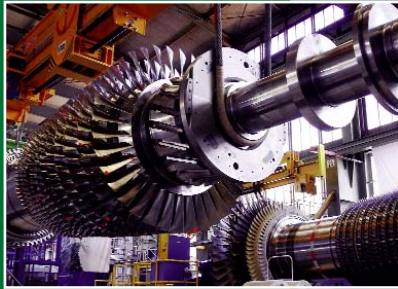


Powering 21st Century Cambodia with Decentralized Generation

A Primer for Rethinking
Cambodia's Electricity Future



The NGO Forum on Cambodia
Probe International
October 2009



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The original English and Khmer versions of this report can be downloaded from www.ngoforum.org.kh

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The NGO Forum on Cambodia

The NGO Forum on Cambodia is a network of national and international organizations working for social justice and sustainable development in Cambodia. The organization encourages debate and advocacy for citizens rights and participation in development decision making.

For more information, email: ngoforum@ngoforum.org.kh or visit www.ngoforum.org.kh



FORWARD

Rethinking Cambodia's strategy for developing its power system may seem like an odd proposal now that power is starting to flow through long-awaited transmission links with neighbouring countries and several large hydropower projects are under construction after years of stalled investment.¹ In five years' time, energy minister Ith Praing says, Cambodia will finally have enough power to meet demand.²

For most Cambodians, any new power supply is an improvement. As the *Phnom Penh Post* described the situation last year:

“Rolling blackouts plague the capital, casting whole neighbourhoods into darkness for hours at a stretch, while vast numbers of people in the countryside resort to car batteries for electricity or pay exorbitant fees for locally produced power.”³

That Cambodians need more and cheaper power supplies to improve their lives and develop their economy is not disputed here.⁴ Only 18 percent of the population is connected to an electricity grid.⁵ Rural Cambodians pay as much as 50 to 60 US cents per kilowatt-hour, which puts Cambodia's electricity prices among the world's highest.⁶

The question is how to bring electricity costs down while extending service to more people, and without destroying the country's environment. The Cambodian government and its international financiers insist the best solution is large-scale power imports *and* large-scale hydro dams linked to a national transmission system.⁷ The alternatives, they say, are worse: either too polluting (coal), too costly and hazardous (nuclear), or too unreliable and insignificant (small-scale renewables).⁸

This report challenges these assumptions and argues that Cambodia has better options for generating electricity. Recent technological advances have made it more economical and reliable to generate power on a much smaller scale, closer to where power is needed, using many smaller power plants and building-scale generating technologies. The global power industry calls this distributed or decentralized generation and it is what's reinventing the electricity business world-wide, rendering further investment in last century's giant-scale power plants obsolete.⁹



The global trend toward decentralized generation holds great promise for millions of Cambodians who languish without access to adequate or affordable electricity service or whose food security, health, and livelihoods are threatened by environmentally damaging large hydro dams and coal-fired plants.¹⁰ Decentralized generation typically includes renewable energy technologies and high-efficiency gas-fired power plants scaled to meet consumers' needs on-site or within the local distribution network. In areas with an established grid, decentralized generation can increase power supply locally without the need for transmission lines to remote power plants. In areas without a grid, decentralized generating technologies can be deployed at the household or building scale or through isolated mini-grids. Unlike large-scale power plants that require extraordinary amounts of capital and take years to build before they can deliver a single kilowatt to consumers, decentralized generating technologies can be quickly installed and delivering electricity to consumers for less cost and environmental damage.

Cambodia has a tremendous opportunity to bypass last century's generating technologies and build its economy using the best available decentralized technologies on the global market. But this window of opportunity is closing fast. With every new big hydro or coal plant deal negotiated by the Cambodian government, shifting energy policy and investment in a more sustainable direction will become more difficult.

Modernizing Cambodia's electricity system, while avoiding pressure to stick with last century's model, requires political will and public demand. We hope this report energizes both.

Chhith Sam Ath

Executive Director

The NGO Forum on Cambodia, and

Grainne Ryder

Policy Director

Probe International

Phnom Penh, October 2009



ACRONYMS AND ABBREVIATION

ADB	Asian Development Bank
BOO	Build-Own-Operate
BOT	Build-Operate-Transfer
CHP	Combined Heat and Power System
CYC	China Yunnan Corporation for International Techno- Economic Cooperation
EAC	Electricity Authority of Cambodia
EDC	Electricite du Cambodge
EGAT	Electricity Generating Authority of Thailand
EGCO	Electricity Generating Company
EVN	Electricity of Vietnam Corporation
HFO	Heavy Fuel Oil
IPO	Initial Public Offering
IPP	Independent Power Producer
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
kV	Kilovolt
kW	Kilowatt
MW	Megawatt
MIME	Ministry of Industry, Mines and Energy
NGO	Non-governmental Organization
PDP	Power Development Plan
PDR	People's Democratic Republic
RE	Renewable Energy
REAP	Renewable Electricity Action Plan
REE	Rural Electricity Enterprise
REF	Rural Electrification Fund
RGC	Royal Government of Cambodia
SHS	Solar Home System
SPP	Small Power Producer
UK	United Kingdom
UNEP	United Nations Environment Programme
US	United States
VSPP	Very Small Power Producer



EXECUTIVE SUMMARY

Cambodians need more and cheaper power supplies to improve their lives and develop their economy. The energy ministry estimates that only 13 percent of rural households have access to grid-based electricity compared to 54 percent of urban households. Where there is no grid, hundreds of small-scale rural electricity enterprises generate electricity from small diesel generators (10 to 75 kilowatt capacity) at a cost as high as 50 to 60 US cents per kilowatt-hour.

The question is how to bring electricity costs down while extending service to more people, without destroying the country's resources and rural livelihoods. The Cambodian government and its international financiers insist the best way to meet the country's electricity needs is with large-scale power imports and a string of hydro dams linked to a national transmission system. The alternatives, they say, are worse: either too polluting (coal), too costly and hazardous (nuclear), or too unreliable and insignificant (renewables). This report challenges those assumptions and argues that Cambodia has a better option: decentralized generation.

Recent technological advances have made it more economical and reliable to generate power on a much smaller scale, closer to where power is needed, using many smaller power plants and building-scale generating technologies.

Decentralized generation typically includes renewable energy technologies and high-efficiency gas-fired power plants scaled to meet consumers' needs on-site or within the local distribution network. In areas with an established grid, decentralized generation can increase power supply locally without the need for transmission lines to remote power plants. In areas without a grid, decentralized generating technologies can be deployed at the household or building scale or through isolated mini-grids.

For years, power utilities have claimed that connecting many smaller generating units to the grid would make the system unstable, difficult to manage, and prone to failure. But industry experts insist this 'truth' no longer applies: connecting multiple producers of all sizes is now



technically and economically feasible.

Recent donor-funded studies recognize that decentralized electricity systems are appropriate for rural Cambodia: dirty, high-cost fuels currently used to produce electricity can be replaced with clean sources such as solar photovoltaics, hydropower, and biomass technologies.

Flexible and high-efficiency gas-fired plants may be the best alternative for supplying urban centres and industrial customers, whereas remote villages far from town centres would benefit from off-grid solar, micro-hydropower, and biomass technologies, which are cleaner and cheaper than diesel.

The pace of deployment of renewable energy generating technologies in rural areas has not been satisfactory. Rather than enable the private sector to procure renewable energy equipment and deliver least-cost electricity services to rural households and businesses, the World Bank and the Ministry of Industry, Mines and Energy have created a new donor-dependent bureaucracy that does not have the right technical or financial capacity to deliver what consumers need, and is unaccountable to the program's intended beneficiaries: rural power consumers.

Cambodia's power development plan is outdated, focused on expansion of 1950s-era large-scale hydro dams and coal-fired plants that are capital-intensive, financially risky, and environmentally damaging. The plan excludes the following:

- More than 170 private power providers currently licensed by the Electricity Authority of Cambodia to generate and distribute power to urban and rural consumers
- Hundreds of rural electricity enterprises operating battery-charging stations that supply power to local businesses and households
- Rural businesses using agricultural waste or biofuel crops to generate their own power and sell surplus to nearby households
- Technology companies selling and installing renewable energy technologies that allow urban and rural consumers to gen-



- erate some or all of their power needs; and
- Hundreds of prospective technology suppliers world-wide with the financial and technical capacity to quickly install customized power plants and generating technologies for different types of consumers and local conditions.

Cambodia's hydro developers have agreed to sell power to the state utility, Electricite du Cambodge, for 8 US cents per kilowatt-hour or less. That may seem like a bargain but the actual costs to Cambodians will be much higher once the cost of transmission, the dams' huge environmental liabilities, and backup coal-fired plants are factored into EDC customers' electricity bills.

For countries like Cambodia, short of capital and in urgent need of new generating capacity, choosing less capital-intensive technologies that can be easily financed without the need for government guarantees and other subsidies makes more economic sense.

Where some decentralized generating technologies are still more costly per unit of output than conventional power plants (i.e., solar panels), it is their *value* – due to improved environmental quality, reductions in transmission and distribution losses, proximity to consumers, reduced requirements for reserve capacity, and grid reliability – that more than compensates for their higher initial cost per unit output.

In rural areas, decentralized generation can be better scaled to match the power needs of rural customers who may only require service for several hours during the day or evening, or may need more than that for powering a small business or factory.

With abundant biomass, hydro, solar, and natural gas, and an electricity sector that is already decentralized, Cambodia is in a unique position to accelerate investment in decentralized generating technologies, including: biomass gasifiers, gas-fired combined cycle plants, micro hydro, fuel-flexible microturbines, and solar photovoltaics.

High fuel prices and environmental concerns have prompted many governments around the world to introduce policies aimed at acceler-



ating investment in renewable energy and cogeneration, though *not* specifically decentralized generation. Cambodia can adapt this experience and modernize its power development strategy accordingly. The Cambodian government already has the legal framework for decentralized generation. The Electricity Law explicitly empowers the electricity regulatory authority (EAC) to promote competition and private ownership in electricity generation, and protect the rights of consumers to reasonably priced and reliable service.

The following policy and regulatory initiatives are recommended to accelerate decentralized generation investment, thereby rendering further investment in large hydro dams and coal-fired plants unnecessary and obsolete.

- Remove import duties on all decentralized generation technologies and equipment. (The Ministry of Economics and Finance currently imposes a 45 percent duty on imported solar equipment.)
- Introduce customer financing programs to help *all* households, businesses, and communities finance the upfront capital costs of build-scale and industrial-scale generating technologies over a 5 to 10 year period.
- Open the market to decentralized generation by announcing specific policies pertaining to the leading technologies, without a cap on the amount of power each can produce.
- Invite competitive bids for new decentralized generating capacity additions, by service territory and in low-risk increments.
- Give all power generators non-discriminatory access to local distribution grids and introduce interconnection standards that accommodate all producers.
- Provide investors and project developers with the stability and price signals they need by providing a transparent and explicit mechanism for tariff-setting and cost recovery.



- Establish explicit and transparent step-by-step procedures for would-be producers to obtain permits and public approval; and
- Make proof of community and land rights holder' approval for project siting a prerequisite to licensing by the regulatory authority.

Decentralized generation benefits

- Gives individuals, families, and communities the lighting and electrical power they need to improve their lives, grow their businesses, and connect with the world
- Replaces environmentally damaging hydro dams and coal-fired plants with cleaner alternatives
- Encourages community and local ownership, thus minimizing public opposition to power projects
- Drives the cost of mass-produced generating technologies down
- Promotes development of local technical skills
- Minimizes grid losses by producing power locally
- Reduces or eliminates the need for costly transmission lines
- Diversifies energy supply and increases energy security
- **And** lowers harmful emissions, which means cleaner air, soil, and water, and healthier, more productive citizens.

The global trend toward decentralized generation holds great promise for millions of Cambodians who languish without access to adequate or affordable electricity service or whose food security, health, and livelihoods are threatened by environmentally damaging large hydro dams and coal-fired plants.

Ultimately, Cambodia's political leaders have to choose between the interests served by last century's model of power generation and the public interest. If political leaders make the right choice, they will be rewarded with the support of their citizens, a healthier environment, and a more prosperous nation.

1.

Introduction



1. Introduction

The Cambodian government is quickly moving ahead with plans for large-scale hydropower development to meet the country's electricity needs, despite the devastating impacts this is expected to have on food security and livelihoods for millions of Cambodians.

The Ministry of Industry, Mines and Energy leads this effort with plans for 14 large hydropower dams to be in operation by 2020. Many projects are proceeding as public-private partnerships without adequate public or regulatory oversight, and without adequate mitigation or compensatory measures to help affected people.

Civil society organizations and local communities are concerned that Cambodia's dam building spree will increase poverty in rural areas, where the majority of Cambodians live. For this reason, The NGO Forum on Cambodia commissioned this report to help develop an alternative vision – one that recognizes the need to balance power supply objectives with competing demands for healthy, productive river systems, and the rights of all Cambodians to participate in decisions affecting their resources.

The underlying theme of this report is simple yet profound: Cambodia's electricity future is not limited by resources or technologies or capital or even the absence of the "right" master plan. What's needed is a bold new set of rules to democratize and decentralize the country's electricity generating business, and do away with last century's oversized and environmentally ruinous hydro and coal-fired plants.

The report has seven main parts as follows

- What is decentralized generation? The concept of decentralized generation is introduced, which is essential for understanding Cambodia's opportunity to shift away from large-scale power projects to less costly and environmentally damaging generating alternatives.
- Cambodia's electricity sector – The national policy and legal



framework, government institutions, power producers and distributors, electricity prices, power development plans, and donor-funded rural electrification plans are presented as background information.

- Rethinking Cambodia's power development strategy – The World Bank-led rural electrification program, the energy ministry's power development plan, IPP (independent power producer) risks, the hidden costs of big hydro, and big hydro's operational disadvantages are critically reviewed. A power industry perspective is then presented, showing why Cambodia's focus on central generation and transmission expansion is not only costly and inefficient, but outdated.
- A better strategy for powering 21st century Cambodia – The resources and proven technologies that could be affordably deployed on a large scale (but in small increments) to meet the country's urban and rural electricity needs are introduced: biomass gasifiers, combined cycle plants, cogeneration systems, industrial gas-fired turbines, micro hydro, microturbines, and solar photovoltaics.
- Central vs. decentralized generation – The evolution of decentralized generation from last century's model of central generation is reviewed in greater detail. Recent trends toward decentralized generation are presented.
- Promotional policies, financial incentives and common barriers – This section reviews a number of key barriers to decentralized generation, promotional policies adopted by governments to promote renewable energy in particular, and financial incentives commonly used to accelerate deployment of solar technologies elsewhere. Thailand's efforts to promote small-scale power producers and renewable energy technologies (as opposed to big-scale power plants) are assessed.
- Powering 21st century with decentralized generation – This last section outlines what policy and regulatory initiatives could be introduced to accelerate private investment in



renewable and decentralized generating technologies in Cambodia, thereby eliminating the rationale for further investment in large hydro and coal-fired plants.

We hope this report advances further discussion between the Royal Government of Cambodia and other interested parties about Cambodia's best energy options for balancing economic, social and environmental objectives.

2.

**What is Decentralized
Generation?**



2. What is Decentralized Generation?

Cambodia's best strategy for meeting the country's electricity needs is modern decentralized generation. Electric power generation is considered decentralized or "distributed" when it is produced and consumed locally via the distribution network or on the customer side of the network. There is no international consensus on a precise definition or scale for decentralized generation because the concept encompasses many different types of technologies and applications. Decentralized generation typically refers to two classes of technologies:

- **renewable energy sources**, which includes biomass, solar, and hydro, with generating capacities scaled from a few kilowatts to as much as 10 MW.¹¹ Renewable energy technologies can either be integrated into local distribution grids or as "stand alone" systems in areas where extension of transmission lines is either not economically viable or a political priority; and
- **on-site generation**, which is power production at or near the consumers not at a remote power plant. On-site generation usually refers to industrial cogeneration or combined heat and power (CHP) systems that are gas-fired. Cogeneration allows consumers to save much of the fuel and cost of generating electricity and heat by using one facility instead of a power plant to make electricity and boilers to make heat.

BOX 1: What is renewable energy?

Renewable energy is best defined as energy from natural sources – sunlight, water, wind, tides, geothermal energy, and energy from wood and agricultural byproducts – which in theory can be used over and over again without depleting the resource. Renewables located far from consumers are part of the central generation system, they are not decentralized.



Not all renewable energy projects can be considered decentralized generation either. Biomass projects and wind farms are often scaled for connection to a central transmission grid rather than local distribution.

Like all forms of power production, renewable energy projects must be carefully evaluated for its economic and environmental costs and benefits, and obliged to win approval from directly affected communities, in accordance with national laws and regulations.

Renewable energy is not always environmentally benign and publicly acceptable. In countries without enforceable property rights and the rule of law, biomass projects may encourage deforestation or illegal seizure of land by developers. Solar panel manufacturers have polluted waterways. Dams of any scale can be environmentally damaging, blocking migratory fish movements, and degrading the water resources upon which people depend. Biomass generation projects are usually cleaner than coal or oil but if not properly designed they may be more polluting than a gas turbine. Even solar and hydro cannot strictly be considered emissions-free if they rely on fossil fuel-fired or biomass-fired backup for the days or months when the wind doesn't blow, the sun doesn't shine, or the rivers and streams aren't flowing.

From 'bigger is better' to 'smaller is cheaper and more reliable'

Decentralized generation is changing the economics of power generation from “bigger is better” to “smaller is cheaper and more reliable” and that is forcing state utilities around the world to change, often reluctantly. For nearly 100 years, the idea of electric utilities as natural monopolies dominated the way electricity was produced and distributed around the world.¹² State regulation provided the necessary legal and economic framework for state utilities to build large power plants outside of urban areas and deliver electricity to urban consumers over high voltage transmission lines, then to distribution wires in the utility's exclusive service areas. Although most of the



electricity sold in developed countries still comes from large coal, nuclear, and gas power plants, the old monopoly structure is giving way to more decentralized and competitive electricity markets with multiple producers and smaller scale power plants. This trend has profound implications for countries just starting to build (or rebuild) their electricity systems for the 21st century.

Even the World Bank, a longtime financier of traditional electricity systems, is beginning to appreciate the significance of decentralized generation. In its 2007 assessment of electricity generating technologies, the Bank's energy sector management assistance program (ESMAP) team writes:

. . . choosing generation technologies and electrification arrangements is becoming a more complicated process. New technologies are becoming more economical and technologically mature, uncertainty in fuel and other inputs is creating increasing risk regarding future electricity costs, and old assumptions about economies of scale in generation may be breaking down.¹³

3.

Cambodia's Electricity Sector



3. Cambodia's Electricity Sector

Cambodia's electricity sector is a rather unique mix of aid-funded state utility expansion plus hundreds of small private power producers supplying electricity to customers in off-grid areas and through isolated distribution grids. This section provides background on the sector as currently structured, including: quick facts, a review of the electricity policy and legal framework, government institutions, power producers and distributors, electricity prices, as well as the energy ministry's power development plans and rural electrification program.

3.1 Quick Facts¹⁴

400 – 600	Number of entrepreneurs supplying power to about 60,000 rural electric customers in Cambodia, using battery charging stations ¹⁵
206 MW	Estimated peak electricity demand in Phnom Penh
180	Number of entities licensed by Cambodia's electricity regulatory authority to generate and distribute electricity
100	Kilowatt-hours consumed annually per capita
95	Percentage of power generated using diesel fuel
85	Percentage of Cambodians living in rural areas
79	Percentage of power supplied by private power companies
60	Percentage of people employed in agricultural sector
54	Percentage of urban households with access to grid-based electricity
48 MW	Capacity of largest power plant supplying Phnom Penh
40 MW	Estimated capacity shortage in Phnom Penh
30	US cents per kilowatt-hour for electricity in Kampot province in 2008 ¹⁶
18	Percentage of the population that have access to grid-based electricity
18MW	Typical daily demand in Siem Reap province
13.4	Million Cambodians, 61 percent below 24 year of age

13	Percentage of rural households with access to grid-based electricity
12 kW	Capacity of the smallest biomass generator in Cambodia
12 MW	Capacity of Cambodia's first hydro dam, Chinese-built Kirirom I, in operation since 2002
7 – 8	US cents per kilowatt-hour. Price range for power sold by big hydro and coal plant developers to state utility Electricite du Cambodge ¹⁷
<5 MW	Typical daily power demand in most Cambodian provinces
3	Number of years of consultations with private entrepreneurs, government, banks to develop Cambodia's first renewable electricity action plan, advocating a decentralized, private sector-led approach to electricity development. ¹⁸

3.2 Policy and Legal Framework

National development policy

Cambodia's national development policy (2003 to 2008) stresses the need for low-cost electricity to attract investment and reduce poverty in rural areas, where the vast majority of Cambodians live.¹⁹ The policy promotes private sector participation in electricity production and distribution, expansion of a national transmission grid that facilitates power imports from neighbouring countries, and the development of large hydro projects (See Table 1).

TABLE 1: Large-scale hydro generation projects²⁰

No.	Project Developer	Project	Province	Installed Capacity (MW)	Status	Capital Cost (US\$ million)	Price per Unit (US Cent/kWh)
1	Sinohydro Corporation (China)	Kamchay	Kampot	193.2 ²¹	U/C 2006-2010	280 ²²	8
2	China Electric Power Technology Import Export Corporation	Kirirom III	Koh Kong	18	A/C 2008-2010	47 ²³	N/A



No.	Project Developer	Project	Province	Installed Capacity (MW)	Status	Capital Cost (US\$ million)	Price per Unit (US Cent/kWh)
3	China Datang Corporation Cambodia Hydropower Development Cambodia Power Grid Company	Stung Atay	Pursat	120	U/C 2008-2012 ²⁴	199 (+133M for T/L see Table 2)	N/A
4	China National Heavy Machinery Corporation	Stung Tatay	Koh Kong	246	A/C 2008-2013	540	7.45 ²⁵
5	Michelle Corporation (China)	Lower Ruessey Chrum	Koh Kong	174 164	A/C 2008-2014	495.7	7.35 ²⁶
6	Vietnam Urban and Industrial Zone Development Investment Corporation	Bokor	Kampot	18	A/C March 08 ²⁷	25	N/A
7	China Southern Power Grid Company	Sambor	Kratie	2600 or 450	FS	N/A	N/A
8	Russian company	Stung Treng	Stung Treng	980	FS	N/A	N/A
9	China Southern Power Grid Company	Chhay Areng	Koh Kong	260	FS	200 ²⁸	N/A
10	Electricity of Vietnam Cooperation	Lower Sesan 2	Stung Treng	420	Drilling started Jan 09 Construction date 2009 /early 2010 ²⁹	662.62 ³⁰	N/A
11	Korean company	Lower Sesan 3	Rattanakiri	375	PFS	N/A	N/A
12	Electricity of Vietnam Corporation	Lower Sesan 1	Rattanakiri	90	FS	90	N/A
13	Korean company	Prek Liang 1	Rattanakiri	64	LP/FS	N/A	N/A
14	Korean company	Prek Liang 2	Rattanakiri	64	LP/FS	N/A	N/A
15	Guangxi Guiguan Electric Power Company (China)	Srepok 3	Rattanakiri	300	FS ³¹	N/A	N/A
16	Guangxi Guiguan Electric Power Company (China)	Srepok 4	Mondulkiri	100	FS ³²	N/A	N/A
17	Chinese company	Stung Pursat 1	Pursat	100	FS	N/A	N/A
18	Chinese company	Stung Pursat 2	Pursat	17	FS	N/A	N/A
19	Korean company	Stung Battambang 1	Battambang	24	PFS	N/A	N/A
20	Korean company	Stung Battambang 2	Battambang	36	PFS	N/A	N/A

A/C = Approved for Construction; FS = Feasibility Study; LP = Letter of Permission; MoU = Memorandum of Understanding; N/A = not available; PFS = Pre-Feasibility Study; T/L = Transmission Line; U/C = Under Construction



Energy development policy

Cambodia's energy development policy states the following objectives:

- Provide an adequate supply of energy throughout Cambodia at reasonable and affordable prices
- Ensure reliability and a secure electricity supply in order to facilitate investment in Cambodia and development of the national economy
- Encourage exploration and environmentally and socially acceptable development of energy resources needed for supply to all sectors of the Cambodian economy
- Encourage efficient use of energy in order to minimize [negative] environmental effects resulting from energy supply and use.³³

Electricity Law

In 2001, the Cambodian government passed the Electricity Law which sets out a number of policy objectives and principles, and makes explicit the separate roles and responsibilities of the national electricity regulator (Electricity Authority of Cambodia) and the national energy policy-making institution (Ministry of Industry, Mines and Energy).³⁴

The Electricity Law sets out the following objectives:

- Ensure protection of the rights of consumers to receive a reliable and adequate supply of electric power service at reasonable cost.
- Promote private ownership of the facilities for providing electric power service.
- Establish competition wherever feasible in the power sector; and



- Establish the Electricity Authority of Cambodia for regulating electricity service providers, granting their rights and obligations, and penalizing suppliers if necessary.

3.3 Electricity Authority of Cambodia

The Electricity Authority of Cambodia (EAC) is the Mekong region's first-electricity regulatory agency of its kind, established under Cambodia's 2001 Electricity Law.³⁵ The law describes the EAC as an autonomous body set up to regulate and monitor the electric power sector throughout the country, and issue licenses to electricity service providers. By law, anyone that wants to operate an electric power company or provide electricity service in Cambodia must hold a valid license issued by the EAC.

The agency's regulatory duties under Article 7 of the Electricity Law are summarized³⁶ as follows:

- issue licenses to power producers and distributors
- approve and enforce performance standards for licensees to ensure good quality power supply and improved service to consumers; and
- ensure that tariffs/rates for electricity services are fair to consumers and licensees.

The EAC consists of three members supported by a secretariat and appointed by the King under the proposal and designation of the Prime Minister for a mandate of three years. The EAC may appoint all staff and hire technical experts and advisors and set remuneration for them based on its autonomous budget, which is derived from the license fees paid by service providers. The EAC determines and submits the license fees within its annual budget directly to the government for review and approval.

Public hearings and dispute resolution

The Electricity Law gives the EAC authority to hold public hearings

and disclose information to the public and investors. This provides all power consumers the opportunity to request or participate in public hearings on issues related to electricity service costs, licensing terms and conditions, as well as power generation, transmission, and distribution projects.

Any licensee or consumer may refer a dispute to the EAC for resolution, as it relates to the tariff or license or any aspect of electrical service. Having recourse to an autonomous regulator (one that is paid by licensees to regulate the sector) signals to investors, consumers, and citizens that electricity service providers will be held accountable. All parties benefit knowing a regulator is obliged to take their complaint seriously and seek to resolve it in a fair, transparent, and professional manner. The regulator is also obliged to take steps to prevent disputes from arising in the first place by, for example, checking developers' costs and proposed tariffs *before* licenses and rates are finalized.

In the case of projects already underway, citizens who feel they have not been fairly compensated by a power plant developer for lost land, resources, or income have the right to present their complaints to the EAC and ask the regulator to review the developers' license and tariff agreements. If power producers, including the state owned utility, Electricite du Cambodge, are undercharging or overcharging consumers for service, the EAC has the authority by law to correct that.

EAC licensed power producers

Cambodia has more licensed power producers than any other country in the lower Mekong region: 180 licensed power producers supplying 97 percent of the country's power supply.

Of the 180 licensed power producers, only three are government entities:

- **Electricité du Cambodge**, a state utility which holds a consolidated license to generate, transmit, and distribute power within (unspecified) service areas;
- **Kratie** provincial government, which has a license to generate



- and distribute power in Kratie province; and
- **Mondulkiri** provincial government, which has a license to distribute power in Mondulkiri province.

In 2007, the EAC issued 41 new generating licenses to private companies and individuals, which is the highest number of new licenses issued to power producers since 2003. EAC does not explain why more companies were licensed in 2007 than in previous years. It further reports that many small licensed producers are making power infrastructure improvements to improve electricity service.³⁷

3.4 Ministry of Industry, Mines and Energy

Article 3 of the Electricity Law states: “The Ministry of Industry, Mines and Energy (MIME) shall be responsible for setting and administrating (*sic*) the government policies, strategies and planning in the power sector.” The law also states that MIME shall transfer in an orderly manner certain functions and duties to EAC as soon as EAC is fully operational, and that MIME and EAC shall be separated from each other as is the normal practice in other countries. MIME shares ownership of the state utility, Electricite du Cambodge, with the Ministry of Economics and Finance.

MIME is responsible for planning all transmission projects and grid connections with neighbouring countries, with technical assistance and grants provided by donor agencies including the Asian Development Bank, the World Bank, and Japan International Cooperation Agency.

Within MIME’s department of energy is a department of hydropower that has identified 29 large hydro projects for development, with technical assistance grants from Japan International Cooperation Agency (JICA) and others. If built as planned, the 29 dams would have a total installed generating capacity of more than 7,200 MW, ten times the capacity of Vietnam’s Yali dam near the Cambodian border.³⁸

Geographically, about 53 percent of the country’s estimated hydropower potential is along the Mekong mainstream; about 26 per-



cent is along Mekong tributaries in the northeast; and about 20 percent is along rivers outside the Mekong river basin in the western Cardamom Highlands.³⁹

The hydropower department's responsibilities are as follows:

- select locations and priority projects
- study, formulate, implement and control the construction of hydropower generation projects
- prepare and implement national power policies related to hydropower
- collect, analyze and utilize all data in studying the development of hydropower; and
- formulate and implement hydropower development plans throughout the country.⁴⁰

3.5 Electricite du Cambodge

Electricite du Cambodge (EDC) is an electric utility owned by the Ministry of Industry, Mines and Energy and the Ministry of Economics and Finance. Under the Electricity Law, EDC has the authority to generate, transmit and distribute electricity under terms stipulated by its license issued by EAC.⁴¹

EDC Mission

To provide sufficient and consistently reliable power supply to consumers in its entire coverage areas at a competitive price. To improve the business operation to be excellent and efficient, and to participate in the government policies on poverty reduction and environment.

According to EDC, the country's power development plans are based on the following objectives:

- Reduce reliance on imported oil for energy generation by diversifying energy sources
- Reduce reliance on the transport of oil to Phnom Penh for power generation

- Increase operational efficiency of the power system (i.e., reduce system losses)
- Encourage least-cost development of provincial load centers with a combination of grid expansion and local private generation
- Increase competition in power generation by providing access to competitively priced external sources of energy from Vietnam, Thailand and Lao PDR
- Maintain reliability of power supply at the level required and financially supported by customers; and
- Facilitate export of energy.

EDC power system rehabilitation

Between 1993 and 2005, EDC invested approximately US\$384 million in rehabilitation of its power distribution networks in Phnom Penh and surrounding provinces after many years of neglect and damage due to war.

The utility's rehabilitation effort was funded by grants and loans from international donors, led by the Asian Development Bank, France, Japan, and the World Bank. Projects included distribution rehabilitation and small (1.0 to 3.5 MW) diesel or gas engines to supply provincial towns.

EDC customers

EDC had 286,660 customers as of 2007.⁴² The utility breaks down electricity consumption by sector as follows:

Residential	39.2
Commercial (shops, businesses)	33.3
Industrial	17.5
Government	9.2
Other (unspecified)	1.0



3.6 Independent Power Producers

Developers financing and building power projects on a BOT (Build-Operate-Transfer) or BOO (Build-Own-Operate) basis, and selling their output to EDC are known as independent power producers (IPPs). The detailed terms of power purchase and implementation agreements signed by IPPs and EDC are not publicly available.

As of 2008, nearly 90 percent of Phnom Penh's electricity is supplied by IPPs operating 13 power plants in the 5- 20 MW range. Most IPP power plants run on (imported) heavy fuel oil and sell power to the state utility Electricite du Cambodge under the terms of a negotiated power purchase agreement (See Box 2).

BOX 2: Wartsila Corporation (Finland) in Cambodia

www.wartsila.com

Wartsila is a global supplier of gas power plants ranging from 4 to 150 MW for flexible base load, peaking, industrial cogeneration, and the oil and gas industry.

IPP projects

In Cambodia, Wartsila teamed up with Phnom Penh-based engineering company, Comin Khmère, and was awarded a contract to supply the Cambodian IPP investor, Khmer Electrical Power Company,* a 30-MW diesel power plant in Phnom Penh. The plant has been operating since March 2005 and consists of four diesel generating sets running on heavy fuel oil and supplying base load power.

EDC power plants

Wartsila has also supplied two power plants to Electricite du Cambodge: an 18.6-MW installation in operation since 1996; and a 5-MW plant in Sihanoukville. Both plants run on heavy fuel oil (HFO). Spare parts and servicing is provided by Wartsila Singapore.

*The Khmer Electrical Power Company is a subsidiary of Oknha Phu Kok An's business conglomerate and plans to expand its power plant business in the future.



3.7 Independent Transmission Providers

The EAC awards “special purpose transmission licenses” to private companies that want to finance and build transmission and distribution lines for delivering power to industrial customers or rural areas (Table 2). In the last few years, several transmission lines have been financed and constructed by entities other than the state utility, Electricite du Cambodge:

- In 2007, EAC issued a “special purpose transmission” license to a new entity called the Cambodia Power Transmission Line Company for construction of a 115-kV transmission line from the Thai grid at the border to three Cambodian provinces: Banteay Meanchey, Siem Reap and Battambang. The company began importing power through its line in November 2007, replacing local oil-fired generation.
- In 2007, the government awarded CYC (China Yunnan Corporation for International Techno-Economic Cooperation) a concession to finance and build a medium-voltage (230 kV) transmission line linking the country’s southern transmission grid to the western grid. The concession is part of CYC’s Stung Atay hydro dam concession package.



A Transmission Line in Cambodia. Photo courtesy of International Rivers.

TABLE 2: Power Development Plan 2007 – 2022 transmission projects⁴⁴

No.	Transmission Project	Project Cost (US\$ Million)	Power Supply	Project Owner	Financiers & Contribution (US\$ Million)	Scheduled Operation
1	115 kV 203-kilometre T/L Thailand - B. Meanchey - Siem Reap - Battambang	34 ⁴⁵		Cambodia Power Transmission Line Company	ADB (\$7 M) Export-Import Bank of Thailand Foreign Trade Bank of Cambodia Gramercy Advisors /Arco Capital Management Family of Funds	2007
2	220 kV 110-kilometre T/L Phnom Penh - Takeo - Vietnam	95 M	To purchase power from Vietnam for supply to Phnom Penh	EDC	WB \$16 M ADB \$44.3 M NDF \$11M RGC \$23.7 M ⁴⁶	2009
3	115 kV 30-kilometre T/L reinforcement and substations at West Phnom Penh	N/A	To accommodate power supply from hydro projects in the western provinces to Phnom Penh.	EDC	WB	2009
4	230 kV 87-kilometre T/L Takeo-Kampot	N/A	193-MW Kamchay Dam	EDC	KFW	2010
5	115 kV 56-kilometre T/L Stung Treng - Lao PDR and one substation in Stung Treng	1st part of \$18.5 M WB loan package		EDC	WB	2010
6	110 kV 68-kilometre T/L and three substations at Kampong Cham, Soung, and Pongnearekreak	2nd part of \$18.5 M WB loan package		EDC		2010



No.	Transmission Project	Project Cost (US\$ Million)	Power Supply	Project Owner	Financiers & Contribution (US\$ Million)	Scheduled Operation
7	230 kV 82-kilometre T/L Kampot - Sihanoukville and substations at Vealrinh and Sihanoukville	\$52.36	Sihanoukville Coal-Fired Plant	EDC	ADB \$20 M JBIC \$22.36M RGC \$10 M ⁴⁷	2001
8	230 kV 310-kilometre T/L Phnom Penh - Kompong Chhnang - Pursat - Battambang and three substations	133.39	120-MW Stung Atay Hydro Dam		IPP (China Datang Corporation, Cambodia Hydropower Development Company, Cambodia Power Grid Company)	2012
9	230 kV 175-kilometre T/L Pursat - Osom and one substation	N/A			IPP	2012
10	230 kV 110-kilometre T/L Kampong Cham - Kratie	N/A			IPP	2012
11	230 kV 126-kilometre T/L Kratie - Stung Treng	N/A			IPP	2012
12	230 kV 100-kilometre T/L Phnom Penh - Kampong Cham	N/A			IPP	2012
13	230 kV 220-kilometre T/L Phnom Penh - Sihanoukville (Running along national road 4)	N/A				
14	230 kV 120-kilometre T/L Phnom Penh - Neak Loeng - Svay Rieng -Vietnam and two substations	N/A	246-MW Stung Tatay Hydro Dam			

No.	Transmission Project	Project Cost (US\$ Million)	Power Supply	Project Owner	Financiers & Contribution (US\$ Million)	Scheduled Operation
15	230 kV 15-kilometre T/L Stung Tatay Hydro Dam - Osom substation	N/A	246-MW Stung Tatay Hydro Dam		IPP	2015
16	115 kV 20-kilometre T/L West - East Phnom Penh	N/A				2015
17	230 kV 100-kilometre T/L reinforcement Phnom Penh - Kampong Cham	N/A	To transmit power from Lower SeSan 2 and Lower Srepok 2 Hydro Dams			2017
18	230 kV 90-kilometre T/L Stung Chay Areng - Osom substation		Stung Chay Areng Hydro Dam		IPP	2017
19	230 kV 250-kilometre T/L Kampong Cham - Kampong Thom - Siem Reap and substation in Kampong Thom	N/A				2019
20	TOTAL T/L = 2,363 Kilometer					

ADB = Asian Development Bank; EDC = Electricite du Cambodge; IPP = Independent Power Producer; JBIC = Japan Bank for International Cooperation; KFW = Kreditanstalt fur Wiederaufbau; MOU = Memorandum of Understanding Signed; NDF = Nordic Development Fund; n/a = not available; RGC = Royal Government of Cambodia; T/L = Transmission Line; WB = World Bank

3.8 Electricity Distribution & Prices

EDC distributes power in Phnom Penh and 11 surrounding provinces. Since 2004, a number of provincial distribution systems have been

transferred to and upgraded by EDC, including those in Kampot, Prey Veng, Ratanakiri and Stung Treng provinces. EDC has self-financed new distribution lines in six provinces from its electricity sales.

In the absence of regulation, electricity prices vary widely from one province to the next (See Table 3). In 2007, EDC charged from 7 to 17 US cents per kilowatt-hour in Phnom Penh and Kompong Speu province, while private power producers charged anywhere from 7 to 41 US cents per kilowatt-hour.⁴⁸

TABLE 3: Cambodian IPP Electricity Prices (2007)

Electricity Tariff (US cents per kWh)	Source/Producer
6.9	Electricity of Vietnam Corporation
7.0	SL Garment Processing (Phnom Penh)
17	Colben Energy (Sihanoukville)
26	Global Technological Support (Kampong Cham)
30	SHC Cambodia (Ratanakiri)
41.24	Kampot Power Plant (Kampot)

Source: Electricity Authority of Cambodia 2008 www.eac.gov.kh

According to the World Bank, the lack of competitive bidding for IPP projects has contributed to higher than necessary electricity prices in recent years, quite apart from high fuel costs.⁴⁹

Electricity prices peaked in early 2008, but by mid-2008 power companies were starting to reduce their prices in line with falling oil and gasoline prices. The Yem Nareth Electricity Company which supplies Pursat province, for example, reduced its price from a high of 50 US cents per kilowatt-hour last July to 42 US cents per kilowatt-hour as of October 2008.⁵⁰

In border provinces, both EDC and licensed private distributors buy power from neighbouring countries and sell it locally. Most distributors operate only for a few hours in the evenings and a few hours during the day on weekends as required by local customers. With the

extension of 22-kV distribution lines in more provinces, more and more licensees are buying electricity from EDC, which is typically cheaper than the cost of operating a diesel-fired generator locally. In Kampong Cham province, for example, the privately owned Electricity Development and Construction Company buys power from EDC at 10 US cents per kWh and distributes it locally. Another company, KEP, buys power from EDC at 7.383 US cents per kilowatt-hour in Kampot province.⁵¹

3.9 Power System Development Plan (2007 – 2022)

By 2020, the energy ministry estimates that the country's total demand will increase from an estimated 808 MW in 2008 to 3,867 MW, with most demand growth occurring in Phnom Penh and southern regions of the country.⁵²

To meet that demand, the energy ministry's strategy is to first import electricity from neighbouring countries through several new transmission lines (Table 2). By 2009, Cambodia expects to have the capacity to import up to 80 MW from Vietnam. Then as demand for electricity grows the ministry will commission a series of large-scale power projects that can supply the domestic market and export to neighbouring countries. A national dispatching centre to coordinate all large grid-connected power suppliers is expected to be completed by EDC in 2009, with loan financing from the World Bank.⁵³

Generation expansion

The energy ministry has prioritized 17 large power generation projects for development between 2010 and 2020 (See Table 4).⁵⁴ More than half the planned new capacity is large hydro. The rest is coal-fired plants to be developed in 100- or 200-MW increments near the port of Sihanoukville. A 450-MW power plant is also scheduled for completion in 2020 running either on coal or natural gas, at an unspecified location.

The largest proposed generation project in the PDP is the Sambor hydro dam on the Mekong mainstream near Kratie. China Southern

Power Grid Company is conducting a feasibility study of Sambor, which could have an installed capacity of 450 MW or 2600 MW depending upon its final configuration. The second largest proposed hydro project is the lower Se San 2 project with an installed capacity of 420 MW. Cambodian officials claim the project has not been approved yet but the project developer, state owned Electricity of Vietnam Corporation, has sent in workers and equipment to start preparing the site for dam construction this dry season.⁵⁵

TABLE 4: Power Development Plan 2010 – 2020 generation projects

No.	Project Name	Fuel/Source	Installed Generating Capacity (MW)	Year Operation
1	Kirirom 3	Hydro	18	2010
2	Kamchay	Hydro	193	2010
3	200 MW coal plant (I) Sihanoukville Phase 1	Coal	100	2011
4	Atay	Hydro	120	2012
5	200 MW coal plant (I) Sihanoukville Phase 2	Coal	100	2012
6	700 MW coal plant (II) Phase 1	Coal	100	2013
7	Lower Stung Russey Chhrum	Hydro	338	2013
8	700 MW coal plant (II) Phase 2	Coal	100	2014
9	Tatay	Hydro	246	2015
10	700 MW coal plant (II) Phase 3	Coal	100	2015
11	700 MW coal plant (II) Phase 4	Coal	100	2016
12	Lower Se San 2 + Lower Srepok 2	Hydro	420	2016
13	Lower Se San 1	Hydro	90	2015
14	Stung Chhay Areng	Hydro	108	2017
15	700 MW Coal Power Plan (II) Phase 5	Coal	100	2017



No.	Project Name	Fuel/Source	Installed Generating Capacity (MW)	Year Operation
16	700 MW coal power plant offshore	Coal	200	2018
17	Sambor	Hydro	2600/450	2019
18	Coal power plant (III) or gas power plant	Coal	450	2020
	TOTAL		5,483/3,333	

Source: "Hydropower development in Cambodia," Tung Sereyvuth, Deputy Director, Energy Development Department, Ministry of Industry, Mines and Energy, power point presentation to the Mekong River Commission's Regional Multi-Stakeholder Consultation on the MRC Hydropower Programme, Vientiane, Lao PDR, September 25-26, 2008. www.mrc.org


Transmission expansion

Transmission planning for Cambodia's power development plan is conducted by the energy ministry with technical assistance and funding (grants and loans) from the World Bank. A national transmission system is being developed in four stages with two economic zones first: the southern zone, which includes Phnom Penh, Kandal, Kampong Speu, Takeo, Kampot and Sihanoukville; and the western zone, which includes Banteay Meanchey, Battambang and Siem Reap provinces. Next these two zones will be interconnected, which will include Kampong Chhnang and Pursat provinces. The last area for grid extension will be Kampong Cham and Stung Treng provinces to facilitate hydro development in the northeast.

International development financiers, including the Asian Development Bank, Germany's development bank KfW, Japan Bank for International Cooperation, and the World Bank are providing low-interest loans to the Ministry of Economics and Finance for related transmission lines and substations (Table 2).⁵⁶

Build-operate-transfer (BOT) hydropower projects

Since 2006, MIME and the Ministry of Economics and Finance have approved five large hydro projects for development on a build-operate-transfer (BOT) basis (Table 1). Additional agreements have been



signed with developers to undertake feasibility studies of projects selected by MIME. All hydro developers are required to sell their output to EDC under power purchase agreements with a 30- or 40-year term or longer.

The first such deal was signed on February 23, 2006: MIME and the Ministry of Economics and Finance signed a 44-year contract for the 193-MW Kamchay dam with China's Sinohydro Corporation, following a letter of authorization from Prime Minister Hun Sen.⁵⁷

Build-operate-own (BOO) coal-fired plants

According to the Electricity Authority of Cambodia, the energy ministry's coal-fired plants are to be awarded to private investors through an international competitive bidding process on a build-operate-own (BOO) basis. However, the country's first 200-MW coal-fired plant has been awarded to a joint venture company through one-on-one negotiations.⁵⁸

Power purchase agreement negotiations got underway with an unnamed developer in 2007. Then in January 2008, the Thai newspaper, *The Nation*, reported that a project developer called Dragon One, (an IT holding company) had signed a 25-year contract with the Cambodian government and construction was scheduled to start in January 2009, with loan financing from Japan Bank for International Cooperation. Dragon One was reportedly seeking a Thai co-investor for its plant which, if completed, would supply Cambodia and sell surplus to the state owned utility in Thailand, Electricity Generating Authority of Thailand (EGAT).⁵⁹

In May 2008, the *Phnom Penh Post* reported a different story: a Cambodian-Malaysian joint venture company called Power Synergy Corporation had signed a 30-year deal with the Ministry of Economics and Finance to build a 200-MW coal-fired plant for US\$391 million, and sell its output for 7.212 US cents per kilowatt-hour. A spokesperson for the Ministry of Economics and Finance, Kong Vibol, is quoted as saying that while hydro would be less environmentally damaging than a coal-fired plant, hydro is not viable due to water shortages in the dry season.⁶⁰ A few days later, the *Bangkok*



Post reported that EGCO, a private subsidiary of EGAT, was negotiating a 50 percent stake in Power Synergy's project.⁶¹

3.10 Rural Electrification

Cambodia's energy ministry estimates that only 13 percent of rural households have access to grid-based electricity compared to 54 percent of urban households.⁶² Small-scale rural electricity enterprises provide service in anywhere from 400 to 600 rural communities where there is no grid. These rural electricity enterprises (REEs) typically generate electricity using diesel generators with 10 to 75 kilowatt capacity, which can cost as much as 50 to 60 US cents per kilowatt-hour.⁶³

2003 Renewable Electricity Action Plan

To support the government's goal of providing 70 percent of all households with grid-based electricity service by 2030, the World Bank provided technical assistance and grant funding to the Ministry of Industry, Mines and Energy for development of a ***Renewable Electricity Action Plan***, which was completed in 2003⁶⁴. The plan aims to provide electricity service in rural areas using renewable energy technologies, such as solar, biomass, and micro-hydro.

In contrast to the traditional donor agency top-down approach to rural electrification in developing countries, the REAP emphasizes a market-oriented approach based on an unprecedented three years' worth of consultations with local businesses, commercial banks, energy experts, rural electricity entrepreneurs, government officials, NGOs, and aid agencies. The REAP's most important conclusions are summarized below:

- Decentralized (or distributed) generation technologies, solar, micro-hydro, biomass, and biogas could be developed quickly "given the entrepreneurial zeal already demonstrated by the 600 to 1,000 Rural Electricity Enterprises, several solar power firms, and donors."
- Only renewable electricity technologies that are deemed eco-



nomically and environmentally least cost will be used.

- Renewable technologies can provide electric power at least cost, especially relative to grid extension to smaller villages and outlying areas.
- Decentralized electricity systems are appropriate for rural Cambodia due to its lack of existing, integrated infrastructure.
- Renewable technologies provide the option of replacing dirty, high cost fuels currently used to produce electricity with clean sources such as solar photovoltaic, hydropower, and biomass technologies.
- Grid-based electric service has limited reach for the next two or three decades.
- In some areas, such as urban centres, fossil fuel power plants may currently be the best alternative, whereas in remote villages far from town centres, solar, micro-hydropower, and biomass technologies may offer cost-effective and efficient options.
- Investment opportunities can be developed through renewable electricity projects that will attract private investors.
- The government will act as a market enabler. Private sector firms will serve as market developers and suppliers. Subsidies will be used carefully.

2004 Rural Electrification Fund

With nearly \$15 million worth of loans and grants from the World Bank, the Cambodian government established a new bureaucracy under the Ministry of Industry, Mines and Energy in December 2004, called the Rural Electrification Fund.⁶⁵ Established by royal decree, REF has two specific objectives:

- To promote and encourage an equitable electrification coverage by assisting the rural population in obtaining electricity services at an affordable price for economic, social and household uses, thus contributing to the poverty reduction effort; and
- To promote and encourage private sector participation in the investment of sustained rural electricity services which espe-



cially utilize the renewable energy technologies that are both technically and commercially viable.

2006 Rural Electrification Master Plan Study

Prepared with technical assistance and grants from Japan International Cooperation Agency (JICA), the master plan study⁶⁶ assesses Cambodia's renewable energy resources as follows:

- **Abundant micro-hydro potential** in mountainous or hilly areas in the eastern and southwestern parts of the country.
- **Abundant biomass resources** all over the country due to plenty of sunshine, rainfall, and land for growing fuel crops. Biomass is the least-cost source for mini-grids in rural areas where power is needed for more than three hours a day, in villages with greater than 200 households. Fuel crops can be grown near most towns providing farmers are willing to grow fuel crops on their land for a reasonable income. Fuel crops can be harvested within one year of planting, and thereafter every 4 to 6 months. The report also recommends measures to counter land-grabbing or other land disputes which occur frequently due to Cambodia's weak rule of law.⁶⁷
- **Abundant solar** all over the country. Annual average monthly minimum is 4.7 kWh/square metre per day.
- **Scarce wind.** Average wind speed at 20 metres above ground is as low as 2.6 metres per second. Wind power could be viable in local wind corridors for battery charging stations and other small-scale applications.⁶⁸

The JICA study of Cambodia's rural electricity needs and resources makes the following conclusions and recommendations to the Cambodian energy ministry:

- "More than 80 percent of villages and households are located within a 40 kilometre radius of provincial towns. . . . rural electrification by grid extension (of a medium voltage line) is



effectively very feasible in Cambodia if the required funds could be procured for grid extension.”

- For off-grid villages and districts with loads between 5 kW and 500 kW, least-cost available RE technologies include biomass, biogas, and microhydro, where sufficient resources are available locally.
- Small and mini-hydro plants are generally more cost effective than diesel generators, and ideal for supplying mini-grids in rural areas with reasonably high population density.
- With mini-grids, it is possible to supply power for such economic activities during daytime as battery charging stations, water supply pumps, rice milling machines, irrigation pumps, handicraft industry, and so forth. Mini-grids should be planned not only for achieving rural electrification for lighting purposes but also to supply economic activities during the daytime as part of village development projects to improve household income.
- In areas that already have mini-grids operated by Rural Electricity Enterprises (REEs), JICA recommends that private investors be invited to implement a regional mini-grid in partnership with government, through a competitive bidding process.
- A footnote in an appendix of the JICA study suggests that “regional mini-grids” serving an entire district might be cheaper and more convenient than village-scale projects, which are the focus of the main report: “In addition to the merit of scale, the regional mini-grids will have such merits as to release [community electricity cooperatives] from the most troublesome power generation work, to save the construction costs of reserve generation capacity by sharing such capacity among the wider region, to facilitate gradual extension of the supply areas, and to facilitate the addition of generating units in accordance with supply requests from latecomers and increase in the demand.”⁶⁹

4.

Rethinking Cambodia's Power Development Strategy

4. Rethinking Cambodia's power development strategy

4.1 Rural Electrification: Failure by Design?

Since Cambodia's Rural Electrification Fund was established in 2004, the pace of deployment of renewable energy generating technologies in rural areas has not been satisfactory, according to the Fund's own assessment.⁷⁰ In its first four years of operation, the Rural Electrification Fund (REF) has failed to meet any of its project targets: no solar home systems have been deployed, no customer financing has been arranged to help rural households afford solar home systems, and no licensing standards or procedures for prospective micro-hydro developers/operators have been developed as planned. REF's target for micro hydro installations has been scaled back by half to 1,200 kilowatts, and the project completion date has been pushed back by two years to 2011.

Originally, REF expected rural electricity enterprises (REEs), including solar home system distributors, to apply for grants as follows:

- \$100 per solar home system (SHS) for a total of 12,000 households.
- \$400 for construction of mini hydro or micro hydro projects and \$300 for biomass projects, for a total new capacity of 6,850 kilowatts; and
- \$45 per household connection by a rural electricity enterprise (REE) for a total of 50,000 households.

To date, only about 6,000 rural households have been connected with the \$45 subsidy passed to REEs.

In its August 2008 report, "Strategy Plan for REF Project and Beyond," REF describes the program as "not satisfactory" and offers a long list of explanations for its lack of progress, which are summarized below:

New household connections – The \$45 subsidy is only about 16 percent of the total cost of \$280 per new connection, which is less than

the 25 percent originally proposed by REF to the World Bank, and more than many rural electricity enterprises can afford to pay upfront. Also, the subsidy to REEs does not assist rural households with their portion of the connection costs, which is about \$37 on average for the connection from the REE meter box to the house, excluding the cost of in-house wiring.

Solar home systems – Even with a \$100 subsidy most rural households still cannot afford the \$400 to \$500 initial investment cost of a solar home system. Also, the type of solar home system specified by REF as eligible for the subsidy proved unpopular because it came with a battery, something that most rural households already have for lighting and television, and therefore did not see the need to purchase another one.

Mini/micro hydro projects – Several companies in Stung Treng and Koh Kong have asked REF about developing micro hydro projects (~1200 kW) but nothing has been done yet because REF has no particular expertise to assist local companies with planning, design, procurement, or financing. Nor has REF worked out the procedures and contractual arrangements that would allow local companies to negotiate with technology suppliers and prospective financiers.

Biomass projects – The World Bank/REF did not make biomass projects eligible for grants until August 2007, almost three years after the fund was established, despite the successful application of this technology in Cambodia. Despite a number of enquiries from REEs, REF has not yet worked out the rules and procedures biomass developers need to secure their fuel sources, negotiate with technology suppliers, and obtain financing.

Rural electrification 2009 and beyond

As advised by the World Bank, REF has scaled back its targets for all but solar home systems, and now plans to purchase 12,000 solar home systems through a World Bank-controlled procurement process for distribution by REEs to rural households. More details are provided below:

Between now and 2011, REF plans to do the following:



- arrange through the World Bank's international procurement agency for the bulk purchase of 12,000 solar home systems (total cost of \$4.8 million) which will then be distributed to REEs or other local distributors. The distributor will sell and install the systems for rural households. Rural households will have the option of paying for the system with a small deposit upfront and the balance in installments over 5 to 10 years. The local distributor will collect the money and return it to REF, less fees for installing and maintaining the system. To ensure all money is collected, REF now has to function until at least 2016, possibly 2021. The money collected will be put into a revolving fund so REF can repeat the process in more rural communities;
- provide the original REF subsidy for two micro hydro projects (700 kW and 500 kW) in the pipeline;
- offer a \$37 cash subsidy to REEs for 10,000 rural household connections from the meter box to the house, with a repayment of three years.
- arrange through the World Bank to hire a consultant to prepare a detailed feasibility study of micro and mini hydro projects that could be financed by REF (in addition to 19 micro hydro projects already identified by Japan International Cooperation Agency consultants).
- consider with the help of World Bank technical advisors building and leasing mini hydro, micro hydro, and biomass power plants to REEs, possibly contracting EDC or other firms for project construction and management;
- prepare for construction of a new REF office building on land given to REF last year by the energy ministry (REF does not explain where the money will come from to pay for the new building).



World Bank's rural electrification "lessons learned" not applied

The World Bank's experience with rural electrification programs – what works and what doesn't – does not appear to have influenced REF's program design. Here's what a 2001 World Bank briefing⁷¹ advised based on its experience in Africa:

- “the private sector can be attracted to participate in rural electrification schemes, even in a poor country, if an appropriate legal framework and risk management options are in place, including the assurance of a level playing field in terms of competition and the ability to charge full cost-recovery tariffs.”
- initial connection charges are often a greater financial barrier for rural families than the monthly electricity bill, and therefore “extended financing arrangements are necessary to make connection more affordable.”
- appropriate procedures are required so that local service providers can plan, finance, and procure the necessary equipment and services; and
- projects are “more likely to be viable and sustainable if local stakeholders are involved in their design and implementation.”

In contrast, the REF program is a case of failure by design. Rather than enable the private sector to procure renewable energy equipment and deliver least-cost electricity services to rural households and businesses, the World Bank and the Ministry of Industry, Mines and Energy have created a new donor-dependent bureaucracy that does not have the right technical or financial capacity to deliver what consumers need, and is unaccountable to the program's intended beneficiaries, rural power consumers.



4.2 Small Power Producers Excluded

Cambodia's power development plan focuses on high-voltage transmission connections with neighbouring countries, large-scale hydro dams, and coal-fired plants (of unspecified technology). Excluded are entities other than big-scale power producers that want to generate power locally or install building-scale technologies that allow consumers to supply their own needs or reduce their demand for grid-based electricity service during the day.

The following entities are excluded from the power development plan:

- More than 170 private power providers currently licensed by EAC to generate and distribute power to urban and rural consumers
- Hundreds of rural electricity enterprises operating battery-charging stations that supply power to local businesses and households
- Rural businesses using agricultural waste or biofuel crops to generate their own power and sell surplus to nearby households (See BOX 3)
- Technology companies selling and installing renewable energy technologies that allow urban and rural consumers to generate some or all of their power needs (See BOX 4); and
- Hundreds of prospective technology suppliers world-wide with the financial and technical capacity to quickly install customized power plants and generating technologies for different types of consumers and local conditions.

Cambodia's private electricity companies provide an essential service yet the EAC describes them as an "interim solution" until the state utility, EDC, can bring its preferred IPP projects online.⁷² According to the Asian Development Bank, rural electricity enterprises (REEs) operate in a difficult business environment.⁷³ Most have little or no access to affordable capital. They have difficulty getting long-term permission to operate from the regulatory authority. They operate without clear rules for stand-alone operations, mini-grid operations, and future larger grid connections. And they don't know when or if EDC



plans to extend the grid into their service territory. The REE's difficulties translate into "high tariffs, underinvestment and constrained demand," which, in turn, stifles rural development and poverty reduction, the Asian Development Bank reports.⁷⁴

BOX 3: SME Renewable Energy (Cambodia)

www.smerenewables.com

SME Cambodia, a Cambodian NGO, has teamed up with E+Co, a US-based non-profit renewable energy investment organization, to establish a new Cambodian renewable energy company. The new venture, SME Renewable Energy, promotes renewable energy technologies and markets biomass gasification power generation systems in Cambodia and the greater Mekong region.

SME Renewable Energy offers turnkey projects, including system design, project feasibility studies, project planning and project financing for rural electricity producers, agro-business processing enterprises, and manufacturers requiring stand alone thermal or electrical energy solutions. Electricity generation and distribution systems, and captive power systems are custom designed to fit individual customer requirements.

The company's primary market includes rice mills, cashew processing plants, ice factories, and noodle factories. Other potential customers are companies that depend on high cost diesel and other petroleum fuels for thermal steam generation, ceramic kiln firing and grain drying.

Equipment offered includes biomass gasification equipment from 10 kW to 800 kW capacity. These units utilize both wood and/or fine grain agriculture wastes for fuel. Cogeneration systems include rice husk gasification units that reduce diesel fuel consumption for rice mills and off-grid rural electricity generation systems by up to 75 percent.

In addition to its technical engineering capacity to design and install biomass gasification systems, the new company has recruited and trained staff with experience in establishing fuel crops (i.e., *Leucaena*, *Gliricidia* and *Acacia*) to supply biomass for the gasification process. Advisory services to farmers and energy plantation development services are available to customers and investors. Financing for periods up to five years will be offered to eligible turnkey project clients at competitive interest rates.

EDC's plans to shut down REEs in western Cambodia, in order to create a market for its power imports from Thailand, provoked complaints from rural electricity providers in 2003. At the time, Leap

**BOX 4: Clean Energy Group (Cambodia)**

www.cleanenergycambodia.com

Clean Energy Group is a new joint-venture established by **Comin Khmère** (Cambodia) and **Sunlabob Renewable Energy (Lao PDR)** in 2008. The company provides renewable energy solutions including photovoltaic solar systems, solar water heating, solar pumping, solar water purification, wind turbines, and hydropower solutions for urban and remote areas in Cambodia. The company offers consultation and customized solutions before selling equipment to customers.

Comin Khmère (www.cominkhmer.com) is Cambodia's largest engineering solutions provider with over 40 years of experience. Sunlabob (www.sunlabob.com) is a Vientiane-based renewable energy solutions company licensed in 2001.

Solar energy systems

Clean Energy Group offers solar energy systems as an affordable power solution for hotels, businesses, offices, houses, hospitals, rural areas, eco-lodges, NGOs, public organizations and schools. Solar panels are a competitive power source compared to the cost of imported fuels, and have a minimum lifetime of 20 to 25 years without the worry of rising fuel costs or maintenance.

The company sells solar home systems in a range of sizes, from a basic 20 watt system to panels with much higher capacities like 5 kW and up. These systems can be used to power lighting and basic appliances including radios, television, and VCD players.

Wind turbines

Clean Energy Group recently partnered with the Dutch wind turbine manufacturer WES (Wind Energy Solutions) to install a wind turbine in the port area of Sihanoukville. Clean Energy Group will provide after sales support once the installation is completed mid-2009. This wind pilot project is being funded by the Government of Flanders, EU EuropeAid and the Port Authority of Sihanoukville. For more information see www.sihanoukvillewind.org

Wind Energy Solutions (www.windenergysolutions.nl) specializes in grid connected wind turbines with capacities of 2.5 kW, 80 kW and 250 kW.

Mann, President of the Cambodian Federation of Rural Electricity Enterprises, wrote to the energy ministry and its transmission financier, the Asian Development Bank, saying: "EDC should not be given



automatic preference over the private sector concerning the right to operate [electricity distribution] businesses. The private sector should be permitted equal opportunity to develop these services to the agreed upon standard.”⁷⁵

4.3 Public Risk, IPP Profit

Independent power plants have been developed around the world using conventional project financing. After securing a contract to sell power to the state utility, the IPP developer then raises financing from private capital markets. In many jurisdictions, regulatory authorities and governments prudently seek to keep the development risks on the private developers, away from ratepayers. In Cambodia, the reverse is true.

Every large IPP deal exposes the Cambodian government, and by extension electricity ratepayers and taxpayers, to financial risks that rightfully belong with the IPP developers. To protect large IPPs against the risk of non-payment by EDC, the government has agreed to guarantee payment for electricity for the duration of their concessions.⁷⁶ So if for any reason EDC cannot pay its IPPs, the government is on the hook.

Without this government guarantee, IPP developers would have difficulty raising financing for large projects in Cambodia. One key deterrent is the poor financial performance of the single buyer of IPP output: EDC. In its 2006 assessment, the World Bank describes EDC’s financial status as “precarious,” having barely progressed over the last six years from “near bankruptcy” to “almost breaking even.”⁷⁷ The Bank notes EDC has trouble collecting payment from government customers, it is vulnerable to political manipulation, it does not insist on competitive bidding, and it has no transparent price-setting mechanism in place to give investors confidence they will be able to recover their costs and receive a fair return on their investment.⁷⁸ EDC, in other words, is a bad business risk.

Government guarantees don’t *eliminate* this risk associated with IPP projects; they simply *transfer* those risks onto the Cambodian govern-



ment. As IPP guarantor, the government will try to do whatever it can to make sure EDC has enough customers for IPP output, even if that means shutting down local producers and distributors in areas EDC wants to boost electricity sales. Just as utilities have done elsewhere, EDC is likely to try and discourage new decentralized generators by imposing hefty charges for access to backup power or by making it difficult to connect to EDC-owned distribution networks.

EDC customers are not well served by such maneuvers. With every new IPP deal, EDC customers are paying for 1950s-era hydro dams and coal plants while decentralized technologies elsewhere are getting better and cheaper all the time. The government has awarded IPPs “special investment concessions”⁷⁹ without forcing them to compete for access to the market, and demonstrate that their proposed projects are the best options for meeting consumers’ needs.⁸⁰

Single-buyer-IPP model invites corruption, encourages oversized expansion

The World Bank has championed the single-buyer-IPP approach to power supply expansion in developing countries for more than a decade; even devising special guarantees itself to cajole IPP investment in high-risk, capital-intensive projects that would otherwise be unbankable.⁸¹ Both the World Bank and the Asian Development Bank have done this to make large IPPs commercially viable, even when less-risky, smaller-scale investments would better serve consumers’ interests.

In his 2000 assessment of IPP experience in Hungary, Indonesia, Pakistan, and Thailand, World Bank energy expert Laszlo Lovei concluded that the single buyer model (whereby IPPs sell their entire output to a state utility) typically “invites corruption, weakens [single buyer] payment discipline, and imposes large contingent liabilities on the government.”⁸²

“The single-buyer model has major disadvantages, particularly in countries with weak or corrupt government and low payment discipline,” writes Lovei.



Decisions about adding generation capacity are made by government officials who do not have to bear the financial consequences of their actions. In countries where investors found government assurances attractive (such as Hungary, Indonesia, Pakistan, and Thailand), there has been an upward bias in the generation capacity procured . . . government officials found it difficult to resist powerful interest groups pushing for state-guaranteed capacity expansion.⁸³

Lovei advocates a market model instead with multiple buyers and generators contracting directly with customers – a model that would save government money and encourage smaller-scale, less financially risky generation projects.

4.4 Big Hydro Costs

Cambodia's first hydro IPPs have agreed to sell power from their hydro projects to Electricite du Cambodge for 8 US cents per kilowatt-hour or less (Table 1). That may seem like a bargain compared to the cost of diesel-fired generation lately, but the actual costs to Cambodians will be much higher.

In the last section, we explained how Cambodia's IPPs are protected from financial risk at the expense of the government and power consumers. This section reviews big hydro's real costs and values from different perspectives: comparison with central generation alternatives, social and environmental liabilities, investor preferences, transmission cost, total delivered cost, and operational disadvantages.

Big hydro not least-cost option

Power system planners often compare electricity generating technologies using the "levelized cost" method. The total electrical energy produced by the plant or technology in its operating lifespan is divided by the total investment cost of construction plus interest, plus operation, fuel, and maintenance costs, all calculated in present money.⁸⁴



Table 5 compares the levelized generation cost of Cambodia's large hydro IPPs with other commercially viable large-scale generating technologies.⁸⁵ Without considering consumer preferences or environmental costs or the cost of transmission and distribution, the following conclusion can be made: Cambodia's large hydro projects (100 MW and up) are more costly than a 300-MW natural gas-fired combined cycle plant and three types of 300-MW coal-fired plants.

TABLE 5: Cambodia's hydro IPPs vs large grid-connected alternatives

Technology	Capacity (MW)	Levelized Generation Cost (US Cents Per kWh)	Typical Uses
Large Hydro IPPs in Cambodia	> 10	7 - 8 (Table 1)	<ul style="list-style-type: none"> ▪ Operating mode not available
Natural Gas-Fired Turbine	150	12 - 14	<ul style="list-style-type: none"> ▪ Peaking plant ▪ Fuel flexible
Natural Gas Combined Cycle	300	5 - 7	<ul style="list-style-type: none"> ▪ Baseload power source connected to a central grid ▪ Fuel flexible
Coal-Fired Steam Turbine	300	4 - 5	<ul style="list-style-type: none"> ▪ Baseload power source
Integrated Coal Gasification Combined Cycle (IGCC)	300	5 - 6	<ul style="list-style-type: none"> ▪ Baseload power source
Oil-Fired Steam Turbine	300	5 - 9.5	<ul style="list-style-type: none"> ▪ Baseload power source

Source: Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies, Energy Sector Management Assistance Program Paper 121, World Bank, December 2007. Note: fuel and technology prices are subject to change; cost ranges are indicative only.

Social and environmental liabilities

Then there are big hydro's social and environmental liabilities which typically are not reflected in project costs. The Asian Development Bank and the World Bank often claim an interest in ensuring hydro developers pay the full range of social and environmental costs. As a 2003 ADB document states: "all environmental costs related to

hydropower should be quantified and evaluated in monetary terms and incorporated into the economic analysis of the various generation projects as well as the transmission line projects. This includes social costs related to loss of habitat and resettlement, which are complex and difficult to handle in traditional cost-benefit analysis.”⁸⁶ The report goes on to suggest that a portion of hydro profits “should be floated back to [locally affected] communities.”⁸⁷

If Cambodia’s hydro IPPs were required to pay for all quantifiable social and environmental costs associated with their projects, and the electricity regulator was required to pass those costs onto consumers, EDC’s customers could expect to see new charges on their electricity bills arising from costs that were either unanticipated or discounted at the time the original contracts were negotiated. These charges could include the cost of compensation for damaged property and livelihoods in the vicinity of the dams, geotechnical and dam safety problems, fisheries mitigation, reservoir dredging, watershed management, bank stabilization, water treatment, and dam removal.

In practice, such costs are borne not by the developers but disproportionately by governments and dam-affected communities.⁸⁸ Hydro developers sell “cheap” electricity to utilities in the Mekong region while countless people living upstream or downstream from their dams suffer uncompensated or inadequately compensated damages to crops, property, resources, and livelihoods.⁸⁹ Governments are then encouraged by the World Bank to borrow money to pay for mitigation measures not covered under the original contracts signed with project developers. Last year, for example, the government of Lao PDR borrowed US\$9 million from the World Bank for irrigation development downstream from the US\$1.45 billion Nam Theun 2 dam, where an estimated 120,000 people have been adversely affected by the dam’s operations.⁹⁰

Worldwide experience suggests the bigger the hydro dam, the more difficult, if not technically and financially impossible, it becomes to mitigate their negative social and environmental effects.⁹¹ Cambodian officials, meanwhile, argue that other countries have dammed their rivers for hydropower at great environmental cost: why shouldn’t Cambodia do the same?



The Manwan Hydropower Dam on the Mekong River in China.

High capital costs, slow lead times

Commercial investors show little interest in building big hydro dams without huge subsidies and monopoly protection from governments, international development banks, and donor agencies.⁹² That's because after nuclear, large hydro dams are the most capital-intensive of all conventional generating technologies.⁹³ Very large hydro dams (100-1000 MW) can cost over US\$2,000 per kW of installed generating capacity and take anywhere from 3 to 15 years to build.⁹⁴ Cambodia's big hydro projects are in the US\$1500 per kW range. At US\$47 million, the capital cost of 18-MW Kirirom 3 dam is about US\$2,600 per kW.⁹⁵ Compare this to gas-fired combined cycle plants, which cost US\$300 to US\$700 per kW, and can be installed in as little as three to six months.⁹⁶ In Vietnam, a 717-MW combined cycle plant cost \$572 per kW compared to \$1,666 per kW for the 720-MW Yali dam.⁹⁷

For countries like Cambodia, short of capital and in urgent need of



new generating capacity, choosing less capital-intensive technologies that can be easily financed by the private sector and quickly installed makes more economic sense than big hydro dams. Consider, for example, the World Bank-financed 1070-MW Nam Theun 2 dam in Lao PDR took more than a decade and cost US\$1.45 billion to build (with environmental mitigation costs still increasing).⁹⁸ Southern Vietnam's 1090-MW Phu My 1 gas-fired combined cycle plant, financed by Japan, took just two years to bring online and cost US\$530 million,⁹⁹ less than half the cost of a hydro dam with the equivalent generating capacity.

Total delivered cost

Most utilities traditionally based their investment decisions on a simple per kilowatt-hour comparison with other generating technologies, without considering the location of the project or customers. Thus transmission and distribution costs were treated as separate from generation, and not considered in the comparison of different generating options.

In this way, planners ignore the larger *diseconomies* of scale associated with getting large-scale power supply distributed to consumers whose demands are quite small and dispersed in comparison.¹⁰⁰ Most Cambodian provinces have a total daily power demand of just a few megawatts, which means most of the output from a large hydro dam (10 MW and up) will have to be transmitted and distributed to consumers in distant towns and cities, and possibly beyond Cambodian borders.

What matters to Cambodian power consumers (and has not yet been disclosed by Cambodia's electricity regulator) is not just the investment cost per kilowatt-hour but the *total delivered cost* of power,¹⁰¹ - which includes:

- the cost of power bought from IPPs by Electricite du Cambodge
- the cost of transmission (115 kilovolts and higher)



- and the cost of distribution (115 kilovolts and lower)
- and the cost of backup capacity

Transmission and distribution costs typically add 30 percent¹⁰² or more to the total delivered cost of power charged to consumers, depending on the location of the power plants and the consumers. Table 6 provides a range of cost estimates for different types of transmission lines compiled by the Asian Development Bank as part of its 2002 master plan for power interconnections in the Greater Mekong Subregion. Costs vary with the type of transmission lines and infrastructure used, as well as the price of steel, aluminum, concrete, labour, terrain conditions, and road accessibility.



Constructing the Mekong Power Grid Transmission Line



TABLE 6: Asian Development Bank transmission cost estimates

Transmission line		Average cost (US\$/kilometre) excluding substations
High voltage	500 kV	230,000 – 615,000
Medium voltage	230 kV	115,000 – 380,000
Low voltage	115 kV	62,000 – 130,000

Source: Regional Indicative Master Plan on Power Interconnection in the Greater Mekong Subregion, Norconsult, Asian Development Bank, June 2002.

A river crossing of one or two kilometres can add another US\$2.8 to US\$10.5 million to the cost of transmission. Transformer stations needed to “download” the power from the high or medium voltage lines to local distribution grids require at least one or two substations, which typically cost US\$2 million each. The bigger the hydro station, the higher the cost of these facilities will be. According to the ADB’s master plan on power interconnections, a single transformer substation designed to handle 3,000 MW of power output from China’s Jinghong and Nouzhadu dams on the upper Mekong in Yunnan province would cost US\$248 million.¹⁰³

Proponents claim big transmission systems are needed to improve system reliability. But in fact, transmission lines are vulnerable to failure caused by flooding, overheating, lightning strikes, landslides, earthquakes, technical problems, and sabotage.¹⁰⁴ This is not to say that Cambodia’s interconnections with Thailand and Vietnam aren’t worthwhile investments. They may help EDC avoid power outages if they can dispatch power from neighbouring utilities when a problem occurs in the Cambodian grid or at a domestic power plant. In general, however, the bigger and more complicated the transmission system becomes, the more vulnerable it becomes to grid failure.

4.5 Operational Disadvantages

Cambodia’s hydro-based electricity system, if completed as planned, will have a number of major operational disadvantages. Large hydro dams in the Mekong region are inherently unreliable because their



output depends upon the vagaries of rainfall and river flow. The World Bank gives large hydro an average capacity factor of 50 per cent.¹⁰⁵

Vietnam, which depends on large hydro dams for about half its power supply, suffers blackouts every dry season when the dams' reservoirs run low on water, either due to lack of rainfall or competing demands on the water resources from farmers and downstream communities. In Cambodia, the 12-MW Kirirom 1 dam in Kompong Speu province doesn't have enough water to generate power in the dry season.¹⁰⁶ The energy ministry estimates that its planned hydro dams can operate on average at about one-third capacity for three to five months of the year.¹⁰⁷ During those months, Electricite du Cambodge plans to run coal-fired plants in Sihanoukville as backup, making its hydro-based electricity system far more inefficient, costly, and environmentally damaging than proponents claim.

Historically, big hydro stations had some operating advantages over large thermal stations. Unlike nuclear reactors and coal-fired plants, dams with reservoir storage capacity can be operated for a wide range of power output, and started up or turned off in a few minutes depending on load. This flexibility and ability to control power output was useful to central utilities for grid control and management. But this flexibility is only an attribute if enough water is available when power is needed. It's also an attribute that is disappearing in jurisdictions where government regulators impose constraints on dam operators to balance power production with the need to protect upstream and downstream ecosystems.¹⁰⁸ In some North American jurisdictions, dam operations are severely curtailed during critical fish migration periods and at other times, which means their output is no longer as valuable to utilities because they can no longer be called upon to ramp up and down quickly to meet electricity demand during peak periods.¹⁰⁹

In the Mekong region, big hydro dams will face constraints on their operations in the future as more and more dam affected communities appeal for less disruptive modes of operation, and as river systems face competing demands for water.¹¹⁰ More constraints on dam operations means higher costs in the power system as a whole, as backup



capacity has to be brought online more frequently and in large increments.

4.6 Power Industry Perspective

Christoph Vitzthum is Vice President of Wartsila, a Finnish company supplying customized power plant technology to private developers and industrial operations globally, including Cambodia, Thailand and Vietnam (See Box 2). Mr. Vitzthum is also Chairman of the UK-based World Alliance for Decentralized Energy, which publishes a quarterly journal, *Cogeneration and On-Site Power Production*. In the journal's September-October 2008 issue, Vitzthum wrote an article entitled, "A better electricity system for the developing world" in which he argues that while centralized electricity networks are still the norm in developed countries, "*this model is now rather outdated for developed countries – and quite inappropriate for developing countries.*"¹¹¹ Below are a few pertinent excerpts:

[W]estern utilities had very detailed planning for all their actions. They believed strongly – and often still do – in the 'economies of scale' principle, which basically means the bigger the better. The bigger the plant, the better the efficiency and the lower the specific cost. The higher the grid voltage, the lower the losses. They constructed large baseload coal, hydro, nuclear, and gas combined cycle plants by the shoreline and built a strong high voltage grid all over the country to 'evacuate' the power. The typical outcome was a rigid, over dimensioned, albeit reliable, electricity system.

Vitzthum points out that all centralized power systems have the same built-in inefficiencies:

- *Excessive baseload capacity was constructed. This was possible as there was an ensured return on asset investments [by state monopolies];*
- *The grid was sized to transmit full peak power from large remote power plants to the consumption centres in cities;*



- *Efficient peaking capacity was not constructed; instead the so-called peaking plants were typically based on the largest possible simple cycle industrial gas turbines located at critical points along the grid. This capacity functioned mainly as an emergency reserve at grid nodes and was hardly ever used as it has such poor [energy conversion efficiency] and relatively long starting time. (Of course this is partly because flexible power plants were not available on the market in the past.) Large, steam-fired power plants, running on part load, were used for frequency and load control. Fast starting [power plants] were not built.*

Vitzthum describes central generation as an “extravagance” belonging to a bygone era of cheap capital and under-valued resources, one that no country can afford to replicate today. Here he describes what’s replacing central generation:

Progressive modern utilities have left the past behind and are striving towards a modern, competitive energy system. Most new generation projects in the United States today are configured to provide flexible multipurpose generating capacity close to consumers. This includes baseload, intermediate load, peaking, and grid stability capabilities, all from the same plant. The fuel of choice for this kind of plant is natural gas.

Such multi-purpose power plants are readily available on the market today, and are capable of operating continuously without any degradation or increase in maintenance costs. These power plants can operate initially on heavy fuel oil (which in many developing countries still is the only practical, accessible and decently priced power generation fuel), but preferably on gas as soon as natural gas infrastructure is installed. They offer a huge opportunity for the developing world as they not only can function as base load plants, but also as the local intermediate, peaking and grid stability plants of the more optimized system of the future.



However, one remainder of the past, still to some extent maintaining the economies of scale thinking, is [utilities] look at and calculate power plant and grid investments separately, as if they had nothing, or very little, to do with each other. Quite often the ‘evacuation’ of power from a new, remote, large power plant to the consumers requires new grid investments, which could in many cases, at least partly, be avoided by optimizing the whole system and not trying to produce all power, included the short time peaking and power reserves, remotely at baseload power plants.

Vitzthum warns developing countries to resist pressure to stick with the old model:

Many active sales agents come to [utilities in developing countries] selling equipment for the ‘western’ concept, and help them to get financing for it. Sometimes it may be difficult for the developing countries to see that in fact they have the relative luxury of going directly for the optimum [system] and bypassing some of the flaws of the western model, which was created under very different competitive terms and market conditions than those prevailing today in the world.

Finally, Vitzthum offers this advice:

[Developing countries] need to have the courage to challenge the past truths and look at the whole system despite the external pressure [they] may face, [which is] trying to push them to repeat what has been done before.

5.

A Better Strategy for Powering 21st Century Cambodia



5. A Better Strategy for Powering 21st Century Cambodia

Cambodia's best alternative to big hydro dams and coal-fired plants is modern decentralized generation. As Michael Brown, former director of the industry-led World Alliance for Decentralized Energy explains:

“. . . increasing [generating] capacity at least economic and environmental cost is best done through substantial investment in on- and off-grid Decentralized Energy, and not in less efficient and more costly central power with its associated transmission and distribution network.”¹¹²

Even the World Bank's energy sector management assistance program offers this advice to power system planners:

When the national or regional grid is developed and includes sufficient transmission capacity, and incremental load growth is fast, large, central-station gas combined cycle and coal-fired plants would clearly be the least-cost alternatives. However, if the size of the grid is limited [Cambodia], or the incremental load growth is small [Cambodia], it may make economic sense to add several smaller power stations rather than one very large power station. Taking advantage of local resources such as indigenous coal, gas, biomass, or geothermal or wind or hydro, and constructing smaller power stations, may provide greater energy security and avoid some of the uncertainty associated with international fuel prices, as well as the risk associated with financing and constructing very large plants.¹¹³

For electrification in rural areas, where the majority of Cambodians live, decentralized generation can be scaled to match the power needs of rural customers who may only require service for several hours during the day or evening, or may need more than that for powering a small business or factory. Decentralized generation can be financed and organized by any number of local organizations and entrepreneurs in ways that create local employment, encourage investment in

rural businesses, and boost farmers' incomes.¹¹⁴ The technologies can be quickly installed directly on rooftops, in homes, shops, factories and buildings. Or as international donors, including JICA and the World Bank, have recommended, electricity service can be provided to consumers through a small village grid or a multi-village grid, or even a district-scale grid operated by community cooperatives or private companies.



*A Micro-Hydropower Project in O Pong Moun,
Stung Treng.*



Solar Panel Installed for a Remote Literacy Class in Rattanakiri Province. Photo courtesy of Clean Energy Group.

Table 7 compares the levelized generation costs of decentralized generating technologies. Note that solar home systems are now more economical than off-grid diesel generators at a cost of 20 to 40 US cents per kilowatt-hour (and dropping). Where some decentralized generating technologies are still more costly per unit of output than conventional power plants (i.e., solar panels), it is their *value* – due to improved environmental quality, reductions in transmission and distribution losses, proximity to consumers, reduced requirements for reserve capacity, and grid reliability – that more than compensates for their higher initial cost per unit output.

Decentralized generating technologies and resources that could be deployed on a large-scale (but in small increments) to meet Cambodia's electricity needs are described in sections 5.1 to 5.8.

TABLE 7: Decentralized generating technology cost estimates

Energy source/ technology	Size (kW)	Cost (US cents/ kWh)	Typical uses
Solar panels (Photovoltaics)	1 – 100	20 – 40 www.solarbuzz.com/DistributedGeneration.htm	<ul style="list-style-type: none"> ▪ Baseload power source connected to a grid, sending surplus into the grid during the day, drawing from the grid at night ▪ Valuable for their capacity to reduce peak loads on the grid ▪ Off-grid homes, remote industrial applications (i.e. telecommunications, signage) ▪ Used in hybrid systems with wind, micro-hydro, diesel
Microturbines	30 – 300	10 – 15 www.solarbuzz.com/DistributedGeneration.htm	<ul style="list-style-type: none"> ▪ Baseload or peaking power source connected to a grid ▪ Cogeneration applications
Diesel/gasoline Generators	0.3	58 – 72	<ul style="list-style-type: none"> ▪ Off-grid power source in rural/remote areas
Diesel/gasoline Generators	1.0	48 – 58	<ul style="list-style-type: none"> ▪ Off-grid power source in rural/remote areas
Diesel Generator	3,000 to 5,000	8 – 11	<ul style="list-style-type: none"> ▪ Baseload power source connected to a grid ▪ Used for peaking, connected to a grid
Biomass Gasifier	100	8 – 9	<ul style="list-style-type: none"> ▪ Baseload power source connected to a central grid or local distribution network
Micro Hydro	100	10 – 12	<ul style="list-style-type: none"> ▪ Off-grid power near water source
Mini Hydro	5,000	5.5 – 8	<ul style="list-style-type: none"> ▪ Off-grid and grid connected applications near water source

Source: Except where noted otherwise, technology cost estimates are from Technical and Economic Assessment of Off-grid, Mini-grid and Grid Electrification Technologies, Energy Sector Management Assistance Program Paper 121, World Bank, December 2007. www.worldbank.org



5.1 Biomass Gasifiers

Biomass gasifiers are a proven and commercially viable technology that have been successfully deployed across Europe, as well as in rural India, Thailand, and Cambodia. The gasifier is a specially designed reactor that heats biomass in a low-oxygen environment to produce a fuel gas. The gas produced is then used to drive a gas turbine or combustion engine which generates electricity. Biomass gasifiers are ideal for rural areas where agricultural residue (i.e., rice husk, corn cobs) is abundant or land for growing fuel crops is available.

Biomass gasifiers¹¹⁵ operate at a number of rice mills in northwest Cambodia, managed by rice mill cooperatives without government subsidies (See Box: SME Cambodia). A cooperative sets its per kilowatt-hour (kWh) tariff so that revenues collected cover all system operation and maintenance expenditures including equipment replacement (i.e., depreciation) costs and debt service charges.

Benefits

- Reduces costs for rice millers and other rural industries by replacing diesel fuel with gas produced from agricultural waste or fuel crops
- Provides lighting for rural homes, schools, hospitals, refrigeration, computers, and so on
- Increases farmers' income by selling locally produced renewable energy fuel crops or agricultural waste that would otherwise be burned in fields (causing air pollution) or left to rot (causing rat and other pest infestations)
- Creates employment for rural residents
- Lower emissions than diesel generation
- Financially sustainable (i.e., beneficiaries pay full cost)



*A Biomass Gassifier in Anlong Tamey, Battambang.
Photo courtesy of SME Renewable Energy Ltd.*

5.2 Combined Cycle Plants

The most energy efficient and economical power plant in the world today is the gas-fired combined cycle plant. A combined cycle gas turbine system consists of a gas turbine followed by a steam turbine.¹¹⁶ Hot waste gases from the gas turbine are used to drive the steam turbine, with an overall fuel efficiency of 45 to 50 percent. Combined cycle plants produce far less harmful emissions compared to coal-fired plants and can be sited close to consumers, thereby eliminating or reducing the need for long distance transmission lines. When the



waste heat from the second turbine is used to provide heating or cooling (via an absorption chiller) onsite or to nearby customers, combined cycle plants can achieve fuel conversion efficiencies of up to 90 percent.

5.3 Cogeneration/Combined Heat and Power Systems

CHP stands for “combined heat and power” and is also known as cogeneration. It is a process that captures waste heat from industrial processes or from gas- or steam-fired turbines to generate electricity or provide hot water, space heating or cooling in buildings.

Cogeneration schemes can have different sizes, ranging from building-scale of 5 kilowatts to several hundred MWs of industrial cogeneration.¹¹⁷ Cogeneration schemes are usually sited close to the consumers; often surplus electricity is sold to the electricity grid or supplied to other nearby customers via the (low-voltage) distribution system.

When on-site power plants are configured for cogeneration, businesses can significantly reduce their overall operating costs because they are using the same fuel to do two things: produce electricity *and* provide heating or cooling to site buildings or industrial processes. Cogeneration systems achieve fuel conversion efficiencies of 50 to 90 percent, which is a dramatic improvement over the 35 percent efficiency in conventional fossil fuel-fired power plants. This translates into fuel savings of between 15 to 40 percent when compared with the separate production of electricity from conventional power stations and of heat from conventional boilers.

Cogeneration can be used in the process industries (pharmaceuticals, paper, brewing, ceramics, brick, cement, food, and textiles), commercial buildings (i.e., hotels, hospitals, swimming pools, universities, airports, and army barracks). Cogeneration’s higher efficiencies reduce air emissions of nitrous oxides, sulfur dioxide, mercury, particulate matter, and carbon dioxide. Cogeneration units can run on natural gas or other fuels, such as biogas or landfill gas.

Hundreds of companies around the world now offer pre-engineered,

factory built and tested combined heat and power systems with capacities ranging from several hundred kilowatts to 10 MW and higher.¹¹⁸ Financing and maintenance packages are tailored to customers' needs, and performance is normally guaranteed under contract.

According to the International Energy Agency, greater use of CHP could dramatically improve energy efficiency in the heat and electricity sectors *and* reduce the need for new transmission and distribution investments by an estimated \$795 billion over the next 20 years.¹¹⁹

The oldest (and least-cost) form of cogeneration is where waste heat from industrial boilers are used to generate electricity. In Vietnam, for example, Siam Cement Group uses waste heat from its paper-making facility to generate power. The companies use the power on-site, which is cheaper and more reliable than buying power from the state utility, Electricity of Vietnam Corporation.¹²⁰

Agricultural byproducts such as bagasse (sugarcane waste) or rice husk are used to fuel industrial boilers which then deliver steam to a high efficiency turbine. In Vietnam, a 2004 study by the Asian Institute of Technology and the University of Dundee's Centre for Energy, Petroleum and Mineral Law and Policy found that cogeneration is a cost-effective option for Vietnam's sugar mills. The study found that cogeneration plants run on bagasse would break even if they could sell excess power to the grid for an estimated 4.5 US cents per kilowatt-hour.¹²¹

5.4 Gas-Fired Power Plants

Dozens of companies worldwide supply decentralized power markets with a range of gas-fired power plants from 1 to 300 MW, which can be used for flexible base load, industrial cogeneration, or peaking. These plants can be run on natural gas, light fuel oil, heavy fuel oil, crude oil, biofuel and biomass, or a combination. Their modular and pre-fabricated design enables fast-track delivery and staged expansion which minimizes initial investment and business risks. A typical 50-MW gas-fired plant can be ordered and installed in under seven months.¹²²



Benefits

- Higher fuel efficiency, lower generation costs
- Fast ramp up rate (less than 10 minutes)
- Low emissions
- Fast delivery
- Simple, proven design
- Extension-ready
- Easy onsite maintenance



A Gasifier. Photo courtesy of Schmitt Enertec GmbH.



5.5 Micro Hydro

The definition of micro hydropower varies from country to country and can even include systems with a capacity of a few megawatts. Some definitions limit micro hydropower capacity to 300 or 500 kW because this is about the maximum size for most stand alone hydro systems not connected to the grid, and suitable for "run-of-the-river" installations.

Electricity is produced from the energy in water flowing from a high level to a lower level. This change in elevation is called "head" and it is what supplies the pressure, which drives the turbine. The volume of water flow also determines how much power can be produced. Hydropower is in theory an efficient renewable energy source because the fuel is water, which is not consumed in the electricity generation process. However, hydro is often extremely damaging to river systems and fisheries, even on a very small scale. Even the smallest hydro projects should be closely evaluated for economic and environmental sustainability.

Micro hydro (<100 kW) and Pico hydro (<5 kW) systems are typically far cheaper per unit of electricity produced than wind or solar power, and they require no dam or expensive construction since the systems run on stream flow. Even on this small scale, projects can be damaging to fisheries and should be carefully evaluated for economic and environmental benefits and costs.

Pico hydro technology is already common in the highlands of China, Lao PDR, Thailand, and Vietnam.¹²³ A picohydro turbine (200 to 300 watts) can be bought in the local markets of Lao PDR and Vietnam for as little as US\$20 or US\$30. Installation of the turbine including wiring, piping, and turbine housing costs under several hundred dollars.¹²⁴ Vietnam has an estimated 100,000 Pico hydro turbines in operation; the number of Pico hydro installations in Lao PDR is not known.

As for micro hydro, Vietnam has 2,500 micro hydro schemes which supply power to 200,000 rural households. In Lao PDR, an estimated 12,000 rural households are supplied by micro or small hydro (up to 5 MW).

For Cambodia, both JICA and the World Bank have recommended mini (< 100 kW) and micro hydro (100 kW – 1 MW) projects as more cost effective than diesel generators and suited to supplying mini-grids in rural areas with loads between 5 kW and 500 kW.¹²⁵

Utilities in Canada and the UK have developed procedures for private development of micro hydropower, which includes a step by step guide to plan development, site selection, siting and permitting procedures, water licensing, grid interconnection, and electricity sales. In these and other countries, all hydro installations on rivers populated by migratory species of fish are required to conduct careful assessments and must include the cost of proven mitigation measures into the project cost.

Small hydro (<10 MW)



Kong Micro-Hydropower Scheme in Laos. Photo courtesy of Ian Baird.

Cambodia's small hydro (<10 MW) potential has been eclipsed by the government's focus on large-scale hydro development. Companies in neighbouring Vietnam and Lao PDR, meanwhile, are moving ahead with several small hydro schemes. In Vietnam, the Nam Khot Hydro Power Joint Stock Company signed a contract in May 2008 to install two 5.5 MW hydro turbines in Son La province, Vietnam. The small

hydro equipment is procured from an Indian-French supplier, Flovel Mecamidi Energy Private Limited. In China, where small hydro is classified as units up to 50 MW, more than 42,000 small hydro stations with a total installed capacity of 28,000 MW are in operation.

Hydro schemes of all scales tend to provoke public opposition in most countries because of their negative impacts on migratory fisheries, river ecosystems, and local communities.¹²⁶



Katu Micro-Hydropower Scheme in Laos. Photo courtesy of Ian Baird.

5.6 Microturbines

Microturbines range from 30 to 300 kilowatt capacities and can run on a variety of fuels, including natural gas, propane, and fuel oil. They are useful for base load, peaking or cogeneration applications.¹²⁷

Capstone is a leading global manufacturer of microturbines designed for “building-scale” cogeneration, which can range from 30 kW to several MWs or higher. The equipment price (excluding installation) of a 30-kilowatt microturbine would be in the US\$30,000 to 35,000 range; and US\$50,000 to 60,000 range for the 60-kilowatt model.¹²⁸



Where natural gas is not available, Capstone's 200kW unit can run on alternative fuels. A Capstone cogeneration unit offers significant fuel savings with a fuel efficiency rating of 85 percent compared to 50 percent for a conventional steam-fired turbine. With building-scale cogeneration, power consumers from oil and gas refineries and chemical plants, to automotive assembly lines to food processing plants, to hotels, hospitals and university campuses – could lower their monthly operating costs^{and} have the option to sell power into the grid when or if a grid becomes available.

As of October 2008, Capstone microturbines are being sold by the Toan Thang Company in Ho Chi Minh City, Vietnam. Capstone also has an office in Shanghai, China. Its micro-turbines have been operating commercially since 1999 and have been successfully installed in office and apartment buildings, hotels, supermarkets, schools, colleges, industrial parks, small industries, and other facilities.

Benefits

- Operate reliably and independent of the grid if necessary
- Low to moderate initial capital cost
- Fuel flexibility allowing them to burn either gases (natural gas, biogas, oil-field flared gas) or liquid fuels
- Low emissions
- Fuel savings

5.7 Solar Photovoltaics

A solar photovoltaic panel is a cell which converts energy from the sun directly into electricity. The technology is defined by the choice of semiconductor, which absorbs light and converts it into electrons: either crystalline silicon in a wafer form or thin films of other materials. Solar cell manufacturers in Germany and the US now say they will be able to deliver solar panels that can produce electricity from between 10 to 12 US cents per kilowatt-hour by 2010. The industry refers to getting the price of solar competitive with other grid-based supply as “achieving grid parity.”

The technology is suited to off-grid homes, remote applications (i.e., telecommunications) and as a supplemental power source for grid-connected customers. Until now, solar's high cost is mainly because *silicon* is used as a *semiconductor* to turn sunlight into electricity and silicon is very expensive. Nanosolar is a fast-growing company in California that has come up with a unique way to bring the price of solar panels down, by making very thin-film solar panels on a machine that's similar to those that print newspapers. The machine itself, which can be seen in operation via the internet, costs under US\$2 million and it produces enough material to make 1,000 MW of solar panels per year.¹²⁹

In Cambodia, a 40 watt solar home system capable of providing lighting and enough power for television a few hours a day costs between \$400 and \$700. According to the World Bank, "solar home systems provide high economic returns for areas with low load density for which grid extension is uneconomic."¹³⁰



*Installing a solar panel on the roof of a security guard post in Kampong Speu province to supply solar lighting in the evenings.
Photo courtesy of Clean Energy Group.*



5.8 Natural Gas

Natural gas is an important fuel for decentralized generation, whether for high efficiency cogeneration applications or for new technologies such as gas-powered cooling systems. Bringing natural gas onshore requires a distribution network of pipelines and compressor stations, which could be readily installed and financed by any number of reputable gas companies in the region and internationally, through a competitive bidding process.

Cambodia is believed to have abundant natural gas reserves offshore but exploration and development has been stalled for years due to political disputes and the absence of a credible legal and regulatory framework to enable the development of a domestic gas industry.

Natural gas is less expensive and cleaner burning than coal and produces no ash or heavy metals. Due to its low carbon content, natural gas produces 30 percent less carbon dioxide per unit of energy than oil does, and 43 percent less than coal, which means less harmful emissions in the atmosphere. Natural gas is also relatively easy to process compared to oil, and less expensive to transport via pipeline than coal by rail or ship.¹³¹

Thailand's Pattani basin has been reliably producing natural gas for years, fuelling Thailand's fleet of modern combined cycle power plants and its rapid industrialization. About 70 percent of Thailand's power supply comes from natural gas-fired combined cycle and cogeneration plants. Similarly, about 40 percent of Vietnam's power supply comes from a single complex of large gas-fired combined cycle plants that run on natural gas brought onshore in the south over the last 20 years.¹³²

Cambodia, meanwhile, lags behind. Natural gas is absent from the country's power development plan (2007 – 2022) until 2020 at the earliest. Without access to natural gas, Cambodians are missing out on the new generation of flexible and smaller-scale gas-fired combined cycle plants and microturbines that could dramatically lower consumers' electricity costs and stimulate much-needed business development.

According to the industry journal, *Oil and Gas*, Phnom Penh authorities are holding out for a 60-40 share of gas found in a disputed 27,000-square kilometre block of ocean, an increase from the 50-50 split of resources agreed to by Thailand and Cambodia six years ago.¹³³



A Natural Gas Separation Plant in Rayong, Thailand.

Renewable energy companies in Cambodia

Several companies are deploying decentralized renewable energy technologies in Cambodia. As of 2008, SME Renewables Cambodia (BOX 3) had 30 small-scale biomass gasifiers in various stages of commercial development as a cheaper, cleaner alternative to using diesel for powering rice mills and other rural businesses.¹³⁴ Another company, KC Solar, has been selling household-scale solar power systems and water heaters since 2006. To date, the company has sold about 2,000 solar home systems at a cost of US\$1,200 each.¹³⁵ More recently, the Lao-based solar technology distributor, Sunlabob (BOX 5), and the Phnom Penh-based engineering firm, Comin Khmere, formed a new joint venture called the Clean Energy Group (BOX 4), which distributes and installs the latest renewable energy technologies, including solar water pumps and power systems.¹³⁶

**BOX 5: Sunlabob (Lao PDR)**

www.sunlabob.com

Sunlabob was established in 2001 as a private energy system and service provider developing solutions for villages in rural Lao PDR where there is no grid and may not be grid extension for many year to come. Sunlabob specializes in solar equipment and hybrid village grids.

Rental solar systems

Sunlabob buys solar equipment then installs and rents the equipment to rural customers. The rent covers all costs, including replacement and operating/servicing costs. Villagers prefer this approach because they don't have to bear the financial and technical risks. If the system breaks down, customers are not required to make payments until the system is fixed. To ensure that rental payments are reliably collected, Sunlabob rents equipment to a village committee which is responsible for rent collection and repayment to Sunlabob. So that Sunlabob can guarantee fast and reliable servicing, it established a network of trained service agents.

Hybrid village grids (HVG)

Sunlabob provides hybrid village grids that run on multiple resources (solar, hydro, and diesel). The company setup its first HVG in 2007, using an abandoned dam. The grid typically uses solar energy, which is available in the daytime, and diesel generators when hydro output is low due to low water flow levels at different times of the year.

The hybrid village grids provide electricity for households and local industries, powering machinery such as rice mills, water pumps, woodworking machines, and food processing equipment. In this way, the system goes beyond improving living conditions at the household level to increase villagers' incomes.

To provide these systems, Sunlabob has partnered with a number of global technology suppliers: for hydro, Entec AG, a Swiss company specializing in small hydro systems globally; for diesel generators, Comin Khmère (Cambodia). Although Lao PDR has limited wind resources, Sunlabob has also established contact with three wind turbine manufacturers and suppliers, Bergey Windpower, Fortis, and Southwest Windpower.



Solar Panels in Kampot Province Used to Run a Solar Pump, which Fills the Water Tower in the Background. Photo courtesy of Clean Energy Group.

6.

**Central vs. Decentralized
Generation**



6. Central vs. Decentralized Generation

The next section reviews: how large hydro dams work in a centralized generation system; the rise of gas turbine technology; and trends in decentralized power production and investment.

6.1 How Large Hydro Dams Work

In a large hydroelectric dam powerhouse, falling water spins turbines and each turbine spins a generator. Each generator produces surges of electricity moving back and forth in the wires at a rate of 50 times per second. This is known as alternating current or AC electricity. AC electricity fed into the wires from a series of generators in the powerhouse must be kept in step with each other and with other generators on the network to avoid damaging the system.

From the powerhouse, electricity is fed into a series of transformers to increase its voltage to 500 kilovolts so the electricity can be sent hundreds or even thousands of kilometres along transmission lines without losing too much energy heating the wires. At the other end of the transmission line, the electricity is “downloaded” or fed into a second series of transformers, this time to decrease the voltage so it can be delivered through distribution networks to users. In Cambodia, this power is delivered to users at 230 volts. This type of arrangement is how power stations are linked to users of electricity systems all over the world.

Most electricity systems generate electricity in much the same way: in large power stations that send electricity over wires to users in the form of alternating current (AC). This central-station system was pioneered by Thomas Edison in the United States during the late 19th century. AC electricity and transformers make it possible to generate electricity in large power stations at remote locations and deliver it via high-voltage transmission and low-voltage distribution to users over a vast area, without incurring unacceptably high



energy losses. Today's power industry evolved on the assumption that large central stations and high voltage transmission were the most economical way to expand electricity service, and so they were until the 1970s or 1980s.¹³⁷

6.2 The Rise of Gas Turbine Technology

The technology that broke the trend to ever-larger power stations is the gas turbine – a machine developed from the jet engine. The gas turbine burning natural gas is more efficient, faster to build, and cleaner than a coal-fired station, and does not have the environmental problems associated with large hydro dams and nuclear reactors.

Gas turbines began displacing coal-fired generation and nuclear plants in Europe, Japan, and the United States in the 1980s. Prior to this, most of the big power plants built were fueled by coal or by nuclear power. Both types of stations used a simple steam turbine: the heat generated by burning the fuel produced steam, which spun a turbine connected to an electricity generator. Nearly two-thirds of the energy used in this process is vented into the atmosphere as waste heat. Because so much fuel ends up as waste heat it made sense to use the cheapest fuel possible, which usually meant coal.

Gas turbines and particularly combined cycle plants changed all that. In a combined cycle plant, the excess heat from a gas turbine is used to power a steam turbine, thereby boosting efficiency and doing more with less. Combined cycle plants developed by General Electric and ABB in the early 1990s were capable of reaching fuel-conversion efficiencies of 50 percent and higher. They cost about half as much as a coal-fired plant to build and even the largest plants could be installed and operating within one or two years.¹³⁸

The gas turbine is responsible for accelerated global investment in combined heat and power systems or cogeneration, in which the waste heat from the gas turbine (or from the second steam turbine in a combined cycle arrangement) is used in factories and buildings.

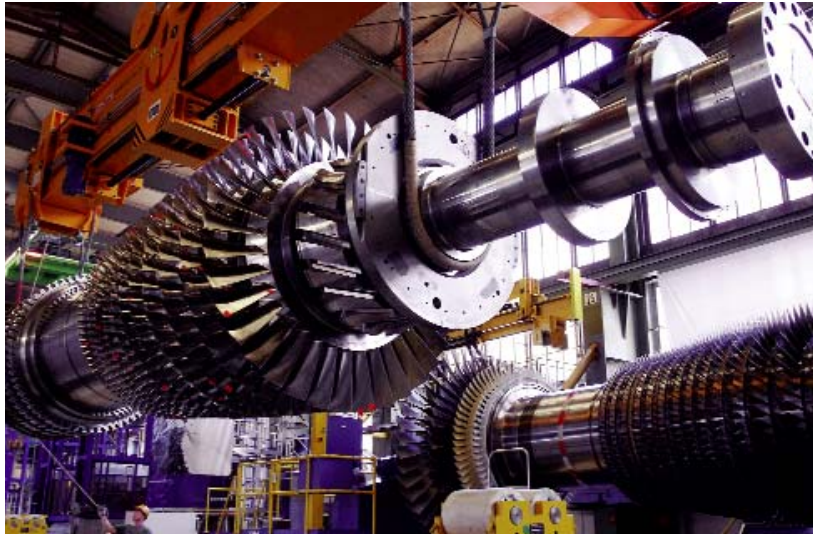
As British energy expert Walt Patterson explains in his book *Transforming Electricity*, the gas turbine was the fastest growing

technology option for generating electricity by the early 1990s. With its low capital costs and fast construction times, gas turbines even began to threaten big hydro proponents in the Mekong region by the late 1990s.¹³⁹ Both Thailand and Vietnam have encouraged private investment in large-scale combined cycle plants run on natural gas from within the region. Today, Thailand and Vietnam rely on natural gas for roughly 70 and 40 percent of their power supply, respectively.

The first generation of combined cycle plants were very large-scale, often 300-MW, 700-MW or larger, operated mainly for base load power, with few start-ups and shut-downs in a year. Since the early 2000s, however, excess generating capacity and high natural gas prices in US and European power markets prompted combined cycle plant manufacturers to develop more flexible and smaller scale units that can be operated economically under many different scenarios depending on actual market demand. Siemens, for example, has developed a new combined cycle plant that can be started up in half the time of the earlier models, giving the operator greater flexibility (and fuel savings) in uncertain market conditions.¹⁴⁰



Southdown Cogeneration Facility in New Zealand.



A 340 MW Gas Turbine in Irsching Bavaria. Photo courtesy of Siemens Press Picture.



The Phu My Complex, a Combined-Cycle Gas Turbine Power Plant in Southern Vietnam.

6.3 Global Trends

Utilities worldwide have been slow to recognize that what matters most to modern businesses and manufacturers is that they have access to *reliable* power more than abundant *cheap* power. In fact, the



need for reliable power is what has driven private investment in distributed (or on-site) generation in the last decade or more. Large industrial power consumers in Japan, Thailand, the United States and Vietnam have opted out of the central electricity system to generate their own power on-site or buy power from a cheaper power producer nearby. Those consumers may pay less or sometimes more than the cost of power from the central grid, depending on fuel prices and the choice of technology. What matters to industrial consumers most is that they get improved reliability. Fewer power supply interruptions can save businesses, particularly hi-tech manufacturers, millions of dollars annually by avoiding lost production time or damaged products.

In their 1994 book *Power Surge: A Guide to the Coming Energy Revolution*, US researchers Christopher Flavin and Nicholas Lenssen write: "If deployed properly, distributed generation and storage may increase reliability and reduce costs, as well as reshape today's utility systems. A utility with 50 generators connected to its system today could see the figure reach 5,000 or even 50,000 by 2010, much as some corporations went from three mainframe computers in the 1980s to 30,000 personal computers in 1994."¹⁴¹

Carl Weinberg, the former research director for PG&E (a leading US utility) who helped develop the concept of decentralized generation, is quoted as saying: "Operating modes for utility systems are likely to evolve along a path similar to that taken by computer networks and telephone switching. . . . The networks of future utilities will manage many sources, many consumers, and continuous re-evaluation of delivery priorities. All customers and producers will be able to communicate freely through this system to signal changed priorities and costs."¹⁴²

Weinberg's vision of future utilities is fast becoming reality. Using advanced computer and communication technologies, utilities across Europe and the United States are modernizing their power grids to handle two-directional flows of power and information between multiple producers and consumers. The power industry refers to this as "smart grid innovation" and the goal is lower costs and greater reliability with increased efficiency on *both sides* of the electricity system:



production and consumption.¹⁴³

The global share of new generation that is decentralized is increasing, and it's being installed either for the purpose of enhancing existing power systems or as a cleaner, cheaper alternative to central generation expansion.

As of 2008, decentralized generation (renewables plus cogeneration) provides anywhere from one-sixth to more than half of all electricity supply in a dozen industrial countries, including 53 percent in Denmark, 38 percent in Finland and Holland, 30 percent in Russia, 20 percent in Germany, 17 percent in Japan and Poland, and about 6 percent in the United States.¹⁴⁴

In the future, the proportion of decentralized generation is expected to go much higher as governments and utilities begin to appreciate the advantages over conventional power plants, and allow decentralized power producers to compete with conventional suppliers or sell direct to local customers. In Canada, for example, the provincial utility BC Hydro recently established an office to help distributed power generators connect to the grid. The office provides a point of contact for decentralized generation applicants and guides them through the process of interconnection with the utility's local distribution network.¹⁴⁵

The Geneva-based International Energy Agency credits five factors for the global rise of decentralized generation:¹⁴⁶

- Advances in decentralized generating technologies
- Public opposition to the construction of new transmission lines
- Increased customer demand for highly reliable electricity
- Electricity market liberalization; and
- Climate change concerns

Renewable energy has become big business (See BOX 6).¹⁴⁷ According to the European Council for Renewable Energy:



Decades of technical progress [has] seen renewable energy technologies such as wind turbines, solar photovoltaic panels, biomass power plants, solar collectors and many others move steadily into the mainstream.¹⁴⁸

BOX 6: Renewable energy investment trends

- European power utilities have spun off their own RE subsidiaries separate from their own utility operations. For example, Electricite de France setup a RE subsidiary and raised half a billion dollars in private capital since its Initial Public Offering (IPO) on the European stock exchange in November 2006.
- RE makes up 9.4 percent of global energy infrastructure investment
- 82 percent of global RE investment is in China, India, and Brazil
- Solar is the fastest growing RE sector although wind is still the largest sector globally
- Solar generating capacity increased by 250 percent in 2007 to \$17.7 billion value
- Solar investment has grown at an annual average rate of 254 percent since 2004
- Chinese solar panel manufacturers are tapping US capital markets: LDK Solar and Tianwei Yingli listed on the New York stock exchange in 2007¹⁴⁹

Excluding large hydro, renewable energy investment in 2007 grew to US\$71 billion, almost twice as much as the previous year. Global investment in large hydro was between US\$15 and US\$20 billion in 2007, which is only 60 percent of that in wind projects and roughly equivalent to that in solar.



*10 MW Solar Thermal Power Plant in California, USA.
Photo courtesy of kjkolb.*

7.

Promotional Policies, Financial Incentives and Common Barriers



7. Promotional Policies, Financial Incentives and Common Barriers

High fuel prices and environmental concerns have prompted many governments around the world to introduce subsidies aimed at accelerating investment in renewable energy and cogeneration, though *not* specifically decentralized generation. Such subsidies would not be necessary if old subsidies for conventional generation technologies were removed and electricity prices reflected true costs. According to the European Renewable Energy Council, if environmental costs were charged to the power producers that create them, and if subsidies to conventional power sources were removed, “the need to [subsidize] renewable electricity generation would seriously diminish or cease to exist.”¹⁵⁰ The problem is that most governments and politicians prefer to *introduce* subsidies for favoured fuels and technologies rather than do what’s required: *remove* subsidies for energy in all its forms, and force consumers to pay the true costs.

This section reviews the most common technical and regulatory barriers to decentralized generation (apart from subsidies for old technologies), and the most common promotional policies for accelerating investment in renewables and cogeneration (without removing old subsidies). Cambodia has the opportunity to learn from this experience and modernize its power development strategy accordingly.

7.1 Technical and Regulatory Barriers

Despite the economic and environmental advantages associated with decentralized generation technologies, there remain a number of common barriers to accelerated market deployment, which are outlined below. Such barriers are neither insurmountable nor inevitable.

Technical misconceptions

Utilities and central planners tend to confuse the total amount of electricity needed with the size of generating components needed to meet demand. But just like a country’s total electricity demand is the sum of many small and dispersed loads, and a few bigger loads (i.e., large



industrial or commercial consumers), the output from many small generators can be more than enough to meet consumers' needs.¹⁵¹

For years, utilities have claimed that connecting many smaller generating units to the grid would make the system unstable, difficult to manage, and prone to failure. But industry experts insist this 'truth' no longer applies: connecting multiple producers of all sizes is technically and economically feasible. Countries such as Denmark, which have a large number of small power plants (including gas cogeneration and wind) connected to the grid, have worked out how to accommodate multiple suppliers, even very small ones, and the technology required to do this is readily available.

Another frequent assertion by utility planners is that decentralized renewables are inferior to conventional generating technologies because they cannot deliver 'firm' or reliable power. Nobody debunks this claim better than US energy expert Amory Lovins, who writes:

"All sources of electricity are unreliable – to differing degrees, for differing reasons, with differing frequencies, durations, failure sizes, and predictabilities. Major grid failures occur during regional blackouts, ice storms, and other disruptions. Individual power plants also break down: the average US fossil fuel fired plant is unexpectedly out of service ~8 percent of the time. Power systems are designed to cope with all this too. Yet size does matter. Even if all sizes of generators were equally reliable, a single one-million-kilowatt unit would not be as reliable as the sum of a thousand 1-MW units or a million 1-kW units. Rather a portfolio of many smaller units is inherently more reliable than one large unit – both because it's unlikely that many units will fail simultaneously, and because 98 – 99 percent of US power failures originate in the grid, which distributed generation largely or wholly bypasses. . . . All generators – not just variable renewables – need reserves, backups, or storage to achieve a given level of reliability. It's wrong to count these as a cost for variable renewables but not for intermittent thermal [or big hydro] plants. Every source's economics should duly reflect the amount of support they require for the desired reliability of retail service."¹⁵²



Inadequate regulatory framework

Transparent and explicit rules are required to create investor confidence and lower transaction costs for assessing resource availability, best locations, local demand, and financing options for decentralized generation. For large-scale project developers such transaction costs are heavily subsidized by governments and government-funded development banks.

Investors in biomass generation facilities, rooftop solar photovoltaics, and micro-hydro schemes require straightforward and explicit procedures for obtaining the necessary permits and public approval. Governments encouraging this type of investment can facilitate this process by making all information and approval requirements clear and accessible to all prospective investors and developers.


7.2 Promotional Policies

Market share mandates

Governments set a target for new capacity and then impose an obligation on electricity producers or distributors to either buy or produce a minimum amount of power from that particular source or technology.¹⁵³ The target helps stimulate business development and investment.

GERMANY – Germany amended its combined heat and power (CHP) law effective January 1, 2009, which sets a target of 25 percent for the amount of power coming from combined heat and power systems by 2020. To meet this target, the government is offering a fixed price for CHP power.¹⁵⁴ Two months later, Germany's heating and air-conditioning specialists, Vaillant, announced it had teamed up with Japanese technology company, Honda, to develop a new gas-fired micro cogeneration system for providing electricity and heating/cooling for single family homes.¹⁵⁵

CHINA – China passed a renewable energy law effective January 1, 2006, which requires all state-owned power companies to buy or pro-



duce a portion of their electricity from renewable energy sources. By 2010, the governments predicts Chinese power consumers will get 10 percent of their power supply from RE sources (excluding large hydro), and 15 percent by 2020.¹⁵⁶ Water is listed as one of the energy sources the government wants to encourage but it remains unclear what scale of hydro generation will be included as “renewable.” Some analysts say the law is aimed at promoting small hydro dams, which in China includes dams with capacities up to 50 MW.

Like most mandated targets, China’s renewable energy law aims at diversifying the country’s sources of power supply, which is currently about 70 percent coal. So far, large solar and wind projects are attracting the most investment but the law includes biomass, ocean energy, and geothermal technologies, all of which can apply for tax exemptions and low-interest loans from the government.

The risk with mandated market share policies is that politicians and governments decide how fast the desired new energy sources and technologies get introduced, rather than the market. This can lead to either underinvestment or overinvestment in renewable energy technologies.

Feed-in tariffs

Utilities offer fixed prices to eligible power producers for the electricity they provide to the grid under long-term contracts. Prices vary for different fuels, technologies, and locations. Any additional cost over and above what the utility would have had to pay itself (known as the utility’s avoided cost) is shared among all consumers.

Governments in more than 40 countries around the world, including Thailand, have adopted some form of feed-in tariff to promote renewable energy investments.¹⁵⁷ Unlike market share targets, the government does not specify how much capacity is required but instead offers a standard range of prices to different producers. That price is public and known in advance of project development. Feed-in tariff proponents insist that a regular review of the program be undertaken by the regulatory authority to ensure that the tariffs are set appropriately and that they are lowered regularly as renewable energy project



costs decrease.¹⁵⁸

Feed-in tariffs are very popular with the renewable energy industry and most international environmental organizations. They are also controversial where governments override democratic decision-making and citizens' property rights to fast-track renewable projects, or where renewable energy producers receive several times as much for their electricity as other power producers.¹⁵⁹

Feed-in tariffs benefit developers because the fixed price gives them the certainty they need to obtain commercial financing. Usually, the feed-in tariff for renewable energy producers is set higher than the utility's existing electricity rates and the extra cost is covered by an additional charge on consumers' electricity bills. Usually no bidding is required, which is typically intended to minimize the developers' investment risk and encourage community and local ownership. Many environmental organizations now argue that planned nuclear and coal plants can be displaced by renewable power sources, using feed-in tariffs to stimulate investment.¹⁶⁰

The risk with feed-in tariffs is that governments set the initial feed-in tariff too high, particularly if it's a new technology and the true cost is difficult to gauge initially. So consumers can end up paying more for renewable energy than they would have under a competitive bidding program. If the feed-in tariff is fixed too high and/or for too long, this can lead to over-sized investments or inappropriately scaled projects and higher than necessary electricity costs, particularly where the market price of the technology (i.e., solar) is dropping rapidly.

For developing countries, feed-in tariffs may be politically difficult to implement if it means higher electricity rates for consumers who either have difficulty paying for service, or who have been accustomed to paying below-cost prices.

In Cambodia's case, feed-in tariffs for biomass generation and microhydro could actually be lower than what consumers are currently paying for service in some areas. So feed-in tariffs, carefully applied, may be a good option for stimulating renewable energy investment in an otherwise uncertain and weakly regulated (read high-risk) market.



Without scrupulous regulatory oversight, however, the danger is that feed-in tariffs for renewable energy projects – just like large-scale IPP fixed price contracts – promote inefficient or unwanted investments (by developers chasing subsidies) at the expense of local communities and the environment.

Even in countries with a well established regulatory tradition in the electricity sector, politicians anxious to go “green” can bypass the regulatory process altogether and secretly negotiate deals with renewable energy producers, locking utility ratepayers into higher and uncompetitive prices for years to come.¹⁶¹

Competitive bidding

The government or utility specifies a target amount of new capacity to be added to the system on the basis of open competitive solicitations or procurement. Project developers submit bids for contracts in accordance with terms and conditions for access to the grid and customers determined by the government. Note this differs from the Cambodian energy ministry’s approach, where developers negotiate concessions for projects selected by the government.

Utilities have used competitive procurement for years to add new generating capacity. In Thailand, the World Bank warned its client-utility (EGAT) back in 1994 that negotiated deals “often produce high prices and unfavourable contract terms” and that the “single best way to obtain good price and non-price terms [from independent power producers] is by competitive procurement. . . . Experience in US utilities show that a combination of several smaller bids often provides a lower-cost and less risky supply alternative than a single larger bid.”¹⁶²

Governments often use competitive procurement to add generating capacity in smaller, less risky increments. The Cayman Islands’ electricity regulatory authority in the Caribbean, for example, invited bids last year from private developers for 16 MW of new generating capacity, without specifying technology or fuel type.¹⁶³

In South America, Europe and China, the World Bank reports that gov-



ernments have used competitive bidding to grant concessions for the development of grid-connected wind farms. England's first attempts at using competitive bidding for renewable energy concessions in the late 1990s were not so successful, resulting in a number of poorly designed projects and a high number of winning bidders unable to raise financing for their projects. China too had difficulties with its first competitive bidding for wind projects. Ireland was more successful, by pre-qualifying bidders to ensure that all bids were realistic and high quality, which led to Ireland having some of the lowest renewable energy prices in Europe.¹⁶⁴

7.3 Financial Incentives

Globally, governments have introduced a number of financial incentives and subsidy programs to accelerate deployment of solar power systems, including:

- **Tax Credits** – Many governments now offer tax credits covering up to 30 percent of the cost of solar home systems (compare this to the 45 percent import duty imposed on solar equipment in Cambodia).
- **Consumer Rebates** – Many governments now provide rebates to customers installing their own solar systems. In 2005, California announced a rebate plan to add 3,000 MW of solar capacity on 1 million homes, businesses, and public buildings within 10 years.¹⁶⁵
- **Net Metering** – Many utilities now allow solar producers two-way access to the grid. At night, they draw from the grid and during the day they generate their own power and/or sell into the grid.¹⁶⁶
- **Rental Programs** – A growing number of companies and utilities offer solar system rentals. Customers can rent the system for a fraction of the cost of buying the system and the company will be responsible for maintenance over the system's life. If something breaks, the renter need not fix it. The



Lao-based solar home system provider, Sunlapob has adopted this business model in Lao PDR (See BOX 4).

India's solar credit market

In 2003, the United Nations Environment Programme (UNEP) established a four-year \$7.6 million partnership with commercial banks in India, which focused on developing a credit market in Southern India for financing solar home systems. Working through the Indian banking groups Canara Bank and Syndicate Bank, two consumer loan programmes for solar PV systems were established to bring down the financing costs for rural customers. With a slightly lower interest rate, the banks build their solar financing portfolios without distorting the credit risk or the existing cash market for solar home systems. Five solar vendors met the programme's qualification criteria, allowing their customers to access PV system financing from any one of the 2,076 participating Canara or Syndicate bank branches across India. As of the first quarter of 2007, a total of 19,533 loans had been financed in the states of Karnataka and Kerala. The loan subsidy has now been phased out and many new banks have started lending for solar. The solar PV credit market which didn't exist in 2002 now seems on its way to commercial scale and sustainability.¹⁶⁷

7.4 Thailand: Small Power Producers

Thailand is one of several Asian countries that have developed government programs aimed at promoting investment in decentralized renewables and cogeneration, even while electricity generation remains monopolized by the Electricity Generating Authority of Thailand and its privatized affiliates. Thailand's efforts to open its power sector to small power producers – amidst strong resistance from the state utility and its labour union – offer valuable lessons for Cambodian policy makers and the public. See below for more details.

1992: Small Power Producer (SPP) Program¹⁶⁸

Thailand introduced its first small power producer program in 1992, at a time when the state utility, Electricity Generating Authority of



Thailand (EGAT), was struggling to keep up with the country's rapid growth in electricity demand. The program aimed to stimulate private investment in renewable energy and cogeneration projects that could supply power for local consumption and sell to EGAT (so not all Thai SPPs can be properly defined as decentralized generation).

Thailand's small power producer (SPP) regulations were modeled on the United States Public Utility Regulatory Policies Act of 1978. The Thai government set the terms for SPPs and through a competitive bidding process received bids from dozens of companies all over the world. As of 2006, dozens of SPPs made up nearly 20 percent of the country's total installed capacity (Table 8).

Roughly one-third of Thailand's SPPs are using natural gas as fuel to produce electricity and steam in cogeneration plants for industrial users nearby (particularly in industrial estates). Under the SPP program, the projects are allowed to sell from 10 to 90 MW worth of power to EGAT, under either a long-term or short-term contract. Renewable SPPs use agricultural by-products as fuels – particularly bagasse from sugar mills, paddy husk from rice mills and woodchips from paper factories.

Originally the SPP program encouraged small power producers to build plants with excess capacity for selling power into the central grid. But when electricity demand dropped in the late 1990s, EGAT suspended its power purchase contracts with SPPs, which bankrupted a number of them. What this suggests is that building dependence on a single monopoly buyer has its drawbacks for SPPs given the risk of non-payment by EGAT and bankruptcy in the event of a market downturn.

Note that from the outset the number of SPPs and the amount of capacity they could install was capped by the Thai government. EGAT wanted the bulk of new power supply to come from a different set of private power producers known as Independent Power Producers or IPPs. Under the Thai IPP program, the government invited bids on large-scale power plants (i.e., 700 MW coal- and gas-fired plants) planned by EGAT for development by private companies. Some of these companies were newly-privatized subsidiaries of EGAT selling

their entire output back to the parent utility under long-term, fixed price contracts. At no time were SPPs allowed to compete with IPPs for access to the market. As with the SPPs, a number of IPP deals were shelved when EGAT's electricity sales plummeted in the late 1990s. Others were stalled due to public and environmental opposition.¹⁶⁹

TABLE 8: Small Power Producers in Thailand

Energy type	Number of projects	Installed generating capacity (MW)	Output to PEA/MEA (MW)
Non-conventional			
Bagasse	17	364.1	111.3
Paddy husk	5	57.3	46.8
Black liquor	1	32.9	25
Municipal solid waste	1	2.5	1.0
Waste and flared gas	2	21.0	7.7
Mixed biomass	11	333.8	220.3
Non-conventional total	37	811.6	412.1
Fossil fuels			
Natural gas	21	2277.6	1465.2
Fuel Oil	4	392.2	196.0
Coal	1	10.4	9.0
Fossil fuel Total	26	2680.2	1670.2
Combination			
Waste gas/coal	1	108	45
Black liquor/coal	1	40	8.0
Eucalyptus bark/coal	2	328	180.0
Combination Total	4	476	233.0
GRAND TOTAL	67	3,967.8	2,315.3

MEA = Municipal Electricity Authority; PEA = Provincial Electricity Authority.

Source: Energy Ministry of Thailand data cited in "Small biomass generation projects thrive with new support from Thailand's government," Piyasvasti Amranand, Cogeneration and On-Site Power Production, July-August 2008.



2006: Very Small Power Producer (VSPP) Program

The energy ministry introduced a number of changes to boost investment in renewables and high-efficiency cogeneration in 2006/2007. Unlike the earlier SPP program, this program was driven not by the need to boost power supply but by concerns about high oil and gas prices, energy security, and the prospect of earning “carbon credits” for renewable energy investments under the UN’s Clean Development Mechanism.

The VSPP program’s stated objectives were reducing energy imports (oil and gas, not hydro) and promoting “indigenous” energy resources. Renewable energy projects with generating capacity under 1MW are allowed to sell power into the grid (to EGAT) while cogeneration facilities are allowed to sell up to 10 MW into the grid.

At that time, the government amended both the SPP and VSPP regulations to be more investor friendly and practical. This included changes to the criteria for qualifying as power producers, and changes to the interconnection requirements.

As with the earlier SPP program, the power purchase price offered by the Thai government is still based on the utility’s avoided cost, which is based on what it would cost EGAT to build a new power plant. The government then grants an “adder” or subsidy to SPPs and VSPPs using renewable energy on top of the normal tariff of 7 or 8 US cents per kilowatt-hour (EGAT’s avoided cost) for the first 7 to 10 years of operation. This subsidy depends on the type of renewable energy used. Notably for biomass VSPPs, the ‘adder’ was determined through competitive bidding.

The subsidy scheme generated an overwhelming response. By the end of March 2008, 325 VSPPs had submitted applications to sell 1,152 MW of power to the grid (Table 9). Of the 325 projects, 319 are renewable energy projects, six are cogeneration, and one is a district cooling facility. Sizes vary with some projects less than 100 kilowatts (i.e., micro-hydro and biogas from pig farms).



Most SPP and VSPP investors are small to medium size companies. The largest companies in the Thai SPP business are Banpu and Glow, both listed on the Thai stock exchange, and Advance Agro, an agrobusiness and paper conglomerate.

All VSPP projects are privately developed except for micro and mini hydro projects, which are developed by the Ministry of Energy and the Provincial Electricity Authority. Since the new rules were introduced the two authorities have started work on 15 mini-hydro projects and 65 micro hydro projects (including refurbishment and expansion). About 112 MW of new VSPP hydro capacity is expected to come online between 2008 and 2011.

What the Thai VSPP experience demonstrates is how quickly financial incentives can work to stimulate investment. Take solar for example: solar producers receive a subsidy of 8 baht/kWh (25.81 US cents/kWh) on top of EGAT's avoided cost. Since the VSPP rules were introduced, 59 solar farm projects have been approved to sell 264 MW to the grid. Also, photovoltaic (PV) factories have sprung up around the country, which has caused a decline in the local price of solar panels.

Despite its apparent success, the program's sustainability is questionable, especially as fuel prices and concerns about climate change decline. High feed-in tariffs for solar producers, for example, mean higher costs for ratepayers than could be achieved under a competitive bidding program. EGAT's customers are forced to pay renewable energy producers high prices whether they want to or not. The subsidy may also encourage unproductive or unwanted investments. And just like earlier SPP and IPP programs, VSPPs are vulnerable to non-payment and bankruptcy in the event that EGAT or the Thai energy ministry decides to change or cancel its VSPP contracts.



TABLE 9: Very Small Power Producers (VSPPs) in Thailand

Energy Source	Number of projects	Installed generating capacity (MW)	Selling to MEA/PEA (MW) as of June 2008
Fossil Fuels			
Coal	1	9.5	3.0
Natural Gas	-	-	-
Fossil Fuel Total	1	9.5	3.0
Solar	36	1.468	1.448
Biogas	17	17.834	11.469
Rice husk	9	49.325	41.05
Baggase	24	432.3	135.3
Other biomass (saw dust, palm)	9	36.7	20.695
Biodiesel	-	-	-
Municipal waste	1	1.0	0.6
Hydro	1	0.4	0.03
Wind	0	-	-
Renewable Total	97	529.733	210.592
TOTAL	98	539.233	213.592

MEA = Municipal Electricity Authority; PEA = Provincial Electricity Authority

Source: Thailand's Energy Planning and Policy Office (EPPO) 2008

<http://www.eppo.go.th/power/data/index.html>

TABLE 10: Thai VSPP Summary

VSPP Status as of June 2008	Number of projects	Installed generating capacity (MW)	Sell to MEA or PEA (MW)
Selling to the grid	98	539.233	213.592
Applications approved	296	1822.831	1054.312
Approval pending	442	2611.45	1858.434

MEA = Municipal Electricity Authority; PEA = Provincial Electricity Authority
 Source: Thailand's Energy Planning and Policy Office (EPPO) 2008

<http://www.eppo.go.th/power/data/index.html>



A 1 MW Rice Husk Biogas Generation Plant in Thailand.

8.

**Powering 21st Century Cambodia
with Decentralized Generation**



8. Powering 21st Century Cambodia with Decentralized Generation

8.1 Policy and Regulatory Initiatives

The following policy and regulatory initiatives are recommended to accelerate decentralized generation investment in Cambodia, thereby rendering further investment in large hydro dams and coal-fired plants unnecessary and obsolete.

- Remove import duties on all decentralized generation technologies and equipment. (The Ministry of Economics and Finance currently imposes a 45 Percent duty on imported solar equipment.)
- Introduce customer financing programs to help *all* households, businesses, and communities finance the upfront capital costs of build-scale and industrial-scale generating technologies over a 5 to 10 year period.
- Open the market to decentralized generation by announcing specific policies pertaining to the leading technologies, and impose no cap on the amount of power each produce.
- Invite competitive bids for new decentralized generating capacity additions, by service territory and in low-risk increments of several megawatts, as different markets require.
- Give all power generators non-discriminatory access to local distribution grids and introduce interconnection standards that accommodate all producers.
- Provide investors and project developers with the stability and price signals they need by providing a transparent and explicit mechanism for tariff-setting and cost recovery.
- Establish explicit and transparent step-by-step procedures for obtaining permits and public approval.



- Make proof of community and land rights holder' approval for project siting a prerequisite to licensing by the regulatory authority.

BOX 7: Decentralized generation benefits

- Gives individuals, families, and communities the lighting and electrical power they need to improve their lives, grow their businesses, and connect with the world
- Replaces environmentally damaging hydro dams and coal-fired plants with cleaner alternatives
- Encourages community and local ownership, thus minimizing public opposition to power projects
- Drives the cost of mass-produced generating technologies down
- Promotes development of local technical skills
- Minimizes grid losses by producing power locally
- Reduces or eliminates the need for costly transmission lines
- Diversifies energy supply and increases energy security
- **And** lowers harmful emissions, which means cleaner air, soil, and water, and healthier, more productive citizens.

BOX 8: Cambodia's electricity future

- Renewable energy
- High-efficiency gas-fired cogeneration
- Fuel-flexible gas turbines
- Private investment
- Competitive bidding
- Multiple forms of ownership
- Effective regulatory oversight
- Accurate electricity pricing
- Standardized contracts
- Transparent and explicit rules
- Low emissions
- Public approval



8.2 Conclusions

The Cambodian government already has the legal framework for promoting competitive decentralized generation. The Electricity Law passed in 2001 empowers the electricity regulatory authority (EAC) to promote competition and private ownership in electricity generation, and protect the rights of consumers to reasonably priced and reliable service. So authorized, citizens must urge the EAC and government representatives to modernize the country's power development plan for the 21st century. By allowing multiple decentralized power producers to sell into local distribution networks or to local consumers directly, the government can surpass its electrification objectives while avoiding costly and high-risk investments in environmentally damaging hydro dams and coal-fired plants.

By introducing explicit and enforceable rules encouraging decentralized generation, the government will empower Cambodians to build a superior electricity system, adding capacity in smaller, more affordable increments, using locally available resources and the best generating technologies available on the global market.

Ultimately, Cambodia's political leaders have to choose between the interests served by last century's model of power generation and the public interest. If political leaders make the right choice, they will be rewarded with the support of their citizens, a healthy environment, and a prosperous kingdom.



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GLOSSARY

The following technical and economic terms are from the Online Energy Dictionary at www.energyvortex.com/energydictionary

Alternating current (AC), direct current (DC)

AC current is a specific type of electric current in which the direction of the current's flow is reversed, or alternated, on a regular basis. Direct current is no different electrically from alternating current except for the fact that it flows in the same direction at all times.

Electrical devices that convert electricity directly into other forms of energy can operate just as effectively from AC current as from DC. Lightbulbs and heating elements don't care whether their energy is supplied by AC or DC current. However, nearly all modern electronic devices require direct current for their operation. Alternating current is still used to deliver electricity to the device, and a transformer is included with these devices to convert AC power to DC power (usually at much lower than the supplied voltage) so that electronic devices can use it.

Avoided cost, short run avoided cost, long run avoided cost

Avoided cost is the marginal cost for the same amount of energy acquired through another means such as construction of a new production facility or purchase from an alternate supplier. For example, a megawatt-hour's avoided cost is the relative amount it would cost a customer to acquire this energy through the development of a new generating facility or acquisition of a new supplier.

Short run avoided cost refers to avoided cost calculated based on energy acquisition costs plus ongoing expenses. Long run avoided cost factors in necessary long-term costs including capital expenditures for facilities and infrastructure upgrades.

Avoided cost is typically used to calculate a fair price for energy produced by cogenerators and other energy producers that meet the specifications of the [US] Public Utility Regulatory Policies Act of 1978. The use of avoided cost rates for cogenerated energy is intended to prevent waste and improve both efficiency and cleanliness by insuring that fair market prices paid for energy generated from renewable resources, small producers and others.

Baseload, base load, baseload demand

Most commonly referred to as baseload demand, this is the minimum amount of power that a utility or distribution company must make available to its customers, or the amount of power required to meet minimum demands based on reasonable expectations of customer requirements. Baseload values typically vary from hour to



hour in most commercial and industrial areas.

Wikipedia: Power plants are designated base load based on their low cost generation, efficiency and safety at set outputs. Baseload power plants do not change production to match power consumption demands since it is always cheaper to run them rather than running higher cost combined cycle plants or combustion turbines. Baseload generators, such as nuclear and coal, often have very large fixed costs and very low marginal costs. On the other hand, peak load generators, such as natural gas, have low fixed costs and high marginal costs. Typically these plants are large and provide a majority of the power used by a grid. Thus, they are more effective when used continuously to cover the power baseload required by the grid.

Nuclear and coal power plants may take many hours, if not days, to achieve a steady state power output. On the other hand, they have low fuel costs. Because they require a long period of time to heat up to operating temperature, these plants typically handle large amounts of baseload demand. Different plants and technologies may have differing capacities to increase or decrease output on demand: nuclear plants are generally run at close to peak output continuously (apart from maintenance, refueling and periodic refurbishment), while coal-fired plants may be cycled over the course of a day to meet demand. Plants with multiple generating units may be used as a group to improve the "fit" with demand, by operating each unit as close to peak efficiency as possible.

Dependable capacity

Literally, capacity which can be depended upon. The dependable capacity of a generating facility or transmission system is a fluctuating value that depends upon the available energy, the demand for that energy, the capability of the system to deliver that energy at a given moment, and the facilities available to handle increased capacity should the need arise.

Distribution

Refers to the process of transporting energy from transmission systems to end-use customers. Transmission systems are somewhat like the interstate highway systems of the energy industry, conducting large amounts of energy along high-volume routes that intersect at strategic locations. Distribution systems are the off-ramps, feeder routes and sideroads. They carry electricity from high-voltage transmission networks to end-use customers.

In some contexts, distribution is considered to be any transmission of energy on lines carrying less than 69 kilovolts. Distribution companies maintain everything from the feeders that tap high-voltage lines to substation transformers that convert this voltage to commercial or household voltage to the service drops that carry energy from power lines to residences and commercial sites.

**Economic efficiency**

Refers to the efficiency with which money is spent or otherwise used as a resource, as opposed to the conservation of financial resources.

Economies of scale

A general economics term that refers to economic functions and results relative to size, and the ways in which economic values change as the size of the economy changes. The term usually refers to comparisons between the same activity performed on two different scales, and the differences in costs and results produced by these differences in scale.

Electric utility

A privately-held company, government agency, publicly-owned body or other entity that meets three specific criteria. It must own and/or operate facilities for provision of a service directly related to electric energy provision, it must sell electrical energy directly to end-use customers, and it must have the exclusive right to provide that service within a given area.

[Traditionally] electric utilities were defined as providers of most or all electrical services, including generation, transmission and distribution, billing, maintenance and ancillary services. Today an electric utility could mean an entity that provides just one of these services.

Utilities are service providers, but not all service providers are utilities. What distinguishes a utility is the exclusive rights it has to its territory, the fact that it provides electricity directly to the customer whether it offers any other services or not, and the degree of regulation under which it operates.

End-use customer

Refers to a customer who acquires energy for their own consumption. Customers who acquire energy for provision to other customers are not the actual users of the energy and are not considered end-use customers.

Energy, power

Power is the capacity to perform work or produce a specific change to a condition. Energy is the measure of the actual performance of that work, or the amount of change produced. The terms are often used interchangeably, even within the energy industry itself, but they have two distinct meanings.

In electricity, power is usually expressed in kilowatts; energy is usually expressed in kilowatt-hours. In other words, the value used to express energy has volume, whereas values that express power only imply the ability to provide that volume. A static



electricity shock such as a carpet shock is an example of enormous power with very little energy. These shocks can deliver thousands of volts, but the total quantity of energy is so small that the shock is harmless. Power can also be available without providing energy. A household circuit connected to a lightbulb always has power, but it uses virtually no energy until the light is actually turned on.

Energy efficiency

The effectiveness with which energy is created managed and/or consumed. Energy efficiency is often used interchangeably with energy conservation, but depending on the context the two terms may have different intended meanings. Efficiency can refer specifically to the effective use of available energy, and conservation can refer to reduction of energy use regardless of its availability.

Firm capacity, firm energy, nonfirm energy, firm power

Firm capacity is the amount of energy available for production or transmission which can be (and in many cases must be) guaranteed to be available at a given time. Firm energy refers to the actual energy guaranteed to be available. Nonfirm energy refers to all available energy above and beyond firm energy.

Firm energy is often available at substantial discounts over nonfirm energy sold on the spot market [in the US]. Energy producers such as hydroelectric plants and wind farms may have nonfirm energy available due to unexpected weather or seasonal conditions.

The meaning of firm power depends on the context in which it is used, and may have different meanings to different parties. It can be synonymous with firm energy, mean capacity to provide firm energy, or both.

Fixed cost

A fixed cost is a production- or transmission-related expense which must be paid regardless of whether the energy is produced or sold. Fixed costs can include capital costs, labor and maintenance charges, taxes and demand charges among others.

Fixed price

A price that cannot or will not be changed. Fixed pricing in the energy industry usually refers to an energy rate which must be paid regardless of the actual free-market value of energy at the time it is delivered to the customer. Residential customers are frequently billed for energy at fixed-price rates which are set monthly, quarterly or annually as a means of insuring that customers can accurately manage their electricity bills even if spikes in energy costs or drastic price cuts occur. If energy prices drop, customers paying fixed-cost rates won't usually receive the benefits of the lower price until the fixed price is reset or renegotiated, but in return they are



protected from the potential hardships of unexpectedly large rate increases.

Fixed price energy is not usually as fixed as the name implies. Utilities typically apply mechanisms . . . to allow for variations in price under some conditions. Among these may be rewards in the form of lower energy prices for consumers who reduce consumption or shift consumption to off-peak periods, or allowances for increases in the event of extreme changes in a utility's provision costs.

Flexible generation

Electrical generating capacity that can be increased or decreased as needed.

Grid, power grid, transmission grid

A system of interconnected generating facilities, transmission corridors and power lines that provide energy to a group of customers. These terms can refer to anything from a network that serves a single suburb or section of a city to a nation's entire power distribution system. Typically "grid" refers only to the high-voltage transmission network that transports large volumes of energy from production facilities to urban areas, industrial sites and end-use customers.

While individual companies may own or control parts of a national, regional or municipal grid, access to the grid comes with responsibilities as well as benefits. As an example, grid access allows owners of distribution infrastructure to acquire energy from many competing producers, but fair treatment must be given to customers in return for this right.

The US national energy grid is divided into three discrete sections: East, West, and Texas. Each of these regional grids is electrically isolated so that problems in one grid can't affect another. Approximately 140 coordinated control centers manage energy flow within these three regional grids to insure that blackouts can be limited to relatively small service areas. Within these three regions, grids or sections of grids may be owned or controlled by transmission companies (TRANSCOs), dedicated companies who assume responsibility for grid management (GRIDCOs) or local/regional utilities.

While the grid is designed to function as a network and has web-like characteristics similar to the Internet, the term "network" usually refers only to municipal/regional grids within the three larger regional grids, or to specific sections of the grid.

Kilowatt-hour

A quantitative measure of electric current flow equivalent to one thousand watts being used continuously for a period on one hour; the unit most commonly used to measure electrical energy, as opposed to kilowatt, which is simply a measure of available power. A 100-watt lightbulb used for 10 hours consumes 1 kilowatt-hour of energy.



Customer billings for all but the largest consumers are usually based in part or in total on the number of kilowatt-hours of electricity used. The standard unit of current flow used in physics is the joule, but since a joule is only equivalent to one watt-second, kilowatt-hour has become a much more convenient standard.

A kilowatt-hour of energy typically costs between two and twenty cents depending on where and when it is purchased and by whom. This much energy will operate a 40-watt lightbulb for a full day, a 19" color television for about four hours, a personal computer for 2-1/2 hours, an electric hairdryer for 30 to 60 minutes, an electric razor for 36 hours, a clothes dryer for 15 minutes, a microfurnace heater for 40 minutes, a clock radio for up to several days, a portable stereo for as long as a week, and a telephone answering machine for as long as a month.

The kilowatt-hour is the base unit for nearly all measurements of energy volume both inside and outside the energy industry, although other values are occasionally used.

Related terms include:

A megawatt-hour (MWh): one thousand kilowatt-hours.

A gigawatt-hour (GWH): one million kilowatt-hours; the standard unit used to measure the capacity of transmission systems and generating facilities, and consumption levels in urban areas.

Local distribution company (LDC), utility distribution company (UDC)

A utility, not necessarily an electric utility, that distributes its commodity (e.g. water or electricity) or service (e.g. urban transportation or waste removal) as a natural monopoly in its assigned service territory. LDC refers to utilities that provide distribution-specific services. UDC is used in the same context in many areas.

Marginal cost, long run marginal cost

The cost of providing an additional kilowatt-hour of energy output over and above any energy currently being produced. The energy industry refers to the next kilowatt-hour or next unit as the basis for determining this cost. Marginal costs only include immediate expenses required to produce more energy. Long run marginal cost includes capital costs and embedded costs which are not included in marginal costs.

Marginal cost is often used interchangeably with incremental cost, but marginal cost can be applied to the average next-unit cost for a large number of additional units, whereas incremental cost applies strictly to the next unit, not to any average of multiple next-units.

**Monopoly, monopsony**

When only one supplier, provider or seller is available for a given commodity in a given market, that individual or entity is referred to as a monopoly, and has monopoly control over that market. When only one buyer is available for a given commodity, this is referred to as a monopsony.

Peak load, peak demand

These two terms are used interchangeably to denote the maximum power requirement of a system at a given time, or the amount of power required to supply customers at times when need is greatest. They can refer either to the load at a given moment (e.g. a specific time of day) or to averaged load over a given period of time (e.g. a specific day or hour of the day).

Peaking capacity

Any generating capacity intended to meet peak demand; generating capacity assigned for use as a peak supply.

Regulation

Three common meanings. In energy generation and provision, regulation can refer to the process of increasing or decreasing capacity in the system in response to changes in customer requirements. This type of regulation usually occurs at generating facilities, although the capacity of transmission and distribution systems can also be regulated.

This term can also refer to the actual amount of generating capacity that can be added to or removed from the system by an independent system operator's energy management system. In this context, a system's regulation is its capacity to be adjusted (regulated) on demand.

Regulation also refers to an enforceable law or a rule of conduct that governs an industry's business practices or operations. Federal and state regulations that apply to the US energy industry must first be put forward for public comment before they can be enacted into law by governing bodies, and these regulations usually prescribe penalties for violators. Regulations which the industry imposes upon itself are not necessarily offered for public comment and may not be subject to penalties if they are violated.

Industry regulations typically refers to regulations imposed on an industry by state and federal officials. Regulations imposed by an industry upon itself are more commonly referred to as internal regulations.



Regulatory commission

An agency under the auspice of a state/provincial or national government which oversees an industry, industry sector, or segment of an industry. Regulatory bodies exist in virtually every state and province in North America to administrate industry cooperation, enforce regulations, oversee construction and financing proposals for utilities, and adjudicate in rate-setting matters.

Reliability

Reliability of electrical service is a function of sufficient supply and consistent transmission capability. Reliability is compromised if there is too little energy created, or if too little capacity exists to carry it to the customer.

In most contexts where this term is used, adequate transmission capacity is a given. The system is expected to be capable of meeting the needs of the market. The overriding reliability concern in transmission is the ability of the system to deal with outages, equipment failures and other types of service interruption. The ability to manage these interruptions is referred to as a system's security.

Reserve margin, reserve capacity

A measure of available capacity over and above the capacity needed to meet normal peak demand levels. Reserve margin and reserve capacity are synonymous. For a producer of energy, it refers to the capacity of a producer to generate more energy than the system normally requires. For a transmission company, it refers to the capacity of the transmission infrastructure to handle additional energy transport if demand levels rise beyond expected peak levels.

Regulatory bodies usually require producers and transmission facilities to maintain a constant reserve margin of 10-20% of normal capacity as insurance against breakdowns in part of the system or sudden increases in energy demand.

Substation

A structure, usually a small building on a fenced-off lot, that contains any combination of routing or cutoff switches, transformers, surge arresters, capacitors, power conditioners and other equipment needed to insure smooth, safe flow of current. Substations are most commonly seen in residential and industrial areas, where one or more high voltage lines can often be feeding into the station and any number of lower-voltage distribution lines spider out to serve customers in the surrounding area.

One of the primary purposes for residential and industrial substations is the maintenance of proper line voltage in distribution systems, which insures proper line voltage for end-use customers. Electricity typically travels over high-tension lines and through underground cables at very high voltage, and transformers must be



used at substations to convert this voltage to a lower voltage suitable for use by the consumer. The energy flow may require additional filtering to reduce its tendency to create magnetic fields or produce unwanted effects when used by sensitive electronic devices.

Producers of energy may maintain their own equipment near generating facilities for converting voltage and managing power distribution, but these facilities are typically not referred to as substations.

Transformer

A transformer is used for converting a primary energy source to a different voltage. Line transformers are usually large devices housed in substations and operated by utility companies.

Transmission voltage

Refers to a high line voltage used on transmission systems. Transmission voltage varies depending on the system. While 69,000 volts [69 kV] is used as a standard figure, actual transmission voltages on a given system or subsystem can range upward of that figure to as high as 750,000 volts [750 kV].



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