# Feasibility Study of Renewable Energy Options for Rural Electrification in Cambodia (REOREC)

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# Task 3

## MARKETS, POLICIES AND INSTITUTIONS

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CRCD

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EPP Emerging Power Partners

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## List of Abbreviations

| | |
|---|---|
| AC | Alternating current |
| ACE | ASEAN Centre for Energy |
| ADB | Asian Development Bank |
| ASEAN | Association of South East Asian Nations |
| BFB | Bubbling fluidised bed |
| BoS | Balance-of-system |
| CC | Combined cycle |
| CCCO | Cambodian Climate Change Office |
| CDC | Council for the Development of Cambodia |
| CDM | Clean Development Mechanism |
| CDRI | Cambodian Development Resource Institute |
| CER | Certified Emission Reduction |
| CFB | Circulating fluidised bed |
| CHP | Combined heat and power |
| CIB | Cambodian Investment Board |
| COP | Conference of the Parties |
| CRA-W | Centre wallon de Recherches Agronomiques |
| CRCD | Cambodian Research Centre for Development |
| CRDB | Cambodian Rehabilitation and Development Board |
| DANIDA | Danish International Development Agency |
| DC | Direct current |
| DNA | Designated National Authority |
| EAC | Electricity Authority of Cambodia |
| EAEF | EC-ASEAN Energy Facility |
| EC | European Commission |
| EDC | Electricité du Cambodge |
| EGAT | Electricity Generating Authority of Thailand |
| EIA | Environmental impact assessment |
| EPP | Emerging Power Partners |
| EU | European Union |
| FBC | Fluidised bed combustion |
| FDI | Foreign direct investment |
| GDP | Gross domestic product |
| GEF | Global Environment Facility |
| GHG | Greenhouse gas |
| HAT | Humid air turbine |
| HFO | Heavy fuel oil |
| ICE | Internal combustion engines |
| IDA | International development assistance |
| IFCT | Industrial Finance Corporation of Thailand |
| IPPs | Independent power producers |
| ITC | Institut de Technologie du Cambodge |
| JICA | Japan International Cooperation Agency |
| LSE | Load serving entity |

| | |
|---|---|
| MAFF | Ministry of Agriculture, Forestry and Fisheries |
| MIME | Ministry of Industry, Mines and Energy |
| MOC | Ministry of Commerce |
| MOE | Ministry of Environment |
| MOEF | Ministry of Economy and Finance |
| MPWT | Ministry of Public Works and Transport |
| NEDO | New Energy and Industrial Technology Development Organization |
| NGO | Non-governmental organisation |
| OM&M | Operation, maintenance and management |
| ORC | Organic rankine cycle |
| PDD | Project design document |
| PPA | Power purchase agreement |
| PV | Photovoltaic |
| RE | Renewable energy |
| REAP | Renewable Energy Action Plan |
| REEs | Rural energy enterprises |
| REF | Rural and Renewable Energy Fund |
| RES-E | Electricity from renewable energy sources |
| REOREC | Feasibility Study of Renewable Energy Options for Rural Electrification in Cambodia |
| RISØ | RISØ National Laboratory |
| SHP | Small hydropower plant |
| SHS | Solar home system |
| SME | Small and medium enterprise |
| SPP | Small power producer |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WB | World Bank |

# 1 Introduction

This report is an output of Task 3 within the “Feasibility Study of Renewable Energy Options for Rural Electrification in Cambodia” (REOREC) Project. The study seeks to address the policy, institutional and market barriers to private sector development and implementation of renewable energy for rural electrification in Cambodia. The objective of this report is to estimate the market potential of renewable energy in rural electricity markets, propose policy interventions and institutional framework to promote renewable energy for rural electrification and provide relevant information to private project developers.

The first part consists of the renewable rural electrification market study. The main objective of this study was to estimate the market potential of renewable energy in rural electricity markets. This task reviewed the rural electrification development strategies and targets of the government, and summarized the medium term rural electricity demand based on the country’s power development plan. The market potential for renewable energy in the rural electricity market was estimated based on the available renewable energy resources in the country. An assessment of the different renewable energy technologies and their applicability in Cambodia was conducted.

The second part deals with the renewable rural electrification policy study. The objective of this study was to analyze the existing policies and regulations related to renewable rural electrification and to propose policy interventions to promote renewable energy for rural electrification and provide incentives to private project developers. The study reviews relevant best practice policies, instruments and regulatory frameworks of the EU member states and other developed and developing countries, and proposes alternative policy and regulatory options for Cambodia.

The last part covers the renewable rural electrification institutional framework study. The main objective of the study was to ensure that there is an institutional support for RE in rural electrification and private investments. The commercial, legal frameworks and regulatory environment concerning renewable energy project development and implementation was assessed and evaluated. Moreover, the study reviews the stakeholders’ activities and the associated project structuring activities needed in the project development and implementation.

The terms and conditions of financing available to the private sector have been assessed to determine their implications on the financial attractiveness of RE projects. Different schemes, sources of finance and incentives to encourage implementation of renewable energy projects were also investigated and evaluated.

# 2 Renewable Rural Electricity Market

## 2.1 Rural Electrification Development in Cambodia

### 2.1.1 Electrification Level

Cambodia has no national grid and the country's electricity supply consists of 24 isolated grids centered at major cities, provincial and small towns, with the exception of the electricity supply system of Kampong Speu which has been connected to the Phnom Penh system through a 115 kV single circuit transmission line since 2002. Electricity service providers in small towns and communes near the borders of Thailand and Vietnam also sourced some of their power from electricity suppliers from their countries.

Three main categories of electricity suppliers exist in Cambodia, and these are: i) Electricité du Cambodge (EDC); ii) licensed electricity providers, and; iii) rural electricity enterprises.

*Electricité du Cambodge* is a state-owned utility with a consolidated license from Electricity Authority of Cambodia (EAC) to generate, transmit and distribute electricity throughout the country. EDC currently supplies electricity in the areas of Phnom Penh/Kandal, 8 provincial towns, and 4 small isolated systems near the Vietnamese border (Table 2-1). EDC's installed generating capacity reached 95.1 MW in 2004. In addition, EDC also purchased 86.4 MW power from independent power producers (IPPs) during the same period. EDC has a total of 128.7 circuit-kilometers of 115 kV transmission network, 460.4 circuit-kilometers of medium voltage (4.0 kV, 6.3 kV, 15 kV and 22 kV) and 842.9 circuit-kilometers of low voltage (380/220 V) distribution networks.

*Licensed electricity providers* are entities with license to supply electricity services granted by EAC. EAC issues 9 categories of licenses: generation, transmission, national transmission, special purpose transmission, distribution, consolidated (combination of some or all categories of licenses), dispatch, bulk sale, and retail license. In 2004, EAC issued 11 generation licenses, 89 consolidated licenses (including EDC) and 7 distribution licenses. Licensed generators (IPPs) in 2004 had a combined installed capacity of 91 MW of which 87.4 MW capacity were supplied to EDC while the remaining 3.6 MW to other licensees. In addition, entities with consolidated licensees had a total generation capacity of 15.6 MW. Most service providers with consolidated licenses have small-scale operations. Around 73% have capacities with less than 100 kW while the remaining 27% have unit generators ranging between 100 kW to 800 kW. The number of licensed providers and their provincial locations are shown in Table 2-1

Outside provincial capitals and small towns *rural electricity enterprises* thrive. These enterprises operate small diesel generators and produce electricity for their own use and for neighboring customers. Their supply operation ranges from 20 to few hundred customers. Almost all of these rural electricity enterprises are not licensed since the travel costs in obtaining a license from Phnom Penh are substantial. Rural electricity enterprises all over the country were estimated to number around 500.

*Table 2-1: Rural Electrification Level*

| | | Population Census | | | Supply by EDC (2004) | | | | Supply by Licensees *1 | | | Supply by Non-licensees *3 | | | Electrif. Ratio by Grid/Mini-grid | | Electrification by Rechargeable Batteries | | | Electrif. Ratio | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Population (2003) | Number of Family | Nos of Household | Nos. of Customer (2004) Domestic | Others | Total | El. Ratio (%) | Nos. Licensees | Nos. of Customer | El. Ratio (%) | Nos. Providers | Nos. of Customer *4 | El. Ratio (%) | Nos. Customer | El. Ratio (%) | Nos. of BCS | Estimated Customer | El. Ratio (%) | Total Customers | El. Ratio (%) |
| 1 | Banteay Meanchey | 669,961 | 130,362 | 122,576 | | | | 0.00 | 9 | 4,930 *2 | 4.02 | | | | 4,930 | 4.02 | | | | | |
| 2 | Battambang | 918,173 | 179,574 | 170,507 | 15,073 | 415 | 15,488 | 8.84 | 8 | 2,794 | 1.64 | | | | 17,867 | 10.48 | | | | | |
| 3 | Kampong Cham | 1,717,769 | 355,800 | 315,558 | 8,099 | 186 | 8,285 | 2.57 | 13 | 4,079 | 1.29 | | | | 12,178 | 3.86 | | | | | |
| 4 | Kampong Chhnang | 430,962 | 88,675 | 83,559 | | | | 0.00 | 5 | 4,275 | 5.12 | | | | 4,275 | 5.12 | | | | | |
| 5 | Kampong Speu | 675,932 | 129,333 | 124,977 | | | | 0.00 | 7 | 1,290 *2 | 1.03 | 19 | 3,365 00 | 2.69 | 4,655 | 3.72 | | | | | |
| 6 | Kampong Thom | 616,370 | 120,693 | 111,059 | | | | 0.00 | 7 | 5,587 | 5.03 | | | | 5,587 | 5.03 | | | | | |
| 7 & 23 | Kampot/Krong Kep | 599,006 | 118,527 | 115,359 | 6,317 | 0 | 6,317 | 5.48 | 5 | 818 | 0.71 | 0 | 3317 | 2.88 | 10,452 | 9.06 | | | | | |
| 7 | Kampot | 565,381 | 111,759 | 109,158 | | | | | 5 | 818 *2 | - | | 3,317 03 | - | - | - | | | | | |
| 23 | Krong Kep | 33,625 | 6,768 | 6,201 | | | | | n.a | n.a | - | | | - | - | - | | | | | |
| 8 & 12 | Phnom Penh/Kandal | 2,168,398 | 413,102 | 375,241 | 137,649 | 13,087 | 150,736 | 36.68 | 14 | 4,495 | 1.20 | | | | 142,144 | 37.88 | | | | | |
| 8 | Kandal | 1,161,443 | 226,460 | 203,264 | | | | | 12 | 4,495 | - | | | | - | - | | | | | |
| 12 | Phnom Penh | 1,006,955 | 186,642 | 171,977 | | | | | 2 | 0 | - | | | | - | - | | | | | |
| 9 | Koh Kong | 126,595 | 24,867 | 24,381 | | | | 0.00 | 2 | 2,370 | 9.72 | | | | 2,370 | 9.72 | | | | | |
| 10 | Kracheh | 280,521 | 55,770 | 49,691 | | | | 0.00 | 1 | 2,557 | 5.15 | | | | 2,557 | 5.15 | | | | | |
| 11 | Mondol Kiri | 43,067 | 9,455 | 7,923 | | | | 0.00 | 0 | | - | | 185 *6 | | 185 | 2.33 | | | | | |
| 13 | Preah Vihear | 137,002 | 27,548 | 24,994 | | | | 0.00 | 1 | 550 | 2.20 | | 240 *6 | | 790 | 3.16 | | | | | |
| 14 | Prey Veng | 1,050,743 | 221,990 | 196,919 | 2,587 | 0 | 2,587 | 1.31 | 5 | 3,652 *2 | 1.85 | | | | 6,239 | 3.17 | | | | | |
| 15 | Pursat | 378,572 | 73,280 | 71,569 | | | | 0.00 | 5 | 5,610 | 7.84 | | | | 5,610 | 7.84 | | | | | |
| 16 | Ratana Kiri | 114,451 | 23,435 | 19,195 | 2,098 | 94 | 2,192 | 10.93 | 0 | 0 *2 | 0.00 | | | | 2,098 | 10.93 | | | | | |
| 17 | Siem Reap | 762,816 | 139,035 | 135,311 | 9,883 | 818 | 10,701 | 7.30 | 3 | 880 | 0.65 | | | | 10,763 | 7.95 | | | | | |
| 18 | Sihanoukvill | 164,364 | 31,212 | 29,646 | 7,376 | 805 | 8,181 | 24.88 | 3 | 1,450 | 4.89 | 3 | 475 04 | 1.60 | 9,301 | 31.37 | | | | | |
| 19 | Stung Treng | 77,372 | 14,960 | 13,429 | | | | 0.00 | 0 | 0 *2 | - | | 1,250 *5 | | 1,250 | 9.31 | | | | | |
| 20 | Svay Rieng | 526,904 | 109,264 | 103,012 | 1,426 | 3 | 1,429 | 1.38 | 0 | 0 *2 | 0.00 | 15 | 2,950 04 | 2.86 | 4,376 | 4.25 | | | | | |
| 21 | Takeo | 862,342 | 167,750 | 160,730 | 2,147 | 408 | 2,555 | 1.34 | 8 | 1,763 | 1.10 | 10 | 04 | | 3,910 | 2.43 | 128 | | | | |
| 22 | Otdar Meanchey | 136,358 | 26,752 | 25,210 | | | | 0.00 | 1 | 511 *2 | 2.03 | | | | 511 | 2.03 | | | | | |
| 23 | Krong Pailin | 45,723 | 10,450 | 9,406 | | | | 0.00 | 2 | 1,104 | 11.74 | | | | 1,104 | 11.74 | | | | | |
| | | 12,503,401 | 2,471,834 | 2,290,252 | 192,655 | 15,816 | 208,471 | 8.41 | 99 | 48,715 | 2.13 | 47 | 11,782 | 0.51 | 253,152 | 11.05 | 128 | 0 | | | |

Remarks:
*1: EAC's licensees in 2003 (excluding licensees by DIME and others)
*2: Provincial Power Supply Project (ADB & AFD). Old power supply system had been managed operated by DIME or private enterprise and transferred in 2004.
*3: Licensees of DIME and/or Non-licensees (by questionnaire or interview of DIME)
*4: Year of information. 04 means year 2004.
*5: Under the operation by DIME (or private), but completely transferred in 2005 after completion of rehabilitation works under Provincial Power Supply Project.
*6: No licensees and no information by DIME. MIME's summary table by year

Source: JICA Master Plan Study - Progress Report May 2005.

As shown in Table 2-1, EDC's domestic customers reach 192,655 households while licensed suppliers are serving around 48,700 customers. In addition, rural electricity enterprises are supplying electricity to almost 12,000 households. In total, there are around 253,152 households with access to grid or mini-grid electricity. On the other hand, the total number of households in the country was estimated to be around 2.29 million in 2004. This translates to around 11% national electrification level.

### 2.1.2 Rural Electrification Development Targets

With almost 90% of the total households in the country do not have access to modern electricity services, the Government of Cambodia has made rural electrification as one of its key energy sector priorities. Rural electrification played prominently in the national energy and power sector development policies (detailed discussion on rural electrification policies is discussed in Section 3.2). Under the Power Sector Policy, the government sets the following long term targets:

- increase the access rate to reliable and good quality electricity services to 70% of rural households by year 2030, and
- 90% of villages will be electrified by year 2030, a village is considered electrified when most community facilities and more than 50% of households have electricity.

In addition, the government also set the medium term target of 25% of households to have electricity connection by 2010. To achieve this electricity access target, the government plans to undertake various electrification strategy options, such as:

- grid extension;
- cross-border power supplies from neighboring countries;
- rehabilitation of existing isolated grid systems in provincial towns;
- creation of new isolated grid systems;
- renewable rural electrification such as solar, hydro (min, micro), wind, biomass, biogas, etc;
- provision of battery-based and stand alone systems for dispersed remote customers.

The government also recognizes the important role renewable energy technologies can play in increasing electricity access particularly in rural areas. Under the Renewable Energy Action Plan or REAP (REAP is presented in Section 3.2), the government aims to achieve the following:

- 5 percent of new electricity generation, about 6 megawatts, will be supplied by renewable electricity technologies,
- 100,000 households will be supplied electricity from renewable technologies on a competitive basis,
- 10,000 households will be served by solar photovoltaic systems,
- Sustainable market for renewable energy systems.

## 2.2 Rural Electricity Supply Market

### 2.2.1 Electricity Demand

#### 2.2.1.1 Electricity Consumption

As presented earlier, only 253,152 out of almost 2.3 million households are currently being served by Electricité du Cambodge (EDC), licensed suppliers and non-licensed electricity providers. There exists therefore a huge latent demand for modern electricity services in the country.

EDC's number of customers reached 208,471 in 2004, an increase of 12.7% from 2003. Of this, the residential sector accounted 92% followed by the commercial sector with the share of 6.5% (Table 2-2). In terms of the total electricity consumption, the total electricity demand of EDC's customers amounted to 643,290 MWh in 2004. The residential sector registered close to one-half while the commercial sector accounted around one-fourth of the total electricity consumption (**Table 3.1.3**). Almost three-fourths of EDC's customers are in the Phnom Penh region which consumed more than 86% of EDC's electricity generation.

As mentioned earlier, there are 88 entities (excluding EDC) currently operating with consolidated licenses and 7 entities with distribution licenses. In 2003, these entities provided electricity services to 48,715 residential customers which correspond to about one-fourth of EDC's customers. The total electricity sold to these customers reached 61.2 GWh during the same period.

*Table 2-2: Number of Customers, Electricité du Cambodge, 2004*

| No. | Distribution Area | Resident | Industry | Comm | Public | Rehab | Total |
|---|---|---|---|---|---|---|---|
| 1 | Phnom Penh | 137,649 | 701 | 11,444 | 695 | 247 | 150,736 |
| 2 | Sihanoukville | 7,376 | 100 | 659 | 46 | | 8,181 |
| 3 | Siem Reap | 9,883 | | 710 | 108 | | 10,701 |
| 4 | Kampong Cham | 4,906 | 5 | 14 | 156 | | 5,081 |
| 5 | Takeo | 2,147 | 20 | 349 | 39 | | 2,555 |
| 6 | Battambang | 15,073 | | 276 | 139 | | 15,488 |
| 7 | Baveth (Svay Rieng) | 1,991 | 5 | | | | 1,208 |
| 8 | Ponhea Krek | 1,202 | 6 | | | | 1,996 |
| 9 | Menut (Kp Cham) | 1,426 | | 3 | | | 1,429 |
| 10 | Kampong Trach | 1,643 | | | | | 1,643 |
| 11 | Kampot | 4,674 | | | | | 4,674 |
| 12 | Prey Veng | 2,587 | | | | | 2,587 |
| 13 | Banlung (Ratanakiri) | 2,098 | | 48 | 46 | | 2,192 |
| | Total | 192,655 | 837 | 13,503 | 1,229 | 247 | 208,471 |

Source: EDC 2005.

*Table 2-3: Electricity Consumption (MWh), Electricité du Cambodge, 2004*

| No. | Distribution Area | Resident | Industry | Comm | Public | Rehab | Total |
|---|---|---|---|---|---|---|---|
| 1 | Phnom Penh | 252,710 | 83,300 | 138,460 | 71,950 | 12,350 | 557,770 |
| 2 | Sihanoukville | 11,087 | 1,736 | 6,133 | 1,114 | | 20,070 |
| 3 | Siem Reap | 15,350 | | 11,275 | 1,393 | | 28,019 |
| 4 | Kampong Cham | 4,994 | 44 | | 1,166 | | 6,205 |
| 5 | Takeo | 1,123 | 32 | 555 | 339 | | 2,049 |
| 6 | Battambang | 8,896 | | 3,050 | 1,036 | | 12,982 |
| 7 | Baveth (Svay Rieng) | 953 | 9 | 3,741 | | | 4,704 |
| 8 | Ponhea Krek | 713 | 2,966 | | | | 3,679 |
| 9 | Menut (Kp Cham) | 1,024 | 2,534 | | | | 3,558 |
| 10 | Kampong Trach | 626 | | | | | 625 |
| 11 | Kampot | 1,984 | | | | | 1,984 |
| 12 | Prey Veng | 412 | | | 254 | | 666 |
| 13 | Banlung (Ratanakiri) | 604 | 8,021 | 158 | 187 | | 957 |
| | Total | 300,478 | 89,629 | 163,373 | 77,438 | 12,350 | 643,290 |

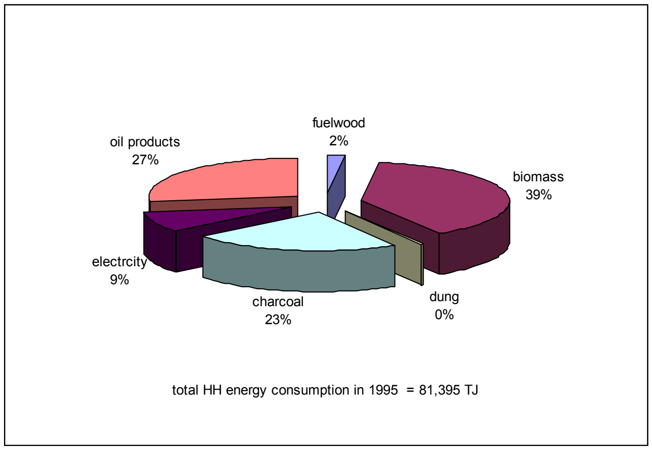
Source: EDC 2005.

#### 2.2.1.2 Profile of Electricity Demand

Energy end-use in the residential sector in general is for cooking, lighting, electrical appliances and air conditioning. In Cambodia, cooking and lighting represents the main energy end-uses, and electricity accounts only a small percentage in the overall household energy demand. Data from the 1998 population census show that almost 95% of households in the rural areas use firewood for cooking. In urban areas, 65% use firewood and 23% utilize charcoal. The remaining number of households are using kerosene, LPG and other sources. The Ministry of Industry, Mines and Energy (MIME) estimated the total household energy consumption in 1995 to be 81,395 Terajoules and electricity represents only 9% of the energy consumption (Figure 2-1).

EDC's residential customers consume an average of 1,560 kWh per year (around 4.3 kWh/day) (Table 2-4). Customers in Phnom Penh region have the highest average of 1,836 kWh per year (around 5 kWh/day) while those in Prey Veng register the lowest consumption rate of 159 kWh per year (below 0.5 kWh/day). This indicates contrasting lifestyles between rural and urban areas. Electricity demand in urban households is high due to variety of end uses such as lighting, electric fans, refrigeration and other household appliances.

*Figure 2-1: Household Energy Use (1999)*




Source: Energy Master Plan Study 2002.

*Table 2-4:Unit Annual Electricity Consumption (kWh per customer), Electricité du Cambodge, 2004*

| No. | Distribution Area | Resident | Industry | Comm | Public | Rehab | Total |
|---|---|---|---|---|---|---|---|
| 1 | Phnom Penh | 1,836 | 117,404 | 12,099 | 103,525 | 50,000 | 3,700 |
| 2 | Sihanoukville | 1,503 | 17,358 | 9,307 | 24,217 | | 2,453 |
| 3 | Siem Reap | 1,553 | | 15,880 | 12,898 | | 2,618 |
| 4 | Kampong Cham | 1,018 | 8,822 | | 7,477 | | 1,221 |
| 5 | Takeo | 523 | 1,587 | 1,590 | 8,700 | | 802 |
| 6 | Battambang | 590 | | 11,051 | 7,455 | | 838 |
| 7 | Baveth (Svay Rieng) | 668 | | 1,247,106 | | | 3,292 |
| 8 | Ponhea Krek | 593 | 494,351 | | | | 3,046 |
| 9 | Menut (Kp Cham) | 514 | 506,804 | | | | 1,783 |
| 10 | Kampong Trach | 381 | | | | | 381 |
| 11 | Kampot | 425 | | | | | 425 |
| 12 | Prey Veng | 159 | | | | | 258 |
| 13 | Banlung (Ratanakiri) | 288 | | 3,298 | 4,057 | | 437 |
| | Total | 1,560 | 107,084 | 12,099 | 63,010 | | 3,086 |

Source: EDC 2005.

### 2.2.1.3 Electricity Demand Projections

Electricity demand in the Energy Master Plan Study is projected based on the increase of number of households and penetration of various household electrical equipments and changes in electricity demand patterns. The baseline average electricity consumption and demand patterns are summarized in Table 2-5. The total number of households is projected to increase to almost 3 million in 2010 and to 3.26 million in 2015 (Table 2-6). Most of these increases are coming from the rural households in the provinces.

*Table 2-5: Baseline Household Electricity Consumption Assumptions*

| |
|---|
| **Grid power use** |
| Average electrical consumption per household: Phnom Penh: urban – 3.98 kWh/day; rural – 1.19 kWh/day; Provinces: urban and rural – 1.19 kWh/day |
| **Battery use (pattern 1)** |
| Energy usage of 156.8 Wh/day, equivalent to using black and white TV (30 W) and lighting (20 W) for three hours daily |
| **Battery use (pattern 2)** |
| Energy usage of 300 Wh/day, equivalent to using color TV (50 W) and 2 lightings (20 W) and fan (10 W) for three hours daily. |

Source: Energy Master Plan Study 2002.

*Table 2-6: Household Projections (thousands)*

| | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|
| **Phnom Penh** | | | | |
| Urban | 108 | 135 | 165 | 200 |
| Rural | 86 | 107 | 131 | 159 |
| **Provinces** | | | | |
| urban | 242 | 309 | 395 | 500 |
| rural | 1,895 | 2,084 | 2,253 | 2,398 |
| **TOTAL** | **2331** | **2635** | **2944** | **3257** |

Source: Energy Master Plan Study 2002.

*Table 2-7: Residential Sector Electricity Demand Projections (GWh)*

| | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|
| **Phnom Penh** | | | | |
| urban | 156.94 | 263.04 | 417.04 | 623.12 |
| rural | 27.93 | 53.85 | 98.66 | 147.41 |
| **Provinces** | | | | |
| urban | 45.12 | 84.12 | 150.55 | 255.51 |
| rural | 113.20 | 187.43 | 283.49 | 401.96 |
| **Cambodia** | | | | |
| urban | 202.06 | 347.15 | 567.60 | 878.63 |
| rural | 141.13 | 241.28 | 382.15 | 549.36 |
| **Total** | **343.19** | **588.43** | **949.74** | **1,427.99** |

Source: Energy Master Plan Study 2002.

Residential electricity demand is forecast to grow by around 3 times between 2000 and 2010 and by more than 4 times between 2000 and 2015. Electricity demand is expected to reach 950 GWh in 2010 and to 1,427 GWh in 2015 (Table 2-7). The highest increase are projected from Phnom Penh region and other urban areas in the country.

### 2.2.2 Electricity Supply

As presented earlier, the electricity supply in Cambodia consists of isolated and decentralized systems provided by EDC, licensed electricity suppliers and unlicensed rural electricity enterprises. The generation assets of EDC and licensed generators (IPPs) are shown in Table 2-8. The current electricity power supply is based on diesel oil. At the national level, EDC accounts slightly more than 50% of the installed generating capacity while the IPPs contribute almost 50%. Entities with consolidated licenses own a total of 188 small-scale diesel generating units with capacities ranging from 8 kW and 800 kW (151 of these generating units have capacities below 100 kW). Among the electricity suppliers in the country, EDC has the most extensive supply network. EDC's transmission and distribution network facilities are summarized in Table 2-8.

*Table 2-8: Installed Capacity, 2004*

| | Plant | Owner | Type | Year in service | Unit no. | Unit capacity (MW) | Capacity (MW) |
|---|---|---|---|---|---|---|---|
| Phnom Penh | C2 | EDC | Steam | 1995 | 3 | 6.0 | 18.0 |
| | C3 | EDC | Diesel | 1995 | 6 | 2.8/2.1 | 15.4 |
| | C5 | EDC | Diesel | 1995 | 5 | 5.0/0.8 | 13.0 |
| | C6 | EDC | Diesel | 1995 | 3 | 6.2 | 18.6 |
| | **EDC total** | | | | | | **65.0** |
| | IPP | CUPL | Diesel | 1997 | 7 | 6.89 | 38.6 |
| | IPP | Jupiter | Diesel | 2000 | 17 | 2.0/1.06 | 24.9 |
| | IPP | CETIC | Hydro | 2002 | 2 | 6.0 | 12 |
| | **IPP total** | | | | | | **75.5** |
| Sihanoukville | | EDC | Diesel | | 8 | 1.3/0.4 | 9.2 |
| Kampong Cham | IPP | GTS | Diesel | | 4 | 1.4/0.7 | 3.6 |
| Battambang | | EDC | Diesel | | 4 | 1.0/0.4 | 2.3 |
| | IPP | Jupiter | Diesel | | 4 | 1.0 | 4.0 |
| Takeo | | EDC | Diesel | | 3 | 0.6/0.3 | 1.1 |
| **TOTAL** | | | | | | | **160.7** |

Source: EAC 2004.

*Table 2-9: EDC's Transmission and Distribution Facilities (circuit-kilometers)*

| | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|
| High voltage line | | 22.7 | 22.7 | 128.7 | 128.7 | 128.7 |
| Medium voltage | 319.4 | 411.6 | 423.1 | 476.3 | 558.0 | 460.4 |
| Overhead head line | 141.1 | 189.0 | 186.6 | 225.0 | 289.3 | 188.3 |
| UGC | 178.3 | 222.6 | 236.5 | 251.3 | 268.5 | 272.1 |
| Low voltage line | 409.1 | 465.7 | 670.6 | 708.6 | 831.6 | 842.9 |
| Transformers (number) | 679 | 712 | 705 | 617 | 602 | 585 |

Source: EAC 2004.

In meeting the growing demand for electricity and achieving electricity access goals and targets, the government recognizes the need to have a balanced development of centralized and decentralized electricity supply systems. In the Power Sector Strategy, the government calls for the extension of the grid-based electricity supply to provincial and district towns and for the promotion of private investments on the development of mini-grids based on diesel and/or renewable energy systems in rural and isolated areas. Most of the activities under the Power Sector Development Plan however are focused on national grid development and investments on large-scale power generation.

The National Transmission Plan is given in Table 2-10. The Plan programs the development of the national grid which covers phase by phase grid extension investments and interconnection (power trade and exchange) with Thailand and Vietnam. Figure 2-2 shows the long term structure of the national transmission network.

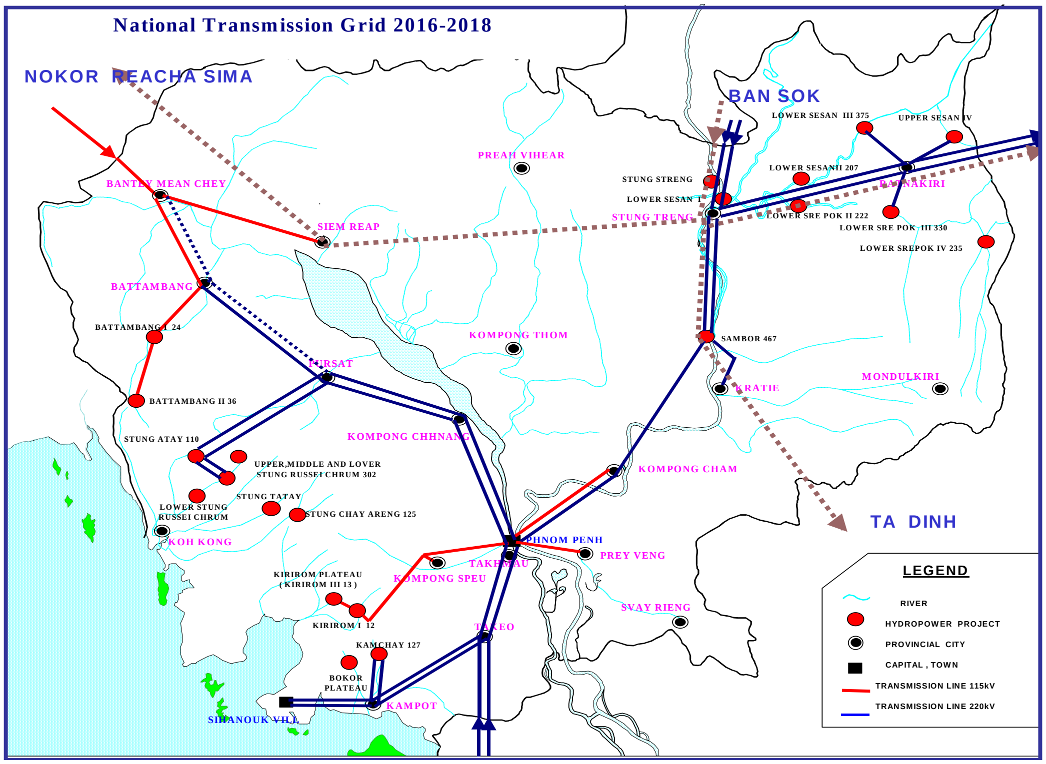
Similarly, the Generation Development Plan supports the development of centralized electric power systems (Table 2-11). Small- to medium-scale diesel generating units are programmed to be commissioned in the short run while mini- and large-scale hydropower units are planned to be phased-in in medium and long terms.

*Table 2-10: National Transmission System Development Plan*

| | |
|---|---|
| Stage 1 | |
| 2007 | 115 kV single line interconnection from Thailand to Banteay Meanchay, Battambang and Siem Reap |
| | 220 kV double circuit interconnection from Vietnam to Phnom Penh substation 220/115/22 kV (WPP) including substation 115/22 kV at East Phnom Penh (EPP) |
| | Establishment of 115/22 kV terminal substation at Phnom Penh (NPP) and stringing a second a 115 kV transmission circuit between GS1 and NPP |
| 2008 | Establishment of Takeo to Kampot 230 kV transmission line including substation 230/22 kV in Kampot, Germany grant aid |
| Stage 2 | |
| 2009 | 120 km single circuit 230 kV transmission line from Phnom Penh (WPP) to Kampong Cham including a substation 115/22 kV at Kampong Cham |
| 2010 | Transmission line 260 km double circuit 230 kV between Phnom Penh (WPP) and Battambang via Kampong Chhnang and Pursat including substations in Kampong Chhnang and Pursat |
| 2011 | Transmission line 230 kV from Sihanoukville to Phnom Penh (WPP) along National road 4 |
| 2012 | 122 km single circuit 115 kV transmission line from Phnom Penh to Svay Rieng via Neak Loeung including terminal substations at Neak Loeung and Svay Rieng |
| 2013 | Transmission line 230 kV From Kampot to Sihanoukville |
| Stage 3 | |
| 2016 | Double circuit 230 kV transmission line linking Stung Atay hydropower plant to Pursat substation, |
| 2018 | Connection of 230 kV line from Kampong Cham substation to Sambor hydropower plant, |
| | Transmission line 230 kV linking Kampong Cham to Siem Reap via Kompong Thom, |
| 2020 | Transmission line 500 kV linking Sambor, Stung Treng, Lower Se San 2 and Lower Srepok 2 and connect to ASEAN grid (power exchange between Cambodia- Viet Nam, Thailand and Laos). |

Source: Cambodia Energy Sector Strategy 2004.

*Figure 2-2: Long-Term National Transmission Grid Structure*




Source: Cambodia Energy Sector Strategy 2004.

*Table 2-11: Power Generation Development Plan*

| | |
|---|---|
| **Stage 1** | |
| 2004 | 10 MW HFO power plant (Siem Reap) (Japanese Grant) |
| | Power supply in 8 provincial towns |
| 2005 | 32 MW HFO (IPP – Khmer Electric) |
| 2006 | 10 MW HFO (Japanese grant) |
| 2007 | Power import: 80 MW from Vietnam; 20 MW Thailand |
| **Stage 2** | |
| 2009 | Kirirum III 13 MW hydropower plant (IPP-CETIC) |
| | Power import extension from Vietnam 200 MW |
| 2012 | Battambang 1,2&3 hydropower plants 73 MW |
| 2013 | 300 MW thermal plant in coastal line area |
| **Stage 3** | |
| 2014 | 180 MW Kamchay hydropower plant |
| 2015 | 125 MW Russey Chrum hydropower plant |
| 2016 | 110 MW Stung Atay hydropower plant |
| 2018 | 465 MW Sambor hydropower plant |
| 2020 | 207 MW Lower Se San 2 hydropower |
| | 222 MW Lower Srepok hydropower |
| After 2020 | 980 MW Stung Treng hydropower plant |
| | 260 MW Stung Chay Areng hydropower plant |

Source: Cambodia Energy Sector Strategy 2004.

### 2.2.3 Renewable Energy Supply Options for Rural Electrification

Renewable energy resources that could potentially respond to the energy needs of the rural population include hydropower, biomass, solar and wind energies. This section reviews the technical potential and current utilization of these resources.

#### 2.2.3.1 Hydropower resources

The technical potential of hydropower resources in Cambodia in terms of installed capacity is estimated between 8,600 – 15,000 MW as shown in Table 2-12. Around 50 percent of these resources are located in the Mekong River Basin, 40 percent on tributaries of the Mekong River while the remaining 10 percent from the South-Western coastal areas. This is reflected in Figure 2-3.

*Table 2-12: Hydropower Resources Technical Potential Estimates and Classification*

Technical potential

- 8,600 MW (Asian Development Bank)
- 10,000 MW (Ministry of Industry, Mines and Energy)
- 15,000 MW (JICA Master Plan Study)

Source: Williamson 2004 and JICA Master Plan Progress Report 2005.

The current utilization of hydropower resources is however relatively low. At present there are only 2 operating projects with installed capacity of 13 MW while 4 projects are under development (Table 2-13). Williamson (2004) identified 42 hydropower projects with total installed capacity of 1,825 MW and capable of generating electricity of around 9,000 GWh per year.

*Table 2-13: Hydropower Projects (existing and under implementation)*

Existing Project

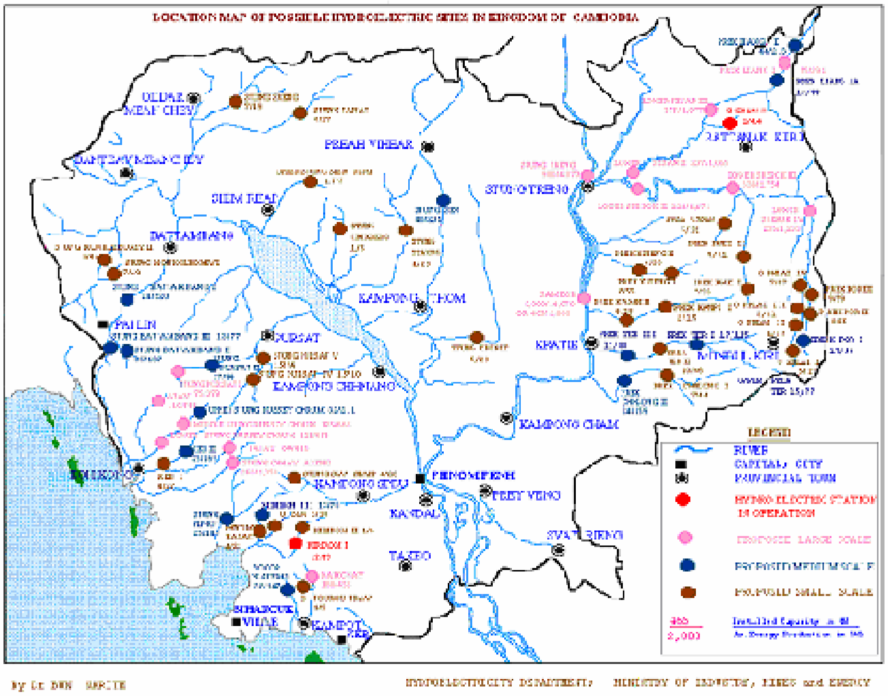
- Kirirom I – Kampong Speu. 12 MW and started operation in 2002
- O Chum 11 – Ratanak Kiri. 1 MW and started operation in 1993

Project under implementation or planning

- Sen Monourom MHP – Mondul Kiri. 200 kW and under basic design by JICA
- Kamchay HEPP – Kampot. 180 MW and an IPP development
- O Katieng Micro Hydro – Ratanak Kiri. 1,076 kW and under development by UNIDO
- Stueng Kronnung River Community MHP – Samlot, Battambang. 4-23 kW under construction.

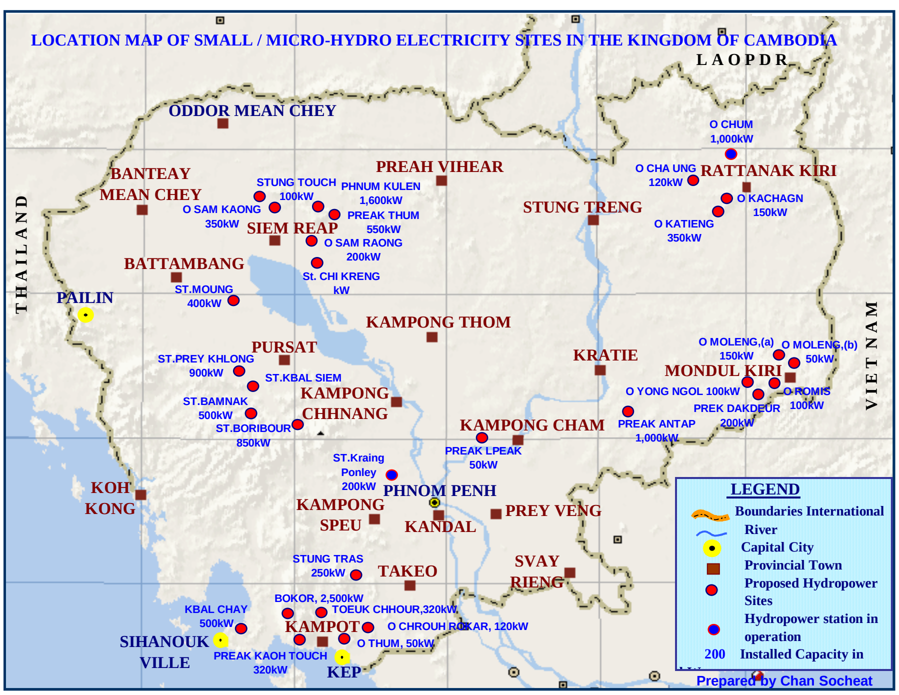
Source: JICA Master Plan Progress Report 2005.

*Figure 2-3: Hydroelectric Sites*




Source: Cambodia Energy Sector Strategy 2004.

*Figure 2-4: Small and Micro Hydropower Sites*




Source: Cambodia Energy Sector Strategy 2004.

#### 2.2.3.2 Biomass Energy Resources

Biomass energy resources in Cambodia include residues from plantation forests (rubber wood), agricultural crops (rice husk), livestock (cattle manure) and municipal waste and sewerage. Williamson (2004) had undertaken a most comprehensive estimate of biomass energy resource potential in Cambodia. Biomass resources are estimated to sustain an annual electricity generation of more than 18,000 GWh (Table 2-14). Other partial estimates of biomass energy resources are also summarized in the same table.

*Table 2-14: Biomass Energy Resource Potential*

| Potential | Source and Description |
|---|---|
| Annual electricity generation: 18,852 GWh | All sources of biomass that are most likely to be available for commercial energy generation (at 34% average conversion efficiency).<br>Williamson 2004. |
| Annual electricity generation: 1,203 GWh | Considers only rice, sugar cane, maize, sugar palm and cattle manure in Provinces of Kampong Cham, Kampot and Battambang<br>NEDO 2002. |
| Annual electricity generation: 327 GWh | Biogas from animal wastes<br>Bhattacharya, Thomas and Salam 1997. |

Source: Williamson 2004.

The exploitation of the country's biomass resources is low. At present only a handful of small-scale projects are implemented. This is summarized in Table 2-15. The table also shows projects that are being considered for development in the near future.

*Table 2-15: Biomass Energy Projects*

| |
|---|
| Existing Projects<br>• 70 kW (2 x 35 kW) biogas power plant in Sihanoukville. NEDO.<br>• Biomass gasifier based charcoal. Private project<br>• FAO funded biodigesters covering 98 households in Takeo Province<br>• Cambodian Rural Development Team 14 biodigesters installed in Kompong Chan and Takeo Provinces<br>• Landfill gas project funded by JICA. |
| Identified projects<br>• Wood fired gasifiers. 10 kW gasifier to power a small grid operated by a village community cooperative; 75-100 kW gasifier to be operated commercially as part of REE's mini-grid; 200 kW rice husk gasifier to be operated by an REE<br>• Rice husk-fired cogeneration. 1.5 MW rice husk cogeneration initially developed by COGEN 3 Programme.<br>• Cashew nut-fired cogeneration. 500 kW cogeneration in a cashew nut factory in National Highway 7.<br>• Cambodia Fuelwood Savings Project (CFSP). Char biomass briquettes to substitute for fuelwood. |

Source: Williamson 2004.

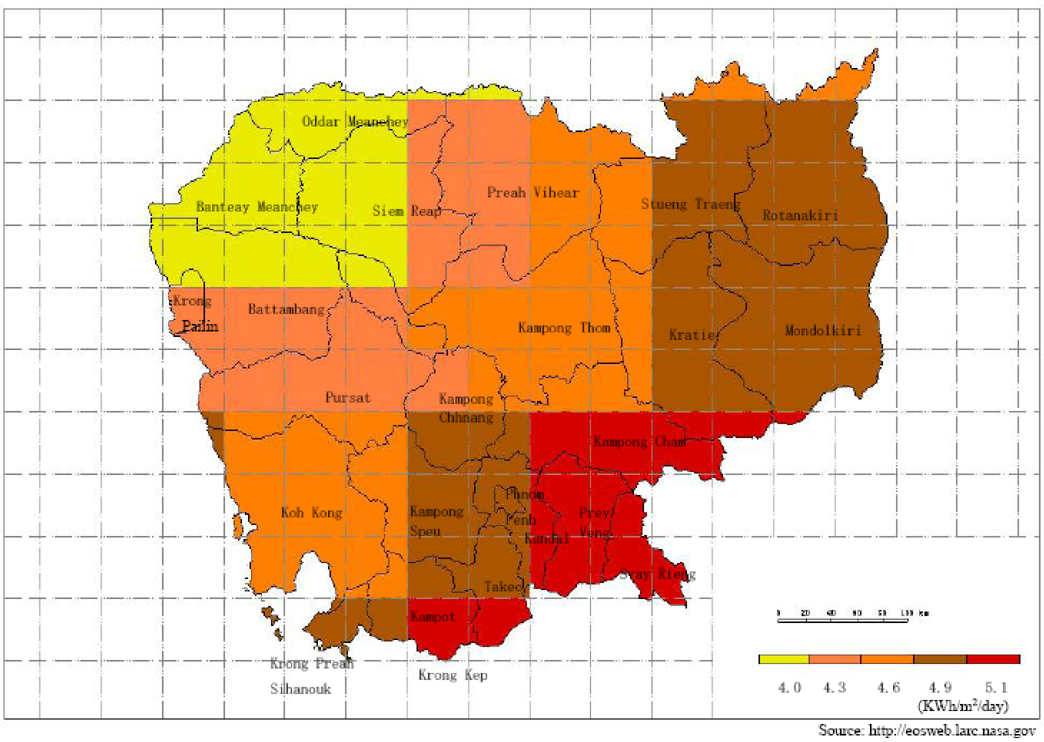
#### 2.2.3.3 Solar Power

Most studies that estimates solar energy potential in Cambodia uses the data generated by NASA´s Global Solar Radiation Model since there is no comprehensive observation on surface solar irradiation in the country. JICA (2005) used the 10 year annual average solar irradiation of 5.0 kWh/m$^2$/day (4.7 kWh/m$^2$/day average in the lowest area and 5.3 kWh/m$^2$/day in highest area). This is shown in Figure 2-5.

Williamson (2004) estimated that the theoretical maximum potential could reach as high as 21 GWh/day which represents 13 times the power generated by EDC in 2002. The calculation assumed 21% of Cambodia´s land area to be suitable for solar PV installation, peak capacity of 4,189 MW and average solar insolation of 5.10 kWh/m$^2$/day.

The current utilization of solar power in the country is low. MIME data shows that the total installed capacity reached 205 kW in 2002. Williamson estimated that at the beginning of 2004 the total installed capacity in the country was more than 300 kW.

*Figure 2-5: Solar Irradiation*




Source: Cambodia Energy Sector Strategy 2004.

#### 2.2.3.4 Wind Power

The most comprehensive source of information on wind energy resources in Cambodia is the Wind Energy Resources Atlas Report in Southeast Asia commissioned by the World Bank which covers Cambodia, Laos, Thailand and Vietnam. The Atlas shows that the theoretical wind energy resource potential in the country amounts to 1380 MW (Table 2-16). The wind atlas report is a good indicator for wind site selection for future development but the potential values must be taken cautiously since the simulation were based on global winds and not supported by ground measurements. Also the development of the wind energy resources is also affected by various factors such as electricity demand, availability of transmission lines, road access, the economic and industrial infrastructure of the country, and a variety of topographical and siting constraints.

In the preparation of the Energy Master Plan study in 2002, NEDO had undertaken a flow analysis of wind speeds taken into account wind measurements available in the country. NEDO's wind map (Figure 2-6) identified 3 promising areas for wind development: i) southern coastal region, ii) Tonle Sap Lake's southern coast, iii) southern mountain regions.

Four small wind turbines were installed in the country: i) NEDO's 6 wind and PV hybrid systems; ii) wind and PV hybrid system in Phnom Chiso and; iii) Mobitel's small turbine to power a communication tower. NEDO's systems and the system installed in Phnom Chiso are currently not operational due to various technical failures (Williamson 2004).

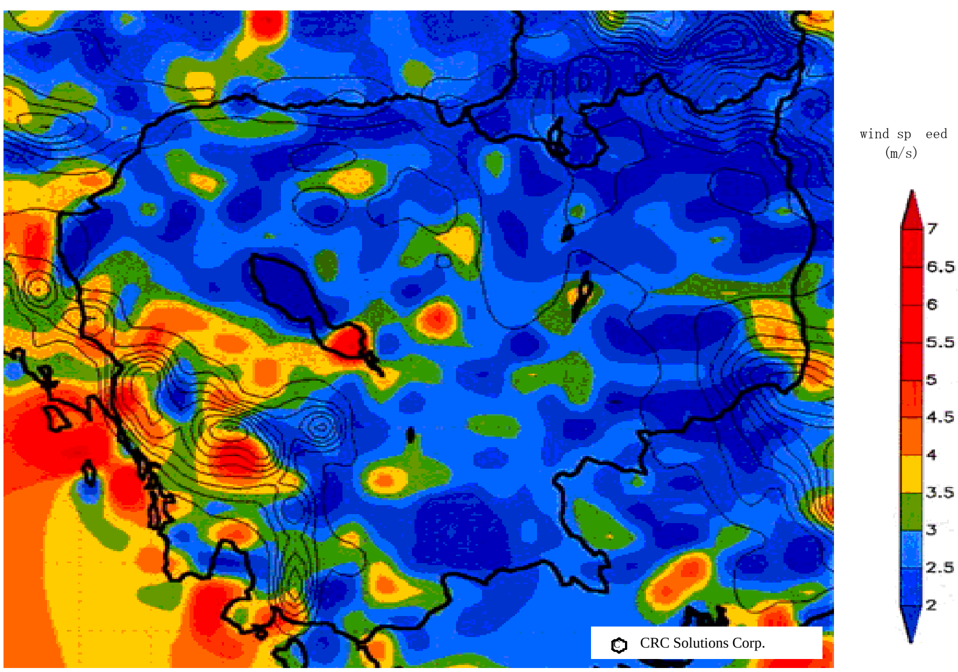
*Table 2-16: Wind Energy Resource Potential of Cambodia (65 m above ground level)*

| Characteristics | Poor < 4 m/s | Fair (4-5 m/s) | Good (5-6 m/s) | Very Good (6-7 m/s) | Excellent (> 7 m/s) |
|---|---|---|---|---|---|
| Land area (sq. km) | 175468 | 6155 | 315 | 30 | 0 |
| % of total land area (%) | 96.4 | 3.4 | 0.2 | 0 | 0 |
| MW Potential | NA | 24620 | 1260 | 120 | 0 |
| *Proportion of Rural Population in Each Small Wind Turbine Resource Class** | 15% | 79% | 5% | 1% | 0% |

* wind speeds are for 30 m height in cleared or open land with no obstructions

Source: TrueWind Solutions LLC 2001.

*Figure 2-6: Wind Energy Resources*

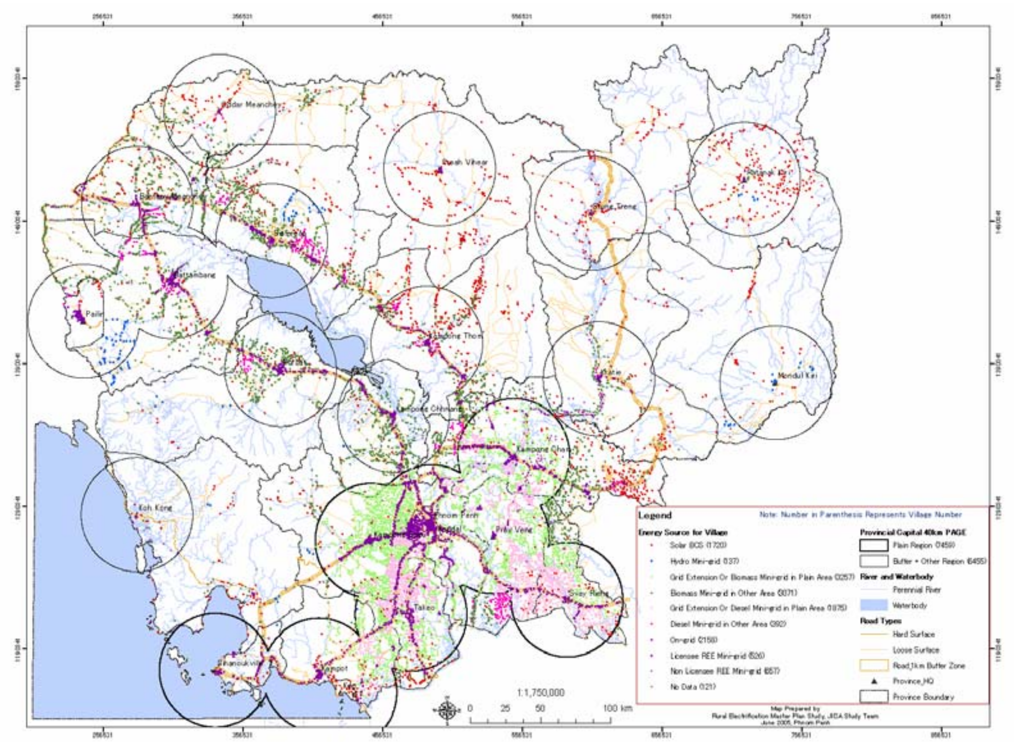



Source: Cambodia Energy Sector Strategy 2004.

#### 2.2.3.5 Rural Electricity Markets for Renewable Energies

Renewable energies can play an important role in meeting the electricity needs of the rural population in Cambodia. Energy options, including renewable energies, in rural areas in the country is shown in Figure 2-7.

*Figure 2-7: Sources of Energy in Rural Areas*




Source: Dr. Sat Samy, 2005.

Task 2 of this study identified 3 clusters of villages that could be potentially served by renewable energies (Figure 2-8), and these are:

- Corn Drying Silo at Malais District, Beantey Meanchey Province
    - Potential for gasifier using waste corn cobs and providing electricity to local village from excess power
    - Cluster of 4 villages with 592 households within 2.5 km radius of the Silo
- REE and Rice Mill at Tma Kohl District, Battambang Province
    - Potential for either gasification or combustion of rice husk for captive power and supply of electricity to un-served villages
    - 12 cluster of villages with 3,944 households within 2.5 km radius of rural electricity enterprise
- Piggery at Kean Svay District, Kandal, Province
    - Potential to capture biogas from waste of 10,000 pigs
    - Cluster of 2 villages with 946 households with no electricity services.

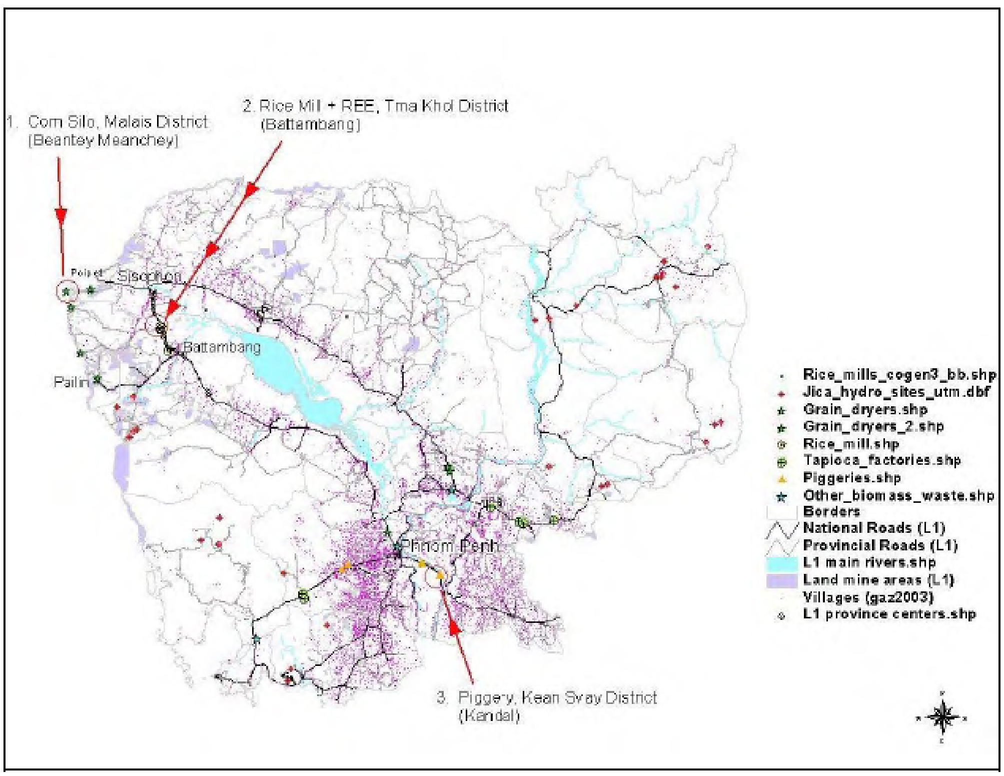
The feasibility studies for these projects will be carried under task 4 of this project. Thus the capacities and the electricity production would only be identified at the later stage of the study. The electricity demand of these clusters of villages however can be estimated using the baseline scenario used in the development of the Energy master Plan Study. This is summarized in Table 2-17.

*Table 2-17: Electricity Demand of Selected Cluster of Villages*

| Project | Total Number of House-holds | Electricity Demand MWh |
|---|---|---|
| Gasifier Project from corn cobs wastes<br>Malais District, Beantey Meanchey | 592 | Low: 34<br>High: 65 |
| Rice husk-fired power plant<br>Tma Kohl District, Battam-bang | 3,994 | Low: 229<br>High: 437 |
| Biogas electricity<br>Kean Svay District, Kandal | 946 | Low: 54<br>High: 104 |

Source: own estimates.

*Figure 2-8: Identified Renewable Energy Development Priority Areas*




Source: REOREC, Task 2 results.

## 2.3 Renewable Energy Technologies

### 2.3.1 Small Hydropower

There is no formal definition of small scale hydro : from country to country, it is below 5, 10 or 30 MW. According to ESHA (2005), mini-hydro typically refers to schemes below 1 MW, micro-hydro below 100 kW and pico-hydro below 5 kW. Small hydropower plants (SHP) are mainly using kinetic energy and pressure freed by falling water, but some plants have been installed based on the principle of river flow energy (hydrauliennes).

Hydropower based on falling water make use of two broad categories of turbines which can cope with different levels of head and flow :

- impulse turbines in which a jet of water impinges on the runner, which is designed to reverse the direction of the jet and thereby extract momentum from the water; of simple conception, their electricity yield is lower than the one of reaction turbines;
- reaction turbines which run full of water and in effect generate hydrodynamic lift forces to propel the runner blades. The conception of these turbines is more complex, but their electricity conversion yield is better. Kaplan turbines are suitable for low head sites, while Francis turbines are suitable for medium head sites but can develop high power outputs with electricity yields above 85 %.

Energy efficiency reached by all types of turbines is in the range of 80-90%. Another interesting technique is the waterwheel floating on the river (hydraulienne). This system does not require falling water nor civil works and hence is less expensive. It is based on the kinetic energy recovery from the river flow. This system is particularly adapted to high speed currents (GWET et al., 1995).

#### 2.3.1.1 Advantages of small hydropower

To outline the advantages of SHP (EREC, 2004):

- it is an efficient resource, and can satisfy energy demand without depleting the resource and with little impact on the environment
- it is a secure resource; small hydropower guarantees the security of supply:
    - SHP has the ability to generate electricity instantly, to supply both base-load and peak-load generation, has a long life, is easy to maintain and is highly reliable
    - hydro is available within the borders of individual countries and not subject to disruption by international political events
- it is a clean resource, and does not involve combustion, therefore avoiding polluting emissions
- it is a renewable resource - the fuel for hydropower is water, which is not modified in the electricity generation process
- it is a sustainable resource, meeting the needs of the present without compromising the ability of the future generations to meet their own needs.

Small hydropower is technically proven and mature. The economic feasibility of small hydropower depends mainly on the location of electricity demand (transmission distances can lead to prohibitive investment costs); low-head sites are much more common and can be found near concentrations of population.

Small hydropower plants can have local environmental and social negative impacts (EREC, 2004):

- water resources, including impacts on other uses of water
- the impact of the reservoir (if applicable)'
- effect on flora and fauna, and especially on aquatic ecosystems
- river water quality
- the impact on the landscape - visual intrusion
- other impacts, such as those from construction activities and noise, and the impact on recreational activities and on public health.

A range of technically and economically viable solutions is available to mitigate such environmental and social impacts.

#### 2.3.1.2 Small Hydropower Costs

Investing in a small hydro plant depends on several parameters : the characteristics of the river site (effective head, flow rate), geological and geographical features (population concentration, ground characteristics, fishes by-pass) , the equipment (turbines, generators, regulation) and civil engineering works, and also whether water flow is constant throughout the year. Making use of existing works (weirs, dams, storage reservoirs and ponds) can significantly reduce both investment costs and environmental impact.

Table 2-18 summarizes the major capital costs of a small hydro power plant and their lifetime.

Nevertheless, these are not the only factors to look at when deciding to invest in and operate an SHP plant. Special attention has to be paid to the cost of using water (water charges and/or concession fees), as well as to the administrative procedure necessary to obtain the water and building licenses. Overhead costs may include : planning and administration costs during construction; taxes; compensations; financing during construction; handling environmental procedures

The cost of a small hydro power plant, with no existing dam or hydro plants, may vary from US$ 2000 to 4000 per kW (BOYLE, 2004; GWET et al, 1995).

*Table 2-18: Capital Costs of Small Hydropower Plant*

| Type | Budget items | Lifetime |
|---|---|---|
| Civil works | dam<br>diversion<br>waterways<br>fishes by-pass<br>flood sluice<br>workshops | 30 to 50 years |
| Hydro-electrical components | turbine and regulation<br>alternator and regulation<br>multiplier | 10 to 30 years |
| Electrical equipment | transformers<br>circuit-breakers<br>lightning<br>cables<br>meters | 10 to 30 years |
| General services | drainage and emptying | 10 to 30 years |
| Dam and water supply equipment | floodgates<br>pipes gates<br>pressure pipes<br>ancillary equipment | 10 to 30 years<br><br>30 to 50 years |

#### 2.3.1.3 Current Industry Status

The European industry has maintained a leading position in the field of hydropower manufacture since the technology started to develop 150 years ago. Very little non European equipment has been installed in European hydropower plants, and one important reason for European dominance has been this strong home market. By developing technology and production methods in a fast-growing home market, European manufacturers have, with a few exceptions, been on the leading edge of the sector, compared to manufacturers from other parts of the world.

A 1998 report (ETSU/IWuP, 1998) estimated that, in 1997, the hydropower manufacturing industry in the EU represented approximately 80 small-scale water turbine manufacturers with a capacity to export equipment. In order to face a competitive market, it is now common practice among the biggest European manufacturers to use subcontractors to a much greater extent, so that they virtually become assembly workshops.

Several hydro manufacturers are active in small hydro in the EU (see *Annexes,* Table 7-1). Four major multinational companies dominate the market for larger turbines, but the market for 0.5-5 MW/site is more open to smaller companies.

The EU has a multi-disciplinary and highly skilled small hydro industry, which offers the full range of products and services required to develop small hydro projects from initial feasibility and design through to manufacturing, financing and operation. Many EU consultants and manufacturers also have a track record in non-EU markets.

### 2.3.2 Wind Energy

#### 2.3.2.1 Wind Energy Technology

Although a number of variations in design continue to be explored, the most common configuration has become the vertical axis, three-bladed wind turbine with its rotor positioned upwind. Technology improvements include more powerful rotors, larger blades, improved power electronics, better composite materials and lighter towers. Some turbines operate at variable speed or avoid a gearbox altogether by direct drive (EREC, 2004).

Wind turbines have a design lifetime of 20-25 years. According to EREC (2004), the largest machines commercially available in 2002 were of 2.5 MW capacity, with 80-metre diameter rotors placed on towers of 70-100 metres height. Each 2.0 MW turbine produces more energy than 200 of the 1980 vintage, and one result of this is that far fewer turbines are required to achieve the same power output.

In the future, even larger turbines will be produced to service the new offshore market. Machines in the range of 3-5 MW are currently under development. In 2002, the German company Enercon erected a land-based prototype of its 4.5 MW turbine, aimed at the offshore market, with a rotor diameter of 112 metres. GE Wind Energy Spain installed its first 3.6 MW offshore prototype turbine at Barrax in Albacete, Castilla La Mancha, in the first half of 2002.

Regarding small scale wind turbines, the development has been limited by the more expensive cost per kilowatt than medium and large scale wind turbines and by the need of batteries which also increase their cost. However, small scale wind turbines can provide electricity for remote communities or farms as well as for cellular telephone masts. Small scale wind turbines are gaining interest again thanks to green electricity certificates systems developed in Europe.

The variability of the wind has produced far fewer problems for electricity grid management than sceptics had anticipated. On windy winter nights, windpower accounts for 100% of power needs in the western part of Denmark, for example, but grid operators are managing it successfully. Modern wind turbines are designed to operate for roughly 120,000 hours over their 20-year lifetime. This is far more than an automobile engine, for example, which will in general only last for some 4000-6000 hours.

#### 2.3.2.2 Costs and Prices

The *Wind Force* 12 feasibility study (EWEA, 2003) estimates current investment costs at approximately € 820/kW, and says that costs have fallen by 20% over the last five years. The breakdown of investment costs is shown in Table 2-19.

*Table 2-19: Wind Power Investment Costs*

| Cost component | Share % (EWEA,1991) | Share % (EWEA,2003) |
|---|---|---|
| Wind turbine | 68 | 82 |
| Site works (foundation, grid connection, road, control systems, electric installation) | 25 | 13 |
| Other capital (land, consultancy, financial costs) | 7 | 5 |

Operation costs represent approx. 2.5 % of the energy production costs.

As wind farms increase in size, economies of scale reduce the cost of some of these elements. The ex-works turbine costs will not decrease, but important costs such as grid connection will become lower, as it is, for example, more cost-effective to connect 10 wind turbines in the same location to the grid via one extension line that it is to use 10 lines. This is particularly relevant when looking at offshore wind farms (EREC, 2004). The cost of wind turbines has decreased from 1050 €/m$^2$ in 1987 to 650 €/m$^2$ in 2001 (total cost per swept area, constant € for 2001) (EWEA, 2003). At the same time, the share of auxiliary costs as a percentage of total costs has also decreased. In 1991, more than 30 % of total investment costs were related to costs other than the turbine itself, while by 2003, this share had declined to less than 20%.

Production costs per kilowatt-hour of wind-generated electricity vary according to a number of parameters, the most important of which is arguably wind speed. Since the energy contained in the wind is a function of the cube of its speed, small differences in average wind speeds can result in large differences in production output, and therefore cost. For a $ 1 000/kW wind turbine, the production cost of one kWh will decrease from $ 0.08 for a 6 m/s mean wind speed at hub height to $ 0.04 for a 9 m/s mean wind speed.

Putting aside for a moment the parameter of wind speed, however, we can say the average cost for producing a kilowatt-hour of electricity at a good site, with a wind speed of around 7 metres/second, for example, has decreased from 7.7 Eurocents/kWh for a 95 kW turbine in 1985 to under 3.4 Eurocents today for a new, 1000 kW machine under optimum conditions (EWEA, 2003). This constitutes a reduction of more than 50% in price; reasons for this include reductions in design and manufacturing costs, improved site selection techniques, and decreased O&M costs. These are usually estimated per kilowatt-hour of output. Danish consultancy BTM Consult gives an average figure of 0.5 Eurocents/kWh during the first years, 0.5-1.1 Eurocents/kWh after five years, and 1.1-2.25 Eurocents/kWh after 10 years in operation. The consultancy also advises the industry to keep O&M costs within the 0.5-1.1 Eurocents/kWh range over the entire lifetime of a turbine.

#### 2.3.2.3 Wind Energy Industry

The top manufacturers of wind turbines and wind farm developers are Vestas, NEG Micon and Bonus (all based in Denmark), Enercon, Nordex and REpower (Germany), Gamesa and MADE (Spain), GE Wind (US) and Mitsubishi (Japan) (see Annexes, Table 7-2).

At present, Europe leads the world wind industry with eight of the top ten turbine manufacturing companies being European. Wind energy is an outstanding European success story, with European companies manufacturing more than 80% of the turbines sold worldwide in 2002. In terms of electricity generation, wind turbines already generate 2% of European electricity; in Germany, this figure is closer to 5%, and in Denmark, to 20%. According to EREC (2004), by the end of 2002, over 31,000 MW had been installed globally, and more than 23,000 MW of this capacity was in the EU-15. Reliable European turbines constituted the backbone of the Californian boom in the 1980s, and European manufacturers have been consolidating and improving their technologies ever since.

#### 2.3.2.4 Environmental Benefits and Impacts

*Carbon dioxide emissions*

Wind technology has an extremely good energy balance. This is to say that the carbon dioxide emissions related to manufacture, installation and servicing over the life-cycle of a wind turbine are 'raid back' after the first three to six months of operation. The benefit to be obtained from carbon dioxide reductions is dependent on which other generation method wind power replaces. Assuming that coal and gas will still account for the majority of electricity generation in 20 years' time - with a continued trend for gas to take over from coal - it makes sense to use a figure of 600 tonnes/GWh as an average value for the carbon dioxide reduction to be obtained from wind generation (EREC, 2004).

*Public acceptance*

There is strong public acceptance for wind power, but concerns remain in some areas, particularly where wind power is reaching relatively high penetration levels. Areas under research include noise, visual impacts including flicker effect, bird impacts and electromagnetic interference. Other studies have shown that factors such as public involvement and proximity to built-up areas may also have a substantial impact on public acceptance.

Noise is no more a problem with modern wind turbines : mechanical noise (from the gearbox or the generator) and aerodynamic noise have been given strong attention from years and have consequently been considerably reduced. Noise regulations, controls and norms are available and are used to test new materials. However, noise remains a sensitive issue and must be given careful attention both at the wind turbine design and the project planning stages, taking into consideration the preoccupation of people who may be affected.

Electromagnetic interference can be caused by some types of wind turbines (metal blades, glass reinforced blades containing metal components, faceted towers) located close to a radio or a television communication service. This is relatively easily dealt with by the installation of relay transmitters or by cable television.

Visual impact of wind turbines is more a subjective question related to psychological and sociological parameters. It is usually linked to the fact that many people dislike changes in the appearance of their landscape. Opinions often change when the new structure becomes more familiar. Another visual impact is the flicker effect when the sun is low on the horizon and houses or buildings are located in the shadow of the wind turbine. This can easily be avoided by careful study of wind turbines implantation by using dedicated softwares.

### 2.3.3 Solar PV

Photovoltaic technology involves direct generation of electricity from light, by use of semiconductor materials (most commonly silicon), which can be adapted to release charged particles, forming the basis of electricity. Each PV cell has two layers of semiconductors, one positively charged and one negatively charged. When light shines on the semiconductor, the electricity field between the two layers causes electricity to flow, generating direct current (DC). The greater the intensity of light, the greater the flow of electricity (EREC, 2004).

#### 2.3.3.1 Solar PV Technology

A photovoltaic system is composed of three main parts: the *cells*, which form the basic building blocks, the *modules*, which bring together large numbers of cells, and the *inverters*, which convert the low-voltage DC electricity generated by PV modules into alternating current (AC), suitable for everyday use.

#### 2.3.3.2 PV Cells

The majority of PV cells are made of *thick crystalline silicon* but future plans centre on *thin-film* technology, which is expected to dominate the market because of its light weight, robustness and visual appearance.

Crystalline silicon: widely available and well understood, their efficiency is typically 13-16%;

Thin films: use thin layers (a few microns) of photosensitive materials on a low-cost substrate (glass, stainless steel or plastic);

Other cells types:

- *concentrators* which focus light onto small area of PV material, thus reducing the quantity of PV cells required, but they cannot make full use of diffuse sunlight and need to be directed towards the sun with a tracking system;
- *organic dye solar cells* still have low efficiencies and poor long-term stability;
- *spheral solar technology*, though not yet fully commercially proven, offers an important cost advantage by reducing the need for silicon by using minute silicon beads bonded to an aluminium foil matrix.

#### 2.3.3.3 PV modules

Modules contain a number of PV cells joined together and sealed under a sheet of glass. Adapted to the size of the site and installed quickly, they are robust, reliable and weatherproof (20-25 years guaranteed).

#### 2.3.3.4 Types of PV Systems

*Grid-connected systems*

They are the most popular type of solar PV systems in developed countries. Grid-connected systems allow excess power to be sold to the utility and electricity importation from the network outside daylight hours.

Inverters convert DC power generated by PV arrays into AC power and protect the PV system against instability into the grid connection as well.

*Off-grid (stand alone) systems*

Most of them contain a battery in order to store the energy for future use. A charge controller protects the battery from overcharge or discharge. An inverter is required to convert DC into AC and protection and wiring are also needed.

*Hybrid systems*

A solar system can be combined with another source of power – a biomass generator, a wind turbine or a diesel generator – to ensure a consistent supply of electricity. A hybrid system can be either grid-connected or stand-alone.

#### 2.3.3.5 Expected Technological Developments

Small- to medium-sized PV systems: for house-based systems, future developments are expected to focus on functional design at reasonable cost by aiming on prefabricated elements, PV kits and better integration into the building process. For commercial or industrial buildings, PV modules are not only electricity generators but also architectural elements of the facade or roof. In these cases future developments are expected to focus on cost reduction through better integration into the building process.

Larger PV power stations (> few hundred $kW_p$): in order to produce clean, reliable PV power at competitive costs, future developments are expected to focus on applications where PV modules perform a second function with an added value, therefore reducing the effective costs of the electricity (sound barriers, shading, …). Other technical issues are envisaged as well, such as the optimisation of inverters and grid connections.

Stand-alone PV systems: used in developing countries or in isolated sites, the main focuses are: lower-cost PV modules and batteries, combined with fully integrated balance-of-system (BoS) components (charge controllers and inverters), and also reliability and low maintenance.

Recent interest has been showed in the use of hydrogen as a medium for energy storage and distribution. Hydrogen would be produced by the electrolysis of water, using PV, stored and converted back to electricity using fuel cells. This system could answer to the electricity demand whenever the PV systems becomes insufficient in case of lack of sunlight (Boyle, 2004).

#### 2.3.3.6 Costs

High investment costs are one of the major barriers to the development of PV markets. However, unlike most conventional electricity generators, the operation and maintenance costs are very low.

PV module costs have been falling steadily over the last 20 years and are expected to continue to fall for the next 20 years.

Other factors can also be optimised, such as the project location and size, the grid connection, the number of intermediaries in the supply chain and the applicable market stimulation measures.

In developed countries, the grid-connected market must still depend for the moment on government incentives (low interest rates, investment subsidies and feed-in tariffs) but this situation is expected to change as the PV market becomes increasingly self-sustaining. The development of a learning curve will lead to cost reductions and the overall annual conversion efficiency of the PV arrays should increase substantially. Furthermore the growing volume of production of BoS components and the decreasing installation costs should reduce substantially the BoS costs.

Recent studies (PIU, 2002) suggest that, with increased production volume and continued technological improvements, the price of electricity from PV systems is likely to fall by 2020 to around “only” twice the current price of domestic electricity in European countries.

In developing countries, where PV systems are mainly used for isolated rural electrification, it is shown that stand-alone plants are a good economic solution to answer small domestic needs (light, television, water pumps, …). They can be easily adapted to low density populations but as no scale economies can be expected with off-grid systems, they become uncompetitive for needs greater than a few kWh/day. Strictly from the economic point of view (i.e. without considering the environmental impacts), the use of charged-on-grid batteries (when near) or diesel generating units is more cost-effective for bigger applications or when the population density increases (Benallou and Rodot, 2002).

#### 2.3.3.7 Benefits and Impacts

The advantages of the PV systems are the following:

- They are modular systems, applicable from the smallest plants to several hundred kW plants and allowing the plant to evolve with the increasing needs and the potential new investments.
- Electricity is produced where it is consumed, reducing the transport costs and losses;
- No fuel is necessary, avoiding problems related to their buying and transport;

- There are no moving parts, allowing a high reliability and a long life of the system (except for batteries which have to be changed every 3 to 7 years);
- Maintenance costs are low, compared to conventional systems;
- No noise disturbance is generated by PV systems;
- The environmental impact of PV is lower than that of any other renewable or non-renewable electricity generating system: they emit no gaseous or liquid pollutants and no radioactive substances.

There are also some drawbacks or risks with the use of PV systems:

- The important investment price constitutes the main barrier to the development of PV systems;
- Small amounts of toxic chemicals are used in the manufacture of some PV modules and might be released into the atmosphere in case of a fire or a bad array recycling;
- As with any other electrical equipment, there are some risks of electric shock (especially in larger systems) but no greater that those of other comparable installations;
- PV arrays have some visual impact (especially multimegawatt PV arrays too big to be installed on roof-tops), regarded as attractive or not, according to aesthetic tastes;
- At the end of their useful life, PV arrays will have to be disposed or, preferably, recycled;
- PV manufacturers had recently to face problems with silicon supply, apparently due to the competition for silicon with the microelectronics industry and a lack of advance planning with long-term secured contracts with silicon suppliers;

If it was true that in the early days of PV almost as much energy was used to manufacture PV cells as they generated during their lifetime, the energy balance of current PV systems is now more favourable, thanks to more modern PV production and improved efficiency of modules. A recent study (Alsema and Niewlaar, 2000) found the energy payback time for PV modules to be between 2 to 5 years in European conditions, and that with future improvements this should reduce to 1.5 to 2 years. The use of materials with low embodied energy (such as wood) in PV array support structures can also improve the overall energy payback time of PV systems.

The main EU manufacturers of solar PV technologies are included in Annexes, Table 7-3.

### 2.3.4 Biomass Energy

Van Loo and Koppejan (2002) define biomass as all kinds of materials that were directly or indirectly derived not too long ago from contemporary photosynthesis reactions, such as vegetal matter and its derivatives: wood fuel, wood-derived fuels, fuel crops, agricultural and agro-industrial by-products, and animal by-products.

Large amounts of forestry residues and other biomass residues remain unused so far and could potentially be used as a source of energy (heat and/or power). In addition energy wood (such as miscanthus) and energy crops (sugar beet, rape) can be grown.

Many countries around the world have become involved in research/pilot projects or actual investments in biomass technologies. These projects prove that biomass can be a technically efficient, economically viable, and environmentally sustainable fuel option adapted to each situation.

Beside the common advantages offered by all renewable energies, such as economic and political benefits by the reduction of the dependence on imported fossil fuels, local employment creation (20 times more than with coal or oil), environmental benefits thanks to the reduction of GHG emissions, the use of biomass as a source of energy has several others advantages:

- unlike the other renewable energies such as wind-, hydro- and solar-power, biomass can be stored and therefore used for energy production on demand;
- biomass is a completely renewable resource as long as it is based on a sustainable production;
- biomass offers a great variety of resources, found in all types of ecosystems, in all regions of the world;
- innovative technologies (such as combined heat and power CHP plants) are available for small- or medium-scale systems;
- wood plantation can be used to sequester carbon (carbon sinks) and become a source of energy at the end of their growing lives;
- biomass can be used in co-combustion with coal, reducing GHG emissions of an existing unit and taking profit of financial incentives implemented in the frame of the Kyoto Protocol. Capitalising on the large investments and infrastructure associated to the existing coal plant, only a relatively modest investment is required to include a fraction of biomass in the fuel.

But the use of biomass as a source of energy also implies some constraints and impacts on the environment:

- a good managing of the biomass production, in order to preserve natural resources;
- biomass harvesting, transports and handling costs and effects on the environment need to be put in balance too;
- biomass supply limits the maximum size of biomass fuelled-units (rarely more than 50 MWel);
- biomass not available all year round needs to be stored or replace by another fuel (renewable or not);
- engines, boilers and turbines used to convert biomass need to be adapted/protected (against fouling or corrosion) according to the physico-chemical characteristics of biomass (moisture content, density, thermochemical behaviour, etc.);
- conversion by-products need to be carefully followed: gas emissions (CO, NOx, $SO_2$) due to incomplete combustion, undesired elements in ashes (alkali metals, chlorine).

#### 2.3.4.1 Technologies for Power Production from Biomass

Technologies for power production using biomass have been developed in many European countries, thanks to a long tradition of using coal and biomass waste from forestry, pulp and paper industries, wood industry and agriculture sector for energy generation.

Power production from biomass can be divided into open cycles and closed cycles (van Loo and Koppejan 2002).

In open cycles, liquid or gaseous fuels drive an internal gas turbine or an internal combustion engine. The fuel is burned directly in the engine or in the turbine, which drives a generator.

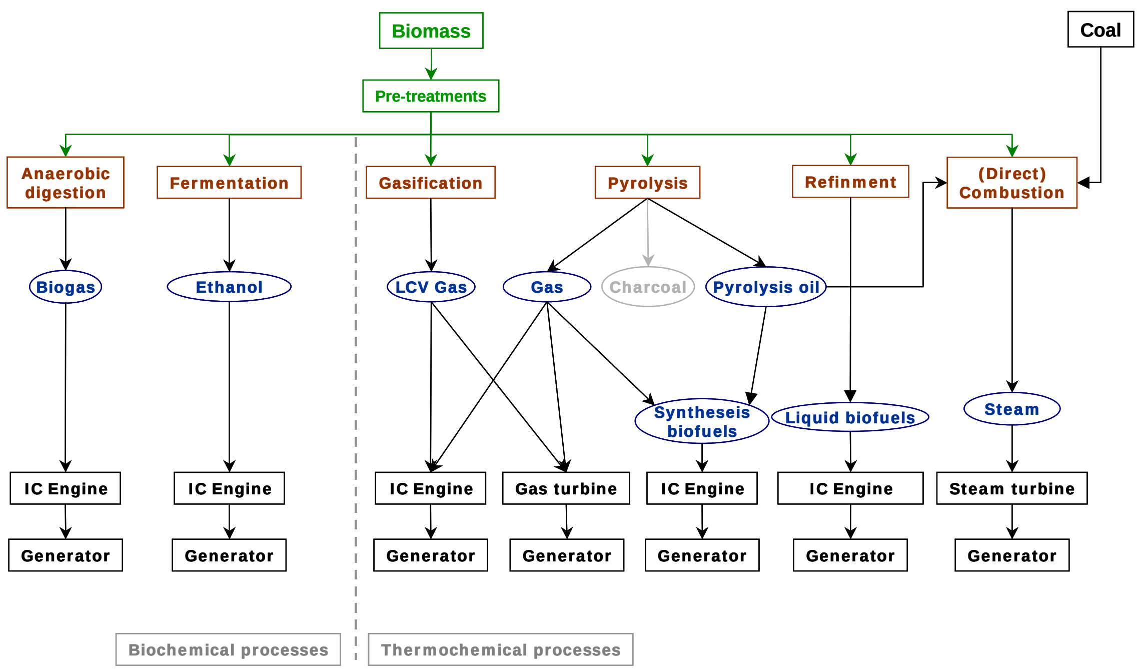
In closed cycles, the combustion of the fuel and the power generation are separated by a heat transfer from the hot combustion gas to a process medium used for power generation in a second cycle. By this separation between fuel and engine, undesired elements in the fuel and the resulting flue gas do not cause damage to the engine.

Following the pre-treatments (such as cleaning, drying, grinding, pressing or refining) the power production technologies can be divided in two types of processes: biochemical processes and thermochemical processes (see Figure 2-9).

Biochemical methods are anaerobic digestion and fermentation. The anaerobic digestion (or biomethanation) of wet biomasses (manure, water sewage sludge, wet wastes from agro-processing industry, etc.) produce a $CH_4$ enriched gas (called biogas) used in a gas engine driving a generator. In the fermentation technology, ethanol is produced from a sugar- or starch-rich crop, which can be used in an Otto engine. A liquid biofuel can also be produced from vegetal oils, pure or after esterification (biodiesel).

Thermochemical primary conversion methods include direct combustion, gasification and pyrolysis of biomass.

*Figure 2-9: Overview of the Main Power Production Technologies from Biomass*




(IC Engine = internal combustion engine).

Each type of generator has its own specific application field depending on the required power and the biomass fuel available.

Note that many conversion process alternatives are not fully proven or commercial in nature. In this report, the following power production systems will be shortly described:

- Steam turbine cycles (proven technology);
- Gas turbine cycles and combined cycle;
- Organic Rankine cycles;
- Steam engines (proven technology);
- Internal combustion engines (reciprocating engine cycles);
- Stirling engines.

Some systems may only generate power, but most of them can simultaneously produce energy in different forms. In cogeneration (or Combined Heat and Power generation CHP), two useful forms of energy are produced simultaneously: power and heat (hot water, process steam, etc).

#### 2.3.4.2 Pre-treatments

Fuel handling, pre-treatments and feeding systems are dependent on both the raw fuel type and characteristics (homogeneity, impurities, fibres, …) as well as on the conversion technology chosen.

Table 7-4 of the Annexes lists some EU manufacturers of large-scale-fuel handling equipment.

#### 2.3.4.3 Boiler and combustion systems

These systems generate heat from biomass used afterwards to produce electricity. Different technologies are available:

- In fixed bed combustion technologies, the primary combustion air passes through the fixed bed of fuel, where drying, gasification and charcoal combustion take place. Secondary air is injected, usually in a separate zone, to complete the flue gas combustion. Fixed bed furnaces usually emit fewer dust particles and show a better burnout of the fly ash than other combustion systems. Fixed bed combustion technologies include grate furnaces (suitable for high ash content biomasses) and underfeed stoker (low ash content biomasses) systems.
- In fluidised bed combustion (FBC) a mixing of bed material, ash and fuel particles is moved by the combustion air, which is blown into a bed through the bottom, making the bed behave like a fluid. The common bed materials are silica, sand and dolomite. The temperature has to be kept low (usually between 800-900°C) in order to prevent ash melting in the bed. Due to the good mixing achieved, fluidised bed combustion plants can deal flexibility with various fuel mixtures. They show lower CO and $NO_x$ emissions due to more homogeneous combustion conditions. Bubbling Fluidised Bed (BFB) and Circulating Fluidised Bed (CFB) can be differentiated by the speed of blown air which makes the bed act like a boiling material (BFB) or take off along with the flue gas (CFB).
- In dust combustion technologies, fuel like sawdust and fine shaving are pneumatically injected into the furnace. The transportation air is used as primary air. For dust combustion, fuel quality must be quite constant. A maximum fuel particle size of 10-20 mm has to be maintained and the fuel moisture content should normally not exceed 20% (wet basis). Due to the explosion-like gasification of the fine and small biomass particles, the fuel feeding needs to be controlled very carefully and forms a key technological unit in the overall system.

Main EU manufacturers of boilers and auxiliaries are included in Table 7-6 of the Annexes.

#### 2.3.4.4 Steam turbines

Power generation by use of steam turbines is a highly developed technology used in thermal power plants or in CHP (combined heat and power generation) plants. This system is used in small units below 1 MWe to the largest power plants (more than 500 MWe).

Steam turbine cycles are typically made of 4 elements. Heat generated in a combustion process is used to produce high-pressure steam in a boiler. The steam is expended in a turbine, driving a generator, then cooled and completely condensed in a heat exchanger and re-injected back to the boiler by a feed water pump.

Table 2-20 below summarizes the advantages and disadvantages of steam turbines for use in biomass combustion (van Loo and Koppejan 2002).

Table 7-7 of the Annexes summarizes the EU manufacturers for steam turbine cycle technologies.

*Table 2-20: Advantages and Disadvantages of Steam Turbines*

| Advantages | Disadvantages |
|---|---|
| Proven technology | Efficiency limited in small, decentralised plants due to investment and technology limitations |
| Can use any kind of fuel | |
| Broad power range available | Low efficiency on partial load |
| High efficiencies for large plants | High specific investment for low power ranges |
| Separation between fuel and thermal cycle enabling the use of fuel containing ash and contaminants | Superheater temperature (and therefore efficiency) limited due to corrosion by chlorine-containing fuels (such as straw) |
| Co-firing of fossil fuels and biomass possible to enhance efficiency | High quality steam necessary |
| | Water source close to unit required |

#### 2.3.4.5 Biomass-fired Organic Rankine Cycles

The Organic Rankine Cycle (ORC) technology is considered as an alternative to the steam turbine cycle. In ORC cycles, the working media is not water but a silicone based organic oil, having a lower boiling temperature. ORC turbogenerators allow an efficient electricity generation in small units with low thermal supply temperatures.

Table 7-7 the Annexes includes the EU manufacturers for biomass fired ORC equipments.

#### 2.3.4.6 Steam Engines

Steam engines are an alternative to the steam turbine, combining the thermodynamic benefits of the traditional steam engine with the design features of a modern combustion engine.

Steam engines have several advantages in comparison to steam turbines. They are less sensitive to water droplets in the outlet. They can be operated with low-pressure, saturated steam, which saves investments on the steam boiler up to 30%. They are also less sensitive to contaminants in the steam than turbines and therefore require less sophisticated boiler water management.

Other advantages of the system include reliability and low maintenance costs along with system adaptation to fluctuations in live steam (pressure/temperature/flow) and changing mass flow rates.

There are two types of steam engines: steam piston engines and steam screw engines.

Steam piston engines show a modular design with one to six cylinders, inside which the steam is alternatively expended, pushing a piston. Like in internal combustion engines, the alternative movement of the pistons drive a crankshaft connected to a generator. The efficiency of the engine depends on the steam parameters. For similar steam parameters piston steam engines have an efficiency comparable to the one of turbine, and even slightly better (Nussabaumer Th. et al. [1998], Dietler R. [1994], Biollaz S. [1996] and Spillingwerk [2000] in van Loo and Koppejan [2002]). Furthermore, steam piston engines have a higher part load efficiency than turbines.

Because of the friction of the pistons in the cylinders, a lubricant has to be added to steam prior to the engine. The exhaust steam contains oil droplets, which have to be removed from the condensate before it enters the feed water tank.

Screw steam engines consist of a continuously changing working space between two spiral rotors. The steam enters the working space, the intake is closing because of the continuous rotor movement, and then the steam begins to expand. Screw engines, where extending steam drives a screw, are in the stage of development and prototype (Piatkowski R. [1996] in van Loo and Koppejan [2002]).

Table 7-8 of the Annexes summarizes the EU manufacturers for steam piston engines.

#### 2.3.4.7 Gas Turbines and Combined Cycles

A gas turbine is made of three parts: the compressor, the combustion chamber and the expander (turbine). In the compressor combustion air is sucked and compressed. The compressed air is fed into the combustion chamber where it reacts with fuel – traditionally natural gas – and the pressurised exhaust gas drives the turbine. Gas turbines have a low electrical efficiency, because the exhaust gases leave the turbine with a high temperature (500-550 °C).

The use of gas turbines is worth with combined cycles with steam turbines. In a combined cycle (CC) the heat of the exhaust gas is recovered in a boiler to produce superheated steam for a steam turbine. Both gas and steam turbines drive a generator. Combined cycles are characterised by a higher efficiency and low investment, operation and maintenance costs.

In BIG-GT or BIG-CC units (Biomass Integrated Gasification – gas turbine or – combined cycle), the product gas from medium- and large-scale fluidised bed gasifier can be used in a gas turbine instead of natural gas. With these efficient systems, a maximum amount of power or steam can be generated from a smaller amount of fuel. Many research and development efforts have been undertaken in this field and some prototype and demonstration plants have been implemented. This technology can however not be considered yet as fully commercially proven with biomass fuels.

#### 2.3.4.8 Internal Combustion Engines (ICE)

Internal combustion engines are liquid fuelled engines of two types: *Otto* cycles and *Diesel* cycles engines. *Gas* engines are often modified versions of liquid fuelled engines. Through the crankshaft, the mechanical energy of the pistons is converted into power in a generator.

Solid biomass needs to be converted in a refined and homogeneous gaseous or liquid biofuel used in ICE.

The conversion processes and biofuels are described here after.

*Liquid biofuels*

- *Vegetal oil*, obtained after trituration, filtration and purification of oleaginous crops, is used pure or mixed with diesel in *diesel* engines;
- *Biodiesel*, an ester of vegetal oil or animal fat, is used pure in conventional *diesel* engines;
- *Ethanol*, produced from sugar- or starch-rich biomass in a fermentation process is used mixed by 5 to 20 % with petrol in conventional *Otto* engines and by 80 to 100% in slightly modified engines.
- *Methanol*, produced from $O_2$ gasified biomass, has found use in both *Otto* and *Diesel* engines. A common problem observed with this fuel are the effects caused by its corrosive and poisoning properties.

*Gasification*

For small-scale systems (1-2 $MW_{el}$), the use of the gas product from a fixed bed gasifier in a gas engine could be a competitive alternative to steam turbine cycles. The product gas must be cooled and cleaned to remove tar and particles prior to be used in the engine. The use of relatively dry biomass leads to a better efficiency while the use of well-calibrated pieces of biomass will reduce the tar content of the gas. However, beside yield consideration, one big disadvantage of gasifiers is that they require an important man-power and an advanced know-how for operation and maintenance.

*Pyrolysis*

*Pyrolysis oil* is produced from disintegrated or pulverised biomass that is rapidly heated up to about 400 – 500°C. Volatile components (hydrocarbons), which are extracted in the pyrolysis process, are cooled and condensed into fluid called *pyrolysis oil*, which can partly replace classic diesel. However, this technology has not been commercially proven.

*Anaerobic digestion*

*Anaerobic digestion* produces biogas from the anaerobic digestion (biomethanation) of very humid biomass like domestic waste from livestock (manure) and organic waste from industries (food processing or paper mill) and municipalities. The biogas mainly contains methane, carbon dioxide and sulphur oxide. Biogas can be fed into boilers for heat production or can be used in small-scale *combined heat and power plants (CHP)*, using modified Otto or Diesel engines, that supply large or small urban communities with district heating while also selling electricity to the grid. The use of gas from anaerobic digestion or gasifier needs to adapt the air/gas ratio with the calorific value of the fuel.

Biomethanation units are generally limited to small or medium scale (up to 2-3 $MW_{el}$), depending on the availability of wet biomass.

Table 7-9 of the Annexes gives some EU manufacturers for biomethanation and biogas utilization.

#### 2.3.4.9 Biomass-fuelled Stirling Engines

A Stirling engine is an externally heated system with a closed gas cycle, in which heat is supplied and removed at constant temperature. The Stirling engine is a piston engine with an inert gas (air, helium or hydrogen) as working media, which is sequentially heated and cooled. Stirling engines reach electrical efficiencies of 25 to 30% in the 10 to 30 kWel range.

Beside its theoretical high efficiency, another advantage of this engine is that any kind of high-temperature source can be taken to heat the working medium.

Not yet commercially proven various Stirling engines are currently under development.

#### 2.3.4.10 Externally-fired Gas Turbines

An alternative method to use solid biomass fuels is externally fired gas turbines. In this case the fuel is burnt in a more or less conventional boiler and the heat is transferred to gas turbine process via a high temperature (gas/gas heat) exchanger.

The gas turbine can be an extension of a more advanced process, for example Humid Air Turbine (HAT) or Cheng Combined Cycle. In HAT concept, water is injected into the combustion air and part of the fuel energy is used to evaporate and overheat the injected water. In the Cheng combined cycle, Overheated steam from a heat recovery boiler is injected into the combustion air.

Both concepts make use of high temperature energy for the evaporation and overheating of the injected water.

The concept of externally firing decreases the risk of harmful impurities getting lodged in the turbine, which is common in gasification systems.

This technology is expected to be commercially available by 2010 for small-scale application subjects to the development of high temperature heat exchangers.

#### 2.3.4.11 Synthesis and Costs

The choice of the better arrangement for power generation from biomass is firstly led by the energy needs and the quantity of fuel available. While steam turbines and steam piston engines are available as proven technology, only steam turbine cycles are suitable for utility size power plants (from 0.5 MWe to more than 500 MWe).

In the table below, different combinations of fuel and techniques are shown. The term “++” means a good combination, “+” means an uncertain combination and “0” means an unsuitable combination. Real or estimated market prices or productions costs are also given.

*Table 2-21: Utilisation of Solid Biofuels, Liquefied Biofuels and Biogas*

| | Price EUR/MWh | ST | Diesel | Otto | Stirling | Conv GT | GT/ HAT | Indirectly fired GT |
|---|---|---|---|---|---|---|---|---|
| **SOLID** | | | | | | | | |
| **Forest fuel** | 10-12 | ++ | 0 | 0 | + | 0 | 0 | + |
| **Refined** | 14-18 | | | | | | | |
| Pellets | | ++ | 0 | 0 | ++ | 0 | 0 | ++ |
| Briquettes | | ++ | 0 | 0 | ++ | 0 | 0 | ++ |
| Powder | | ++ | + | 0 | + | + | + | + |
| **Energy forest** | | | | | | | | |
| Willow | 10-15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Energy crops** | | | | | | | | |
| Straw | 9-13 | + | 0 | 0 | 0 | 0 | 0 | 0 |
| Red canary Grass | 12-16 | ++ | 0 | 0 | + | 0 | 0 | + |
| **FLUID** | | | | | | | | |
| **Alcohol** | | | | | | | | |
| Methanol | 45 | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Ethyl Alcohol | 55-75 | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| **Bio oil** | | | | | | | | |
| Rape oil-RME | 40-60 | ++ | ++ | 0 | ++ | + | + | ++ |
| Tall oil | 9-12 | + | + | 0 | + | 0 | 0 | + |
| Pyrolysis oil | 20-25 | + | + | 0 | + | 0 | 0 | + |
| **GAS** | | | | | | | | |
| Biogas | 35-40 | ++ | ++ | ++ | ++ | + | + | ++ |
| Thermal gas | 20-30 | ++ | + | + | + | 0 | 0 | + |

Source: (EC-ASEAN COGEN III, 2003).

*For small-scale power production (0.5 to 3 $MW_{el}$)*,

Internal combustion engines (ICE) are largely used. Liquid or gaseous fuels produced from biomass replace conventional fossil fuels:

| | | |
|---|---|---|
| Anaerobic digestion of wet biomasses | produces biogas | used in Diesel or Otto ICE. |
| Oleaginous crops | produce vegetable oil | used in Diesel ICE. |
| Sugar- or starch-rich crops | produce ethanol | used in Otto ICE. |
| Dry biomass burned in fixed bed gasifiers | produces gas | used in gas ICE (<1 $MW_{el}$). |
| Dry biomass burned in steam turbines | produces steam | used in gas ICE (>1 $MW_{el}$). |
| Dry biomass burned in gasifiers | produces methanol | used in gas ICE (not proven). |

Steam piston engines are another solution: they are proven technology and have a better electrical efficiency than steam turbines.

For electrical capacity between 0.5 and 2 $MW_{el}$, ORC turbines are attractive because they operate at lower temperature and therefore can be combined with a thermal oil boiler instead of a costly steam boiler.

For micro power applications, the biomass fuelled Stirling engine is a promising technology but not fully proven yet.

*For medium-scale power production (3 to 5 $MW_{el}$),*

Steam turbines cycles are proven and mature technologies and have a higher efficiency at this scale.

The heat feeding these turbines is often produced by fixed bed combustion with grate furnaces chosen according to the main fuel to be used:

- water- or air-cooled grate according to the fuel moisture content
- horizontal or staged grate according to the necessary residence time
- spreader stoker for pasty fuels as water sludge or poultry manure

*For larger-scale power production (>10 MWel)*

Steam turbines cycles are still proven efficient at these rates but although they are able to reach powers up to 500 MWel, the supply of biomass (manufacture, transport) limits today the size of biomass-fuelled units to 50 MWel.

BIG-GT (gas turbines) and BIG-CC (combined cycles) are also attractive because of their potential electrical efficiency of about 30% and because they are easy to implement and operate. However these technologies are not commercially proven yet.

When biomass is not abundant, concentrated or available throughout the year (like agricultural residues), a good alternative is co-firing, i.e. the simultaneous combustion of different fuels in the same plant. It is most of the time by substituting part (typically less than 10%) of a main fuel (generally fossil) in a plant for another fuel (generally renewable).

Co-firing allows an efficient energy use of biomass because of the high parameters of the steam and the size of the turbine reached by coal fuelled units. However, the steam production from biomass/ coal co-firing requires adapted technologies due to the structural differences (fibrous biomass) between the two combustibles (milling, mixing, ashes treatment).

#### 2.3.4.12 Environmental Benefits and Impacts

As an essential player in the environment preservation, biomass as bioenergy needs to be carefully used and its effects –beneficial as well negative – taken in consideration.

*Carbon dioxide emissions*

It is well known that $CO_2$ released by biomass combustion does not increase the atmospheric $CO_2$ level because it was once fixed from the atmosphere by this biomass and is therefore part of the current $CO_2$ cycle.

But biomass production and combustion do not constitute the complete carbon life cycle. Other parameters have to be taken account: i.e. the $CO_2$ emitted by fertilizers production and spreading, by biomass harvesting, transport, pre-treatments before combustion, … Furthermore, associated acid rain gases emissions ($SO_2$ & $NO_x$) may be more important with the combustion of some types of biomass, such as poultry litter or municipal wastes, than with fossil fuels.

Taking account of all the carbon life cycle components, it is hopefully clear that all the bioenergy systems have lower $CO_2$ emissions than any of the fossil fuel plants, whether used for heat and/or power generation, or for conversion to liquid fuel (Boyle, 2004).

$NO_x$ is produced by any type of combustion – renewable or fossil – because of the high nitrogen content of air. Bio-energy systems will need to meet the same clean-up requirements as those using fossil fuels.

*Methane emissions*

Methane, which is a powerful greenhouse gas (23 times more than $CO_2$), is produced by anaerobic digestion of biomasses, whether naturally (from ponds, peat bogs) or related to human activities (animal dung, landfill wastes).

The full combustion of methane taking place in bio-energy conversion processes is beneficial to greenhouse effect by replacing each $CH_4$ molecule by a $CO_2$ molecule.

*Other emissions*

Other atmospheric emissions (heavy metals and organic compounds such as dioxins) are released at lower concentration by any biomass combustion (especially with landfill wastes). Special disposals are necessary for their treatment before release.

*Land-use*

One can argue that biomass requires much more land for an equivalent energy production than any of other renewable energy (such as PV solar or wind) but it must be kept in mind that all these bioenergy systems use a different type of land: when wind turbines will be placed on high lands and PV arrays on roof tops, biomass will grow on surplus farm land.

Concerns about biodiversity, agricultural landscapes and fertilizers and pesticides inputs have been showed too. But in fact it is demonstrated that the fertilizer demand for energy crops is only a tenth of that for food crops and that short rotation coppice can be planted with different indigenous tree species, showing a great biodiversity. Furthermore coppice can be used as bio-filter, improving groundwater quality by sewage sludge treatment.

# 3 Renewable Rural Electrification Policy

## 3.1 Opportunities and Barriers to Renewable Energies for Rural Electrification

### 3.1.1 Rural electricity supply issues

The rural electricity supply in Cambodia currently suffers from some serious issues. These are summarized by JICA 2005 as follows:

- Only 11% of rural households are electrified by grids (2004 figures), and about 50% of rural households depend on batteries for lighting.
- Electricity tariffs in rural areas are extremely high, \$0.30 to \$0.91 per kWh, due to the high fuel prices and the prevalence of small scale systems with low load factors and poor fuel efficiency.
- Rural households are inequitably facing higher electricity costs than urban dwellers who are offered subsidized tariffs (up to 12 times less than the cost faced by rural users to charge batteries) despite generally having higher incomes.
- Rural electricity services generally suffer from low reliability and poor power quality.

The Government has ambitious goals for providing "reliable, affordable and clean electricity services to the rural population", and more specifically to provide grid-quality electricity services to 70% of rural households by the year 2020 (MIME 2005).

The huge gap between the current situation in rural Cambodia and the Government's targets presents significant opportunities for the development of renewable energy resources as part of the solution for rural electrification. This section outlines these opportunities, and also the existing barriers to such development.

#### 3.1.1.1 EDC electricity supply issues

EDC currently provides electricity services to 10 provincial towns and 4 district towns using its own equipment or buying from an Independent Power Producer (IPP), or else importing from Vietnam. EAC has granted consolidated licences to EDC for generating and distributing power to an additional 4 provincial towns where infrastructure is currently being upgraded and installed. This is part of the Provincial Power Supply Project implemented by EDC with about 30% of the cost covered by an ADB loan (ADB 2000). EDC plans to assume operations in these towns in early 2006 (EAC 2006).

These 18 power systems are based on relatively small generator sets, and most have minimal reserve capacity or redundancy (JICA 2005). Consequently the power quality and reliability of these systems can be expected to be low, and worsening as load grows. EDC customers in Phnom Penh have experienced the effects of this especially in the hot season of 2005 (February to May) when the installed capacity was not sufficient for the peak loads. During peak times of the day EDC was often forced to implement rolling blackouts across the city as loads were disconnected to relieve the system.

#### 3.1.1.2 REE supply issues

REEs face many of the same issues as EDC with respect to operating small diesel power systems. They also face the additional challenges common to small businesses, including limited access to finance, small economies of scale across the business, limited bargaining power for fuel or equipment and limited access to technical advice and assistance. Some small surveys of REEs have also highlighted the issues of limited technical knowledge about power generation and distribution or business management, the cost of complying with tightening regulatory requirements, the high rate of chronic bad debtors (mainly government customers), and the high rates of unofficial fees extracted by various levels of government.

*Supply of peak load*

The situation of inadequate supply during peak times presents an opportunity for small generators to supplement the base load. The output of small 'peaking plants' should, in theory, be valued at a premium during these peak times due to the high marginal cost to EDC or REES of expanding capacity to cover these periods. This presents an opportunity for small renewable energy systems, provided that the availability of the energy source coincides with the peak demand periods. This may include micro-hydro where there is sufficient flow in the dry season, or else based on an existing storage system, and also biomass systems with sufficient fuel storage capacity. Solar photovoltaic and thermal technologies may be suitable in Cambodia, as the peak loads generally correspond to peak insolation.

The feasibility of using renewable energy technologies for peaking plants is limited by the high initial capital cost relative to their installed power capacity. This means that they should be used in applications with a high capacity factor to reduce the cost of generation. One possible solution to this issue is where a renewable generator is used to supply a non-essential load, such as for a factory, and then during peak times the factory is able (and willing) to connect the generator to the grid and export power to the grid to assist with the peak load.

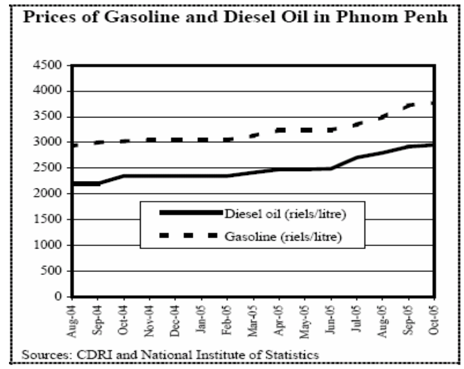
*Small system sizes*

Over 70% of REEs licensed by EAC have installed generating capacities under 100kW (EAC 2004b). At this scale even new and well-designed diesel or HFO systems would suffer from low efficiency and high generating cost (most of these suppliers use old pre-used equipment). However there are a range of renewable energy technologies that are well-suited for systems of this size such as biomass gasifiers, micro-hydro plants and wind turbines. The losses involved in distributing power on a small low voltage network can be minimised if modular technologies, such as photovoltaics or small wind turbines, are distributed throughout the system.

*Imported fossil fuels*

Almost all of the power generated in Cambodia is done so using diesel oil or HFO that is fully imported from either Thailand or Vietnam. Consequently EDC and REEs face the same issues of being completely exposed to price fluctuations on the international market and supply insecurity. EDC are in a better position to mitigate some of these risks due to their greater buying power, longer term supply contracts, leverage from government stakeholders and some small storage capacity.

The chart shown here of diesel and gasoline prices in Phnom Penh indicate the scale of price fluctuations faced recently: around 25% increase for the 12 months up to October 2005 (CDRI 2005). Considering these issues, it follows that renewable energy




technologies may provide a unique opportunity for EDC and REEs to control the issues of future fuel costs and availability. In the case of public resources such as wind or solar the fuel cost will almost certainly remain 'free' for the foreseeable future. Other resources, such as hydro and some biomass, are likely to have some market value but will generally be more predictable because these are based on small local markets rather than the international oil market. Similarly, the security of supply of indigenous resources should be greater than for imported fuel which are prone to disruptions ranging from political disputes with its neighbours (as happened in the Thai riots of 2003) to transport problems (much of the oil transport relies on Mekong river shipping routes). The issue of price and supply security of some biomass supplies is discussed in further below. It is not hard to appreciate the long term benefits, for a business of any size, of reducing the long term price variability and supply insecurity of its single biggest operating cost. These benefits could be significant, even for a modest substitution for conventional fuels. For example, a typical REE with around 1000 customers and 260kVA of generation capacity would consume around 130,000 litres of diesel fuel per year, implying an annual cost of almost $100,000.[1] The rise in diesel price for the 12 months to October 2005, shown in the chart above, would imply an extra $18,000 in fuel costs (based on average price). REEs are theoretically allowed to raise tariffs in the event of fuel price increases, as discussed below, however anecdotal evidence suggests that tariffs are already so high relative to customers' ability to pay that REEs will resist further increases as long as possible in order to avoid losing customers. REEs may also delay necessary tariff increases for fear of the implications on their small rural communities and the adverse reactions it may provoke. EDC faces similar issues on a larger scale, however EDC's political stakeholders are the ones who may feel the risk of adverse customer reactions because it is a public utility.

*Tariff regulations*

EAC regulates tariff rates and in 2004 the Asian Development Bank (ADB) funded a project to establish new regulations, guidelines and procedures for tariff-setting in Cambodia, which came into force in April 2005 (EAC 2005a). The new process aims to improve consistency and sustainability of tariffs, while also providing a framework for progressive tariff reductions over the licence period. However the process also introduces some significant barriers to the use of renewable energy technologies.

The new policy establishes a tariff table listing the maximum allowable tariff for each type of licensee. If a licensee disagrees with the maximum tariff then it may submit a request to EAC for a special tariff review. The process which EAC must follow to review the tariff involves analysing the REE's business costs and determining if they are 'reasonable' in terms of supplying efficient and affordable power services. Unfortunately the proposed review process does not require EAC to consider any issues other than the tariff.

This creates an obvious barrier for any licensee wishing to use a renewable energy technology that has higher initial costs, but offers long term benefits such as a reduced risk of future tariff rises (eg: in the face of rising oil prices) plus broader economic, social and

[1] Assuming electricity annual sales of 264MWh and relatively inefficient, but typical, specific consumption of 0.5L/kWh, and diesel fuel price per litre of 3000 Cambodian Riels converted at 4000R = USD .

environmental. However, ironically, the new procedure makes special allowance for licensees to raise their tariff in the event of rising fuel prices, so as to pass the cost onto consumers. It is interesting to note that the sub-decree does not differentiate between fossil fuels and renewable fuels, so theoretically the operator of a biomass energy system could be covered against rises in biomass supply costs.

*Import taxes*

Cambodia imports most of its renewable energy and energy efficiency equipment. Such imports incur a 35% import duty plus a 10% value added tax which is calculated on the cost of the equipment plus the duty, so the total tax paid is effectively about 48%. The government has been urged to reduce or remove this duty on a number of occasions by various stakeholders including the WB and private equipment suppliers (IFC 2005).

The total volume of such equipment imported into Cambodia is relatively small, and there is no local manufacturing industry to speak of. Therefore it would appear that removing or reducing the tariff would provide net-benefits to the country. The one or two local companies that are locally manufacturing small components such as solar charge controllers could be protected more efficiently by removing the import tariffs and providing some form of direct assistance.

### 3.1.2 Market barriers to renewable energy for rural electrification

Key market barriers to renewable energy investments for rural electrification in Cambodia include the following i) limited information and low levels of awareness, ii) weak coordination between relevant agencies, iii) lack of skilled personnel and training facilities, iv) non commercial viability of RE projects, v) in-adaptive financial institutions; and vi) unfavourable import taxes and tariff system. This is summarized in Table 3-1**.**

*Limited information and low levels of awareness*

The levels of awareness of renewable energy technologies are low among policy makers, private sector firms, and the general public The potential for using renewable energy is not systematically explored due to a lack of knowledge and understanding of such technologies. Without any clear action plan, adequate manpower and budget for the promotion and support of renewable energies, government are unable to provide sufficient technical information to end-users, energy supply companies and policy makers.

*Weak coordination between relevant agencies*

Energy development in Cambodia is not addressed as a cross-sector issue with link to climate change, environment, and human and economic development. The absence of an integrated mainstreaming approach in renewable energy planning and development leads to the implementation of electrification options with adverse social and environmental impacts. There is a need for better inter and intra-agency coordination and cooperation to ensure that renewable energies be adopted in a cross-sectoral manner.

*Lack of skilled personnel and training facilities*

Most government institutions responsible for renewable energy development have been recently established. Local technical capacity and work experience remains limited. There is neither specialised training programme nor training facility for human resources development. Companies commercialising renewable energy technologies in Cambodia employ a limited number of local staff, backstopping support from expatriate technicians. On the job in-house training provides basic practical skills as there is currently no curriculum in renewable energy and energy efficiency available in Cambodia, either at the university level or at the vocational level. The dearth of skilled personnel both in the private and public sectors constitute major obstacles to the successful implementation of bio-energy technologies in Cambodia.

*Commercial viability*

Cambodia has an estimated population of some 13 million inhabitants. Since some 36% of Cambodians live on less than a dollar per day, large sections of the population may not be able to afford consume rural electricity or to connect their homes. Lower costs of renewable energy rely on economies of scale and large sales volume. Because of the small size of the Cambodian market, these may not be achievable. Limited sales volumes combined with low purchasing power also imply low profitability for distributors and manufacturers of renewable energy equipment.

*In-adapted financial institutions*

The implementation of renewable energy technologies requires high initial investment costs. Yet, the Cambodian financial sector remains weak and is able to perform only basic savings and loans operations. The total assets held by commercial banks in Cambodia represent less than 20% of the GDP. Because of this shortage of capital, interest rates on loans may range from 12% to 35% per year for the private sector. High interest rates and unfavourable terms of payment represent major obstacles even for investments with high returns. In addition, it may be near impossible to obtain financing, as Cambodian financial institutions are unfamiliar with renewable energy technologies.

*Unfavourable import taxes and tariff system*

Cambodia has to import most of its renewable energy and energy efficiency equipment from foreign countries. Local distributors sell solar panels and small wind turbines manufactured in the European Union, Japan and the USA. A tariff of 35% is currently levied on renewable energy equipment imported into Cambodia, considerably adding to initial investment costs.

*Table 3-1: Summary of Barriers to Renewable Energy Investments in Cambodia*

Limited information and low levels of awareness
- rural electrification options
- existing renewable energy technologies

Lack of trained personnel
- Limited available technical skills (engineering, law, business development, economics, foreign languages)
- Inadequate training, research and education facilities

Commercial viability
- Small and fragmented markets, limited number of national industries and potential customers

Inadaptive financial institutions
- National financial sector only undertakes basic consumer savings and loans operations
- High interest rates, no grace period, short duration loans
- Stringent collateral requirements for loans
- Loans available only for traditional technologies and activities

Unfavourable Investment Climate
- “weak rule of law, bureaucratic costs and corruption” (World Bank 2004)
- private sector faces high unofficial trade facilitation costs and barriers to establishment and operations

Central planning favours establishment of national grid over decentralised systems
- construction of national grid with support from multilateral lending agencies
- imports of competitively priced electricity from neighbouring countries
- licensing uncertainties for smaller independent power producers

## 3.2 Renewable Rural Electrification Policies and Instruments

### 3.2.1 Rural electrification and renewable energy policies

#### 3.2.1.1 Rural electrification policy objectives

Increasing access to electricity services in rural areas is one of the main priorities of the energy sector development in Cambodia. This is one of the prime objectives in the national energy sector development policy of the country (Table 3-2). The provision of electricity services is moreover pursued by the government as an instrument to meet national developmental objectives such as poverty reduction, standard of living improvement and foster economic development in rural areas. These objectives are also enumerated in Table 3-2.

*Table 3-2: Rural Electrification Policy Objectives*

**Energy Sector Development Policy Objectives**

- to provide an adequate supply of electricity throughout Cambodia at reasonable and affordable price,
- to ensure reliable, secure electricity supply at prices, which facilitate investment in Cambodia and development of the national economy,
- to encourage exploration and environmentally and socially acceptable development of energy resources needed for supply to all sectors of the Cambodian economy,
- to encourage efficient use of energy and to minimize detrimental environmental effects resulting from energy supply and use.

**Rural Electrification Objectives**

- Rural electrification forms an integral part of government's wider rural development and poverty alleviation agenda,
- Rural electrification contributes to rural development through supporting livelihoods, income-generating opportunities and improvement of social welfare, education and health,
- Rural electrification will reduce regional inequalities in access to electricity supply,
- Rural electrification should provide communities with the basic electricity service needed to satisfy the demand for lighting and productive application,
- Within the electrified area, rural electrification should aim to connect as many households as possible to the extent of affordability.

Source: Cambodia Energy Sector Strategy.

#### 3.2.1.2 Proposed renewable energy-based rural electrification policy

As presented in Section 3.1, renewable energies could play an important role in meeting government's electricity access and developmental objectives particularly in rural areas. Recognizing these opportunities and in coherence with the national energy policy, the renewable energy-based rural electrification policy *has been proposed* to the government. The rural renewable electricity policy sets out 6 policy statements with specific objectives and guidelines for the development of infrastructure that provides renewable electricity services in rural areas (Table 3-3). These statements relate to the provision of electricity services in rural areas, encouragement of private sector participation, provision of legal and regulatory frameworks, development of a rational tariff policy, promotion of renewable energies, and establishment of appropriate institutions.

*Table 3-3: Rural Renewable Energy Policy*

**Rural Renewable Energy Policy Statements**

- Provide access to reliable, safe and environmentally clean electricity services to rural areas, at an affordable cost to the national community
- Enable and encourage private sector participation in providing rural renewable electricity services
- Provide effective legal and regulatory framework for enabling access to reliable, safe and clean electricity services to rural areas, at an affordable cost to the national community
- Encourage the most efficient systems for generation, transmission and distribution of electricity from clean and renewable energy sources, to enable a rational electricity tariff policy through promotion of differentiated tariffs based on cost recovery principles
- Promote renewable electricity systems for rural applications, as part of a national portfolio of grid and off-grid technologies, provided they are the least-cost option for the national communities; and
- Ensure adequate resources and appropriate institutional mechanisms to empower the poor, particularly those in rural areas.

Source: Proposed National Policy on Renewable Energy-Based Rural Electrification.

### 3.2.2 Rural renewable electrification strategies

#### 3.2.2.1 Rural electrification strategy

To achieve both long and medium term rural electrification policy objectives and physical targets discussed in *Section 3.1*, the government is pursuing a strategy that combines grid extension, development of isolated grid systems, and installation of individual household systems (Table 3-4). This strategy calls for a balanced development in the provision of electricity services in rural areas using technologies that provide the highest net benefit. The strategy also takes into account renewable energy technologies such as hydro (mini and micro) and solar PV systems as well as cross border supply of electricity in the provision of energy services in rural areas.

*Table 3-4: Rural Electrification Strategy and Program Criteria*

**Rural Electrification Strategy**

- Grid-extension
- Cross-border power supplies from neighboring countries
- Rehabilitation of existing isolated grid systems in provincial towns
- Creation of new isolated grid systems
- Renewable energy options such as solar, hydro (mini, micro), wind, biomass, biogas, others
- Provision of batteries-based and stand-alone systems for dispersed remote customers.

**Rural Electrification Program Criteria**

- The program composition should provide the least-cost, economically viable form of rural electricity.
- The program composition should be matched to the most appropriate technology.
- Areas with the best potential for economic development and higher levels of income are likely to be the most attractive. However, the government should extend the electrification to as many villages as possible in order to achieve its broader development objectives.
- The composition should not be constrained by institutional structures
- The program must be flexible to take into account of changing technology and circumstances.

Source: Cambodia Energy Sector Strategy.

#### 3.2.2.2 Proposed renewable energy-based rural electrification strategy

The *proposed* rural electrification strategy based on renewable energies aims to initiate the process of maximizing the use of indigenous natural resources in providing least-cost option in the power sector and to create equitable access to electricity services and associated opportunities for increased social welfare, education, health and economic improvement through income generating activities. The strategy's specific objectives include expansion of electricity services; promotion of private sector participation; creation of legal and regulatory frameworks; development of appropriate tariff policies; promotion of small scale technologies, and; creation of economic opportunities (Table 3-5).

The *proposed* strategy also calls for the development of decentralized rural electrification alternatives using small hydropower for mini-grids; solar PV systems; village level hydro systems and other systems using indigenous renewable energy resources.

*Table 3-5: Rural Renewable Energy Strategy*

**Rural Renewable Energy Strategy Specific Objectives**

- Widely expand the access for electricity services to the rural population through development of appropriate programs and action plans to promote the RETs;
- Expand the supply base for renewable energy services by motivating and promoting the participation of private entrepreneurs so as to provide efficient and cost-effective services, which will benefit the whole community;
- Facilitate systematic market and institutional development in renewable electricity sector by creating a comprehensive legal and regulatory framework to enable effective participation of government, private and community based entities in providing electricity services to the rural consumers;
- Ensure a wide and equitable access of electricity services to all sections of the rural population by developing appropriate tariff policies and instituting a rational tariff regime;
- Promote environmentally sustainable small power technologies including RETs in on-grid and/or off-grid mode in order to create wide access for rural consumers to affordable electricity services; and
- Contribute to empowerment of the rural poor by creating economic opportunities and uplifting standards of living through electricity services, and through involving them in planning, operation, maintenance and management (OM&M) of programs providing those services.

**Proposed Strategy Elements**

- Development of long-term plan
- Formulation of tariff policy
- Introduction of investment incentives and other subsidies
- Establishment of capacity building program
- Promotion of equitable access
- Harmonize rural renewable energy access with activities in other developmental sectors
- Standardization of procedures for small power producers.

Source: Proposed National Policy on Renewable Energy-Based Rural Electrification.

#### 3.2.2.3 Renewable Energy Action Plan

The Renewable Energy Action Plan (REAP) is one of the key initiatives developed with the support from the World Bank within the framework of the proposed renewable energy-based rural electrification policy and strategy. REAP embodies the government's aspirations to improve the living conditions in the rural areas by improving energy access through renewable energies. The provision of energy services contributes to the fulfillment of social and economic needs of rural population which results in the improvement of the living standards of the rural communities (Table 3-6).

The REAP study recognizes that the private sector could play an important role in the supply and provision of energy services particularly in rural areas and that the government could stimulate private investments through active partnership with the private sector.

REAP's long term objectives are summarized in Table 3-6. This covers renewable energy generation capacity target, target number of households to be supplied by renewable electricity and solar home systems, and the development of sustainable market for renewable electricity. REAP's timeframe to realize these objectives is 10 years which is divided into 3 phases: market preparation phase, early growth and rapid growth.

*Table 3-6: Renewable Energy Action Plan's Mission, Guiding Principles and Objectives*

**Mission**

To improve the living standard of Cambodian people, especially the rural communities, by working together and sharing knowledge and information to formulate effective strategies and a work plan for the development of affordable and reliable electricity from renewable energies.

**Guiding Principles**

- Use renewables where economically least cost.
- The Royal Government of Cambodia, through its ministries, acts as a market enabler.
- Private sector firms invest in and supply the market.
- Poverty reduction is a critical element and is included in all project components.
- Subsidies are used cautiously to avoid market distortions.

**Long Term Objectives**

- 5 percent of new electricity generation, about six megawatts, will be supplied by renewable electricity technologies
- 100,000 households will be supplied electricity from renewable technologies on a competitive basis
- 10,000 households will be served by solar photovoltaic systems
- A sustainable market for renewable electricity systems will develop and be evidenced by households willingly purchasing renewable electricity products and services in a competitive business environment

Source: World Bank 2003.

The REAP document has not been officially accepted by the government of Cambodia but the REAP study results and recommendations were used as reference in the establishment of the Rural and Renewable Energy Fund or REF described in the next section.

### 3.2.3 Policy instruments

The main instrument to support market deployment of renewable energies for rural electrification in Cambodia at present is the grant from the Rural and Renewable Energy Fund (REF) established as one of the components of the Rural Electrification and Transmission Project funded by the World Bank and Asian Development Bank. Renewable energy technologies covered by the subsidy are mini and micro hydropower and solar home systems. The grant could cover up to maximum of 25% of the total project investment costs (Table 3-7). The subsidy grants are financed by funds from the International Development Assistance (IDA) and the Global Environment Facility (GEF).

In addition to the subsidy grant, renewable energy project developers could also avail both the fiscal and non-fiscal incentives offered to foreign investors under the 2003 Amendment of the Investment Law. These incentives are summarized in Table 3-8. Taxes and tax rates applicable to private investments are shown in Table 3-9.

*Table 3-7: Rural and Renewable Energy Fund (REF) Subsidy*

<table>
<tr><td>REF Mechanism</td><td>The REF will call for proposals from private developers to implement rural electrification solutions in particular nominated areas, consisting of either:<br><br>a) new mini-grids based on generation from diesel, solar or hydro-power generation<br>b) extension of an existing small grid systems to connect new households<br>c) solar home systems (SHS), or<br>d) mini or micro hydropower system<br><br>Proposals will be selected according to eligibility criteria. Successful proposals will receive an REF grant which is expected to contribute approximately a quarter of the total project investment costs:<br><br>• REF Grant 25%<br>• Private equity 25%<br>• Bank Loan 50%<br><br>The intended effect of the REF grant is to reduce the capital costs and thus the retail cost of power in rural areas and also, combined with an operating licence from the Electricity Authority of Cambodia EAC, to enable the proponent to successfully obtain the remaining finance from a private finance institution. Technical assistance will be provided to further assist proponents to secure appropriate debt finance.</td></tr>
<tr><td>Subsidy Rates</td><td>
<table>
<tr><th>Project Type</th><th>Total Cost</th><th>REF Grant (max)</th></tr>
<tr><td>New household connected to existing diesel mini-grid</td><td>US$ 150<br>per connection</td><td>US$ 45</td></tr>
<tr><td>Mini-hydro<br>(0.75-5 MW)</td><td>US$ 1,744/kW<br>Installed</td><td>US$ 400/kW<br>Installed</td></tr>
<tr><td>Micro-hydro<br>(average 50 kW)</td><td>US$2,700/kW<br>Installed</td><td>US$ 400/kW<br>Installed</td></tr>
<tr><td>Solar Home System</td><td>US$400<br>Per set of 40 Wp</td><td>US$ 100<br>Per set of 40 Wp</td></tr>
</table>
</td></tr>
<tr><td>REF Finances</td><td>
<table>
<tr><th>Source of Finance</th><th>Technical Assistance</th><th>Project Grants</th></tr>
<tr><td>International Development Association (IDA) – World Bank</td><td>$ 2.59 million</td><td>$ 5.10 million</td></tr>
<tr><td>Global Environment Facility (GEF)</td><td>$ 3.6 million</td><td>$ 1.54 million</td></tr>
<tr><td>Private Sector<br>(personal equity and debt)</td><td></td><td>$ 21.59 million</td></tr>
<tr><td>Total</td><td>$ 6.19 million</td><td>$ 28.23 million</td></tr>
</table>
</td></tr>
</table>

Source: www.recambodia.org

*Table 3-8: Foreign Investment Incentives*

| Fiscal incentives | Non-fiscal incentives |
|---|---|
| Automatic *income tax holiday* of three years, with up to three additional years, beginning on the first year that profit is made or three years from first revenues, whichever comes first.<br><br>Exemption from *import duties* for construction materials, production equipment, and input materials for export-oriented investment projects and for physical infrastructure and energy projects<br><br>Exemption from *export tax* | Guarantee against nationalisation.<br><br>Renewable land leases of up to 99 years on concession land for agricultural purposes.<br><br>Employment of foreign expatriates where no qualified Cambodian nationals are available<br><br>No price controls on products and services produced by investment projects<br><br>No nationalisation adversely affecting the property of investors<br><br>Remittance of foreign currencies abroad |

Source: De Lopez, T. 2005.

*Table 3-9: Taxes Applicable to Private Investments*

| | |
|---|---|
| Profit tax | A profit tax is levied on all businesses. It is calculated either on actual profit or estimated profit. The corporate tax rate is 20 percent for all taxpayers. Taxpayers are required to make a profit tax prepayment on a monthly basis, equivalent to 1 percent of monthly turnover. Taxable profit is defined as the net profit obtained from all results of all types of operations realized by taxpayers. |
| Value-added tax | A standard 10 percent VAT is chargeable on a wide range of goods and services, including imported goods and used goods. On imports, the VAT is payable on the value of the import, including customs, insurance, and freight. Exports of goods and services are exempted. |
| Import Duties | Import duties, as set by the annual customs tariff schedules, range from 7 percent to 35 percent. Humanitarian aid and goods related to international relations are exempted. |
| Patent tax | All businesses must pay an annual patent or “business registration tax” of $300 to tax authorities. |
| Registration tax on land and vehicles | A 4 percent registration tax is payable on the ownership of real property and immovable assets as a result of either direct transfer or contribution to the capital of an enterprise. Taxation is based on the assessed value of the land. A 4 percent registration tax is also payable on the transfer of ownership of motor vehicles and boats. |

Source: De Lopez, T. 2005.

## 3.3 Renewable Energy for Rural Electrification Policy Options for Cambodia

The previous section presents renewable energy policies, strategies and instruments recently implemented in Cambodia. While it is still early to assess the effectiveness of these measures, it is useful to review the experiences of European countries in promoting market deployment of renewable energies. The lessons learned in Europe could provide guidance in moving forward with renewable energy policies in Cambodia.

### 3.3.1 European Renewable Energy Policies and Strategies

#### 3.3.1.1 From monopolized energy markets to liberalized internal EU Market

Since the 1990$^{th}$, the European Union introduced regulations on the liberalisation of electricity markets. Theses Directives set the transition from – 15 at this time, but now 25 monopolised energy markets into a single energy market based on open and competitive functioning rules. Member states are required to gradually open up an important proportion of their national electricity market to competition and therefore to restructure them. The EU considers that the introduction of competition in the electricity sector is a mean to enhance the competitiveness of the European industry and that the creation of a single market will also strengthen the security of supply across the EU by allowing the diversification and flexibility of supplies as a result of the closer integration of internal energy market. Presently, the EU internal energy market is still made of 25 different markets, which are going through a convergent restructuring process.

#### 3.3.1.2 From political declarations to a legislative framework

The development of RE - particularly energy from wind, water, solar power and biomass - is a central aim of the European Commission's energy policy. Early in the nineties, in addition to efforts made for more than thirty years and still ongoing to develop renewable technologies through R&D, Demonstration and Innovation programmes (Joule, Thermie, Altener, Intelligent Energy for Europe, etc.), the EC has deployed substantial efforts to build up a common and stable policy framework in the EU to foster the market penetration of renewable energy sources. In 1996 the European Commission published its Green Paper on renewable sources of energy[2], which identifies the obstacles of RES-E development and asks for a public debate on a EU energy strategy. Following the Green Paper, the European Commission's White Paper *on renewable energy sources* for a Community Strategy[3] sets out a strategy to achieve EU Kyoto commitments including a timetable of actions and instruments to achieve this objective in the form of an Action Plan. The main features of the Action Plan include internal market measures in the regulatory and fiscal spheres; reinforcement of those Community policies which have a bearing on increased penetration by renewable energies; proposals for strengthening co-operation between Member States; and support measures to facilitate investment and enhance dissemination and information in the renewables field. Although it asks Member States to defines objectives and measures to achieve them, the White Paper is a political, and not a legally binding tool.

Faced to the weakness of EU energy supply (increasing demand and dependence) and forced by the environmental pressure (Kyoto commitments) and the new functioning of the EU internal energy market under structuring process, the EC launched a debate in 2001, with its Green Paper on energy supply for an energy reference framework. The Green paper has sketched the bare bones of a long-term energy strategy for Europe for

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[2] Green papers are discussion papers published by the Commission on a specific policy area. Primarily they are documents addressed to interested parties - organisations and individuals - who are invited to participate in a process of consultation and debate. In some cases they provide an impetus for subsequent legislation.

[3] White papers are documents containing proposals for Community action in a specific area. They sometimes follow a green paper published to launch a consultation process at European level. While green papers set out a range of ideas presented for public discussion and debate, white papers contain an official set of proposals in specific policy areas and are used as vehicles for their development.

both demand and production/supply sides. For energy production side, priority has been given to RE.

#### 3.3.1.3 The EU Directive for the promotion of electricity produced from renewable energy sources

Since the Green and White Paper on RE are not legally binding documents but only define political directions to be taken by the Community and the Member States in the field of RE, and because a policy framework, which combines legislative and support measures was necessary to increase and encourage renewable market penetration, the EC issued in 2001 the Directive for the promotion of RES-E.

The Directive requires Member States to take appropriate steps to encourage a greater consumption of electricity produced from RES by setting and achieving annual national indicative targets and by creating a convergent legislative framework for electricity production from RES.

The Directive addresses political, financial, technical and administrative issues facing RES-E development:

- the establishment of national targets for electricity form renewable energy sources
- the financial support schemes for RES-E
- the guarantee of origin of electricity produced from RES
- the access to grid issues
- the administrative procedures for RES-E producers.

*Financial support scheme for RES-E*

In 2001, the Member States already operated different financial mechanisms to support renewable energy at national level. Considering the limited experience and feed-back with these different national support schemes, the EC estimated – even if they judge it constitutes a necessity – that it was too early to decide on a Community-wide framework regarding the support schemes. The Directive then sets a transitional period during which the national systems will go on as they are. In order to maintain investor confidence, the Directive asks the Member States to guarantee the proper functioning of the support mechanisms, until a Community framework is put into operation.

The EC currently makes an analysis on each national system, compiling experience and success gained with the application of the mechanisms. With regards to its conclusion, this report will be accompanied by a proposal for a Common Community framework for renewables support. The proposed framework will (i) be compatible with the principles of the internal electricity market, (ii) take into account the characteristics of the different SER, with geographical difference, (iii) maintain investors' confidence by a transition period of at least seven years, and (iv) promote the use of RES-E in an effective way, particularly in terms of cost.

*Guarantee of origin*

The Directive also asks the Member States to step up a system to guarantee the origin of the electricity produced form renewable energy sources. This "guarantee of origin" must be transparent, non discriminatory and should be mutually recognised by the Member States. The guarantee of origin serves to enable producers of RES-E to demonstrate that the electricity they sell is produced from renewables and hence it increases transparency while facilitating the consumer choices.

*Administrative procedures for RES-E producers*

The Directive also addresses the particular problem of lengthy and difficult administrative procedures that potential RES-E producers must respect in the Member States. It asks them to review their existing legislative and regulatory framework in order to speed up authorisation procedures. This is especially good news for the SMEs. The objectives are:

- to reduce the obstacles to increasing production;
- to rationalise and speed up administrative procedures;
- to ensure objective, transparent and non discriminatory rules;
- to take the characteristics of renewables into account.

*Grid access issues*

Concerning the issue of the high costs of grid connection, the Directive asks the Member States to take the necessary measures to ensure that transmission system operators and distribution system operators guarantee the transmission and distribution of electricity produced form renewable source of energy in their territory. Member States also have to implement a legal framework or ask the transmission or distribution operators to set up and publish their standard rules relating to

- the bearing costs of technical adaptations, such as grid connections and grid reinforcement, which are necessary to integrate new producers feeding electricity produced from renewables into the interconnected grid;
- the sharing costs of system installations, such as grid connections and reinforcements, between all producers benefiting from them.

Where appropriate, Member States have to give priority access to renewable energy sources for grid connections. All over Europe, network operators are obliged to set up transparent cost calculations for the distribution and the fees have to be non discriminatory and the rules must be objective. A further improvement is that the grid capacity is no longer a reason not to give access. If necessary, the grid operators have to reinforce their grid for the connection.

Finally, Member States have to ensure that the charging of transmission and distribution fees do not discriminate against RES-E, including in particular renewable electricity produced in peripheral regions, such as island regions and regions of low population density. Otherwise, Member States must put in place a legal framework or require transmission and distribution system operators to ensure that fees charged for the transmission and distribution of electricity from plants using renewable energy sources reflect realisable cost benefits resulting from the plant's connection to the network. Such cost benefits could arise from the direct use of the low-voltage grid.

#### 3.3.1.4 Guidelines on state aid for environmental protection

At the time of the publication of the White Paper, some Member States have or had already introduced measures and related programmes to support RES. These instruments were made up of non-financial (public awareness, market regulation rules, etc.) and financial instruments. (aids, taxes, deduction and financial support), which can be considered as a state aids. These aids take into account the need to internalise external costs of electricity generation.

To define the conditions under which such state aids are allowed in the context of the liberalization of EU energy markets and the international trade rules, the EC has promulgated in 2001 the Community guidelines on state aid for environment protection (Ref. 10). The Guidelines form a legal framework for Member States' financial incentives for renewables by assessing whether aid administered by Member states for environmental protection is or is not compatible with the rules of the energy common market. The principle of the guidelines is that the beneficial effect of aids for RE on the environment must overweigh the distorting effects on competition within EU energy market. In this document, the EC regards the use of RE as actions to protect the environment.

Investment grant of the eligible costs up to 100 % gross of eligible costs are possible to support of renewable energy. Operating aid may be justified to cover the difference between the cost of producing energy sources and the market price for energy, eligible investment costs are normally the extra costs borne by the firm compared with a conventional power plant with the same capacity in terms of the effective production.

In the field of RE, the guidelines allow state aids, in certain conditions, for investment aid, aid to SME for advisory/consultancy services in the environmental field or operating aids. For the latter, three basic options are defined:

- grant aid to compensate the production cost of RE and the market price;
- grant support by using market mechanisms such as green certificates or tenders;
- grant to new RE plants that are calculated on the basis of external costs avoided.

The market mechanisms allow all RE producers to benefit indirectly from guaranteed demand for their energy, at a price above the market price for conventional power. These forms of aids should result in an overall increase of RES and not in shifts in form one renewable energy technology to another or from one Member State with less favourable renewable energy incentives to another with more favourable state aid for RES in place. Furthermore, state aid based on avoided external costs but not internalised in the pricing system is not allowed to exceed 0.05 €/kWh.

However the community guidelines on State aid for environmental protection do not show the level of transparency needed to create a level playing field for the private sector agents operating in the RE field. As a result of hard-negotiated political compromises, too few choices are given in the guidelines on allowable support mechanisms into the direction of EU-wide breakthrough for renewables.

### 3.3.2 Renewable Energy Policies of EU Member States

#### 3.3.2.1 Policies and instruments in EU Member States

EU Member States instruments for the development of electricity produced from renewable energy sources can be split into several categories:

- R&D and technological innovation programmes;
- demonstration programmes;
- public awareness programmes;
- measures and instruments on simplification of administrative and authorisation procedures;
- measures and instruments related to access to grid and energy market regulation;

- financial (and fiscal) instruments as market deployment policy measures.

In most case, R&D and technological innovation programmes have been the first step of policy for RE in the Members States under national or EC funded programmes related to energy or specifically to renewables (Thermie, Altener, Intelligent Energy for Europe, etc.). Such programmes have been launched since the seventies. At present, R&D and technological innovation programmes are in operation in all Member States. They aim, among others, at reducing investment and operating costs of RE technologies and then at making theses technologies more competitive and more cost-effective with regards to conventional electricity production technologies.

Demonstration programmes typically follow the R&D programme by putting forward their achievements. Demonstration programmes foster investors' confidence because they prove concretely the technical and economic performances of new technologies. Public awareness programmes, as information campaigns, supports market development by creating a multiplier effect of the other policies. They aim at modifying consumer choices and at reducing public and/ or investors' apprehension towards implementation of RES-E plants (especially for wind energy).

As mentioned in the Green Paper on energy supply, the implementation and the operation of RES-E plants are often slowed down because of the complexity and the lengthy of administrative procedures, such as authorisations and permissions: for instance, windfarms or small hydro plants may be subject to authorisations in the field of building, environment and land management strict regulations. As asked by the Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, Member States started in 2001 to modify their administrative procedures in order to facilitate the implementation of RES-E generators, mainly by simplifying and merging the different authorisations required. Member States have also been obliged by the Directive on RES-E to introduce in their national legislation, laws or decrees providing a non-discriminatory access to grid and transmission conditions, these legislative modifications also include technical reinforcement of grid capacity and distribution as well as energy market regulation rules. These measures and instruments have been inserted in the Member States legislation and experienced with more or less success.

#### 3.3.2.2 Market Deployment Policies

Market deployment policies are market-based financial and fiscal instruments, which provide a level playing field for renewables. In general, renewable energy technologies are not cost competitive with fossil fuel technologies in the electricity market. Although technological advances have generated enormous progress in recent year, present renewable energy technologies other than large-scale hydro, can only be deployed commercially if support measures as financial incentives are used. Market intervention for this purpose is justified considering that market prices for electricity generated from fossil fuels do not reflect the full economic costs of generation. In particular, they exclude the negative externalities of environmental degradation, which is not associated with the generation of electricity from renewable fuel sources and the positive environmental benefits of renewable energy.

Since the eighties, R&D and demonstration programmes on renewable technologies have been followed in EU countries by the launch of market deployment measures like tax measures and investment incentives. In the late 1990's, Member States started to experiment tradable certificates systems. At present, series of financial instruments and mechanisms to support RES-E have been implemented throughout the EU:

- investment subsidies;
- fiscal mechanisms;
- incentives tariffs;
- quota obligation and green certificates;
- tendering systems.

Most of these instruments also have a market regulation role by controlling the penetration rates of renewable technologies in the electricity market (quota) and/or by putting forward a technology to develop (preferential systems).

**Investment subsidies** aim at encouraging and favouring investment for the implementation of RES-E generators by the way of investment incentives to reduce capital costs and thus to overcome the barriers of a high initial investment. Investment subsidy is commonly employed to stimulate investments in less cost-effective RE technologies. Capital grants and third party finance arrangements reduce investors' risk and are generally funded out of national budget and thus compete with other public funding needs. Incentives must be of adequate size and must predictable and consistent over time to be effective. Loans accorded with a low interest can also be considered as an investment subsidy. These tools must be in line with the Guidelines for States aid on environment. Investment subsidies are generally around 20-50 % of eligible investment costs. For example, under the Greek National Development Law (2601/1998), investments in RES-E installations are subject to a public subsidy of up to 40% of the total eligible RES-E investment cost plus 40 % subsidy on the interest of loans obtained for the purpose of financing the RES-E investment.

***Fiscal measures*** mainly consist of tax exemptions or tax reductions as low VAT rates for project owners but may also take different forms as production tax credit offered to RES-S at kilowatt-hour rate, which often serves to reduce their tax burden. For customer-owned systems, a tax credit or rebate systems allow the owner to recover a portion of the upfront capital costs more quickly after the investment is made. Provisions are sometimes made for sales tax rebates. These instruments are used in all Member States and may only concern one technology the State wants to develop preferentially (i.e. under a solar PV plan or a wind energy plan), or concern a wide range of RE technologies. All these instruments must be in line with the Guidelines for States aid on environment. Furthermore, fiscal measures can also be used to capture the external costs associated with conventional energy production and consumption, such as environmental degradation, etc. For example, the Belgian fiscal legislation allows a tax exemption of up to 13.5 % of the investment costs for investments in energy production from RES.

***Incentives tariffs at above-market rates (feed-in tariffs)*** are commonly used throughout EU for the promotion of renewable electricity production. Many different adaptations of incentives tariff instruments are applied. They are adapted to Member States objectives and to the renewable energy sources available to be exploited. The two main mechanisms are:

- a minimum guaranteed price per kWh of renewable electricity produced
- a premium paid in addition to market electricity prices to be paid to the producer.

Regulatory measures are usually applied to impose an obligation on electricity utilities to pay the independent producer a price as specified by the government. The tariff may be supplemented with subsidies from the state. The level of the tariff is commonly set for a number of years to give investors security on income for a substantial part of the project lifetime. A feed-in tariff can be based on the avoided cost of the utility that has the purchase obligation, or on the end-price to the consumer. However, the level of the tariff need not have any direct relation with either cost or price, but can be chosen at a level to motivate investors for green power production.

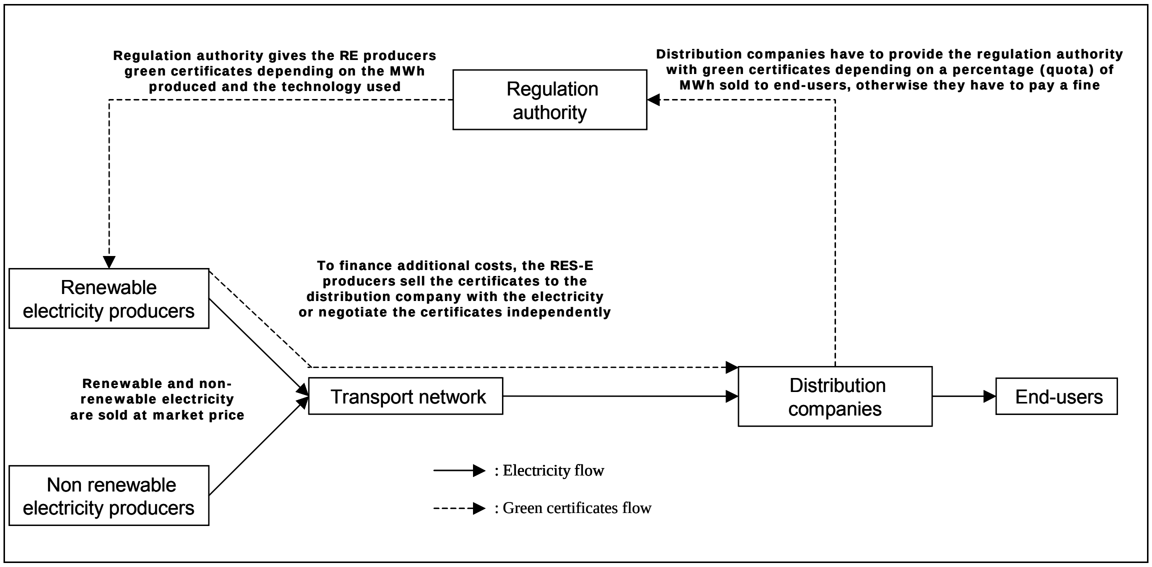
***Fixed price schemes*** are characterised by a specific price established for RES-E that must be paid by electricity companies, usually distributors, to domestic producers of RES-E. In such schemes, in principle, there is no quota, or maximum limit for RES-electricity set in the Member States. This limit or quota is however set indirectly by the level at which the RES-E price is fixed. A variant of the fixed-price scheme is a fixed premium mechanism, according to which the government sets a fixed-premium or an environmental bonus, paid above the normal or spot electricity price, to RES-E generators.

In cases the fixed prices are related to the market of electricity, there will in reality be little difference between the fixed price and the fixed premium schemes. The IEA (Ref. 18) estimates that the level of the fixed price or of the fixed premium may be revised by the government to reflect falling costs.

***Quota obligations and green certificates*.** Quota obligations are used to impose a minimum production or consumption of electricity from renewable energy sources. The government sets the framework within which the market has to produce, sell, or distribute a certain amount of energy from renewable sources. The obligation is imposed on consumption (often through distribution companies) or production. Quota control can be obtained by a tradable green certificates mechanism since it provides an accounting system to register production, authenticates the source of electricity, and checks whether the demand has been met.

Under a **green certificate** system, renewable-certified electricity producers receive a certain amount of green certificates per MWh produced from the regulation authority. The calculation mode of the amount of certificate to be received varies with the technology used and with the various national or regional systems. The RES-E producers sell their electricity at market price to distribution companies or traders, which also purchase non-renewable electricity. In order to finance the additional cost of producing RES electricity, and to ensure that the desired level of RES electricity is produced, an obligation is placed to on all consumers (distribution companies) to purchase a certain amount of green certificates to RES-E producers according to a fixed percentage, or quota, of their national electricity consumption. Otherwise, the consumers have to pay a fine to the regulation authority. The RES-E producers sell their green certificate to the consumers with the green electricity they sell or they can negotiate them to others, independently of the green electricity sold, creating a second market for the green certificates. Since consumers wish to buy these certificates as cheap as possible, a secondary market of certificates develops where RES producers compete with one-another for the sale of the green certificates.

*Figure 3-1: Green Certificates System*




The maximum price of the certificate on the market is set by the price of the fine, while a minimum price system could also be organised by a guarantee of the regulation authority or of the government to purchase certificates to renewable electricity producer to a minimum fixed price. The value of the green certificates on the market then fluctuates between a maximum and minimum price. This system is a combination of green certificate and fixed price mechanisms.

Green certificate mechanisms are consistent with the EC's Directive on RES-E, which requires Member States to establish appropriate mechanisms "to enable producers of electricity from RES to demonstrate the electricity they sell is produced form RES".

In the Walloon Region of Belgium, as a direct aid to production, a minimum price is set at € 65 per green certificate (certificate buy-out price guaranteed by the Government) while the penalty for each missing green certificate not given to the regulation authority is fixed at € 100. The market price of the green certificate currently ranges around € 90. The green certificates are given to the producer according to this production and the technology used. For example, 1 green certificate is given per MWh produced from a 1 MW wind turbine, hydro or photovoltaic plant, while a 0.7 MW wood chips gasification unit would receive around 7,900 certificates per year (depending on the electricity production and the chips origin).

In Sweden, a green certificate system has been introduced in 2003 for wind, solar, geothermal, wave, some biofuels, peat energy and some hydropower systems. With this mechanism, one certificate is given to green electricity producer per MWh, the certificate can be sold in parallel with the electricity produced. In 2005, electricity users are required to purchase an amount of certificates corresponding to 10.4 % of the electricity used, and return them to the Swedish Energy Agency. Parties failing to meet this obligation must pay a penalty charge to the State, calculated as 150 % of the average price of electricity certificates during the previous year. In 2004, the penalty charge was capped at SEK 240.

The UK's Obligation mechanism requires suppliers to source an annually increasing percentage of their sales from renewables. For each megawatt hour of renewable energy generated, a tradable certificate called a Renewables Obligation Certificate (ROC) is issued. Suppliers can meet their obligation by:

- acquiring ROCs ;
- paying a buy-out price of 30 £/MWh ;
- a combination of ROCs and paying a buy-out price.

When a supplier chooses to pay the buy-out price, the money they pay is put into the buy-out fund. At the end of the 12-month obligation period, the buy-out fund is recycled to ROC holders.

**Tendering procedures** are another way to reach quota. Under a tendering procedure, the state places a series of tenders for the supply of the RES-E, which would thereafter be supplied to the local utility on a contract basis at the price, which emerged form the tender. The surplus costs generated by the purchase of RES-E are charged on to the end-consumer of electricity through a specific levy.

**Bidding systems** can be used to select the beneficiary of an investment support or a production support (such as through feed-in tariff), or for other limited rights, such as site for wind energy. Potential investor or producers have to compete through a competitive bidding procedure. The system is based on competition for contract to build project. The bidding is accompanied by an obligation on the part of electricity providers to purchase a certain amount of electricity from RES at a premium price.

The difference between the premium and market price is reimbursed to the electricity provider and is financed by through a non-discriminatory levy on all domestic electricity consumption. The mechanism leads to the lowest cost options because the most cost-effective offers will be selected to receive the subsidy in each bidding round.

In **net metering** arrangements, an individual user installs a small-scale renewable energy generator, to meet some or all of its electricity need and pass the excess electricity to the grid, as a bank, for a later use. By the way of a two-way meter, the customer pays only for the electricity used net of the electricity generated over the entire billing cycle. Net metering has been successfully promoted by Denmark, Greece and Sweden as a means of encouraging small-scale renewable energy power production.

**Green pricing** schemes are based on the principle that some consumers are willing to pay more for renewable electricity, which is more expensive to produce than conventional-fossil technologies. The green pricing strategy is underlain by the same principle that some customers are willing to pay more for organic food. One of the advantages of this scheme is that it can create a market for electricity from renewable sources where none existed but it operates in a manner counter to the polluter pays principle.

The IEA observed that the significant RE market growth has always resulted from combinations of policies rather than from a single policy initiative. Furthermore, in most case, the success of RE market penetration is due to the fact that local, provincial or regional initiatives, independent of the national government, strengthen the effects of national efforts by its own policy support instruments.

The longevity and the predictability of the support policy is important to overall market success by ensuring investors' confidence. In most case, financial incentives as feed-in tariffs have an 8 to 10 years time frame.

While the more the incentive is important, the more the technology deployment on market will be important, the incentives instrument must stimulate the development of the most cost-effective technologies as well as the development of R&D works to reduce the generation between renewable and conventional technologies. Then, the challenge is how to incorporate strong incentives for cost reduction and completion while ensuring longevity and predictability of support policy.

The Member States presently operates different mechanisms to support RES-E, at the national or regional level, form R&D to systems for technology penetration into electricity market. In most case, Member States operate several market deployment mechanisms, typically the combination of investment subsidies, tax incentives and direct price support mechanisms, the latter being in most Member States the main promotion tool. For example, under the German 250 MW Wind Programme, the wind energy producers can receive an investment subsidy of up to 25 % to a maximum of € 46,016. Additionally, the programme provides operation subsidies of up to 3.1 €cents/kWh fed into the public grid.

As a consequence of the publication of the EC Directive on RES-E, the Member States have had to restructure their electricity framework, including their support policy. Most of them have changed from a feed-in tariff to a green certificates system. Generally, the green certificate systems have been implemented around 2000-2001 and their positive effects on the share of RES-E on the electricity production begin to be observed.

# 4 Renewable Rural Electrification Institutional Framework

## 4.1 Electricity Sector Institutional Frameworks

### 4.1.1 Electricity Sector Legal Framework

The basic law governing the power industry in Cambodia is the Electricity Law promulgated by a royal decree in February 2, 2001. The Law establishes the governance structure and framework for electric power supply and services throughout the country. It covers all activities related to the supply, the provision of services and use of electricity and other associated activities of the power sector. The main purpose is to establish various principles in the functioning of the electricity supply industry. These principles are given in Table 4-1.

*Table 4-1: Electricity Law Objectives*

| |
|---|
| The purpose of the Electricity Law is to establish<br>1. the principles for operations in the electric power industry and the activities of licensees in the provision of electric power services;<br>2. favourable conditions for capital investments in, and the commercial operation of, the electric power industry;<br>3. the basis for the regulation of the supply of electric power services to the extent such services are monopolistic;<br>4. the basis for (i) the protection of the rights of consumers to the reliable and adequate supply of electric power services at reasonable cost, (ii) the promotion of private ownership of the means of providing electric power services, and (iii) the establishment of competition wherever feasible within the electric power sector;<br>5. the basis for establishing the rights, obligations and penalties which shall apply to suppliers and consumers of electricity and also the public and land owners in relation to electricity facilities and supply; and<br>6. the Electricity Authority of Cambodia for regulating the provision of electric power services. |

Source: Electricity Law of the Kingdom of Cambodia.

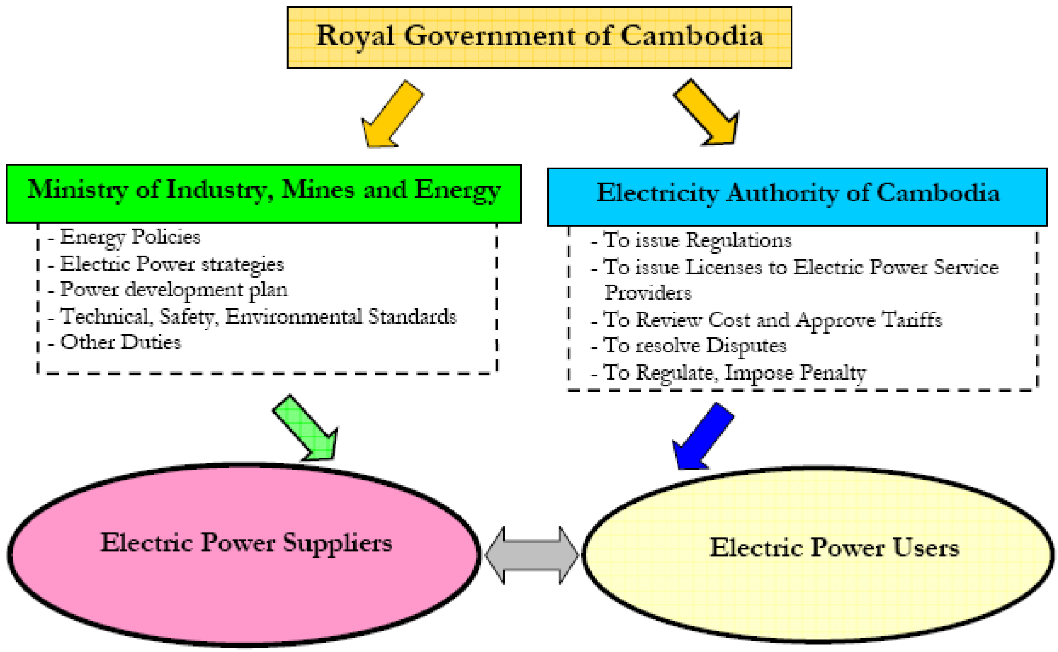
There are two main important components of the Electricity law and these are:

i. the establishment of an independent regulatory body, the Electricity Authority of Cambodia (EAC), and definition of its functions, and

ii. the promotion of private sector participation in generation and distribution segment of the industry.

In the establishment of EAC, the Law clearly distinguishes the policy making and regulatory functions in the governance of the electric supply industry. The Law assigns the Ministry of Industry, Mines and Energy (MIME) to be responsible for the policy making roles e.g. drafting of energy policies, power strategies and development plans, technical safety, environmental standards, etc and EAC to be responsible for economic regulation e.g. power and duties to issue licenses, approve tariff rate and charges, issue regulations, procedures, rules, orders, and decisions, and the right to resolve complaints and disputes related to the provision of electricity services (Figure 4-1).

*Figure 4-1: Policy and Regulatory Making Bodies of the Electricity Supply Industry*




Source: Electricity Authority of Cambodia, 2004.

### 4.1.2 Electricity Supply Industry Structure and Governance

As mentioned in Section 3.1, the electricity supply system in Cambodia consists of 24 fragmented systems centered in major cities and provincial towns. EDC is the largest integrated company in generation, transmission and distribution. EDC is a public utility jointly owned by the Ministry of Industry, Mines and Energy (MIME) and Ministry of Economy and Finance (MOEF) (Figure 4-2). Other industry players are private companies. Eight companies are involved in generation business, another eight in distribution business and more than 80 companies have consolidated operations in generation and distribution.

The Electricity Law, as presented earlier, have defined and delineated key functions of agencies in the governance of the power industry. MIME is the key policy making body and responsible for the development of technical standards while EAC is the main regulatory agency (Figure 4-2). The specific functions of MIME and EAC, as stipulated in the Electricity Law, are shown in Table 4-1 and Table 4-3.

For rural electrification and promotion of renewable energies to improve electricity access in rural and remote areas, MIME is responsible for the development of policies, strategies and in the design of policy instruments while EAC focuses on the economic regulation of those entities operating in rural areas.

*Figure 4-2: Governance of the Electricity Supply Industry*

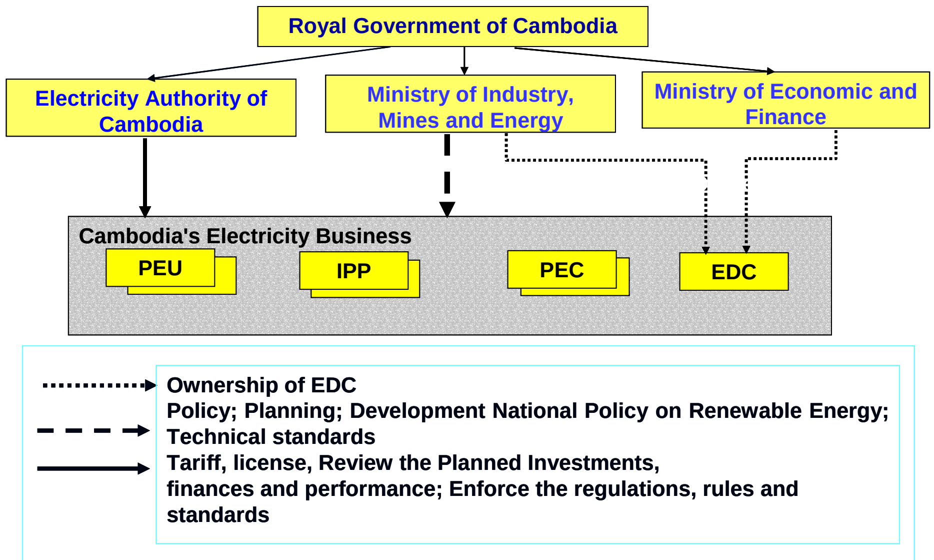



*Table 4-2: Key Functions of the Ministry of Industry, Mines and Energy (MIME)*

| |
|---|
| 1. Approval of investments in the rehabilitation and development of power sector in the short, medium and long term; |
| 2. Developing policies and strategies related to restructuring, private sector participation and privatization of public utilities; Promotion of the use of indigenous energy resources in the generation of electricity; |
| 3. Planning related to the export and import of electricity, as well as approval of electricity export/import agreements; |
| 4. Planning/approval of subsidies to specific classes of customers and priorities regarding consumers of electricity; |
| 5. Promotion of efficiency in generation, transmission, distribution and consumption of electricity; |
| 6. Creation of a comprehensive electricity conservation program for Cambodia; |
| 7. Development of electricity sector emergency and energy security strategies; and |
| 8. Issuing and publishing standards related to technical operation, safety and environment. |

Source: MIME.

*Table 4-3: Key Functions of the Electricity Authority of Cambodia*

| |
|---|
| To issue, revise, suspend, revoke or deny the licences provided for in article 29 of this Law;<br>1. to approve the rates and charges and terms and conditions of electric power services of licensees, except where the Authority considers those rates or charges and terms and conditions are established pursuant to a competitive, market-based process;<br>2. to implement procedures and standards for investment programmes by licensees;<br>3. to review the financial activities and corporate structure of licensees to the extent they directly affect the operation of the electric power industry and the efficient supply of electric power;<br>4. to approve and enforce performance standards for licensees;<br>5. to evaluate and resolve consumer complaints against and contractual disputes involving licensees, to the extent the complaints and disputes relate to the violation of the Conditions of Licence;<br>6. to approve and enforce a uniform system of accounts for all licensees consistent with generally accepted accounting practices;<br>7. to prepare and publish industry reports and relevant information received from licensees for the benefit of the Government and the general public;<br>8. to prescribe fees applicable to licensees;<br>9. to determine procedures for informing the public about issues within its jurisdiction, in order to ensure that the Authority complies with the principle of transparency set forth in Article 3;<br>10. to promulgate rules and regulations and to make appropriate orders, and to issue temporary and permanent injunction;<br>11. to impose monetary fines or penalties, to suspend or revoke the licence of any licence for violations of this Law and regulations imposed by the Authority;<br>12. to impose on the licences and customers obligations to obey the regulations that relate to the national security, energy, economic, environmental, and other policies of the Government in all proceedings before it;<br>13. to perform any other function incidental or consequential to any of the foregoing as described above;<br>14. to establish the terms and conditions of employment of the officers and employees of the Authority, including consultants and advisors. |

Source: Electricity Law of the Kingdom of Cambodia.

### 4.1.3 Electricity Supply Industry Regulatory Frameworks

#### 4.1.3.1 Economic Regulation

Among the various functions specified in the Electricity Law, issuance of licenses, tariff-setting and performance regulation are the main regulatory roles being carried out by the EAC.

*Licenses*

EAC issues eight types of licenses: generation, transmission, distribution, consolidated, dispatch, bulk sale, retail, and subcontract licenses. The description of each license type is given in Table 4-4. To financially support EAC's operations, the Electricity Law allows

EAC to charge fees on licenses. The fees charged on various types of license are shown in Table 4-5.

In 2004, EAC issued around 104 licenses. Of these, 87 were consolidated generation and distribution licenses, 8 were generation licenses, another 8 were distribution licenses and 1 consolidated generation, transmission and distribution license. This is shown in Table 4-6.

*Table 4-4: Types of Licenses Issued by EAC*

**The Generation License** grants the right to generate electricity power from specifically fixed identified generation facilities.

**The Transmission License** grants the right to provide the transmission service. There are 2 types of Transmission License: National Transmission License and Special Purpose Transmission License.

**The National Transmission License** can be issued only to state power transmission company, under the Government control, to have the right to provide the transmission service for delivering the electric power to the distribution companies and bulk power consumers throughout the Kingdom of Cambodia

**The Special Purpose Transmission License** grants the right to construct, own and operate the specifically fixed identified transmission facilities in the Kingdom of Cambodia and have the specified purpose.

**The Distribution License** grants the right to provide the electricity distribution services in a determined contiguous territory.

**The Consolidated License** is a license, which may be the combination of some or all types of licenses. The Consolidated License can be issued to EDC and to the isolated systems to grant the right to generate, transmit, dispatch, distribute and sale the electric power to the consumers.

**The Dispatch License** grants the right to control, to manage and operate the dispatch facilities for facilitating the delivery and receiving the electricity from the generation, transmission and distribution systems.

**The Bulk Sale License** grants the right to buy the electricity from any Generation Licensee or from the power systems of neighboring country for sale to Distribution Licensees or to the large customers in one connected power system.

**The Retail License** grants the right to engage in the sale of electric power to consumers in a contiguous service territory.

**The Subcontract License** grants the right to supply the electric power services according to the subcontract agreement with existing licensee.

Source: Electricity Authority of Cambodia, 2004.

*Table 4-5: License Fees*

| Type | Riels/kWh |
|---|---|
| Generated or Power Purchased from any other country | 1.6 |
| Transmission | 0.6 |
| Distribution and Sale | 1.10 |
| Retail | 0.50 |
| Other services license fee | 0.1% |

Source: Electricity Authority of Cambodia, 2004.

*Table 4-6: Types and Number of Licenses Issued (end of 31 December 2004)*

| No | Type of License Issued | Number of license issued | | Number of licence | |
|---|---|---|---|---|---|
| | | Up to 2003 | During 2004 | Not valid | valid |
| 1 | Consolidated license consisting of generation, distribution and transmission licenses | 1 | | | 1 |
| 2 | Generation license | 8 | 3 | 3 | 8 |
| 3 | Distribution license | 7 | 1 | | 8 |
| 4 | Consolidated license consisting of generation and distribution licenses | 69 | 18 | | 87 |
| Total | | 85 | 22 | 3 | 104 |

Source: Electricity Authority of Cambodia, 2004.

*Tariffs*

EAC also reviews electricity tariffs. Currently, the Electricity Law allows full cost recovery principle in setting tariffs for distribution utilities since power service providers are self-financed and did not receive any form of subsidies from the government. Some form of cross-subsidies were introduced between poor and non-poor residential customers, and between domestic and non-domestic customers.

At present, tariffs are set by each licensee based on full-cost recovery principle. The tariff levels, therefore varies from place to place and there is a huge discrepancy between rural and urban customers. Rural customers are often paying high tariff rates than their urban counterparts. For example the lifeline rate in Phnom Penh is around 350 Riels/kWh while in some rural areas tariff rates are high as 4000 Riels/kWh. This gap is due to various factors such as differences in supply capacity, load factor, fuel transportation cost, procurement cost of capital finance, supply systems losses, risk premium for rural customer's low capacity to pay, etc. Figure 4-3 shows the correlation between tariff rates and installed capacity. Rural customers who are serviced by small electric power providers pay more for each kWh of electricity than their counterparts in urban areas serviced by large operators. Electricity tariffs in Phnom Penh are shown in Table 4-7.

*Figure 4-3: Tariffs and Installed Capacities*

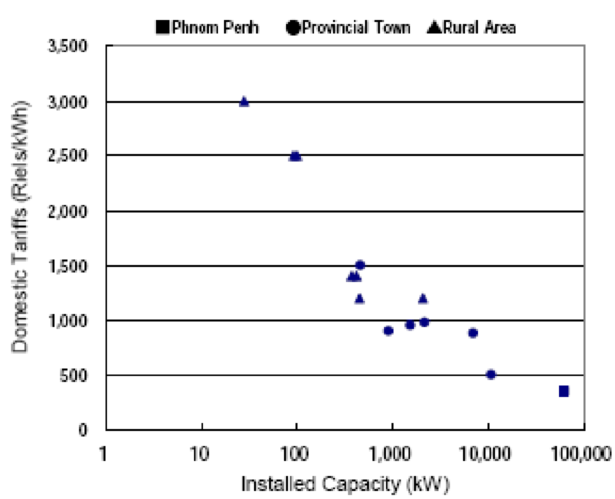


*Table 4-7: EDC's Electricity Tariff in Phnom Penh and Kandal Province*

| Category of Customer | Description | Riels/kWh |
|---|---|---|
| Domestic | 0 - 50 kWh/month | 350 |
| | 51 – 100 kWh/month | 550 |
| | More than 100 kWh/month | 650 |
| Government institutions | | 700 |
| Embassy, NGO, Foreigner's residence | | 800 |
| Commercial and service sector | Small | 650 |
| | Medium | 600 |
| | Big | 700 |
| | Medium voltage | 800 |
| Industrial | Small | 600 |
| | Medium | 550 |
| | Big | 500 |
| | Medium voltage | 480 |

Source: Electricity Authority of Cambodia, 2004.

*Performance regulation*

During the assessment of the status of electric power providers in the country, EAC had found out that i) many electric power service facilities are obsolete or very old, not compliant with technical standards and unsafe in operation and use; ii) licensees and staff do not have enough knowledge on the operation and maintenance of the generation and distribution of facilities, and iii) licensees and staff do not have enough knowledge regarding business management, financial work, accounting, human resource management and customer relation services, etc. The overall situation of the electric power service in the country is shown in Table 4-8**.**

*Table 4-8: Actions to Improve Electric Power Services*

| Type of service | Generation Efficiency or Fuel Consumption Rate, L/kWh | Distribution efficiency | Management |
|---|---|---|---|
| Consolidated license of EDC | 0.27 to 0.31 | Average loss 13%, good power quality | Medium, many aspects need to improve |
| Generation license | 0.27 | Good power quality | Medium |
| Distribution license | | Average loss 12%, medium power quality | Lack of experience in electricity business |
| Big consolidated license | 0.32 | Average loss lower than 17%, medium power quality | medium |
| Small consolidated license | 0.29 to 0.5 | Average loss 33%, low power quality | Low, need to have more training |

Source: Electricity Authority of Cambodia, 2004.

To improve the overall performance of electric power providers and ensures that the customers get the benefit of use of electricity, EAC has implemented approaches addressing the main issues describe above. EAC has provided advice and guidance and conduct trainings for power service providers; provide incentives and imposed penalties, and monitored financial performance and adopt tariff setting mechanism that induce competition.

*Table 4-9: Actions to Improve Electric Power Services*

**Advise, guidance and training**

- EAC visits the facilities of service providers and provides technical advice on how to improve the facilities and operation.
- Conduct workshops and exchange ideas on facility and operation improvement.
- Conduct trainings for service providers

**Incentives and penalties**

- Longer term license extension for service providers who improved facilities to comply with technical standards and managed the business operations efficiently.
- Revocation of license for non-compliance of technical standards and inefficient business operation.

**Financial monitoring and competition**

- Service providers are required to prepare financial report and EAC monitors the financial statement
- Set tariffs for small power service providers through tariff table that will induce competition.

Source: Electricity Authority of Cambodia, 2004.

#### 4.1.3.2 Environmental Regulation

The legal and regulatory frameworks for the protection of the environment are contained in the Law on Environmental Protection and Natural Resources Management issued in 1996 and other environmental protection sub-decrees (Table 4-10). Environmental regulation is Cambodia is bestowed on the Ministry of Environment.

*Table 4-10: Environmental Laws*

- Law on Environmental Protection and Natural Resources Management (1996)
- Sub-Decree No. 72 on Environmental Impact Assessment Process (1999)
- Sub-Decree no. 27 on Water Pollution Control (1999)
- Sub-Decree on Solid Waste management (1999)
- Sub-Decree No. 42 on Air Pollution Control and Noise Disturbance (2000)

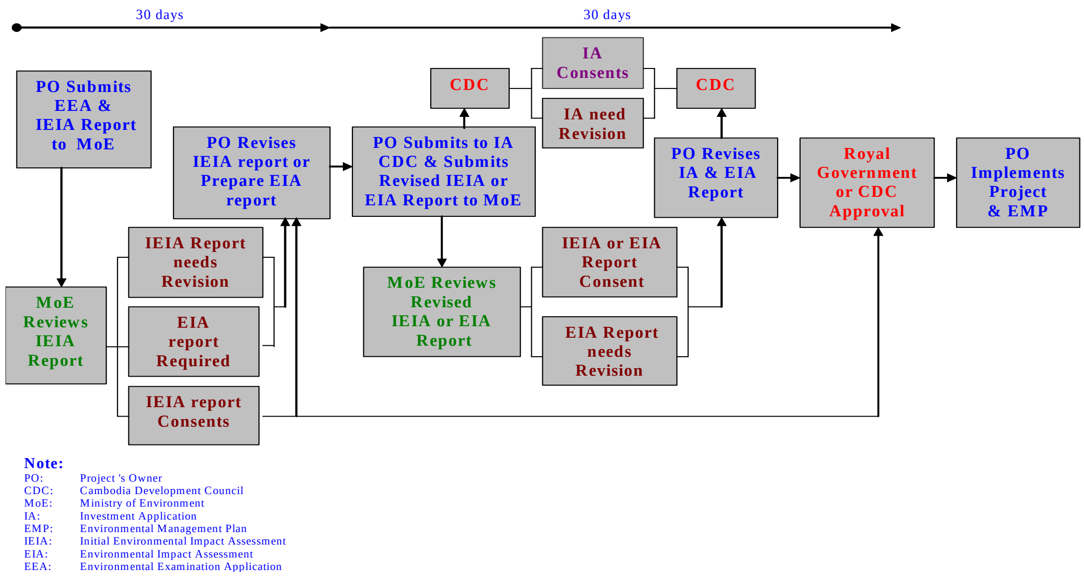
Source: De Lopez, 2005.

Power projects with capacities higher than a certain threshold defined by the environmental agency are required to undertake environmental impact assessment (EIA) evaluation study. The EIA process is shown in Figure 4-4. The threshold capacities are the following:

- power plants ≥ 5 MW

- hydropower ≥ 1 MW
- waste processing all sizes.

*Figure 4-4: EIA Process*




Similarly, all power plants are required to satisfy other environmental standards such as water, air, noise and solid waste discharge standards. Effluent standards, hazardous substances and allowable limits for pollutants discharged in public waters are defined in Sub-Decree on Water Pollution Control. Ambient air quality standards and maximum levels of discharge from stationary and mobile sources are outlined in Sub-Decree on Air Pollution and Noise Pollution. Hazardous waste regulations from factory wastewater, product manufacturing processes, agriculture and coal-fired power plants are specified in Sub-Decree on Solid Waste Management.

### 4.1.4 Investment Laws

The institutional and legal frameworks for investments in Cambodia are specified in the Law on Investment (promulgated in 1994 and amended in 2003). The Council for the Development of Cambodia (CDC) is the agency responsible for the development and management of foreign direct investment (FDI). CDC is composed of two executive boards: the Cambodian Rehabilitation and Development Board (CRDB), and the Cambodian Investment Board (CIB). CRDB is manages the international assistance and public investment while CIB coordinates private investments. Local investors may register directly with the Ministry of Commerce (MOC) and are not required to apply for a license with the CDC.

CDC provides a one-stop service for rehabilitation, development and investment activities in Cambodia (Sub-Decree 70). Renewable energy project developers are required to obtain an investment license from CDC. The license is in return required for application of incentives and preferential taxation. The current services provided by CDC include the following: information, investment application and approval, customs duty and tax exemption, visa and work permits, and company registration. The process in obtaining an investment license is summarized below:

- Submission of application to the Cambodian Investment Board (CIB) of the Council for the Development of Cambodia (CDC), which should include memorandum, articles of association, and a feasibility study.
- Meeting with members of the CIB/CDC to provide additional information during the review process.
- Approval by the CIB/CDC within 28 days.
- Commercial registration of the company with the Ministry of Commerce.

### 4.1.5 Clean Development Mechanism

The Clean Development Mechanism (CDM) is one of the flexible mechanisms established under the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) to assist industrialized countries in meeting their emissions reduction obligations at lower cost and at the same time to stimulate investments that promote sustainable development in developing countries. The UNFCCC is an international treaty formulated in 1992 and entered into force in 1994, which sets a goal of stabilizing atmospheric concentration of greenhouse gases at safe levels. The UNFCCC's supreme body, the Conference of Parties (COP), supervises the activities towards the achievement of the Convention's goals. During the body's third meeting in Kyoto, Japan, the supreme body set a legally binding requirement for Annex-1 countries to trim down their greenhouse gas emissions to an average of 5.2% below their 1990 emissions levels. This legally binding commitment is also known as the Kyoto Protocol.

The Clean Development Mechanism is a project-based mechanism where Annex 1 countries can purchase or claim CERs from projects implemented in developing countries (non Annex 1 countries) to be used for meeting their emissions reduction targets. Projects that qualify for CDM include the following: end-use energy efficiency, supply-side energy efficiency, renewable energy, fuel switching, agriculture, industrial processes, solvent and other product use, waste management, and sinks (afforestation and reforestation). These projects must also satisfy two main conditions set by the protocol: additionality and contributions to sustainable development. The additionality condition states that projects must result in reductions in emissions that are additional to any that would occur in the absence of the project activity, and that the projects must lead to real, measurable and long term benefits. The sustainability condition states that projects must assist developing countries in achieving their sustainable development goals. There is however no guideline provided by the Protocol except that each country must develop its own criteria and assessment procedures. For developing countries to participate in CDM, the Protocol requires that each country must establish a national authority responsible for CDM, ratify the Kyoto Protocol and participate voluntarily.

Renewable energy projects for rural electrification in Cambodia could potentially benefit from CDM by quantifying and registering the emissions reductions the project generates. The Government of Cambodia is quick to recognize CDM as a new instrument in financing renewable energies in the country. The Government ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1995, and acceded to the Kyoto Protocol in 2002. The Government also established the necessary institutional framework as a necessary requirement for CDM participation and for effective functioning of the CDM process in the country.

#### 4.1.5.1 DNA Structure

The Ministry of Environment is Cambodia's Designated National Authority (DNA) for Clean Development Mechanism (CDM) activities. The Cambodian DNA comprises three players: (1) the National CDM Board, (2) the DNA Secretariat, and (3) the Inter-ministerial Technical Working Groups.

The National CDM Board issues the official approval letter confirming voluntary participation and project conformity with national sustainable development objectives. It is composed of representatives from the Ministry of Environment (MOE), the Ministry of Agriculture Forestry and Fisheries (MAFF), the Ministry of Industry Mines and Energy (MIME), the Ministry of Planning (MOP), the Council for the Development of Cambodia (CDC), and the Ministry of Public Works and Transport (MPWT). The board members are at least of the undersecretary of state level. It is chaired by the Minister of Environment or, in his absence, a vice chair (representative of MAFF or MIME). Decisions of the board concerning proposed CDM projects require the full consensus of all board members.

The Cambodian Climate Change Office (CCCO) acts as the DNA Secretariat and is the national contact point for CDM activities in Cambodia. CCCO is part of the Department of Planning and Legal Affairs of the Ministry of Environment and oversees all technical aspects of climate change activities in Cambodia. The DNA Secretariat receives and screens project design documents (PDD) for completeness, coordinates technical working group activities, and communicates directly with the National CDM Board. In addition, it is responsible for collating relevant information for the CDM Board to make an informed decision on proposed CDM projects.

There are two main Inter-ministerial Technical Working Groups: the Energy Technical Working Group and the Forestry Technical Working Group. The composition of the Energy Technical Working Group is as follows: three representatives of MIME (renewable energy, planning, hydroelectricity), three representatives of MOE (CCCO, environment impact assessment, one other relevant department), one representative from the Royal University of Phnom Penh (RUPP), one from the Royal University of Agriculture (RUA), one from the Institut de Technologie du Cambodge (ITC), and one from MPWT. The technical working group reviews PDDs against national sustainable development criteria, but does not have any decision-making authority. The technical working group prepares a project technical assessment report, including technical and policy recommendations for the National CDM Board.

#### 4.1.5.2 Sustainable development criteria

The Cambodian Designated National Authority aims to assess projects in an efficient and transparent way, and to ensure that projects approved for CDM support Cambodia's development in a sustainable manner, giving due consideration to the Royal Government of Cambodia's development strategy (CCCO 2005). Cambodia has developed a *sustainable development matrix* to be used as a tool for assessing CDM projects. This matrix of 25 indicators is based on Cambodia's existing laws, regulations, policies, statements, and commitments to international conventions. The matrix focuses on four aspects of sustainable development: economic, social, environmental, and technology transfer.

All CDM projects are assessed by rating each indicator on a scale ranging from positive to negative rating. A positive rating indicates best practice for a particular criterion, while a negative rating signifies that the project has serious impacts. A neutral rating indicates that the project has no significant positive or negative impact. Projects must achieve a positive or neutral rating for each of the 25 indicators of the matrix. The absence of negative impacts is considered to be the minimum threshold with which project proponents must comply. In addition, Cambodia's DNA explicitly specifies that the *monitoring and verification plan* not be limited to GHG emissions reduction; it must also cover all commitments of the project outlined in the PDD pertaining to the sustainable development matrix.

## 4.2 Stakeholders' Activities

### 4.2.1 Power Licenses

The Electricity Law of the Kingdom of Cambodia, adopted in 2001, provides the legal framework for electric power supply and services throughout the country. Article 15 requires each power service supplier to obtain a power license from the Electricity Authority of Cambodia. Chapter VI of the Electricity Law (Articles 29 to 40) defines eight different types of licenses issued by EAC. Table 4-11 shows the characteristics of these licenses.

*Table 4-11: Types of Licenses Required From Electricity Supply Providers*

| License Type | Characteristics |
|---|---|
| 1. Generation License | • Needed for generating electricity for sale, not needed for own consumption or captive power.<br>• Usually valid for the expected useful life of the generation facility. |
| 2. Transmission License | • Grants right to own, operate and manage transmission facilities for transferring and delivering or selling electricity in bulk.<br>• Two types of transmission licenses:<br>o National Transmission License: issued to the state power company, Electricité du Cambodge.<br>o Special Purpose Transmission License: Grants the right to own and operate specific transmission facilities. Granted for indefinite term or useful life of facilities. |
| 3. Dispatch License | • Grants right to control, manage and operate dispatch facilities for electricity from generation, transmission and distribution systems.<br>• Issued for indefinite term but subject to revocation. |
| 4. Distribution License | • Grants right to provide electricity distribution services to customers in a determined contiguous area.<br>• Issued for indefinite term but subject to revocation. |
| 5. Bulk Sale License | • Grants right to buy electricity from generation licensees and neighbouring countries for sale to distribution licensees and to large customers.<br>• A bulk market is defined as a market where producers may supply numerous buyers, and where generation and transmission services are separated.<br>• Issued for indefinite term but subject to revocation. |
| 6. Retail License | • Grants right to sell electric power to consumers in a contiguous service territory.<br>• Electricity sold must be purchased from a utility licensed by EAC.<br>• Issued for a five-year term, extendable. |
| 7. Subcontract License | • Grants right to the same electric power services as existing licensee from which it is subcontracted. |
| 8. Consolidated License | • A combination of some or all types of licenses.<br>• A generation license must be obtained for each new generation facility.<br>• Issued for the state power company and for isolated systems. |

Source: Adapted from Electricity Law of the Kingdom of Cambodia and the EAC website.

### 4.2.2 Procedures for Obtaining Power Licenses

The Electricity Law provides guidelines for the issuing of licenses by the Electricity Authority of Cambodia. First, EAC shall take into consideration government policies, strategies and planning in the power sector, in particular with regards to public interest and the reduction of the marginal cost of supplying electricity. Second, EAC shall take into consideration the capacity of licensees to operate according to prescribed technical, safety and environmental standards.

The "Procedures for Issuing, Revising, Suspending, Revoking or Denying Licenses", adopted by the Electricity Authority of Cambodia in 2002, outlines the necessary steps for obtaining a license. A one-page application form for new service provider must be submitted to EAC with supporting documents, including an information sheet bulletin relevant to each one of the existing types of licenses. The information sheet bulletins all require applicants to provide details on their technical ability and experience, financial standing and planned facilities and services. A monetary deposit for applying for a license is required, as well as a prior no-objection letter from EAC for distribution, generation and consolidated licenses.

Upon submission of an application, EAC issues a receipt of acceptance. Within a week of the submission of the application, EAC shall set a working schedule for publishing the application, site inspection, public consultation, consultation with the applicant, and evaluation of the application. Within two weeks of submission, EAC shall publish a summary of the application for local authorities and the general public living in the proposed service area. The public consultation period shall last a minimum of thirty days. The procedures for application evaluation do not specify in any detail the timeframe within which EAC shall issue a license, but the publication of the application and the public consultation alone, will require a minimum of 6 weeks. A sample application form for new service provider and sample information sheet for power licenses is given in a Companion Report.

### 4.2.3 Power Purchase Agreements

There is currently no published formal procedure for obtaining a PPA with EDC, and no standard form of agreement, however the basic process required of any potential IPP is as follows (EDC 2006):

i. Developer seeks permission from MIME to perform detailed feasibility study;

ii. On the basis of this study, the developer proposes to EDC the terms, time period, conditions and price for the project;

iii. EDC negotiates these terms and conditions with the developer and formalises them into a PPA;

iv. The draft PPA is submitted to EAC for their review and approval;

v. Once agreement is reached with the developer, and with EAC's approval, the PPA is proposed to the EDC Board;

vi. If accepted, then the EDC board will propose to MIME for approval; and

vii. Once MIME approves it then EDC executes the PPA with the developer and the project begins.

The Public Private Infrastructure Advisory Facility (PPIAF)[4] funded a project in Cambodia in 2001 to 2004 that produced a series of procedures and model agreements to facilitate the greater participation in Cambodia's power sector by private interests.[5] This project produced the following documents, among others, for small scale generators which are most likely to be relevant for renewable energy generators:

- Policy Paper on Private Participation in the Power Sector;
- Guidelines on Power Procurement for Small Scale Generation; and
- Model PPA for Small Scale IPPs.

The guidelines for small scale procurement suggested by the PPIAF project include the following general procedure for generation projects under 5MW:

- MIME's planning processes identifies the need for a Load Serving Entity (LSE) in a particular location;
- An LSE proposes a plan to describe how the new project will service a new area, or increased coverage of an existing area, at least cost within defined reliability and quality of service standards;
- EAC reviews the LSE plan to ensure it complies with relevant standards and requirements;
- Prices are negotiated within the range of reference prices regularly calculated and published by EAC for each type and size of project; and
- The LSE may call for tenders for 3rd party companies to build and/or operate the project under a PPA with the LSE; or the LSE may itself choose to build, own and operate the plant.

In this proposed procedure, EDC would be an LSE in all the areas where it has already been granted a franchise, i.e.: most of the provincial towns. So in this case an IPP, or a developer with a project idea, would propose an 'LSE Plan' to EDC. However these proposed guidelines appear to recommend that EDC would then invite public proposals from other potential IPPs for the same project to ensure it is achieving the best value and quality for the public's interest. The guidelines proposed by the PPIAF project have not been adopted by the Government in Cambodia.

#### 4.2.4 Environmental Permits

The 1996 Law on Environmental Protection and Natural Resources Management and its associated sub-decrees provide the legal basis for the protection of environmental quality and public health, and the rational and sustainable conservation, development, management and use of Cambodia's natural resources. Potential renewable energy projects for rural electrification fall under the jurisdiction of the law and would be required to comply with all of the existing environmental sub-decrees. Permits for discharge of wastewater, solid waste, emissions of air and noise must be obtained from the Ministry of Environment.

An Environmental Impact Assessment (EIA) is required for all types of power plants of installed capacity exceeding 5 MW. However, hydropower projects above 1 MW of in-

[4] PPIAF is a multi-donor facility that was created in 1999 by the governments of Japan and the United Kingdom, with help from the World Bank (see www.ppiaf.org).
[5] PPIAF Activity ID: C051601-L-ETY-RF-KH, approved 31/12/01, grant budget: US$393,500 (see www.ppiaf.org).

stalled capacity also require an EIA. The Ministry of Environment evaluates and reviews the EIA report in collaboration with other relevant government agencies. A decision is made within 30 working days of submission.

### 4.2.5 Accessing the Rural Electrification Fund

The Rural Electrification Fund (REF) is a relatively small component of the Rural Electrification and Transmission Project being implemented by MIME and EDC with loans from the Word Bank and Asian Development Bank. The REF is intended to operate as an autonomous agency that offers grant subsidies to any rural electrification project proposal that complies with its requirements for providing new services to an area that currently has none, or else extends an existing electricity service to additional households.[6]

The REF has been in the design and preparation stages for more than four years and the current status is unclear. It appears that the relevant World Bank loan to the Cambodian Government became effective in 2005 but there have been a number of procurement delays in Cambodia and the REF Secretariat (REFS) that will be responsible for implementation has not yet been established (REPSA 2005).

Consequently the procedures, requirements and standards for eligible REF projects have not yet been established. However early project design documents contained general descriptions of how the procedures might work. Two different types of projects were defined:

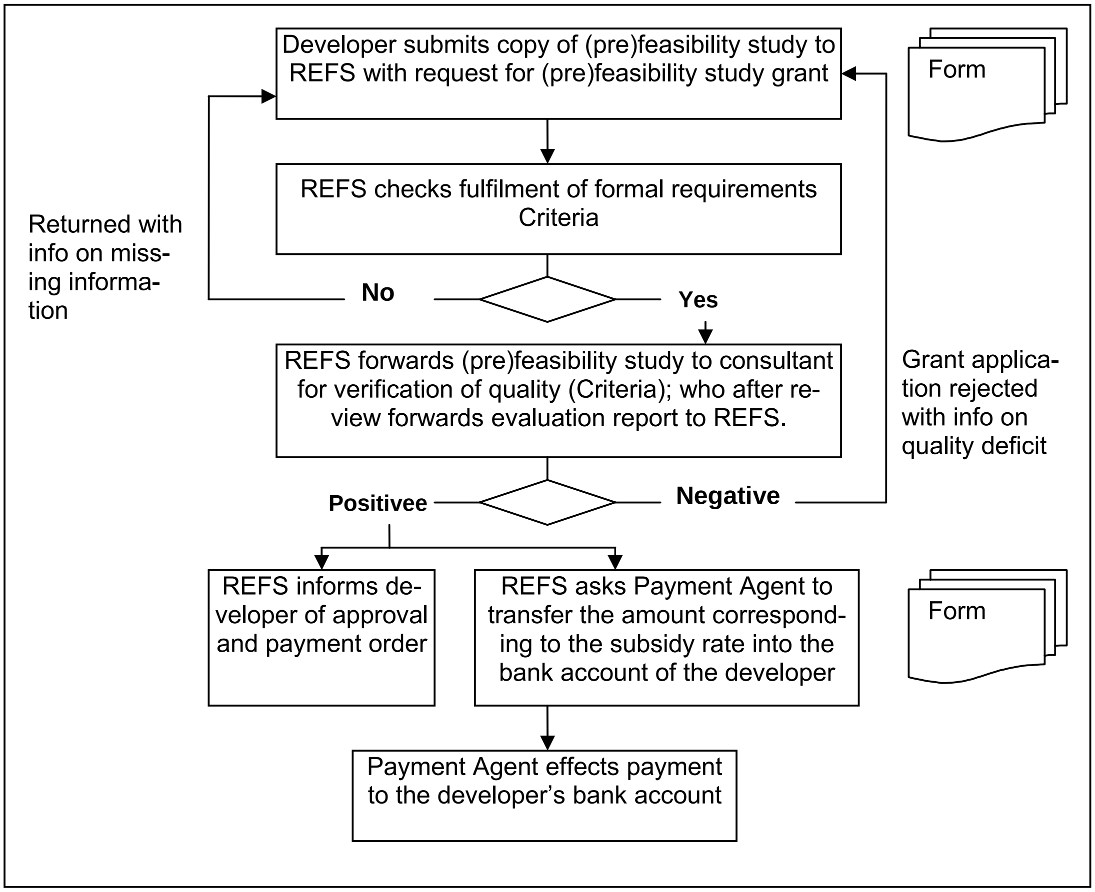
a. Locally Initiated RE Projects - prepared and developed by a private project developer, NGO or community; and

b. Priority RE Projects – that have been identified in a rural electrification planning exercise and prioritised by the government.

The first type of project is the default scenario, where private developers identify a rural electrification opportunity and propose it to the REF Secretariat (REFS) for funding assistance. One possible procedure for this proposal and assessment by the REFS is illustrated below (Figure 4-5).

[6] See www.recambodia.org and navigate to the Rural Electrification Fund (REF) pages.

*Figure 4-5: Possible General REF Procedure for Private Projects*




Source: World Bank 2004.

In the case of projects that have been identified by the government's rural electrification master plans as high priority, then the following procedure might be implemented (World Bank 2004):

- The REFS will monitor progress of REF projects with respect to the list of identified high priority projects;
- If it appears that progress on priority projects is insufficient, then the REFS would commission private consultants to produce pre-feasibility studies on one or more of these projects;
- These pre-feasibility reports would then be published and the REFS would call for expressions of interest for parties to develop the projects;
- An appropriate procurement process would then be followed to find the bidder with the best value proposal and lowest proposed power price; and
- REFS and EAC negotiate with the winning bidder for award of appropriate subsidy grant and operating licence, including required implementation time frame.

Some early draft formats of possible REFS project documentation can be found in the Companion Report, however MIME and the REFS should be consulted for the latest versions prior to use.

#### 4.2.6 Accessing Investment Incentives

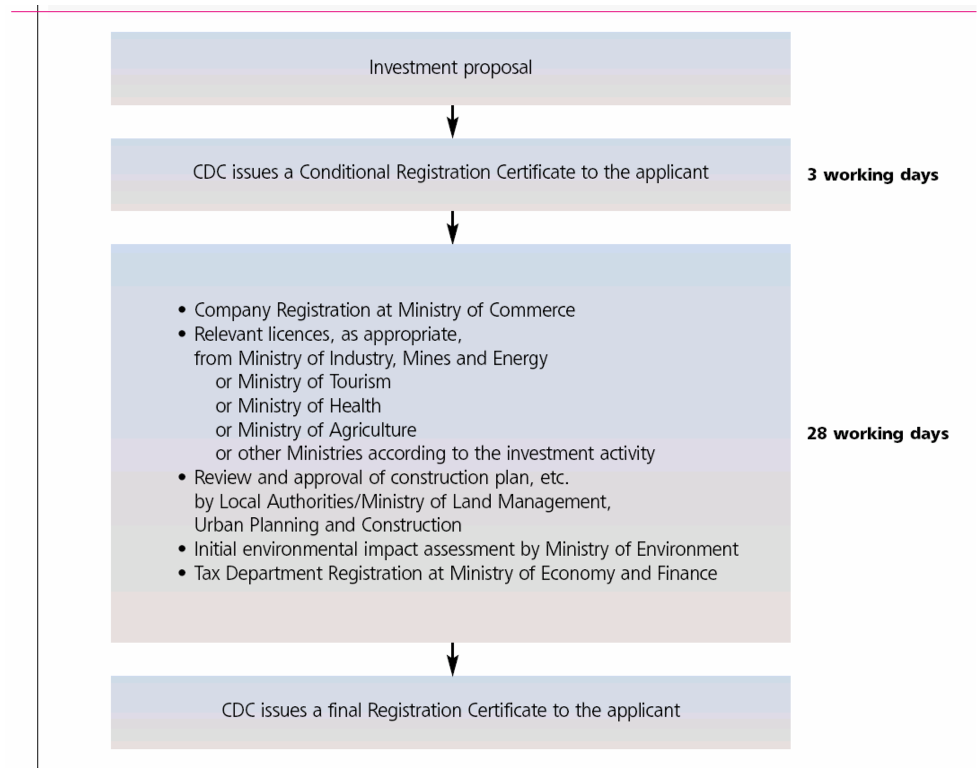
The Council for the Development of Cambodia (CDC) was established in 1994 after passing of the Law on Foreign Investment. The CDC is chaired by the Prime Minister and composed of senior ministers from related government agencies. The Cambodian Investment Board (CIB) is the operational arm of the CDC for private sector investment. The CIB reviews investment applications and grants concessions to investors and investment projects according to the 1994 Foreign Investment Law (CDC 2006).

The CDC's website includes a list of twenty investment types that are considered to be a high priority for Cambodia, including the construction of physical infrastructure such as for power production. The CDC can offer a range of incentives to entice potential investors, including (UN 2003):

- An automatic tax holiday of three years, with up to three additional years depending on the activity or sector, the tax holiday to commence with the first year in which profit is made but no later than the fourth year of operation;
- 100% exemption from import duties on construction materials, production equipment, machinery, intermediate goods, raw materials and spare parts used for exports;
- Guarantee against nationalization;
- Renewable land leases of up to 99 years on concession land for agricultural purposes and land ownership permitted to joint ventures with over 50% equity in Cambodian hands;
- No price controls;
- No discrimination between foreign and local investors;
- A one-stop service in the CDC to facilitate and speed up the investment process and to provide a Conditional Registration Certificate (CRC) or Letter of Non-Compliance within three working days and a Final Registration Certificate within 28 working days from the date of issuance of the CRC.

The standard process for a potential investor to apply for approval and assistance through the CDC is depicted below in Figure 4-6.

*Figure 4-6: Process of Seeking CDC Approval and Assistance for Foreign Direct Investment Projects*




Source: UN 2003.

### 4.2.7 Clean Development Mechanism Approval Procedures

Cambodia's DNA approval procedures for CDM activities provide detailed information as to the timeframe and nature of assessment activities undertaken by the key DNA players. The approval process is takes 55 working days and is divided into three phases:

- Phase I (ten working days) consists of the initial screening of the PDD for completeness by the DNA Secretariat. The PDD must be submitted with (1) relevant official investment approvals (from the Council of Ministers, CDC, provincial authorities, etc.) if required, and (2) an environmental impact assessment report, if required. PDDs deemed complete are then subject to public notification.
- Phase II (30 working days) consists of a technical assessment of the PDD against the sustainable development matrix, as well as collection of all stakeholder comments submitted to the DNA Secretariat. The relevant Inter-ministerial Technical working group in energy, forestry, or other areas, is responsible for preparing the *technical assessment report*, which assesses the proposed CDM project against national sustainable development objectives using the sustainable development matrix. NGOs, local communities, the public-at-large, academics, and other stakeholders have twenty working days to submit their comments on the proposed project to the DNA Secretariat. The Secretariat then prepares the assessment report, which consists of the technical assessment report by the working groups, all

stakeholder comments, and any other relevant information. At the end of phase II, the assessment report is submitted to the National CDM Board.

- Phase III (15 working days) consists of deliberations by the Board, which takes a decision concerning the proposed CDM project after ten working days. An approval or a rejection letter is issued five days after the Board's decision.

Cambodia's first CDM project, a biocogeneration power plant using rice husk, was smoothly approved by the DNA in January 2006. The assessment procedures of the Cambodian DNA are attached in the Companion report.

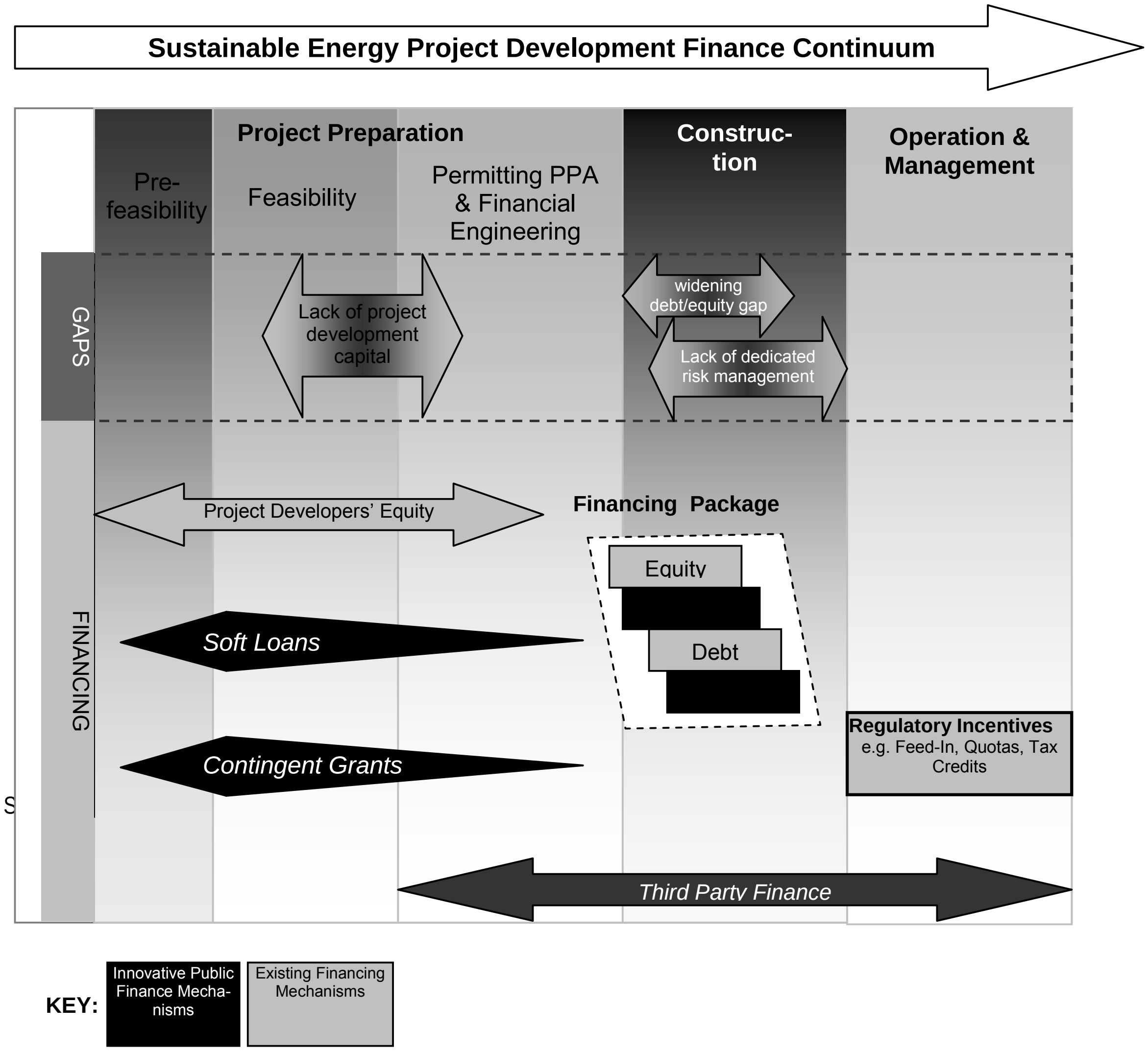
## 4.3 Financing Renewable Energy Projects

### 4.3.1 Background

In many cases, financing of renewable energy (RE) projects particularly in developing countries is a challenging exercise. Normally, commercial financiers are risk-averse. When considering a project, a financier will prepare a risk/return analysis to asses each major risk and the means to mitigate its potential impact on the project. Assessing the return involves verifying potential costs if something goes wrong and the project revenue projections, and then comparing the financials of the project and its cost of financing. Unfamiliar technologies, inexperienced developers, risky jurisdictions are some of the major risks that financiers factor in when considering financing renewable projects. Because of these perceived risks, too often large financiers are not keen on financing renewables.

Renewable or sustainable energy projects do not normally have the large scale viability of conventional energy projects, and therefore do not enjoy the financing opportunities and terms that are given to the larger and more financially attractive energy projects. A study launched by UNEP has shown that there is a gap in financing that exists particularly during the project preparation stage, reflected in the lack of development capital to support the efforts of project developers (see Figure 4-7).

*Figure 4-7: Sustainable Energy Project Finance Continuum*




Source: Public Finance Mechanisms to Catalyze Sustainable Energy Sector Growth, UNEP.

This reluctance by the financing institutions in financing RE projects and the resulting gaps happen because of the barriers that exist.

*Lack of developers with the skills to prepare financing packages that responds to the requirements of financial institutions*

Small-scale project developers lack the in-house expertise to look for funds, prepare the financial plan of the project, and negotiate with lenders to obtain the most favourable financing terms. Project developers too often underestimate the complexities of obtaining bank financing and the requirements that go with it; so they meet with financing institutions and present their projects unprepared and with inadequate information. This results in rejection or lack of interest by the banks and thus, discouragements on the part of the developers.

*Financial institutions lack the expertise to evaluate renewable energy projects*

Although financial institutions are normally adept at developing financing plans, their knowledge of RE investments is often limited and, therefore, find it difficult design the right financing scheme that would suit these projects, as well as construct a credit structure that would be acceptable to all parties involved.

Financial institutions do not normally maintain among its staff people who have enough background and expertise to evaluate renewable energy projects. The staff who evaluate projects requesting for financing are, in general, not familiar with these technologies. This leads to reluctance in even starting to consider doing a due diligence exercise on these types of projects. Whenever financing institutions do not have the in-house expertise to evaluate RE projects, the alternative is to hire an external consultant for this purpose. The cost for this activity is then passed on to the project developer which increases the overall financing costs for the project.

*High capital and project development costs*

Renewable energy projects are expensive compared to conventional energy systems. Because the implementation of renewable technologies are new in many countries, the costs to develop these project tend to be expensive. The capital costs of renewable energy tend to be much higher than the conventional means even if the amortised costs over the lifetime of the technologies are lower compared to conventional sources. The impact that transaction costs have on energy system prices should also be considered. Transaction costs, which are the costs incurred when buying or selling assets, increase the price of renewable energy technologies at all stages of the delivery chain. These affect the viability of the project, a factor which is of prime importance for the participation of the private sector.

*Lack of assets that could be used as collaterals and guarantees to secure loans*

The potential investors in RE projects are either the agro-industries producing the wastes to be used as fuel, or small to medium-sized third party developers. These companies generally lack untied assets that could be used as collaterals required by banks as security for the provision of loans. Some may also lack the financial muscle to provide or mobilize guarantee instruments in lieu of collaterals in the form of assets.

*Lack of experience by financing institutions working in new service areas leads to a higher perception of risk.*

There is a general lack of confidence among financial institutions in technologies involving renewable energy. This is partly because they are unfamiliar with the technologies, and partly because of concerns related to the availability of feedstock supply/resources such as biomass, wind, sunlight and river water. This makes them too cautious in lending to these kinds of projects. Although references of projects successfully operating in similar environments are available, very few financiers have visited these projects and have seen them operating. In addition, the existing financing schemes usually require a long application and approval procedure and are not appropriate for small renewable energy projects.

*Many energy efficiency and renewable energy projects are considered too small*

The classic complaint of lenders when dealing with these projects is that it takes about the same efforts to evaluate a small project as a big one. Thus, if a project does not reach a certain critical mass in terms of project cost, lenders are not willing to take the project into its portfolio of possible lending candidates.

Despite the above barriers, there are a number of renewables that had been successful in, or are currently in the process of, raising financing.

### 4.3.2 The project cycle of RE projects and their financing

Just like the conventional energy project, the project cycle of a renewable energy project has several stages. The sources of funds are different in each stage as well as the risks associated with the completion of each stage.

It is important to note that until the project is built and capable of operating, there is no revenue source to repay the investment. Without revenue, the project's lenders and investors are unable to recover their original investment. Until the plant is operating, the risks increase for the participants as more money is lent or invested in the project. The risk of non-completion is the greatest risk of the project during the construction stage. This phase is lengthy and needs to be managed carefully. As the development and construction stages proceed, there are more and more sources of funding. Then, once a project demonstrates that it is capable of operating commercially, the sources of capital increase dramatically. In addition, unlike a company that has multiple sources of revenue, an energy project generally has one or two sources of revenue, which adds a premium to its borrowing costs.

#### 4.3.2.1 Development

The development stage encompasses the period during which a developer is trying to create a project. It is important to understand that in creating a project, the developer is starting a business where no business operations existed before.

During the development stage, one cannot be certain that a "financeable" project will result. The project must first be defined in terms of the buyer's needs, site, fuel availability and permitting requirements. The feasibility work should also be done. This generally consists of engineering, cost estimation and environmental work, as well as the development of preliminary project pro formas. The developer must then obtain contracts, secure the site, select the technology and suppliers, and complete the permitting for the plant. The contract that sets the direction for the rest of the project's development is the Power Purchase Agreement. It is when the PPA is agreed where the greatest "value" is being created.

Putting together a project is expensive. The source of funds generally used during this period is equity. The developer and owner of the project provide these funds. It is on-balance sheet financing, and development money are rarely borrowed. In certain cases, particularly when the industry is immature and many of the companies are small, other parties lend this form of capital. If the project is successful, the development lender usually receives a significant percentage of the project's equity as well as the repayment of the loan. This loan is sometimes secured by the developer's other assets, which could range from his house and personal effects to larger corporate assets.

At the development stage, the financial management and investment planning process for a project takes precedence. There should be some cap on total expenditures, so that costs do not get out of control.

#### 4.3.2.2 Financial close

Once all project agreements, approvals, legal documentation and negotiations with financing parties have been accomplished, all that remains is financial closing. As the project approaches financial closing, the legal people take over the process and inputs from the sponsors/developers are not required unless substantive issues arise which send everyone back to the drawing board. In practical terms the sponsor/developer should not consider financial closing a done deal until checks are written or funds transferred for the start of construction.

#### 4.3.2.3 Construction

A project enters the construction stage when it has met all the requirements necessary to put together a project financing. This means that all of the contracts are negotiated and signed, the permits are granted, and the technology and equipment are selected. Essentially, if anything goes wrong with the project, the lenders can only look to the assets of the project to recover the borrowed funds. There is limited or even no recourse to the developer/sponsor if there is a problem. Therefore, all the risks must be allocated through the contractual arrangements.

The lenders, in general, provide the majority of the construction funds. The period of greatest risk for them is just before the plant is completed, because they have almost all their loan outstanding and the plant is still not producing revenues. The traditional sources of construction period financing are the commercial banks, which have experience in assessing project construction risk. Commercial banks may also provide a term loan during the operating period. A project financing is always structured to have a term lender "take-out" of the construction loan when the project reaches commercial operation. The term lender can also be the construction lender.

Once the project reaches the construction phase, the developer/sponsor has more financing options. He can continue to develop and start construction using corporate funds, or raise the financing through limited or non-recourse project financing. In order to reduce the time between the commencement of the development period and commercial operation, some developers choose to begin construction with few outstanding issues. In this case, the developer uses its full credit (or balance sheet) to support the project. The company would then be at risk for any problems, such as cost overruns and force majeure events. If the developer elects to start construction before non-recourse financing is available, he can choose to obtain project financing during construction period once all the criteria are met.

#### 4.3.2.4 Operation

The primary financial management issue throughout the project life cycle is to minimize the financial and operating costs of the project. Once a project reaches commercial operation, a developer/owner has many options in terms of additional lending sources. For example, institutional buyers such as insurance companies and pension funds, as well as the public markets (which do not take construction risk), can now participate. The project now has real operating and financial data that can be used to assess the plant's performance and financial expectations. The key is planning and constant attention to the project finance debt market.

During the operating period, the project can be refinanced to take advantage of lower interest rates or longer terms, if the developer negotiated the right to refinance in the security documents.

### 4.3.3 Financing Mechanisms and Options for Renewable Energy Projects

Renewable energy projects tend to have high initial costs and low operating costs compared to conventional technologies. The success of any financing approach for these options depends on the degree to which it meets and completes several key tasks including finding sustainable financing mechanisms, making strategic alliances, reducing transaction costs and minimizing risks. Moreover, broad institutional groundwork is needed including good pricing policies, efficient power sector management, viable lending institutions, credible regulatory policies and solid legal frameworks. Success will also depend on conducive frameworks for market and investment growth.

Projects using renewable energy sources use traditional financing routes and sources that are available to investors of other energy installations. However, because of the nature, size and peculiarities of these types of projects, these normally are not adequate to attract funds to finance renewable energy investments. Thus, newer and innovative schemes are evolving. These are described in the section below.

#### 4.3.3.1 Conventional Financing Routes and Sources

Generally, any of the three conventional financing routes and associated sources is used by renewable energy investors.

*On-balance sheet (corporate finance)*

On-balance sheet finance is generally the simplest means of raising finance. It is likely to be used only by strong corporate sponsors. Although corporate finance can be raised by the issuance of shares or bonds or internal reserves, in most cases it involves raising debt based on the full corporate strength of the borrower at a price that reflects the corporate creditworthiness.

Corporate loans are generally easy to arrange if the borrower is considered creditworthy, but repayment periods are normally less than ten years. As the lender does not scrutinize the project documents and contracts rigorously, the up-front expenses and time invested are far less than that for project finance. The structure of the project and the project risk profile would not influence the price of the loan as the corporate borrower accepts all the project risks. The arrangement fees and interest margins over base rate will vary considerably depending on the standing of the borrower.

*Project finance*

Project finance is a means of raising the funds required for a capital investment project wherein the providers of equity rely primarily on the cash flow of the project for the return on their investment, and the providers of debt for the payment of interest and repayment of the principal borrowed by the project.

Projects using the project finance route are developed by borrowing funds based on the creditworthiness of the project alone rather than of the sponsor. All project assets such as the plant hardware and the equity shareholding, would be pledged in support of the loan, as a security in the event of default. As the loan is not borrowed directly by the sponsor of the project, this transaction is not recorded on the balance sheet of the sponsor.

Sometimes, lenders may require some recourse to the sponsors, for example, in the form of guarantees. This type of limited recourse project finance has been used to finance projects involving energy generation, among others. Many renewable energy projects, however, are too small for traditional project finance. Some banks may lend to these types projects if there is a strong prospect that the sponsor will bring forward more similar projects.

The banks place more stringent criteria for lending on a project finance basis. This imposes heavy requirements and contractual implications upon the developers of the projects. Some of these implications are:

- Longer time required to arrange and are more expensive to establish than conventional corporate loans

- Strict requirements for due-diligence as well as for legal and technical assessments
- High compliance expected for administration and reporting requirements
- Involves complex legal documentation and contractual arrangements

Despite the above constraints, for many developers, the benefits of using project finance outweigh the disadvantages. The contractual arrangements implicit in project finance effectively transfer many of the risks away from the developer to those better able to manage and control them. Although the up-front expense is greater for the project finance, the overall cost of finance may be lower. Two things mainly contribute to this: the high gearing attained by a project, with some debt finance meeting up to 85% of the capital cost, and debt is cheaper to service than equity (as interest payments are tax deductible). The lower cost of capital, coupled with the fact that projects are often developed by joint venture companies which are anxious to avoid balance sheet treatment of a project loan for non-core business, means that limited recourse finance is often the preferred route.

Experience in the implementation of small-scale renewable energy projects in the region shows that using the project finance route for these types of projects is difficult, if not impossible, to arrange.

*Self-financing*

Self-financing means that the company uses its own internal funds to finance the investment. Usually, this will come from the retained earnings or from existing cash reserves. Where a project is being developed by individuals or a small or new company without reserves, it may be necessary to raise funds from private entities/individuals, either to provide equity or to fund the whole project. This may be in the form of 'cash', unsecured or secured loans (mortgage) from friends, associates and/or local banks/building societies.

Since the cost of equity is normally higher than the cost of debt, self-financing is not the most efficient route to finance a project, except for some circumstances where it is not attractive to leverage the project, or when the project is small enough for the company to pay for the whole project cost from its own funds.

#### 4.3.3.2 Other Financing Options

In order to facilitate financing of renewable energy projects, a number of innovative financing mechanisms have become available. Several of these approaches are being used to improve affordability, such as:

- Offer of long-term credit so monthly payments are not higher than current energy expenditures, either through third-party commercial credit, dealer credit, or micro-financing
- Provision of "first-cost subsidies" to reduce initial consumer payments
- Offer of energy services on a fee-for-service basis (energy-services business)
- Sale of smaller-size systems initially and provide trade-in or resale mechanisms for consumers to "trade up" to more expensive systems
- Change in trade policies to reduce import duties on certain components such as PV systems

Some of the more common existing financing mechanisms that are used in the ASEAN region to help promote investments in small-scale projects are presented below:

*Grants*

Some projects can not attain commercially viability, and have to be offered fixed cash grants in order for them to be implemented. Grants are appropriate for demonstrating technologies that are still too expensive for commercial dissemination, or for projects that have "missionary" intentions, such as to provide electricity to remote rural areas. However, they do not often lead to sustainable financing solutions. Thus, some innovations in the giving of grants have been introduced. An example is the provision of declining cash grants which allows a decreasing scale over the life of the project.

*Risk Capital*

From the early stage of the development of the RE projects, the developer starts spending money to develop the project. A risk capital to fund this stage of the project development could be sourced from venture capitalists, private equity funds or strategic investors, such as equipment manufacturers. This becomes an equity investment which is then recovered later when the project becomes successful through dividends or pre-agreed exit routes.

*Mezzanine finance*

Providing a flexible structure that groups together a variety of structures positioned in the financing package between high risk/high upside equity position and the lower risk/fixed returns debt position, this innovative scheme offers opportunity to customise a package for the specific need of a project. This scheme offers a good scope for public/private funding.

*Renewable energy service companies (RESCOs) /Micro-utilities*

The RESCO concept is most suitable for small-scale renewable energy systems like PV solar home systems (SHS). Rather than sell SHS to homeowners, the RESCO sells the service that is produced by the SHS and in turn collect a monthly fee. In this approach, the RESCO is responsible for owning, operating and maintaining the SHS while the consumer is responsible only for paying for the service. This concept applies not only to SHS but to other renewable energy installations as well. This is very similar to the concept of a utility selling electricity from its power plant. By implementing a renewable energy system, a "micro-utility" is created which essentially sells energy services for a price. Financing can be aggregated to the level of the "service provider" rather than the end-user and can be more easily appraised and managed. The end-user is relieved of the operation and maintenance responsibilities of the renewable energy systems which remain with the energy service provider. The end-user's responsibility is to make monthly payments based on the level of energy services received.

*First-cost-subsidies and lower import duties*

First-cost subsidies are incorporated into projects to reduce household monthly payments for a renewable energy system such as a solar home system (SHS). The aim is to make the monthly payments of the households to the new system as close as possible to current monthly payments for energy. First-cost subsidies are generally related to the difference between the life-cycle costs of the SHS and the costs of kerosene, candles, batteries and other fuel sources displaced by the SHS. First-cost subsidies are given on the expectation that the costs of equipment will reduce, thereby gradually eliminating the need for subsidies as the market for such equipment becomes purely commercial.

*Leasing*

The leasing concept is very similar to the RESCO approach with one key exception: the leasing companies are usually not responsible for maintaining and operating the renewable energy systems. This approach helps overcome the high first-cost barrier as it allows end-users to lease rather than purchase the renewable energy systems. As project financing is arranged by the leasing company, this can be bundled with other equipment that are not necessarily within the same project. The principal drawback is that the financial costs to the end-user could be higher due to additional costs levied by leasing companies. Moreover, the tax benefits from depreciation of equipment could accrue to the leasing company.

*Supplier's credit*

Customers of renewable energy equipment are requiring more and more the participation of suppliers in the financing of their projects. On the other hand, having recognized that providing credit to customers can help boost their sales, suppliers are now including financing schemes such as supplier credits in their offers to help close financing gaps and in the process to help secure their sales. Some of the larger suppliers have created special departments and business groups to handle this aspect and support their sales efforts. For suppliers coming from the EU, this scheme is supported and guaranteed by the Export Credit Agencies of the member states.

*Micro-credit*

Micro-credit is a financing approach in which households borrow from community-based micro-credit lenders. These micro-credit organizations, on the other hand, generally receive loans from national banks designated to provide support to the projects.

*Financial bundling*

The amount of efforts involved in appraising and processing financing requests of small projects are nearly the same as for large projects. Thus, financing institutions are often reluctant to attend to requests for the financing of small-scale projects. To achieve critical mass in the request for financing and reduce the transaction costs of processing requests for small loans, the idea whereby a number of small-scale projects may be bundled into one single financial package for submission to the financial institutions has been put forward. This financing technique allows small projects related to energy efficiency, renewable energy and greenhouse gas abatement to access large financial institutions. Although the technique sounds good in theory, it still has to be proven that it works well in practice.

The table below summarizes the possible financing mechanisms relevant to energy efficiency, renewable energy projects and greenhouse gas abatement projects and their applicability to the different size ranges of the projects.

*Table 4-12: Ranges of Projects and Possible Financing Mechanisms*

| System | Scope | Financing mechanisms/schemes |
|---|---|---|
| Small-Scale/ Off-Grid | ▪ Solar photovoltaic home systems<br>▪ Small windpower systems and hybrid solar/wind/diesel systems that have no associated distribution network<br>▪ Pico- and micro-hydropower<br>▪ Size is < 1 MW | Should develop innovative financial mechanisms to cascade affordable financing to the end-users, and seek assistance for institutional, infrastructure and capacity building. Applicable schemes include:<br>▪ Self-financing<br>▪ On-balance sheet<br>▪ Micro-credit<br>▪ Grant/subsidy<br>▪ RESCO/ESCO<br>▪ Leasing<br>▪ First-cost subsidies and lower import duties<br>▪ Supplier's credit<br>▪ Dealer's credit<br>▪ Financial bundling |
| Medium-Scale/ Isolated-Grid/ Grid-Connected | ▪ Mini- hydropower<br>▪ Biomass gasifiers and co-generation systems<br>▪ Wind/diesel/solar hybrids and other medium-scale renewable energy systems in the range of 1-15 MW | Should use innovative mechanisms, while exploiting the benefits of financing schemes applied to conventional energy. Applicable schemes include:<br>▪ On-balance sheet<br>▪ Equity financing<br>▪ Venture capital<br>▪ Project finance (limited recourse)<br>▪ Corporate guarantee<br>▪ Grant/subsidy<br>▪ RESCO/ESCO<br>▪ Leasing<br>▪ Supplier's credit<br>▪ Financial bundling |
| Large-Scale/ Grid Connected | ▪ all renewable energy systems with capacity greater than 15 MW | Should operate within the same financing rules applied to conventional energy projects. Applicable schemes include:<br>▪ Project finance (limited/non-recourse)<br>▪ Venture capital<br>▪ Multilateral agency lending<br>▪ Export Credit Agencies<br>▪ Political risk guarantee<br>▪ Bonds issuance<br>▪ Supplier's credit |

Source: Gonzales, A.D. (2001).

### 4.3.4 Examples of successfully financed projects in ASEAN

#### 4.3.4.1 Roi-Et Green: 8.8 MW Rice Husk-Fired Power Project

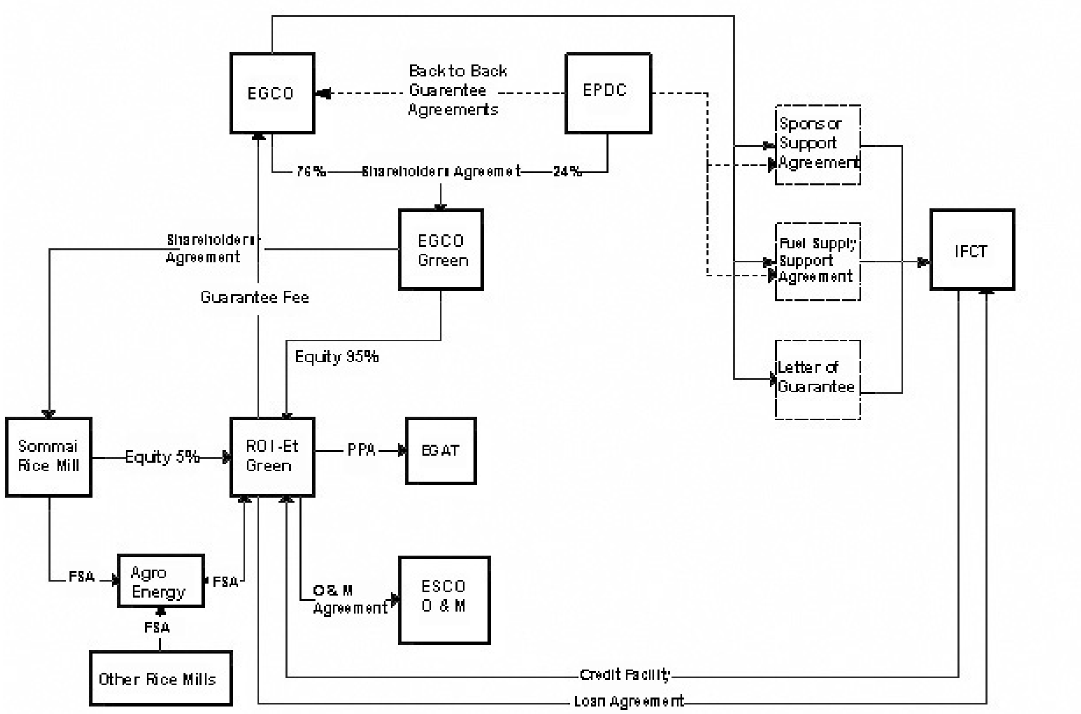
*Project Description*

Roi-Et -ET Green is a special purpose company which was set up to implement a power plant using rise husk as a fuel to generate power. The plant is located adjacent to Sommai Rice Mill in Roi-Et province, Northern Thailand. Roi-Et is well suited for the project as rice is widely cultivated in this region.

The net power output of the project, which is sold to the Electricity Generating Authority of Thailand (EGAT), is 8.8 MW. Around 300 tons/day of rice husk is used to fuel up the power plant. This is supplied by Sommai Rice Mill and entirely comes from its own milling operations. The Sommai Rice Mill group generates around 630 tones of rice husk per day. Under its Power Purchase Agreement (PPA) signed within the framework of the Small Power Producers (SPP) program of the Thai government, Roi-Et Green holds a "firm" contract with EGAT for the sale of electricity for a duration of 21 years. The electricity tariff has two components: the energy payment which is indexed to heavy fuel oil, and the capacity charge which is indexed to the Yen exchange rate.

Sommai Rice Mill holds 5% stake in the project, while EGCO Green holds the remaining 95%. EGCO Green is 26% owned by EPDC, a Japanese wholesale electricity utility, and the remaining 74% is owned by the Electricity Generating Public Company (EGCO), the first Independent Power Producer (IPP) in Thailand. The structure of the Roi-Et Green project is given below.

*Figure 4-8: Project Structure of Roi-Et Green*




### *Project Cost and Financing*

The total project cost is THB 600 million (USD 13.64 million). The equity is provided by Roi-Et Green at 30% of the total project cost or an equivalent of THB 180 million (USD 4.1 million). The loan portion, which covers 70% of the project cost, and is denominated in Yen for an equivalent of JPY 1,300 million (USD 9.54 million), was lent by the Industrial Finance Corporation of Thailand (IFCT). The tenure of the loan is for the period of twelve (12) years with two years of grace period.. The lending cost of the loan is set at 4-5 percent per annum. In order to secure the repayment of loan, IFCT required EGCO to provide the following:

- Sponsor support during the construction period
- Fuel supply support
- Letter of guarantee for the whole portion of the loan

The above sponsor guarantees gives IFCT full recourse to the sponsor in the event of default by the project.

The following table give the summary of the financial aspects of this project.

| | |
|---|---|
| Total Project Cost : | THB 600 million |
| Shareholders' Equity:<br>Loan: | THB 180 million (30%)<br>Yen 1,300 million (70%)<br>(THB 420 million) |
| Interest rate: | 4 - 5% p.a. |
| Maturity: | 12 years |
| Grace Period: | 2 years |

*Summary of the Project Details*

| | |
|---|---|
| Owner/Developer: | Roi-Et Green Co., Ltd. |
| Industry: | Rice |
| Location: | Roi-Et, Thailand |
| Equipment: | Steam thermal power plant |
| Fuel: | Rice husk |
| Project status: | Under construction |
| Expected COD: | April 2003 |
| Electrical output (gross): | - |
| Electrical output (net): | 8.8 MW |
| Power off-take: | Electricity Generation Authority of Thailand (EGAT) |
| GHG mitigation potential: | 56,000 tons of $CO_2$ eq./year |

#### 4.3.4.2 Renewable Energy Financing in the Philippines: North Wind (north Wind) Bangui Bay Project.

*Project Description*

North Wind built in Bangui, Ilocos Norte in Luzon, Philippines consists of a 25 MW capacity wind power project that will generate annual power production of 80.23 GWh. North Wind had signed an Electricity Sales Agreement with Ilocos Norte Electric Cooperative (INEC) wherein INEC will purchase all the generated energy by North Wind. The project developer is North Wind Power Development Corporation, a private company whose sponsors include the Danish International Development Agency (DANIDA). North Wind is the first renewable energy project in ASEAN to sign a greenhouse emission purchase agreement (ERPA) under the Clean Development Mechanism (CDM) of the Kyoto Protocol. The project cost is USD 35.0 million, of which 90% is financed by debt.

Wind power is one of the most promising renewable energy technologies in the Philippines. It is projected to be a major source of renewable energy that will compete with other sources such as coal, bunker, natural gas, geothermal and hydro.

*Project Cost and Financing*

The development of the wind farm costs US$45.8 Million, plus another US$2.2 Million for the 57km 69kV transmission line. The financial mix used for financing the wind farm was 61% loan, 23% grant and 16% equity. The loan was taken from two Danish Banks with DANIDA buying down the interest to 0%, and guaranteed by the Phil EXIM bank. The loan term is 10 years with 2 years grace period on principal payment. The 23% is DANIDA's grant. The remaining 16% is the equity of North Wind with infused capital from its Danish partners.

DANIDA belongs to Denmark's Ministry of Foreign Affairs. DANIDA has an allocated budget from the Danish government to finance "socially acceptable projects". The granting of subsidized credits tied to purchases in donor countries is regulated by the OECD Consensus Agreement on Export Credits.

DANIDA performed the due diligence in coordination with the Danish banks. The loan of USD 29.35 million is 50% tied to the purchase of turbines manufactured in Denmark and covered by Eksport Kredit Fonden (KEF) for extraordinary risks such as political and commercial risks, not normally covered by private credit insurance.

With an average projected energy production of 74.48TWH per year at a selling price of P4.24/kWh, Northwind expects a gross annual revenue of around P315.8M or $5.54M. With an operation and maintenance cost of 6%, the $29.35M loan can be paid up within six to eight years after the two-year grace period.

### 4.3.5 Sources of financing in Cambodia

#### 4.3.5.1 Commercial Banks

Although the capital market in Cambodia is not very well developed, there are several banks, both foreign and local, which could be tapped as sources of commercial loans for renewable energy projects. These banks offer loans in the local currency, in major currencies such as US dollars or Euro, and for foreign banks, in currencies of the country they are based in. For instance, KrungThai Bank, which is a subsidiary of a Thai bank by the same name, provides loans in Thai Baht if preferred by the customer.

A major difficulty faced by developers in the financing of energy projects is the high cost of borrowing. The interest rates are between 15 to 20 %, and for corporate loans, collaterals are required for up to 300 % of the loan amount. Moreover, the processing of the loan could take a long time to get approval, which could last up to one year from the application to financial close.

#### 4.3.5.2 Rural Electrification Fund (REF)

The REF which is part of the initiatives under the World Bank/Royal Government of Cambodia joint project on Renewable Electricity Promotion Project/Renewable Energy Action Plan has been briefly discussed in the previous section. The REF is also an important component of the government development policy to reduce poverty of the Cambodian population. Its objectives are to promote equitable rural electrification coverage and the exploitation of technically and commercially proven energies, and of new and renewable energy technologies in rural areas. A Royal Decree and Sub-Decree govern the creation and operation of the fund, both of which are under examination at the Ministry of Industry, Mines and Energy (MIME).

The REF shall be established as an autonomous state agency. Its funds will come from two sources:

a) A levy approved by the Parliament on the power transmission business and/or on the power supply business in the city or on electricity consumption.

b) Donations, gifts, grants and loans.

Its obtained resources shall be used to co-finance on a grant basis the implementation of projects consistent with its objectives, such as:

- providing general support activities for the preparation and implementation of rural electrification projects;
- providing private sector and local community investments in rural electrification projects; and
- promoting commercialisation of well proven, technically and commercially, of new and renewable energy technologies.

REF has a Board, which is responsible for the administration of the Fund. The Board has nine members: 4 from the government and 5 from representatives of NGO and of Associations of donors, bankers, Rural Electricity Enterprises, and local rural communities.

Its day-to-day operations are assured by the REF Secretariat, which is under the Board’s supervision.

As of today, the REF has been approved and funds are available. However, the setting up of the modalities for accessing, disbursements and operation of the funds are currently being formulated.

# 5 Policy Analysis and Recommendations

Cambodia is endowed with significant renewable energy resources. The exploitation of these resources provides various benefits to the country such as enhanced energy security, increased access to electricity services and improved living conditions in rural areas, protection of local and global environment, and promotion of sustainable energy development.

The main focus of the present energy policy of the Government of Cambodia is to provide energy services and improve the living conditions of the rural population. This is reflected in the Energy Sector Development Policy and Rural Electrification Policy. In energy sector and rural electrification strategies, the government adopted various approaches in meeting the above objectives including the development of renewable energies. While the government recognizes the importance of renewable energies, there is no specific policy devoted to the development of renewable energies. A renewable energy-based rural electrification policy and strategy had been put forward but the government has not officially adopted the proposed policy and strategy. This may however change when the current Master Plan Study for Renewable Energy-based Rural Electrification will be completed. The main lesson that could be learned from the European and other developing countries´ experience is that these countries have introduced policies and strategies that enhance the development of renewable energies.

At present the government relied on two main policy instruments to stimulate investment on renewable energies, and these are investment incentives and rural electrification fund (REF) subsidy. REF has just been recently introduced thus it is too early to assess its effectiveness in stimulating private investments on renewable energies. Some of the key policy instruments introduced in many European countries are however not applicable in Cambodia given the status of electricity market, energy sector institutional framework, and human capacities. The summary of policies and instruments in Cambodia is shown in Table 5-1.

REF subsidy is for rural electrification and not for general renewable energy development *per se*. REF documents specify that only the solar home systems and mini/micro hydropower development may qualify for subsidies. It is uncertain whether the projects identified in this study - gasifier fueled by corn cobs, rice husk power generation and biogas - can benefit from REF.

*Table 5-1: Summary of Policies and Instruments*

**Policies**

- Energy Sector Development Policy and Strategy
- Rural Electrification Policy and Strategy
- Renewable Energy Action Plan

**Instruments**

- Investment incentives
- REF Subsidy

The electricity generated from renewable energies remains relatively high compared with those produced using conventional fuels, and it needs a kind support to make it attractive and competitive. Various options exist for the Cambodian government to reduce the cost of generating power from renewable energies (Table 5-2) . The Government can target the following:

- Cost of investments
- Price of output
- Operating costs, and
- Combination of the above options

*Table 5-2: Subsidy Options for Renewable Energies*

| | **Subsidy Targets** | | |
|---|---|---|---|
| | Cost of investment | Price of Output | Operating costs |
| Public budget finance instruments | • Direct capital subsidies<br>• Soft loans<br>• VAT exemption<br>• Import duty exemption<br>• Accelerated depreciation<br>• Tax holidays on income<br>• Subsidies to exporters of RET | • Topping-up premiums to producers<br>• Production tax credit<br>• Topping-up premiums to consumers<br>• VAT exercise duty exemptions<br>• Public green electricity purchases | • Subsidies to the marketing of green electricity |
| Electricity invoiced financed instruments | • Grid reinforcement (deep connection costs) paid by utilities<br>• Part of (shallow) connection costs paid by utilities<br>• R&D of power utilities on inter-faces between wind parks & regional and/or national power system | • Premium feed-in-tariffs for RET-electricity<br>• Renewable portfolio standards with or without RECs<br>• Eco-taxes on alternative fuels<br>• Voluntary green consumer premium tariffs | • Wheeling tariff below the true opportunity cost of utility<br>• Balancing costs charged to consumers not to generators<br>• Use-of-system charges fixed below cost<br>• Subsidised administration of green invoicing |
| Subsidized export credits to RETs | • Soft loans for RE-investments<br>• Grants for project preparation | | |
| Greenhouse gas payments | | • CO² certificate<br>• CER/ERUs revenue per KWh | |

These subsidies on the other hand can be financed by the following:

- Public budget
- Electricity invoices
- Export credits for RETs, soft loans from development banks, and grants for project preparation
- Payments from greenhouse gas emissions reductions

The government can introduce appropriate policy instruments in the future as the market and institutions mature, and human capacities are strengthened.

The government of Cambodia has in the past years established the necessary legal and regulatory frameworks and procedures for energy sector development and rural electrification (Table 5-3). These created an enabling environment and removed some of the major barriers to energy sector development including renewable energies. The Government´s participation in the international framework to prevent global climate change through the Clean Development Mechanism (CDM) and the establishment of CDM´s institutional and regulatory frameworks have resulted an additional incentive to private investments on renewable energies.

*Table 5-3: Summary of Legal and Regulatory Procedures*

**Legal Framework**

- Electricity law
- Environmental laws
- Investment law
- CDM Directive

**Regulatory Procedures**

- Licensing
- Power purchase agreements
- Environmental permits and assessment
- REF subsidy approval procedures
- Investment incentives approval procedures
- CDM approval procedures

The current institutional frameworks promote enhanced development of rural electricity markets including renewable energies. On the other hand, the government could optimize the benefits that can be derived from renewable energy development by establishing specific frameworks for renewable energies such as renewable energy law, policy and strategies.

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# 7 Annexes

*Table 7-1: EU Manufacturers for Small Hydro Power*

| Manufacturer | Country | Website |
|---|---|---|
| **ALSTOM Hydro** | France/UK | http://www.hydro.power.alstom.com |
| **Andritz** | Austria | http://www.andritz.com |
| **Ansaldo** | Italy | http://www.ansaldoenergia.com/ |
| **Cargo & Kraft** | Sweden | http://www.cargo-kraft.se/ |
| **CKD Blansko Engineering** | Czech Republic | http://www.cbeng.cz/ |
| **ESAC Energie** | France | http://www.esac-sa.com |
| **Franco Tossi Meccanica** | Italy | http://www.francotosimeccanica.it/ |
| **Gajek Engineering sp. Z.o.o** | Poland | http://www.geg.pl/ |
| **Ganz Energetics Co Ltd** | Hungary | http://www.ganz-holding.hu/enindex.htm |
| **Geppert** | Austria | http://www.geppert.at |
| **Gilbert. Gilkes & Gordon** | UK | http://www.gilkes.com/ |
| **Gugler** | United Kingdom | http://www.gugler.com/ |
| **Hydrohrom** | Czech Republic | http://www.hydrohrom.cz/ |
| **IREM** | Italy | http://www.irem.it/ |
| **Litostroj EI** | Slovenia | http://www.litostroj-ei.si |
| **Koessler** | Austria | http://www.koessler.com/ |
| **Mavel** | Czech Republic | http://www.mavel.cz/ |
| **Mecamidi** | France | http://www.mecamidi.com |
| **Moller Undenas** | Norway | http://www.moller-energi.no/ |
| **Newmills Hydro /** | United Kingdom | http://www.newmillshydro.com/ |
| **Orengine** | Italy | http://www.orengine.net/ |
| **Ossberger** | Germany | http://www.ossberger.de/ |
| **Rutten (hydrauliennes)** | Belgium | rutten@skynet.be |
| **THEE** | France | Phone :+33 3-83432982 |
| **TURAB** | Sweden | http://www.turab.com/ |
| **Turbinenbau Troyer** | Italy | http://www.troyer.it/ |
| **VA Tech** | Austria | http://www.vatech-hydro.at |
| **Voith Siemens Hydro** | Germany | http://www.vs-hydro.com |
| **Waplans Mekaniska Verk** | Sweden | http://www.waplans.se/ |
| **Wasserkraft Volk** | Germany | http://www.wkv-ag.com/ |
| **Waterpumps Oy** | Finland | http://www.wpoy.sci.fi |
| **Wiegert and Bähr** | Germany | http://www.wiegert-baehr.de/ |
| **Willot** | Belgium | http://microhydro.bizhosting.com/JLA/ |
| **WKA Anlagenbau** | Switzerland | http://www.stellba.ch |

*Table 7-2: EU Manufacturers and Developers for Wind Power*

| Manufacturer | Country | Website |
|---|---|---|
| **Bonus** | Denmark | http://www.powergeneration.siemens.com/en/windpower/product |
| **Enercon** | Germany | http://www.enercon.de |
| **Fuhrländer** | Germany | http://www.fuhrlaender.de/start.php |
| **Gamesa** | Spain | http://www.gamesa.es/gamesa/index.html |
| **Lagerwey** | The Netherlands | http://www.lagerwey.nl |
| **Made** | Spain | http://www.made.es |
| **NEG Micon / Vestas** | Denmark | http://www.vestas.com/uk/Home/index.asp |
| **Nordex** | Germany | http://www.nordex-online.com |
| **Repower** | Germany | http://www.repower.de |
| **Wind farm developers** | **Country** | **Website** |
| **ABEnergy** | UK | http://www.abenergyuk.com |
| **Airtricity** | Ireland | http://www.airtricity.com |
| **Alpha Wind Energy** | Denmark | http://www.alphawind.dk |
| **Amec Wind** | UK | http://www.amec.com/wind/index.asp?pageid=8000 |
| **Anglesey Wind & Energy** | UK | http://www.anglesey-wind.co.uk |
| **B9 Energy** | UK | http://www.b9energy.co.uk |
| **ECO2** | UK | http://www.eco2.uk.com |
| **EcoGen** | UK | http://www.ecogen.co.uk |
| **EnergieKontor** | Germany | http://www.energiekontor.com |
| **Eole-Res** | France | http://www.eoleres.com |
| **E.ON** | UK | http://www.eon-uk.com |
| **Energia Hidroelectrica de Navarra** | Spain | http://www.ehn.es |
| **Falck Renewables** | UK | http://www.wind4energy.co.uk |
| **Garrad Hassan** | UK | http://www.garradhassan.com |
| **InnoVent** | France | http://www.innovent.fr/Internet |
| **National Wind Power** | UK | http://www.natwindpower.co.uk/homepage/index.asp |
| **Natural Power** | UK | http://www.naturalpower.com |
| **ReSoft** | UK | http://www.resoft.co.uk |
| **SIIF** | Portugal | http://www.siif-energies.fr |
| **The Clean Energy Company** | UK | http://www.cleane.com |
| **Voltwerk** | Germany | http://www.voltwerk.de |
| **Westwind** | Ireland | http://www.westwind.ie |
| **Windkraft Nord** | Germany | http://www.windkraftnord.com |

*Table 7-3: EU Manufacturers for Solar PV*

| Manufacturer | Country | Main products | Website/Tel. |
|---|---|---|---|
| **Abraso** | Spain | PV modules with integrated solar water heater | www.abraso.com |
| **Air Therm Solar Technik** | Germany | PV Modules, PV Systems, battery charge controllers, solar boats, solar heating | www.CleanEnergy.de/companies/airtherm |
| **Aixcon Elektrotechnik** | Germany | DC to AC power inverters for grid-connected and stand-alone PV systems, PV systems, PV modules, solar water heating system components. | www.aixcon.de |
| **Aleo Solar** | Germany | PV modules, solar electric power systems | www.aleo-solar.de |
| **Alten** | Italy | PV modules, solar panels, energy efficient lighting, solar garden lights, ballast for neon lamps, voltage regulators, battery charge controllers, LCD volt-ammeters, meters and monitoring equipment, solar water pumping systems, hybrid renewable energy systems (wind and PV). | alten@tin.it |
| **Ampliflaire** | UK | solar air heating, solar water heating, PV modules | http://www.ampliflaire.co.uk |
| **Atersa** | Spain | PV modules, complete BOS, PV module mounting systems, PV turn-key systems | www.atersa.com |
| **Dansk Soltec** | Denmark | PV cells, PV modules | http://www.dansksoltec.dk |
| **Denmark Solar Industry** | Denmark | PV modules, PV cells, solar water pumping systems, solar roofing systems | http://www.dsindustry.biz |
| **Droben s.a.** | Belgium | PV systems, PV modules | www.droben.com |
| **Dunasolar Photovoltaic** | Hungary | PV modules, transparent modules, roof constructions, power plants (1.5 MW), relocable small solar power systems (2.58 kW), family houses (2.58 kW) | http://www.Dunasolar.com |
| **Energy Solutions s.a.** | Bulgaria | PV modules | +359-88-7349053 |
| **Ersol Solar Energy** | Germany | high power crystalline solar cells | http://www.ersol.de |
| **Eurosolare** | Italy | PV modules, monocrystalline and polycrystalline PV cells, PV systems | http://www.eurosolare.it |
| **Filsol Ltd** | UK | solar water heating components & systems, solar pool heating systems, PV modules, Solar Powered Conservatory Ventilator | www.filsol.co.uk |
| **Fitcraft Production s.r.o.** | Czech Republic | PV panels, Cutting process of solar ingots, Solar lights | www.fitcraft.cz |
| **Free Energy Europe** | The Netherlands | thin-film amorphous PV modules | www.free-energy.net |
| **Gällivare PhotoVoltaic** | Sweden | PV modules | www.gpv-solar.com |
| **GB Sol** | UK | PV modules | www.gb-sol.co.uk |
| **GiraSolar** | The Netherlands | PV cells, PV module components, PV module mounting systems, PV modules, PV systems | http://www.girasolar.com |
| **Helios Technology** | Italy | PV modules, PV cells, PV systems, DC to AC power inverters, battery charge controllers, solar water pumping systems. | www.heliostechnology.com |
| **IBC Solar** | Germany | PV modules, PV systems, system components (charge regulators, inverters, batteries) | http://www.ibc-solar.de |
| **Il Portale del Sole** | Italy | PV modules, battery chargers, PV systems | www.ilportaledelsole.it |
| **Inersol** | Spain | PV systems, hybrid power systems, DC lighting | www.inersol.com |
| **Isofoton** | Spain | Energy solutions and projects based on photovoltaic and thermal energies | www.isofoton.com |
| **Istar Solar** | Italy | PV modules from 10Wp to 200Wp, photovoltaic systems, energy efficient lighting, battery charge controllers, solar water pumping systems, DC to AC power inverters | www.istarsolar.com |
| **J.H. Roerden CIA y s.a.** | Spain | PV modules, regulators, inverters, accessories, solar energy products | roerden@jhroerden.com |

| Manufacturer | Country | Main products | Website/Tel. |
|---|---|---|---|
| **Kyocera Europe** | Germany | PV modules, solar panels, solar water heating systems | http://www.kyocera-europe.com |
| **Kyocera Fineceramics** | Germany | PV cells, PV modules, PV systems, remote home power systems, solar electric power systems, water pumps, telecommunication power systems | www.kyocerasolar.de |
| **Logic Electronics** | The Nether-lands | solar charge controllers, solar lighting, PV modules, PV systems | www.le.nl |
| **Naps Systems Oy** | Finland | PV systems, solar electric power systems, telecommu-nications power systems, obstruction light systems, solar roofing systems, rural electrification | www.napssystems.com |
| **OTB Engineering** | The Nether-lands | Solar cell production equipment (from wafer to finished PV cell) | www.otb.nl |
| **Photovoltech s.a.** | Belgium | PV cells, PV modules | www.photovoltech.be |
| **Photowatt Interna-tional** | France | PV cells, PV modules | http://www.photowatt.com |
| **Prosolar s.r.o.** | Czech Republic | PV modules, solar outdoor lighting systems, solar gar-den lights, solar charge controllers, mobile's solar bat-tery charger and GPS solar battery charger | http://www.prosolar.net |
| **PV Enterprise** | Sweden | PV modules, PV module mounting systems, PV module manufacturing equipment, PV module components | www.pv-enterprise.com |
| **PWS Ireland** | UK | PV modules, solar powered portable variable signs, solar powered portable changeable signs | +44 28 3026 4511 |
| **Quasar Solar Electric Company** | Ireland | PV modules, energy efficient lighting | Quasar@tinet.ie |
| **RWE Schott Solar** | Germany | thin-film amorphous PV modules, thin-film amorphous PV cells. | http://www.rweschottsolar.com |
| **Saules Energija** | Lithuania | PV modules, PV systems, portable power systems | http://www.aet.eaf.ktu.lt/se/eindex.php |
| **S.E. Project** | Italy | PV cell manufacturing equipment, PV solar modules, turn-key plants, slicing unit | www.se-project.it |
| **Siliken** | Spain | PV modules, PV module manufacturing equipment | http://www.siliken.com |
| **Solara a.g.** | Germany | PV systems, PV modules, solar electric power systems, PV cells, DC to AC power inverters, grid-tied and non-grid connected solar systems | info@solara.de |
| **Solar Cells Ltd** | Croatia | PV cells, PV modules | http://www.solar-cells.net |
| **Solarconvert** | Italy | hybrid thermal-PV solar collectors, building integration | +39 055 499678 |
| **Solar Fabrik** | Germany | PV modules, power inverters, components for PV sys-tems, solar home stations, solar powered water pump-ing and purification system | http://www.solar-fabrik.de |
| **Solarfotonica Sunlight** | Italy | PV module manufacturing equipment, PV modules, PV systems, solar garden lights | www.solarfotonica.com |
| **Solarit** | Italy | PV modules, PV module mounting systems, PV module manufacturing equipment, solar charge controllers, battery, inverter grid-connected, solar street light struc-ture. | http://www.solarit.it |
| **Solaris** | Italy | PV modules | +39 0984 937557 |
| **Solar Power Limited** | Malta | PV modules | +356 495469 |
| **Solartech s.r.o.** | Czech Republic | PV solar cells, PV solar modules, PV solar systems, solar electric power systems, solar outdoor lighting systems | www.solartech.sk |
| **SolarWatt Solar Sys-teme** | Germany | Photovoltaic modules, photovoltaic systems | http://www.solarwatt.de |
| **Solar Ways** | Spain | PV module components and mounting systems, PV modules | +34 936 350 440 |

| Manufacturer | Country | Main products | Website/Tel. |
|---|---|---|---|
| **SolarWerk** | Germany | PV modules, PV-roofing systems, integrated PV module and solar water heating panel | +49 (0) 3328 / 448 300 |
| **Solems s.a.** | France | indoor solar cells, PV modules, PV systems, radiation sensors | www.solems.com |
| **Solon a.g.** | Germany | PV modules, solar panels, PV power plants, building-integrated PV systems | http://www.solonag.com |
| **Soltech** | Belgium | PV systems, PV modules | http://www.soltech.be |
| **STC** | Germany | solar chargers for mobile phones and notebooks, solar modules 4,5W up to 120W | +49-651-4360933 |
| **Sunerg Solar Wind Energy** | Italy | PV modules, PV cells, solar pool heating systems, solar water heaters, solar water pumping systems, selective solar collectors, evacuated tube solar collectors | http://www.sunergsolar.com |
| **Sunflower Farm Ltd** | Poland | PV modules, PV cells, PV systems, deep cycle batteries, renewable energy system batteries, portable power systems | http://www.sunflowerfarm.net |
| **Suntaics Ltd** | Germany | PV systems, PV modules | http://www.suntaics.com |
| **Sunovation** | Germany | PV modules, PV systems, PV module components | http://www.sunovation.de |
| **Sunset Energietechnik** | Germany | PV modules, PV cells, solar water heating system components | www.sunset-solar.de |
| **Sunware** | Germany | PV (crystalline) modules, FOX solar charge regulators, portable power systems, solar cells laser cutting, cell tabbing & cell stringing, development and sale of lasers, laminators & fully automatic stringing machines (robots) | http://www.sunware.de |
| **TOTAL Energie** | France | PV modules, complete PV solar systems, PV water pumping systems | infos@total-energie.fr |
| **TRIMEX TESLA s.r.o.** | Czech Republic | monocrystalline and multicrystalline PV wafers, PV cells, PV modules, wire saw equipment | +42 651 60 32 45 |
| **Wagner & Co Solartechnik** | Germany | PV modules, PV systems, solar water heating systems, solar water heating system components | http://www.wagner-solartechnik.de |
| **Wuerth Solar** | Germany | Thinfilm, solar electrical modules, pure black architectural modules, solar electric power systems (grid and off-grid), sinewave inverters, PV modules, charge regulators, high voltage DC pump modules | http://www.wuerth-solar.de |

*Table 7-4: EU manufacturers of Large-Scale-Fuel Handling Equipment*

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Bano** | Manufacturer | Boilers, auxiliary systems, fuel handling | www.banoeco.com |
| **Compte** | Manufacturer | Boilers, fuel preparation and handling | compte-r.com |
| **Eurec** | Manufacturer | Fuel handling and preparation | www.eurec-technology.com |
| **Kara Energy Systems** | Manufacturer | Boilers, gasifiers, fuel preparation | www.kara.nl |
| **Lindner Recyclingtech** | Manufacturer | Fuel handling and preparation | www.lindner- |
| **Mc Burney Energy Sys-** | Service Provider | Turnkey Plants | www.mcburney.com |
| **Raumaster Oy** | Manufacturer | Fuel handling | www.raumaster.fi |
| **Saxlund International** | Manufacturer | Fuel handling | www.saxlund- |
| **Weiss** | Manufacturer | Boilers (+ HRSG), fuel handling equip- | www.weiss-as.dk/ |

*Table 7-5: EU Manufacturers of Boilers and Auxillary Equipment*

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Aalborg Industries** | Manufacturer | Boilers (+ HRSG) | www.aalborg-industries.com |
| **Aker Kvaerner Group** | Manufacturer | Boilers (+ HRSG) | www.kvaerner.com |
| **Alstom Power Uk Ltd** | Manufacturer | Turbines, steam turbines, boilers (+ HRSG) | www.power.alstom.com |
| **Austrian Energy & Environment** | Manufacturer | Boilers (+ HRSG), steam turbines | www.aee.co.at |
| **Babcock & Wilcox Volund** | Manufacturer | Boilers (+ HRSG) | www.volund.dk |
| **Babcock Borsig Power** | Manufacturer | Boilers (+ HRSG) | www.babcockborsigpower.de |
| **Bano** | Manufacturer | Boilers, auxiliary systems, fuel handling | www.banoeco.com |
| **Bay Eurokessel Gmbh** | Manufacturer | Boilers (+ HRSG) | www.bay-boiler.com |
| **Bersey Limited Company** | Manufacturer | Boilers | www.berseykazan.com |
| **Binder** | Manufacturer | Boilers (+ HRSG) | www.binder-gmbh.at |
| **Bioener Aps** | Manufacturer | Boilers (+ HRSG), turnkey plants | www.bioener.dk |
| **Bono Energia** | Manufacturer | Boilers (+ HRSG) | www.bono.it/ |
| **C.C.T.** | Manufacturer | Boilers (+ HRSG), gasifiers | www.gruppomarcegaglia.com/aziende/cct |
| **Classen Apparatebau Wiesloch Gmbh** | Manufacturer | Boilers, thermal heating systems | www.apparatebau-wiesloch.de |
| **Cmi HRSG** | Manufacturer | Boilers HRSG | www.cmi.be/utility-boilers/ |
| **Cockerill Mechanical Industries** | Manufacturer | Boilers (+ HRSG) | www.cmi.be |
| **Compte** | Manufacturer | Boilers | compte-r.com |
| **Continental Energy Systems (Habo)** | Service Provider | Flue gas cleaning, oil/gas, turnkey plants | www.lekhabo.nl |
| **Dahlman** | Manufacturer | Heaters, coolers, flue gas boilers, Recuperators | www.dahlman.nl |

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Danstoker** | Manufacturer | Boilers (+ HRSG) | www.danstoker.dk |
| **Energy Innovation** | Service Provider | Control systems, combustion system | www.energyi.com |
| **Fortum** | Manufacturer | Boilers (+ HRSG) | www.fortumengineering.com |
| **Foster Wheeler Energia Oy** | Manufacturer | Boilers (+ HRSG) | www.fwc.com |
| **Gekakonus Energie- Und Umwelttechnik Gmbh & Co. Kg** | Manufacturer | Boilers | www.siempelkamp.com |
| **Gruppo Marcegaglia - Cct** | Manufacturer | Boilers, Generators | www.cctenergy.com/ |
| **Hephaestus Boiler & Engineering Sa** | Manufacturer | Boilers (+ HRSG) | www.hephaestus.gr |
| **Innovation Steam Technologies** | Manufacturer | Boiler - Once Through Heat Recovery Steam Generators (OTSGs) | www.otsg.com |
| **Kablitz & Mitthof Gmbh** | Manufacturer | Boilers | www.kablitz.com |
| **Kara Energy Systems B.V.** | Manufacturer | Boilers, gasifiers | www.kara.nl |
| **Kraftanlagen Energie- Und Umwelttechnik** | Service Provider | Waste, boilers/HRSG, flue gas treatment | www.keu.de |
| **Loos International** | Manufacturer | Boilers (+ HRSG) | www.loos-int.com |
| **Macchi** | Manufacturer | Boilers (+ HRSG) | www.macchiboiler.it |
| **Maxxtech** | Manufacturer | Boilers (+ HRSG) | www.maxxtec.com |
| **Mc Burney Energy Systems** | Service Provider | Turnkey Plants | www.mcburney.com |
| **Mitsui Babcock Energy** | Manufacturer | Boilers | www.mitsuibabcock.com |
| **Ness** | Manufacturer | Boilers (+ HRSG), steam generators | www.ness.de |
| **Omnical** | Manufacturer | Boilers | www.omnical.de |
| **Petrokraft** | Manufacturer | Boilers (+ HRSG), combustion system | www.petrokraft.se |
| **Pillard** | Manufacturer | Boilers | www.pillard.com |
| **Raumaster Oy** | Manufacturer | Fuel handling | www.raumaster.fi |
| **Rizzi Energy Spa** | Manufacturer | Boilers (+ HRSG) | www.rizzi.com |
| **Salcon Limited** | Manufacturer | Boiler, HRSG, water and waste water treatment, refractories and insulation. | www.salcongroup.com |
| **Scam Spa** | Manufacturer | Boilers/HRSG, heat exchangers, dearators, steam system, cooling systems, pumps | www.scam-spa.it |
| **Schneider-Kessel Berlin** | Manufacturer | Boilers (+ HRSG) | www.schneider-kessel.de/schneider.htm |
| **Seghersenergy** | Manufacturer | Boilers, anaerobic biogas systems, incineration, turnkey plants | www.bettertechnology.com/solids-air |
| **Standardkessel** | Manufacturer | Boilers (+ HRSG) | www.standardkessel.de |
| **Talbott´S** | Manufacturer | Boilers | www.talbotts.co.uk |
| **Tecnical S.R.L.** | Manufacturer | Material, storage silos, transport system, fluegas cleaning system, furnaces for heat of solid | www.tecnical.net |

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| | | fuel, boilers for hot water, super-heated water, diathermal oil, steam, electric generation plants | |
| **Thorne International Boiler Services Ltd** | Manufacturer | Equipment supplier, consultant, boilers (+ HRSG) | www.tibsltd.com |
| **Tuba Turbinen - Und Anlagentechnik Gmbh** | Service Provider | Inspection, maintenance | www.tuba-turbine.com/eng.htm |
| **Vkk Standardkessel Köthen Gmbh** | Manufacturer | Boilers for steam, hot water and power generation HRSG boiler components | www.vkkstandardkessel.de |
| **Vyncke Nv** | Manufacturer | Boilers (+ HRSG) | www.vyncke.com |
| **Wärtsilä Nsd Corp** | Manufacturer | Engines | www.wartsila.com |
| **Weiss** | Manufacturer | Boilers (+ HRSG), fuel handling equipment | www.weiss-as.dk/ |
| **Wellman Robey** | Manufacturer | Boilers (+ HRSG) | www.wellmanrobey.com |

*Table 7-6: EU Manufacturers for Steam Turbine Cycle Technologies*

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Aalborg Industries** | Manufacturer | Boilers (+ HRSG) | www.aalborg-industries.com |
| **Alfa Laval** | Manufacturer | Heat exchangers, condensers, pumps, valves, tanks | www.alfalaval.com |
| **Alstom Power Uk Ltd** | Manufacturer | Turbines, steam turbines, boilers (+HRSG) | www.power.alstom.com |
| **Ansaldo Energia Spa** | Manufacturer | Gas turbine, steam turbines, generators | www.ansaldoenergia.it |
| **Austrian Energy & Environment** | Manufacturer | Boilers (+HRSG), steam turbines | www.aee.co.at |
| **B+V Industrietechnik Gmbh** | Manufacturer | Steam turbines, engines | www.bv-industrie.de |
| **Bowman Power Systems Ltd** | Manufacturer | Gas turbines, micro-turbines | www.bowmanpower.co.uk |
| **Brush Electrical Machines** | Manufacturer | Generators | www.fki-et.com |
| **Centrax Ltd** | Manufacturer | Gas turbines | www.centrax.eu.com |
| **Cmi Hrsg** | Manufacturer | Boilers (+HRSG) | www.cmi.be/utility-boilers/ |
| **Cummins Power Generation** | Manufacturer | Engines, gensets | www.cumminspower.com |
| **Danstoker** | Manufacturer | Boilers (+HRSG) | www.danstoker.dk |
| **Eagle Filters** | Manufacturer | Filters for GT air inlets | www.eaglefilter.fi |
| **Emc Ag** | Service Provider | Engineering, Management Consulting | www.emcag.com |
| **Fp Turbomachinery** | Manufacturer | Gas turbine compressor & cleaner, cooling system | 209.61.233.248 |
| **Hanwel B.V.** | Manufacturer | Steam turbines | www.hanwel.com |
| **Izar (En Bazan)** | Manufacturer | Steam turbines, engines | www.enbazan.es |
| **Kuhnle, Kopp & Kausch (KKK)** | Manufacturer | Steam turbines | www.agkkk.de |
| **Man Rollo Bv** | Manufacturer | Steam turbines, gas turbines | www.manrollo.nl |

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Man Turbo** | Manufacturer | Steam turbines, gas turbines | www.ghh-borsig.de |
| **Mtu Motoren- Und Turbinen-Union Friedrichshafen Gmbh** | Manufacturer | Engines, gensets, gas turbines | www.mtu-friedrichshafen.com |
| **Opra Optimal Radial Turbine Bv** | Manufacturer | Gas turbine | www.opraturbines.com |
| **Peter Brotherhood Ltd** | Manufacturer | Steam turbines, engines | www.peterbrotherhood.co.uk |
| **Rolls-Royce Plc(Power Generation)** | Manufacturer | Engines, gas turbines | www.rolls-royce.com |
| **Scam Spa** | Manufacturer | Boilers/HRSG, heat exchangers, deaerators, steam system, cooling systems, pumps | www.scam-spa.it |
| **Siemens Power Generation** | Manufacturer | Turnkey Power Plants Power Plant Components | http://www.powergeneration.siemens.com/en/index.cfm |
| **Skoda Energo** | All | Turbine halls turbine islands turbosets steam turbines modernizations retrofits consultancy | www.skoda.cz/energo |
| **Standardkessel** | Manufacturer | Boilers (+HRSG) | www.standardkessel.de |
| **The Turbo Genset Company** | Manufacturer | Turbo Genset, design and manufacture a range of innovative products for distributed generation, cogeneration and power quality applications | www.turbogenset.com |
| **Thorne International Boiler Services Ltd** | Manufacturer | Equipment supplier, consultant, boilers (+HRSG) | www.tibsltd.com |
| **Tuba Turbinen - Und Anlagentechnik Gmbh** | Service Provider | Inspection, maintenance | www.tuba-turbine.com/eng.htm |
| **Turbec Ab** | Manufacturer | Gas turbines, micro-turbines | www.turbec.com |
| **Turboden** | Manufacturer | Turbines ORC | www.turboden.com |
| **Turbomeca** | Manufacturer | Gas turbines | www.turbomeca.fr |
| **Tuthill Nadrowski Turbinen Gmbh** | Manufacturer | Steam turbines | energy.tuthill.com/Steam_Turbines/Nadrowski.html |
| **Verdesis S.A.** | Manufacturer | Microturbines, siloxanes removal, CO2 removal, H2S removal, biogas, landfill gas | www.verdesis.net |
| **Volvo Aero Corp** | Manufacturer | Gas turbines | www.volvo.com |
| **Vyncke N.V.** | Manufacturer | Boilers (+ HRSG) | www.vyncke.com |
| **Wellman Robey** | Manufacturer | Boilers (+HRSG) | www.wellmanrobey.com |

*Table 7-7: EU Manufacturers of Biomass Fired ORC Equipments*

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Aalborg Industries** | Manufacturer | Thermal oil boiler | www.aalborg-industries.com |
| **Bay Eurokessel GmbH** | Manufacturer | Thermal oil boiler | www.bay-boiler.com |
| **Bono Energia** | Manufacturer | Thermal oil boiler | www.bono.it/ |
| **Turboden** | Manufacturer | Package for Biomass fired OCD | www.turboden.com |

*Table 7-8: EU Manufacturers of Steam Piston Engines*

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Spilling** | Manufacturer | Steam engines | http://www.spilling.de/uk/index-spillingwerk.htm |

*Table 7-9: EU Manufacturers and Service Providers for Biomethanation and Biogas Utilization (engines, gas boilers, biomethanation plants)*

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **AALBORG INDUSTRIES** | Manufacturer | Boilers (+ HRSG) | www.aalborg-industries.com |
| **AAT Gmbh & Co** | Manufacturer | Gas cleaning | www.aat-corp.com |
| **ABB Oy, Plant Automation – Utilities** | Service Provider | Turnkey solutions, Consulting, Maintenance and repair | www.abb.com |
| **ABZ AGGREGATA-BAU** | Manufacturer | Engines, gensets | www.abz-aggregate-bau.de |
| **ARCADIS HEIDEMIJ REALISTATE BV** | Service provider | Engineering, infrastructure, waste treatment, environment, facilities | www.arcadis.nl |
| **B+V INDUSTRIETECHNIK GMBH** | Manufacturer | Steam turbines, engines | www.bv-industrie.de |
| **Babcock & Wilcox Vølund ApS** | Manufacturer | Biomass and waste-to-energy technology supplier for power generating plants based on a wide spectrum of fuels. | www.volund.dk |
| **BABCOCK BORSIG POWER** | Manufacturer | Boilers (+ HRSG) | www.babcockborsigpower.de |
| **BEAVER POWER** | Manufacturer | Engines, gensets | www.beaverpower.co.uk |
| **BIOSCAN A/S** | Service provider | Organic waste treatment | www.bioscan.dk |
| **BROADCROWN LTD** | Manufacturer | Engines, gensets | www.broadcrown.co.uk |
| **BTA gmbh & Co** | Manufacturer | Biomethanation plants | www.bta-technologie.de |
| **Burmeister & Wain Scandinavian Contractor A/S** | Service Provider | Engineering, installation of diesel engine power plant | www.bwsc.dk |
| **CITEC INTERNATIONAL LTD OY** | Service provider | Engineering, environment, biofuels | www.citec.fi |
| **CLARKE GROUP** | Service Provider | Turnkey biogas plants | www.clarke-energy.com |
| **Cobra** | Service Provider | EPC, consultant, services | www.grupocobra.com/indexframe.html |
| **Continental Energy Systems (HABO)** | Service Provider | Flue gas cleaning, oil/gas, turnkey plants | www.lekhabo.nl |
| **CUMMINS POWER GENERATION** | Manufacturer | Engines, gensets | www.cumminspower.com |
| **DANSTOKER** | Manufacturer | Boilers (+ HRSG) | www.danstoker.dk |

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **DEUTZ AG** | Manufacturer | Engines, decentralized power plant, renewable energy | http://www.deutz.de |
| **DRANCO ORGANIC WASTE SYSTEM** | Manufacturer | Biomethanation plants, organic waste treatment | www.ows.be |
| **DSD INDUSTRIEANLAGEN GMBH** | Service Provider | Engineering and construction | www.dsd-steel.com |
| **E. VAN WINGEN** | Manufacturer | Engines | www.vanwingen.be |
| **EMC AG** | Service Provider | Engineering, Management Consulting | www.emcag.com |
| **ENERGY INNOVATION** | Service Provider | Control systems, combustion system | www.energyi.com |
| **FARMATIC BIOTECH ENERGY AG** | Manufacturer | Biomethanation plants | www.farmatic.com |
| **FG WILSON** | Manufacturer | Engines | www.fgwilson.com |
| **GBU mbH** | Service Provider | anaerobic biogas systems, adsorption chillers | www.gbunet.de/startseite-e.html |
| **GENERGY** | Manufacturer | Engines, gensets | www.ttgenergy.co.uk |
| **GUASCOR S.A.** | Manufacturer | Engines, gensets | www.guascor.com |
| **HAASE ENERGIETECHNIK** | Service Provider | Anaerobic biogas systems, turnkey plants | www.haase-energietechnik.de |
| **HEPHAESTUS BOILER & ENGINEERING SA** | Manufacturer | Boilers (+ HRSG) | www.hephaestus.gr |
| **INTERPOWER INTERNATIONAL** | Manufacturer | Engines, gensets | www.interpower.co.uk |
| **ISKA Gmbh** | Service provider | Waste management | www.u-plus.de |
| **IZAR (EN BAZAN)** | Manufacturer | Steam turbines, engines | www.enbazan.es |
| **JENBACHER** | Manufacturer | Engines, gensets | www.jenbacher.com |
| **KEMA POWER GENERATION** | Service Provider | Consultancy, engineering | www.kema.nl |
| **KOMPOGAS AG** | Manufacturer | Biomethanation plants | www.kompogas.ch |
| **KRAFTANLAGEN ENERGIE-UND UMWELTTECHNIK** | Service Provider | Waste, boilers/HRSG, flue gas treatment | www.keu.de |
| **KRIEG UND FISHER INGENIURE GmbH** | Service Provider | Anaerobic biogas systems, turnkey plants | www.kriegfischer.de |
| **Lurgi Energie und Entsorgung GmbH** | Service Provider | Turn-key plants, engineering | www.mg-lee.de/english/nbsp/index.html |
| **MAN ROLLO BV** | Manufacturer | Steam turbines, gas turbines | www.manrollo.nl |
| **Mc Burney Energy Systems** | Service Provider | Turnkey Plants | www.mcburney.com |

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **MDE Dezentrale Energiesysteme GmbH** | Manufacturer | Gas engines, cogeneration systems for natural gas and biogas, gensets | www.mde-online.com |
| **MICROGEN BG-GROUP** | Manufacturer | Engines, stirling | www.microgendirect.com |
| **MTU MOTOREN- UND TURBINEN-UNION FRIEDRICHSHAFEN GMBH** | Manufacturer | Engines, gensets, gas turbines | www.mtu-friedrichshafen.com |
| **NOVAENERGIE** | Service provider | Engineering, organic waste treatment | www.novaenergie.ch |
| **OBERDORFER** | Manufacturer | Engines, HRSG | www.oberdorfer.at |
| **OPRA Optimal Radial Turbine BV** | Manufacturer | Gas turbine | www.opraturbines.com |
| **Perkins Engines Company Ltd** | Manufacturer | Gas engines | www.perkins.com/ |
| **PETER BROTHERHOOD LTD** | Manufacturer | Steam turbines, engines | www.peterbrotherhood.co.uk |
| **POWERGEN - POWER TECHNOLOGY** | Service Provider | Engineering, development, construction, operation and maintenance of power plant | www.powertech.co.uk |
| **PROGRESS GROUP** | Manufacturer | Engines, gensets | www.progressplant.co.uk |
| **PUMA POWER PLANT** | Manufacturer | Engines, gensets | www.pumauk.com |
| **ROLLS-ROYCE PLC(POWER GENERATION)** | Manufacturer | Engines, gas turbines | www.rolls-royce.com |
| **SCAM SPA** | Manufacturer | Boilers/HRSG, heat exchangers, dearators, steam system, cooling systems, pumps | www.scam-spa.it |
| **SEGHERSenergy** | Manufacturer | Boilers, anaerobic biogas systems, inceneration, turnkey plants | www.bettertechnology.com/solids-air |
| **SKL MOTOR GmbH** | Manufacturer | Engines | www.skl-magdeburg.de |
| **SOKRATHERM GMBH ENERGIE- UND WÄRMETECHNIK** | Manufacturer | Engines, gensets | www.sokratherm.de/english/englischeindex.html |
| **Spark Energy** | Service Provider | EPC, equipment supplier, consultans, services, engines, gensets | www.sparkenergy.it/site/cogeneratori.htm |
| **SPILLINGWERK GMBH** | Manufacturer | Engines, steam engines | www.spilling.de |
| **STEAG encotec GmbH** | Service Provider | Engineering, operation, maintenance | /www.steag-encotec.de |
| **STEINMUELLER VALORGA** | Manufacturer | Biomethanation plants, organic waste treatment | www.steinmueler-valorga.fr |
| **SUMMERLEAZE REGENERATION** | Service Provider | Engines, biogas systems, landfill gas systems | www.summerleaze.com/regen |

| Company | Type of business | Main products/services | Website |
|---|---|---|---|
| **Tractebel Engineering** | Service Provider | Consulting Engineer, EPC, support to operation | www.engineering.tractebel.be |
| **TUBA TURBINEN – UND ANLAGENTECHNIK GMBH** | Service Provider | Inspection, maintenance | www.tuba-turbine.com/eng.htm |
| **WÄRTSILÄ NSD CORP** | Manufacturer | Engines | www.wartsila.com |
| **WEHRLE WERK AG** | Turnkey plant supplier | CHP, waste treatment, bioenergy | www.wehrle-werk.de |
| **WELLMAN ROBEY** | Manufacturer | Boilers (+ HRSG) | www.wellmanrobey.com |
| **YML** | Manufacturer | Engine, gensets | www.yorpower.com/ |