilns

Total wood used in PP kilns	36,360	cu.m/yr
Wood density	600	kg/cu.m
Wood heating value	14.5	MJ/kg
Total energy used in PP kilns	88	GWh/yr
Brick kilns in Phnom Penh	71	kilns
Energy use per PP kiln	1.2	GWh/yr
Brick kilns in Cambodia	446	kilns
Total energy used in Cambodia kilns	552	GWh/yr

Source: FAO 1998

Table 25: Results of Energy Audits on Commercial Buildings in Phnom Penh

	Lighting	**Air Con.**	**Other**
Hong Kong Centre	14%	84%	2%
Bayon Clinic	9%	47%	44%
Mong Rethy Building	23%	68%	9%
Sunway Hotel	24%	55%	21%
Average	**18%**	**64%**	**19%**

Source: MIME 2002

Table 26: Estimate of Potential Savings from Residential Energy Efficiency Improvements

Project Type	Total Energy Use (GWh/yr)	Proportion of Energy Use by Technology	Potential Efficiency Improvement	Potential Energy Saving (GWh/yr)
Residential Sector				
Improved cook stoves	22,212	98%	30%	6,530
Energy saving fluorescent lamps	105	80%	72%	61
Total				**6,591**

Notes:

1. Source of energy data: Energy Balance 1995 (MIME 1996 as cited in NEDO 2002)
2. Assumed that 98% of household biomass (fuelwood, charcoal, dung) is used for cooking on traditional stove, based on CFSP 2004
3. Source of potential cookstove efficiency improvement data: CFSP 2004
4. Assumed that 80% of household electricity consumption is used for lighting with 25W incandescent lamps
5. Assume project involves replacing 25W incandescent lamps with 7W energy saving globes (both providing approximately 250 lumens).

Table 27: Projected Energy Savings from the Use of Improved Cookstoves (ton of charcoal)

Year	Business as Usual	With Improved Cookstove	Savings Achieved,
2000	60,196	60,032	164
2001	61,400	60,841	559
2002	62,628	60,263	2,365
2003	63,880	57,967	5,913
2004	65,158	54,317	10,841
		Average	**3,968**
		or	**103 TJ/year**

Calorific value of charcoal: 26 MJ/kg

Source: CFSP 2003

Table 28: Calculation for Potential Energy Efficiency Improvements

Project Type	Proportion of Energy Used by Technology	Potential Efficiency Improvement	Potential Energy Saving (GWh/yr)	
Power Sector				
		Total Energy Use:	*1,335*	Source: Energy Balance 1995 (MIME 1996 as cited in NEDO 2002)
Generation	100%	15%	200	Source: Efficiency estimate based on Sharp, 2004
Distribution	9%	10%	12	Source of proportion: Energy Balance 1995 (MIME 1996 as cited in NEDO 2002), source of eff improvement estimate: Sharp, 2004
Cogeneration	15%	30%	60	Note: for cogen the 'proportion of energy use' column refers to the estimated appropriate sites where cogen may be feasible. Source of efficiency estimate: COGEN3, 2003
Industrial Sector				Note: over 55% of this energy is consumed in large or medium industries, thus assume that steam systems and lighting are major energy users.
		Total Energy Use:	*148*	
Steam system	15%	20%	4	Source: US Dept of Energy
Lighting	10%	15%	2	
Brick kilns	50%	50%	138	Source of efficiency estimate: Voerword, 2001, energy proportion estimated based on FAO 1998
Cogeneration	30%	30%	13	Note: for cogen the 'proportion of energy use' column refers to the estimated appropriate sites where cogen may be feasible. Source of efficiency estimate: COGEN3, 2003
Commercial Sector				
		Total Energy Use:	*275*	
Lighting	18%	15%	7.41	Source: proportions of energy use based on energy audit survey summarised in table below (MIME 2002)
Air conditioning	64%	40%	70.30	
Water heating	10%	95%	26.09	Note: proportion of energy use is a rough estimate based on the study above
Cogeneration	15%	30%	12.36	Note: for cogen the 'proportion of energy use' column refers to the estimated appropriate sites where cogen may be feasible. Source of efficiency estimate: COGEN3, 2003
	Total potential savings		**546.59**	GWh/year
	Efficiency improvement		**34%**	

Table 29: Greenhouse Gas Emissions Baseline for Grid Power in Phnom Penh

Power Plant (Capacity MW)	Production (GWh in 2003)	Proportion	Fuel Consumption kg/kWh*	Emission Factor tCO_2/MWh
EDC C2 - 18 MW HFO	45	9%	0.407	1.3024
EDC C3 – 14 MW Diesel	15	3%	0.26	0.819
EDC C5 – 10 MW Diesel	29	5%	0.213	0.67095
EDC C6 – 18 MW HFO	63	12%	0.238	0.7616
IPP - CUPL - 35 MW Diesel	229	43%	0.23	0.7245
IPP - Caterpillar – 20 MW Diesel	95	18%	0.216	0.6804
Kirirom Hydro – 10 MW	53	10%	0	0
Total	**529**	**100%**		
			Phnom Penh weighted average emissions	**0.697**

Source: Ministry of Environment

Table 30: Energy Balance 1995 (Source: MIME 1996)

1995 TJ Fuel	Fuel-wood	Bio-mass	Dung	Hydro	Charcoal	Electricity	LPG	Gasoline	Jet Fuel	Kerosene	Diesel Oil	Fuel Oil	Sub Total Petrol Fuels	Total
Calorific value	14.5 MJ/kg	14.5 MJ/kg	13.8 MJ/kg	4.235294 MJ/kWh	29 MJ/kg	3.6 MJ/kWh	45.26 MJ/kg	44.29743 MJ/kg	43.51199 MJ/kg	44.45553 MJ/kg	42.71269 MJ/kg	40.67804 MJ/kg		
DOMESTIC SUPPLY	81,505	1,624	17.94	3.070588	0	0	169.5133	6,466.688	467.67	1,112.044	7,834.815	2056.4	18,107.13	101,257.1
Production	81,505	1,624	17.94	3.070588									0	83,150.01
Imports							169.5133	6,466.688	467.67	1,112.044	7,815.461	2,082.949	18,114.32	18,114.32
Exports	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bunkers												46.77509	46.77509	46.77509
Stock Changes											-19.3545	-20.2264	-39.5809	-39.5809
CONVERSION INPUTS	3,784.132	0	0	3.070588	0	0	0	377.8115	0	0	2,433.828	1,991.501	4,803.14	8,590.342
Charcoal Production	3,784.132												0	3,784.132
Elec gen: EdC											839.2787	1,991.501	2,830.779	2,830.779
Elec gen: Provinces				3.070588							511.9419		511.9419	515.0125
Elec gen: Private								377.8115			1,082.607		1,460.419	1,460.419
CONVERSION OUTPUTS	0	0	0	0	1,097.398	1,067.529	0	0	0	0	0	0	0	2,164.927
Thermal electricity	0	0	0	0	0	1,064.919	0	0	0	0	0	0	0	1,064.919
EdC						617.279							0	617.279

1995 TJ Fuel	Fuel-wood	Bio-mass	Dung	Hydro	Charcoal	Electricity	LPG	Gasoline	Jet Fuel	Kerosene	Diesel Oil	Fuel Oil	Sub Total Petrol Fuels	Total
Calorific value	14.5 MJ/kg	14.5 MJ/kg	13.8 MJ/kg	4.235294 MJ/kWh	29 MJ/kg	3.6 MJ/kWh	45.26 MJ/kg	44.29743 MJ/kg	43.51199 MJ/kg	44.45553 MJ/kg	42.71269 MJ/kg	40.67804 MJ/kg		
Steam turbine						345.9773							0	345.9773
Diesel						271.3017							0	271.3017
Provinces						137.2192							0	137.2192
Private	0	0	0	0	0	310.4207	0	0	0	0	0	0	0	310.4207
Phnom Penh	0	0	0	0	0	233.1795	0	0	0	0	0	0	0	233.1795
Household						38.862							0	38.862
Service sector						173.6075							0	173.6075
Industrial						20.71004							0	20.71004
Other Private						77.24118							0	77.24118
Hydro-electricity						2.61							0	2.61
Elec generation losses				0.460588				307.1861			1,785.511	1,645.523	3,738.221	3,738.681
Elec. auxil consumption						44.70115							0	44.70115
Transm & distr losses						196.2247							0	196.2247
NET ENERGY SUPPLY	77,720.87	1624	17.94	0	1,097.398	826.603	169.5133	6,088.877	467.67	1,112.044	5,400.988	64.89949	13,303.99	94590.8
Statistical difference	0	0	0	0	0	0	0	0	0	0	0	-9.9E-14	-9.9E-14	-9.9E-14
FINAL CONSUMPTION	77,720.87	1624	17.94	0	1,097.398	826.603	169.5133	6,088.877	467.67	1,112.044	5,400.988	64.89949	13,303.99	94,590.8

1995 TJ Sector & Sub-sector	Fuel-wood	Bio-mass	Dung	Hydro	Charcoal	Electricity	LPG	Gasoline	Jet Fuel	Kerosene	Diesel Oil	Fuel Oil	Total Petrol	Total
Household	*77,328.5*	*1,624*	*17.94*	*0*	*934.96*	*378.1997*	*56.62298*	*0*	*0*	*878.7935*	*175.6551*	*0*	*1,111.072*	*81,394.67*
Urban total	4,683.5	0	0	0	772.56	317.5833	56.62298	0	0	310.2141	62.00624	0	428.8433	6,202.487
Phnom Penh	768.5				601.46	231.5378	48.58088			96.66729	19.32206		164.5702	1,766.068
Other urban	3915				171.1	86.04547	8.042105			213.5468	42.68419		264.2731	4,436.419
Rural total	72,645	1,624	17.94		162.4	60.61639				568.5794	113.6488		682.2282	75,192.18
Service Sector	*22.62219*	*0*	*0*	*0*	*149.1853*	*390.9576*	*112.8903*	*0*	*0*	*233.2503*	*79.75159*	*0*	*425.8922*	*988.6573*
Phnom Penh	3.712	0	0	0	116.145	366.2833	96.66938	0	0	109.7356	55.06321	0	261.4682	747.6085
Shops	0.609				75.777	55.52444	39.30677			29.9944	5.995343		75.2965	207.2069
Offices, banks					1.218	130.3212	16.12395						16.12395	147.6632
Schools						4.079332							0	4.079332
Hospitals					0.087	13.39933				1.463141	0.292456		1.755597	15.24193

1995 TJ Fuel	Fuel-wood	Bio-mass	Dung	Hydro	Charcoal	Electricity	LPG	Gasoline	Jet Fuel	Kerosene	Diesel Oil	Fuel Oil	Sub Total Petrol Fuels	Total
Calorific value	14.5 MJ/kg	14.5 MJ/kg	13.8 MJ/kg	4.235294 MJ/kWh	29 MJ/kg	3.6 MJ/kWh	45.26 MJ/kg	44.29743 MJ/kg	43.51199 MJ/kg	44.45553 MJ/kg	42.71269 MJ/kg	40.67804 MJ/kg		
Restaurants	2.958				38.889	26.59755	1.70899			78.27806	15.64638		95.63343	164.078
Hotels	0.145				0.174	133.3032	39.52968				33.12903		72.65871	206.2809
Other														
Public Lighting						3.058224							0	3.058224
Provinces	18.91019				33.04028	24.67426	16.22096			123.5147	24.68838		164.424	241.0488
Agriculture													*0*	*0*
Industry	*369.75*	*0*	*0*	*0*	*13.253*	*57.44573*	*0*	*0*	*0*	*0*	*29.32089*	*63.4584*	*92.77929*	*533.228*
Phnom Penh	174	0	0	0	6.235	52.84364	0	0	0	0	29.32089	63.4584	92.77929	325.8579
Large & medium ind	174					44.3487					21.78	54.8892	76.6692	295.0179
EdC (Non gen. use)						1.035958					7.540889	8.5692	16.11009	17.14605
Small ind/handicrafts					6.235	7.458979							0	13.69398
Provinces	195.75				7.018	4.602087							0	207.3701
Transport	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*6,088.877*	*467.67*	*0*	*5,116.26*	*1.441092*	*11,674.25*	*11,674.25*
Road								6,088.877			4864.284		10,953.16	10,953.16
Rail											34.17583	1.441092	35.61693	35.61693
Air									467.67				467.67	467.67
Marine											217.8		217.8	217.8
TOTAL	77,720.87	1,624	17.94	0	1,097.398	826.603	169.5133	6,088.877	467.67	1,112.044	5,400.988	64.89949	13,303.99	94,590.8
NET ENERGY SUPPLY	77,720.87	1,624	17.94	0	1,097.398	826.603	169.5133	6,088.877	467.67	1,112.044	5,400.988	64.89949	13,303.99	94,590.8
Statistical difference	0	0	0	0	0	0	0	0	0	0	0	9.95E-14	9.95E-14	9.95E-14

APPENDIX B: SUMMARY TABLE OF PROJECT STATUS

Table 31: Summary Table of Sustainable Energy Project Pipeline

Project Name	Technology	Province Location	Installed Capacity (MW)	Annual Generation or Saving (GWh'year)	Potential GHG Saved (T CO_2e/year) [1]	Study Report	Status
1. Hydro Projects (larger than 5 MW)							
Kirrirom 1	Hydro	Kompong Speu	12	53	36,941		Operating - IPP "CETIC"
Kamchay	Hydro	Kampot	128	558	388,926	CEPEC(1995), NEWJEC (1996)	Govt announced BOT March 2004
Western Kirirom	Hydro	Kompong Speu	13	57	39,687	NEWJEC (1996)	
Stung Menam 2	Hydro		90	466	324,802	CEPEC(1995), NEWJEC (1996)	
Stung Atay	Hydro		110	588	409,836	CEPEC(1995), NEWJEC (1996)	
Battambang 2	Hydro	Battambang	36	187	130,339	CEPEC(1995), NEWJEC (1996)	
Sambor	Hydro		465	2,800	1,951,600	CEPEC(1995), NEWJEC (1996)	
Bokor Plateau	Hydro	Kampot	28	147	102,459	CEPEC(1995), NEWJEC (1996)	
Battambang 1	Hydro	Battambang	24	120	83,640	CEPEC(1995), NEWJEC (1996)	
Stung Phlophot 2	Hydro		25	110	76,322	NEWJEC (1996)	
Stung Sen	Hydro		38	166	116,009	CPEC (1995)	
Stung Russei Chrom	Hydro		125	548	381,608	CPEC (1995)	
Stung Chhay Areng 2	Hydro		260	1,139	793,744	CPEC (1995)	
Stung Tatay 2	Hydro		80	350	244,229	CPEC (1995)	
Stung Metook	Hydro		77	337	235,070	HECEC (1998)	
Stung Kraehung	Hydro		50.4	221	153,864	HECEC (1998)	
Phnom Kolan	Hydro		104.7	459	319,634	HECEC (1998)	
Prek Tatal	Hydro		24.8	109	75,711	HECEC (1998)	
Phnom Veal Chhuk	Hydro		60.8	266	185,614	HECEC (1998)	
Phnom Batau B	Hydro		29.2	128	89,144	HECEC (1998)	
Stung Sva Stap	Hydro		19.4	85	59,225	HECEC (1998)	
		Total Large Hydro:	1,800.3	8,893	6,198,403		
2. Mini-Hydro (500 kW to 5 MW)							
O Chum	Mini-Hydro	Ratanakiri	1	2.5	2,250		Operating - Govt owned

Project Name	Technology	Province Location	Installed Capacity (MW)	Annual Generation or Saving (GWh'year)	Potential GHG Saved (T CO_2e/year) [1]	Study Report	Status
O Tuou Trao	Mini-Hydro	Kampot	1.1	5.5	4,950	Meritec Pre-investment Study (World Bank 2002)	Potential
Phnum Batau	Mini-Hydro	Koh Kong	4.2	21.3	19,170	Meritec Pre-investment Study (World Bank 2002)	Potential
Stung Sva Slab	Mini-Hydro	Kampong Spoe	3.8	20.3	18,270	Meritec Pre-investment Study (World Bank 2002)	Potential
O Sla	Mini-Hydro	Koh Kong	2	10.2	9,180	Meritec Pre-investment Study (World Bank 2002)	Potential
Stung Siem Reap	Mini-Hydro	Siem Reap	1.7	6.6	5,940	Meritec Pre-investment Study (World Bank 2002)	Potential
Upper Stung Siem Reap	Mini-Hydro	Siem Reap	0.65	2	1,800	Meritec Pre-investment Study (World Bank 2002)	Potential
Phunum Tunsang Upstream	Mini-Hydro	Koh Kong	3.1	15.9	14,310	Meritec Pre-investment Study (World Bank 2002)	Potential (from desk study only)
Phunum Tunsang Downstream	Mini-Hydro	Koh Kong	3	14.3	12,870	Meritec Pre-investment Study (World Bank 2002)	Potential (from desk study only)
O Phlai	Mini-Hydro	Mondulkiri	3.5	12.4	11,160	Meritec Pre-investment Study (World Bank 2002)	Potential (from desk study only)
		Total Mini-Hydro:	24.05	111	99,900		
3. Micro- Hydro (10 kW to 500 kW)							
Toeuk Chas	Micro-Hydro	Kompong Cham	0.04	0.1	126		Operating - NEDO Demo Project, hybrid PV
Srae Chang	Micro-Hydro	Kampot	0.126	0.33	297	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
O Samrel	Micro-Hydro	Battambang	0.032	0.075	68	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
Ta Taok	Micro-Hydro	Battambang	0.038	0.092	83	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
Kampong Lpov	Micro-Hydro	Kampot	0.032	0.07	63	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
O Pramoie	Micro-Hydro	Pursat	0.034	0.065	59	Meritec Pre-Investment Study (NZMFAT 2003)	Potential

Project Name	Technology	Province Location	Installed Capacity (MW)	Annual Generation or Saving (GWh'year)	Potential GHG Saved (T CO_2e/year) [1]	Study Report	Status
O Chum III	Micro-Hydro	Ratanakiri	0.074	0.325	293	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
Ta Ang	Micro-Hydro	Ratanakiri	0.01	0.016	14	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
Beisroc	Micro-Hydro	Ratanakiri	0.078	0.132	119	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
Busra	Micro-Hydro	Mondulkiri	0.054	0.103	93	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
Prek Dak Deur	Micro-Hydro	Mondulkiri	0.2	0.576	518	Meritec Pre-Investment Study (NZMFAT 2003)	Potential
		Total Micro-Hydro:	0.718	1.92416	1731.744		
4. Biomass							
NEDO Demonstration	Hybrid bioreactor/PV	Sihanoukville	0.07	0.6	504	None available	Operational, testing
FAO Biodigesters	Biodigester (open trough)	Takeo					Operational
CRDT Biodigesters	Biodigester (open trough)	Takeo					Operational
Phnom Penh Dumpsite	Waste capture						Study underway
Community Wood Gasifier (SME project)	Biomass gasifier (Wood from energy crop)	Battambang	0.01	0.04	39		Identified
REE Wood Gasifier (SME project)	Biomass gasifier (Wood from energy crop)	Battambang	0.075	0.3	296		Identified
REE Rice Husk Gasifier (SME project)	Biomass gasifier (Rice husk from mill)	Siem Reap	0.2	0.9	788		Identified
Angkor Rice Mill	Biomass cogeneration (Rice husks firing a boiler and steam turbine)	Phnom Penh	1.5	10.2	8,119	COGEN3 Pre-Investment Study	Seeking finance

Project Name	Technology	Province Location	Installed Capacity (MW)	Annual Generation or Saving (GWh'year)	Potential GHG Saved (T CO_2e/year) [1]	Study Report	Status
Cashew Nut Factory	Biomass fired boiler	Kompong Cham	0.5	4	3,600	None available	Identified
		Total Biomass:	2.4	16	13,347		
5. Photovoltaics							
Various Applications	PV (stand alone)	Various	0.5	0.92	828		Operational
NEDO Demonstration	Hybrid PV/micro-hydro	Kompong Cham	0.068	0.13	113		Operational
NEDO Demonstration	Hybrid bioreactor/PV	Sihanoukville	0.05	0.09	83		Operational, testing
		Total PV:	0.618	1.14	1,023		
6. Wind							
NEDO Demonstration	Hybrid wind/PV	Takeo	0.0024	0	0		Disconnected
Sihanoukville Port Wind Turbine	Wind turbine	Sihanoukville	0.66	1.7	1,561	Interim Wind Monitoring Report (3E 2003)	Final feasibility report imminent
		Total Wind:	0.66	1.7	1,561		

Note: [1] For simplicity the baseline for all hydro over 5 MW is taken as the calculated weighted average for Phnom Penh. For mini and micro hydros the baseline is taken as the emission factor for a small diesel engine as defined in UNFCC 2003.