INTRODUCTION

This report summarises the results of the analysis of greenhouse gas (GHG) mitigation technologies available in Cambodia in other countries, which is one of the activities under Phase 2 of the Cambodia Climate Change Enabling Activity Project (CCEAP 2). The GHG mitigation technologies, measures and policies available in the world and applicable to Cambodia will be described as well as those already being used in Cambodia. The barriers in their implementation will also be identified. A country-specific matrix showing the technical, socio-economic and environmental aspects of the identified GHG mitigation technologies is attached to this report.

In 2001, the following activities for the energy sector were completed under Phase 1 of the CCEAP:

An inventory of GHG emissions and removal following the Guidelines adopted by the Conference of the Parties (CoP);
An analysis of potential measures to abate the increase in GHG emissions in Cambodia and the corresponding GHG reduction using the LEAP[1] program;
A national action plan to address climate change and its adverse impacts; and
The Initial National Communication of Cambodia to the CoP.

STATUS OF THE CAMBODIA'S ENERGY SECTOR

In Cambodia, the major source of GHG emissions in the energy sector is fuel combustion. All oil products are imported as there are no oil production activities in the country.

Cambodia imports 100% of the required petroleum products from countries in the region. Petroleum products are the main source of commercial energy for power generation, industry, transport, and the residential and commercial sectors. Woodfuel and other biomass are the major energy source for cooking for Cambodian people, especially in rural areas. It was estimated that in 1994 indigenous and renewable biomass energy covered over 85% of the total national energy supply.

PRESENT ENERGY SITUATION[2]

Only 12 % of the Cambodian households have access to electricity. There is no national grid, except a 115 kV single circuit transmission line of 120 km to Phnom Penh from Kirirom mini-hydropower station rehabilitated under a BOT system by a Chinese company CETIC, which was put into operation in late May 2002. Power supply is available through small isolated systems using diesel generators with medium and low voltage distribution systems, and as a result the price of power is the highest in the region. The total installed capacity of the country is about 150 MW, of which 100 MW are in Phnom Penh. Per capita consumption is only about 48 kWh per annum. Annual growth of power demand is forecasted at 12%.

GREENHOUSE GAS INVENTORY

Cambodia's 1994 GHG Inventory was established using the revised 1996 IPCC Guidelines for National GHG Inventories. The result of the inventory indicated that in 1994 Cambodia removed 64,850 Gg of CO_2-eqv. and emitted 59,708 Gg of CO_2-eqv. Therefore, in 1994, Cambodia was a net carbon sink country with a net total carbon removal of 5,142 Gg of CO_2-eqv. The distribution by gas is follows: i) carbon dioxide 74%, ii) methane 18% and iii) nitrous oxide 8%.

The main source of carbon dioxide emissions was the land use, land use change and forestry (LULUCF) sector (97%), followed by the energy sector (3%) while the contribution of the industry sector to the total CO_2 emissions was insignificant.

[1] The LEAP 2000 is the Long-Range Energy Alternatives (LEAP) system, a scenario-based energy-environment modeling tool. This program is used to evaluate the GHG mitigation options considered for Cambodia. LEAP 2000 is a user-friendly software developed by the Stockholm Environment Institute (SEI) - Boston Center at the Tellus Institute.
[2] Opening Remarks of His Excellency Ith Praing, Secretary of State of the Cambodia's Ministry of Industry, Mines and Energy (MIME), at the Cambodia Investment and Trade 2002 Conference, 16 May 2002.

GREENHOUSE GAS EMISSIONS FROM THE ENERGY SECTOR

A projection of GHG emissions from the energy sector was done using LEAP-2000, a software package that was developed by the Stockholm Environment Institute. The data used for the projection were taken from the MIME study undertaken by the Asian Development Bank Technical Assistance project, 2241-CAM "Strengthening the Institutional and Legal Framework for the Energy and Minerals Sectors Project" which was completed in October 1996. The data from the MIME study is only up to 2010, thus the projections from 2011 to 2030 were done using exponential formula[3]. Therefore, the projection may not reflect any structural changes and other government plans. It is recommended that the projections should be updated when more reliable data are available. In addition, the approach used in LEAP also differs from that used in the IPCC methodology. LEAP calculates the energy demand using "bottom up" approach where energy demand is calculated by multiplying the energy intensity and the sector activity level, while in the IPCC method the energy demand data are taken directly from the MIME study. As a result, some of the energy demand data from MIME may not be in conformity with those from LEAP.

GREENHOUSE GAS EMISSIONS FROM INDUSTRIAL PROCESSES

GHG projections for this sector were not performed since the main industrial activity which emits GHGs, i.e. Cambodia's only cement production factory, was already closed at the end of 1999.

In the Cambodia's "Second Five Year Socioeconomic Development Plan, 2001-2005 (SEDP-II, page 193)" limestone for production of cement in Kampot province was identified as one of the industries to be developed. The Cambodian Investment Board (CIB) has approved a total of 8 cement projects for the period 1994-2001, with a total fixed assets value of US$408,497,000.

FUEL COMBUSTION ACTIVITIES

In 1994, GHG emissions from fuel combustion activities were estimated at 1,881 Gg of CO_2-eqv. The biggest share of GHG emissions from the energy sector was the transport sub-sector, which accounted for 44%. The residential sub-sector accounted for 36% of energy sector emissions due to CH_4 emissions from fuel wood combustion while the energy industries accounted for 18%. Manufacturing and commercial sub-sectors accounted for approximately 2% of the total emissions from this sector. By gases, CO_2 is the dominant gas emitted in combustion activities, followed by CO, NMVOC, CH_4, NO_x and N_2O.

Table 1: Total 1994 CO_2-Eqv. Emissions from Fuel Combustion Activities (Gg)

Sub-Sector	Total Emissions	Percent Share
Energy industries	332	17.7
Residential	683	36.3
Manufacturing industries	7	0.4
Transport	831	44.1
Commercial	28	1.5
Total	1,881	100

EMISSIONS FROM BURNING OF TRADITIONAL BIOMASS FUELS

Biomass fuels are the main source of energy for over 90% of Cambodian households. Cambodia's biomass fuels are divided into firewood, charcoal, dung, and other biomass (including agricultural residues). Biomass is the cheapest and most accessible source of energy used for cooking. According to the IPCC, CO_2 emissions from biomass used as fuels are excluded from the total CO_2 emission figure. This is true as long as there is good biomass resource management, because biomass growth reabsorbs CO_2. It is therefore assumed that any CO_2 emissions from burning biomass are reabsorbed during plant growth. However, in order to assess the direction of the "net flux" of CO_2 emissions (a balance between emission and absorption), CO_2 emissions from biomass is

[3] Future Value = (Base Year Value) * (1 + Growth Rate)^t, where t= number of years between the future year and the base year.

included in the LULUCF section. Non-CO_2 emissions are included since they are not reabsorbed by plant growth. This study indicated that CO was the main gas emitted from traditional biomass burning activities.

INDUSTRIAL PROCESSES

Industrial emissions arise directly from industrial processes associated with manufacturing cement and food processing and are not due to the fuel consumption of these industries, which are already accounted for in the Energy Sector. The amount of CO_2 emitted from industrial processes is estimated to be approximately 50 Gg and all came from Cambodia's only cement factory. Up to 1994 there were very few factories in Cambodia and as a result the only industries taken into account for the calculation of GHG emissions are food processing and the cement factory.

GREENHOUSE GAS PROJECTION

Results from the projection analysis of GHG emissions and removals by sectors indicated that in 2000 Cambodia was already a net emitter of GHGs. The net emissions were approximately 6,244 Gg of CO_2-eqv. In 2020, the net emissions would increase to approximately 43,848 Gg of CO_2-eqv. Among the sectors, LULUCF would be the main source of GHG emissions (63.0%), followed by agriculture (27.5%). Energy would contribute to only about 9.0% of the total national emissions.

In 1994, CO_2-eqv. emissions from the energy sector were approximately 1,881 Gg. The largest contributor to the total emissions was the transport sub-sector followed by households. In 2020, the total CO_2-eqv. emissions would be approximately 8,761 Gg, about four times that of 1994 and the transport sub-sector would contribute to approximately 62% of the total. CO_2 dominated the emissions of GHGs from the energy sector, followed by CH_4 and N_2O. The percentage contribution of CO_2 to the total GHG emissions will increase while percentage CH_4 and N_2O will decrease. The main source of CO_2 is the transport sub-sector, while the main sources of CH_4 and N_2O are from the households sub-sector.

Table 2: Projection of GHG Emissions and Removals by Sectors (Gg)

Source/Sink	1994*		2000		2010		2020	
Emissions		%		%		%		%
Energy	1,881	2.8	2,622	3.6	4,780	5.9	8,761	9.0
Industrial Processes	50		-		-		-	
Agriculture	10,560	15.5	12,030	16.4	17,789	22.1	26,821	27.5
Waste	273	0.4	331	0.4	425	0.5	523	0.5
LUCF	55,216	81.2	58,379	79.6	57,627	71.5	61,512	63.0
Total Emissions	67,980	100.0	73,362	100.0	80,621	100.0	97,617	100.0
Removal by LULUCF	-73,122		-67,118		-61,090		-53,769	
Net Emissions	-5,142		6,244		19,531		43,848	

* Cambodia's 1994 inventory (IPCC methodology).

II. ASSESSMENT OF GHG MITIGATION TECHNOLOGIES, MEASURES AND POLICIES IN THE ENERGY SECTOR

II.1. GHG MITIGATION TECHNOLOGIES, MEASURES AND POLICIES IN THE ENERGY SECTOR AVAILABLE AND PRACTICED INTERNATIONALLY AND MAY BE APPLICABLE IN CAMBODIA

II.1.1. TRANSPORT

In 1990[4], one fifth of CO_2 emissions from global fossil fuel use came from the transport sector[5]. Other important GHG emissions from the sector include N_2O from tailpipe emissions from cars with catalytic converters; CFCs and HFCs, which are leaked and vented from air-conditioning systems; and NO_x emitted by aircraft near the tropopause (at this height, the ozone generated by NO_x is a very potent GHG). World transport energy use grew faster than that in any other sector, at an average of 2.4% per year, between 1973 and 1990.

The largest transport sector sources of GHGs through to 2050 are likely to be cars and other light-duty vehicles (LDVs), heavy-duty vehicles (HDV) and aircrafts. Current annual percentage growth in all of these is particularly high in Southeast Asia.

Recent advances in fuels and vehicle design are helping increase fuel efficiency and reduce toxic substances discharged into the air.

The following are the technologies and approaches to reduce GHG emissions in transportation:

- Improved petroleum-based fuels;
- Improved petroleum-based vehicles;
- Alternative fuels;
- Alternative fuel vehicles;
- Components;
- Materials;
- Use of non-motorized vehicles (bicycles) and walking.

The following are the issues in the reduction of GHG emissions in transportation:

- Reducing vehicle miles traveled;
- Air emissions and standards;
- Petroleum supply and demand;
- Alternative fuel infrastructure;
- Regulations, laws and incentives.

II.1.1.1 Technologies and Approaches

a. Improved Petroleum-Based Fuels

Improved gasoline and diesel fuel will reduce emissions.

Reformulated Gasoline

Reformulated gasoline generally uses an oxygenate such as ethanol, ethyl tertiary butyl ether (ETBE), or methyl tertiary butyl ether (MTBE) to maintain performance and reduce the emissions of smog-forming volatile organic compounds. Environmental concerns about MTBE have increased interest in ethanol as a fuel additive, causing an increased focus on ethanol fuel supply.

Low-sulfur Gasoline

[4] IPCC Technical Paper 1: Technologies, Policies, and Measures for Mitigating Climate Change, November 1996.
[5] Global CO_2 emissions from transport sector energy use amounted to about 1.25 Gt C.

Low-sulfur gasoline will reduce sulfur oxide emissions from vehicles. It is currently produced by treating the petroleum feedstock at high pressure and temperature, but a room-temperature biodesulfurization technique using biological catalysts is also under development.

Advanced Petroleum-based Diesel Fuels

Advanced petroleum-based diesel fuels include dimethyl ether (DME), which can be made from a variety of feedstocks, as well as dimethoxymethane (DMM) and di-oxymethylene dimethyl ether (DOMDME). It also includes reformulated diesel fuels, such as low-sulfur diesel fuel. These fuels are primarily being investigated to achieve both performance and emissions goals, particularly when used in heavy trucks and buses.

Fischer-Propsch Diesel

Fischer-Propsch diesel fuel, also referred to as synthetic diesel or gas-to-liquid (GTL) diesel, is produced from natural gas using a catalytic process. It has the potential to lower emissions while achieving good performance.

b. Improved Petroleum-Based Vehicles

New technologies such as hybrid electric vehicles and fuel cells may double or triple the efficiency of current vehicles. The advanced vehicles under development involve technologically advanced engines or drive trains. Advanced vehicles also incorporate lightweight advanced materials for energy efficiency.

Advanced Engines

- Compressed Ignition Direct Injection (CIDI) Engines

The direct injection of fuel into the combustion chamber of an engine yields improvements in thermal efficiency and overall fuel efficiency. Engines that ignite the fuel solely by compressing it - known as "compression ignition" or diesel engines - have a high energy efficiency, and the application of direct-injection technologies can further boost the fuel efficiency of these engines.

- Turbocharged Direct Injection (TDI) Diesel Engines

The turbocharged version of the CIDI is popular in Europe, and is now available in automobiles sold in the United States.

- Spark Ignition Direct Injection (SIDI) Engines

Standard gasoline engines use a spark to ignite the fuel, so they are technically known as spark ignition engines. Like CIDI engines, SIDI engines inject fuel directly into the combustion chamber. SIDI engines have the advantage of burning gasoline and many alternative fuels.

Advanced Drive Trains

- Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) combine an engine with an electric motor in the drive train to achieve high fuel efficiencies. To achieve high performance, high-power batteries are needed to power the electric motor. Because of battery cycling, battery thermal management becomes an issue for HEVs. In addition, HEVs - and other advanced vehicles with small engines - benefit from improved climate control systems, which improve vehicle efficiency.

HEVs may incorporate advanced engine technologies such as compressed ignition direct ignition (CIDI) engines, or spark ignition direct ignition (SIDI) engines, gas turbine engines, or Stirling engines.

- Fuel Cell Vehicles

Fuel cells generally convert hydrogen and oxygen into water, producing electricity. Because they produce only water vapor as emissions, fuel cells are ideal power sources for transportation, providing power for an electric motor drive motor. Using hydrogen as a fuel raises issues about transport and storage.

Most current concepts take advantage of existing fuel infrastructures by relying on a fuel reformer to convert liquid fuels into hydrogen; the reformer can be on-board or installed in a fueling station. However, the direct-methanol fuel cell converts methanol directly into electricity without a fuel reformer.

- Heavy-Duty Trucks and Buses

Various technologies exist to increase fuel efficiency and reduce emissions for heavy-duty trucks and buses.

c. Alternative Fuels

Alternative fuel vehicles use alternative fuels instead of gasoline or diesel fuel. Many alternative fuels are being used today in place of gasoline and diesel fuel. Alternative fuels include biodiesel, electricity, ethanol, hydrogen, methanol, natural gas, propane, and "P-series" fuels.

<u>Biodiesel</u>

Biodiesel is a low-polluting diesel alternative that can be made from vegetable oils, animal fats, and even recycled cooking greases. The health effects of biodiesel are low, its emissions are low, and it's biodegradable.

<u>Electricity</u>

Electricity is considered a fuel when used in electric vehicles. Electricity as a fuel shifts the burden of pollution control to the electrical supply systems, resulting in much lower emissions per mile traveled.

<u>Ethanol</u>

Mainly used today as a fuel additive, ethanol is also used in an 85% ethanol/15% gasoline blend, called E85. The main technical goals are to lower the cost of ethanol while expanding the ethanol infrastructure. Currently, the industry is supported by various fuel standards, codes and legislation.

<u>Hydrogen</u>

Although hydrogen can fuel an engine directly, or serve as a fuel additive, the current emphasis is on the use of hydrogen to supply fuel cells, which power electric vehicles. Hydrogen has also been blended with methane to form a fuel called Hythane.

<u>Methanol</u>

Like ethanol, methanol is blended with gasoline in a ratio of 85 to 15. to form M85. When burned in an engine, methanol produces low emissions. Methanol is also the fuel for the direct-methanol fuel cell. Developing a methanol refueling infrastructure is essential to expand the use of M85.

<u>Natural Gas</u>

Natural gas is a clean-air alternative to conventional fuels. It is used in vehicles as compressed natural gas (CNG) or liquefied natural gas (LNG). At issue is the availability of refueling sites for vehicles that run on these fuels.

<u>Propane</u>

Propane is usually used in the form of liquefied petroleum gas (LPG). Again, the availability of refueling sites is an issue for vehicles that run on this fuel.

<u>P-series</u>

P-series fuels are new fuels that are now classified as an alternative fuel. The fuels are blends of methyltetrahydrofuran (MTHF), ethanol and hydrocarbons. The fuels contain at least 60% non-petroleum energy content derived from MTHF (manufactured solely from biomass feedstocks) and ethanol.

d. *Components*

Research on advanced engines, drives, and other components will enable progress in other areas. There is a vast array of components and technologies that make up alternative fuel and advanced vehicles. Research continues through government and industry partnerships to optimize the components for various vehicle configurations and applications. Components can be categorized into advanced engines, electric drive components, natural gas vehicle components, fuel cell components, and emission control components.

Advanced engines

- Compressed Ignition Direct Injection (CIDI) Engines

The direct injection of fuel into the combustion chamber of an engine yields improvements in thermal efficiency and overall fuel efficiency. Engines that ignite the fuel solely by compressing it - known as "compression ignition" or diesel engines - have a high energy efficiency, and the application of direct-injection technologies can further boost the fuel efficiency of these engines.

- Turbocharged Direct Injection (TDI) Diesel Engines

The turbocharged version of the CIDI is popular in Europe, and is now available in automobiles sold in the United Sates.

- Spark Ignition Direct Ignition (SIDI) Engines

Standard gasoline engines use a spark to ignite the fuel, so they are technically known as spark injection engines. Like CIDI engines, SIDI engine engines inject fuel directly into the combustion chamber. SIDI engines have the advantage of burning gasoline and many alternative fuels.

- Gas Turbine Engines

Gas turbine engines run efficiently on a wide variety of fuels. Because of their loss of efficiency at low power and their slow response time, they are best suited for hybrid electric vehicle applications.

- Stirling Engines

Stirling engines use a heat source external to the engine's cylinders to expand gases within the cylinders and driving pistons, which provide the drive power. These "heat engines" are truly external combustion engines, and may be applicable to hybrid electric vehicles.

Electric Drive Components

- Electric Drives

Motors, power electronics, and controllers are essential components of electric drive systems, whether used in purely electric vehicles or in hybrid electric vehicles.

- Regenerative Braking

Regenerative braking generates electricity to recharge the electric drive's batteries while braking, essentially converting the momentum of the vehicle into electricity.

- High-power and high-energy batteries

High-power and high-energy batteries are essential components of electric drive systems.

Natural Gas Vehicle Components

- Natural Gas Engines

Lean-burning natural gas engines produce low emissions with high thermal efficiency.

- Natural Gas Storage Systems

Natural gas must be stored under pressure or in liquid form. Advanced materials are needed to achieve strong storage tanks with the necessary capacity.

Fuel Cell Components

- Fuel Cells

Fuel cells generally convert hydrogen and oxygen into water, producing electricity. Because they produce only water vapor as emissions, fuel cells are ideal power sources for transportation, providing power for an electric drive motor.

- Fuel Reformers

Fuel cells generally convert hydrogen and oxygen into water, producing electricity. Most current concepts take advantage of existing fuel infrastructures by relying on a fuel reformer to convert liquid fuels into hydrogen; the reformer can by on-board or installed in a fueling station.

- Emission Control Technologies

Catalytic Converters. Catalytic converters treat exhaust gases to remove nitrous oxides. Such after-treatment technologies are less effective for advanced lean-burning engines.

Oxygen Sensors. Oxygen sensors measure the air/fuel ratio and are critical to fuel economy and emissions. Cost effective, highly sensitive sensors that are quick to respond are needed.

Particulate Filters and Traps. Filters and ceramic traps may help remove particulates from diesel engine emissions.

e. Materials

Materials being examined for alternative and advanced vehicles include plastics, composites, lightweight metals, ceramics and catalysts. Special applications include engines, natural gas storage tanks, and catalytic converters. Materials are an important part of developing alternative and advanced vehicles. Because vehicle efficiency is very important, the vehicle body and components need to be light and aerodynamic, while maintaining the strength and durability of today's conventional vehicles.

Lightweight Materials for Vehicles

- Plastics

Long used for body panels, trim, and interiors, plastics (or more generally, polymers) are now finding applications in other parts of vehicles.

- Composite Materials

Composites combine a "matrix", often of plastic or metal, with fibers to yield high-strength materials. Fiberglass and carbon-fiber polymer matrix composites are widely used, although metal matrix composites show promise.

- Lightweight Materials

Most attention is focused on the use of aluminum for engines and body parts, although magnesium and titanium are also providing lightweight solutions to automotive applications.

Special Needs for Advanced Materials

- Lightweight Engines

Engines made of aluminum, ceramics, or other lightweight materials increase fuel efficiency by decreasing the total vehicle weight.

- Material Engineering for CNG Storage

Fiberglass and other composites are used to make storage tanks for compressed natural gas vehicles.

- Material Engineering for Catalytic Converters

Catalytic converters and other so-called after-treatment devices require advanced catalysts to achieve lower emissions and to work with lean-burn engines.

f. Use of Non-motorized Vehicles (Bicycles) and Walking

While societies the world over define transportation in terms of engine power, the greatest share of personal transport needs is met by human power[6]. The use of bicycles or walking can help ease traffic congestion. However, there is a need to construct bicycle lanes and pedestrian lanes in order to implement this.

The economic and social costs of congestion, already daunting, are bound to multiply if car commuting persists. The Confederation of British Industry warns that traffic congestion costs Britain $24 billion a year - including employee lost time through tardiness, and inflated goods prices resulting from higher distribution costs. The U.S. Federal Highway Administration put the country's loss to traffic jams at $9 billion in 1984.

In Phnom Penh, traffic congestion is getting worst during peak hours.

II.1.1.2. Issues

a. Reducing Vehicle Miles Traveled

A variety of approaches can be employed to slow the growth of vehicles on the road and the miles they travel. Mass transit, telecommuting, and "small transportation" are just a few of the approaches that could contribute to a sustainable transportation future.

A variety of approaches can be employed to slow the growth of vehicles on the road and reduce the vehicle miles traveled. These may include:

- Urban planning;
- Carpooling;
- Mass transit systems;
- Shared vehicles;
- Alternative transportation;
- Telecommuting; and
- Smart transportation technologies.

Urban Planning

Since most vehicle miles are used for commuting and for running errands, proper urban planning - for instance, with centrally located services and a good public transportation system - can minimize or eliminate the need to use a vehicle.

6 Marcia D. Lowe, "Bicycles Can Replace Gasoline-Powered Cars", Worldwatch Paper 90, September 1989.

Carpooling

Encouraging carpooling is an inexpensive approach to reducing vehicle miles. One incentive is to set up high-occupancy vehicle (HOV) lanes to smooth the commute for those in carpools.

Mass Transit Systems

Mass transit systems are the ideal urban transportation mode. Mass transit includes bus and rail systems, among others.

Shared vehicles

Various concepts are being tested to provide the mobility of a car without owning one, including car sharing programs and station car programs.

Alternative Transportation

One way to reduce vehicle miles is to encourage alternative methods of travel, including biking and walking. Bike paths and pedestrian paths are essential components of encouraging alternative transportation. Electric bikes may encourage people to use bikes that otherwise wouldn't.

Telecommuting

The best way to reduce a commute is not to commute at all. For many workers, telecommuting - working outside the traditional workspace, often from home - is a practical alternative, at least some of the time.

b. Air Emissions and Standards

The transportation sector is currently the dominant source of air pollution in Phnom Penh and other major cities in Cambodia. Imposing of emission and fuel economy standards would help address this issue.

c. Petroleum Supply and Demand

Estimates of worldwide petroleum resources vary substantially, but many reports suggest that resources will be readily accessible for about the next 50 years. Demand for petroleum continues to rise dramatically around the world, fueled by economic development and growth.

d. Alternative Fuel Infrastructure

The existing gasoline and diesel infrastructure represents hundreds of billions of dollars of investment over many years. To be widely used, alternative fuels may require similar investments in fuel infrastructure. Thus far, most attention has been focused on the development ethanol, methanol, natural gas, propane, and hydrogen infrastructures.

e. Regulations, Laws and Incentives

There are various rules and regulations that require certain fleet types to purchase and operate alternative fuel vehicles. In the future, incentives need to be promoted for individuals to purchase.

II.1.2. POWER SUPPLY

Many power companies have programs that encourage their customers to invest in energy efficiency products that lower consumer energy bills, delay the need for new electrical generation capacity, and reduce the emission of greenhouse gases and other pollutants. Technologies that maximize the efficient generation, transmission, and storage of energy are fundamental to such programs. Renewable electricity generating technologies also play a major role in many programs and are discussed separately under the solar, geothermal, bioenergy, ocean, wind, hydropower, and hydrogen subjects.

II.1.2.1. Technologies

a. Superconductivity

Superconducting materials have the ability to conduct electrical current with no resistance and extremely low energy losses. Their capacity to efficiently handle large amounts of current can be applied to electric devices and to electricity transmission.

b. Energy Storage

Energy storage can improve the efficiency and reliability of the electric utility system by reducing the requirements for spinning reserves to meet peak power demands, making better use of efficient baseload generation, and allowing greater use of intermittent renewable energy technologies. Energy storage technologies include utility battery storage, flywheel storage, superconducting magnetic energy storage, compressed air energy storage, pumped hydropower, and supercapacitors.

II.1.2.2. Issues

a. Demand-Side Management (DSM)

DSM refers to actions taken on the customer's side of the meter to change the amount or timing of energy consumption. Utility DSM programs offer a variety of measures that can reduce energy consumption and consumer energy expenses. Electricity DSM strategies have the goal of maximizing end-use efficiency to avoid or postpone the construction of new generating plants.

Technologies Under the Demand-Side Management (DSM)

i) Load Reduction

These energy conservation technologies are implemented to reduce total energy use. Specific technologies include energy-efficient lighting, appliances, and building equipment.

ii) Load Leveling

These technologies are used to smooth out the peaks and dips in energy demand - by reducing consumption at peak times ("peak shaving"), increasing it during off-peak times ("valley filling"), or shifting the load from peak to off-peak periods - to maximize use of efficient baseload generation and reduce the need for spinning reserves.

iii) Load Control

Energy management control systems (EMCSs) can be used to switch electrical equipment on or off for load levelling purposes. Some EMCSs enable direct off-site control (by the utility) of user equipment. Typically applied to heating, cooling, ventilation, and lighting loads, EMCSs can also be used to invoke on-site generators, thereby reducing peak demand for grid electricity.

iv) Energy storage devices

Located on the customer's side of the meter can be used to shift the timing of energy consumption. Energy storage can improve the efficiency and reliability of the electric utility system by reducing the requirements for spinning reserves to meet peak power demands, making better use of efficient baseload generation, and allowing greater use of intermittent renewable energy technologies. Energy storage technologies include utility battery storage, flywheel storage, superconducting magnetic energy storage, compressed air energy storage, pumped hydropower, and supercapacitors.

Technologies Under Energy Storage Devices

a. Utility Battery Storage (UBS)

UBS systems allow utilities or utility customers to chemically store electrical energy for dispatch at a time when its use is more economical, strategic, or efficient. Existing UBS systems use lead-acid batteries. Compact, low-maintenance valve-regulated lead-acid (VRLA) batteries have been developed for distributed power applications. The suitability of a battery system to utility applications is affected by factors such as its response time, power density (the amount of power available from a battery in relation to its mass and volume), discharge rate, and life cycle costs.

b. Flywheel Storage

A flywheel spinning at very high speeds can be used to store energy by combining it with a device that operates either as an electric motor that accelerates the flywheel to store energy or as a generator that produces electricity from the energy stored in the flywheel. Modern flywheels use composite rotors made with carbon-fiber materials. The rotors have a very high strength-to-density ratio, and rotate in a vacuum chamber to minimize aerodynamic losses. The use of superconducting electromagnetic bearings can virtually eliminate energy losses through friction.

Superconducting Magnetic Energy Storage (SMES)
SMES systems store energy in a magnetic field created by the flow of direct current in a coil of superconducting material that has been cryogenically cooled.

Compressed Air Energy Storage (CAES)
Utilities can use off-peak electricity to compress air and store it in airtight underground caverns. When the air is released from storage, it expands through a combustion turbine to create electricity.

e. Pumped Hydropower
Pumped hydro facilities use off-peak electricity to pump water from a lower reservoir into one at a higher elevation. When the water stored in the upper reservoir is released, it is passed through hydraulic turbines to generate electricity.

f. Supercapacitors
With characteristics of both batteries and capacitors, supercapacitors (also called electrochemical capacitors or ultracapacitors) could be used by utilities to regulate power quality.

<u>Issues Under the Demand-Side Management (DSM)</u>

i) Public Benefits Program
Prior to electricity industry restructuring, utilities were responsible for a variety of programs (including DSM) that meet social objectives. Under restructuring, funding for these programs is typically through a small surcharge ("wires charge" or "system benefits charge") on utility bills.

ii) Rate Schedules
Utilities can schedule their rates to encourage customers to modify their pattern of energy use.

Time-of-use rates (TOU)
Involve charging higher prices for peak electricity as a way to shift demand to off-peak periods.

Interruptible rates
Offer discounts in exchange for a user commitment to reduce demand when requested by the utility.

Power factor charges
Can be implemented to discourage commercial and industrial utility customers from partially loading their electrical equipment, as this requires the utility to generate extra current to cover the resulting system losses.

Real-time pricing
Is where the electricity price varies continuously (or hour by hour) based on the utility's load and the different types of power plants that have to be operated to satisfy that demand.

b. Distributed Generation
Small, modular electricity generators sited close to the customer load can enable utilities to defer or eliminate costly investments in transmission and distribution system upgrades, and provide customers with more reliable energy supplies and a cleaner environment.

<u>Technologies Under Distributed Generation</u>

i) Power Generation
Technologies for distributed electricity generation include wind, solar, fuel cells, and combined heat and power systems.

a. Wind Power
Wind energy is a form of solar energy, created by circulation patterns in the Earth's atmosphere that are driven by heat from the sun. The energy that the wind contains can either be used directly

(example: wind mills to grind grain or sails in boats) or can be converted into electricity. The simplest way to describe a wind-electric turbine generator (or "wind turbine") is that it works just like a hydroelectric generator. At hydropower stations, the energy that is contained in falling or flowing water is used to spin the rotor of a turbine (a rotor looks a bit like an ordinary electric fan), and the turbine rotor drives the shaft of a generator to produce electricity. Wind energy works in a very similar fashion, especially similar to "run-of-river" hydro stations that make use of the flowing water in a river or stream. In the case of wind, the "river" is an invisible one made of air, but the principle is still the same. As the air flows past the rotor of a wind turbine (the rotor looks a lot like an airplane propeller), the rotor spins and drives the shaft of an electric generator.

To assess the potential of wind power, the "rule of thumb" is that it is worth looking into a household system if you have average winds of 10 miles per hour and are paying 10 cents or more per kilowatt-hour for electricity.

b. Solar Power

Photovoltaic (PV) devices, also called "solar cells", are semiconductors that convert solar energy directly into electricity. Although there are about 30 different types of PV devices under development, there are three main technologies in commercial production: monocrystalline cells, polycrystalline cells, and thin-film cells.

Monocrystalline (single crystal) solar cells are manufactured from a wafer of high-quality silicon and are generally the most efficient cells for converting solar energy into electricity. Polycrystalline solar cells are cut from a block of lower-quality multicrystalline silicon and are less efficient, but also less expensive to produce. Thin-film solar cells, manufactured in a process similar to tinting glass

c. Fuel Cells

In principle, a fuel cell operates like a battery, but unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied. Oxygen and hydrogen are the chemical inputs. A fuel cell system which includes a "fuel reformer" can utilize the hydrogen from any hydrocarbon fuel – from natural gas to methanol, and even gasoline. Since the fuel cells rely on chemistry and not combustion, emissions from this type of system would still be much smaller than emissions from the cleanest fuel combustion processes.

d. Combined Heat and Power or Cogeneration

Cogeneration is the sequential generation of two different forms of useful energy from a single primary energy source. The two different forms of energy are: 1) electrical energy and thermal energy (for heating and cooling), or 2) mechanical energy and thermal energy.

The typical cogeneration applications are:

- Industrial cogeneration – wood and agro-industries, food processing, pharmaceutical, pulp and paper, oil refinery, textile industry, steel industry, glass industry, ceramic industry
- Residential/commercial/institutional cogeneration – hospitals, schools & universities, hotels, houses and apartments, stores and supermarkets, office buildings

ii) Grid Interconnection

Connecting a distributed power system to the electricity grid has potential impacts on the safety and reliability of the grid. Several states are developing their own interconnection standards while awaiting completion of IEEE SCC21 P1547, the national standard.

iii) System Control

Real-time information and system control technologies currently under development will facilitate the integration of distributed power systems into the electricity grid.

iv) Load Control

Utilities can use energy management control systems (EMCSs) to remotely control a customer's electrical equipment - switching it on or off for load levelling purposes. Typically applied to heating, cooling, ventilation, and lighting loads, EMCSs can also be used to invoke on-site generators during peak periods.

Issues Under Distributed Generation

i) Transmission System Support

Strategically placed distributed resources, especially those placed toward the ends of distribution feeders, can be used to defer or eliminate the need for T&D additions or line upgrades that would otherwise be required to serve a new load.

ii) Islanding and Safety Issues

Circuit protection is the biggest technical challenge with adding generation to distribution circuits. Of particular concern is islanding, in which a distributed generator energizes a portion of a distribution system when the rest of the system is de-energized. This can create safety hazards and damage equipment.

iii) Net Metering

Net metering allows the electric meters of customers with generating facilities to turn backwards when they are feeding power into the grid, so that they receive retail prices for the excess electricity they generate. This encourages customer investment in distributed generation, including renewable energy.

c. Electricity Industry Restructuring

Utility deregulation has the potential to bring greater customer choice among energy products and suppliers. Electricity rates could also drop, as the price of energy will be determined less by federal and state regulations and more by energy supply and demand.

Technologies Under the Electricity Industry Restructuring

i) Transmission System Control

High-voltage silicon switches (thyristors) enable engineers to change the flow of electricity on the power grid much more quickly than before. This makes it possible to operate closer to the power grid's thermal limits, delivering more electricity without sacrificing reliability.

Issues Under the Electricity Industry Restructuring

i) Transmission Grid Access

For competition to prevail, all power producers need open access to the power grid. Utilities that control transmission lines are now required to charge other wholesale producers the same transmission rates they charge themselves, and open access is being implemented in some retail power markets.

ii) Electricity Reliability

A stable and reliable electricity grid is the backbone of modern society. With the electricity industry being restructured, additional demands are being placed on the grid, making it even more important to maintain reliability standards.

iii) Power Markets

A power market is a commodity exchange where electricity is traded at prices determined by supply and demand. In addition to this spot market, there is a need for a futures market to hedge contract prices.

iv) Public Benefits Programs

Prior to restructuring, utilities were responsible for a variety of programs - promoting energy efficiency, DSM, low-income assistance, consumer education, and the development and demonstration of emerging technologies such as renewable energy - that meet social objectives. Under restructuring, funding for these programs is typically through a small surcharge ("wires charge" or "system benefits charge") on utility bills.

v) Net Metering

Net metering allows the electric meters of customers with generating facilities to turn backwards when they are feeding power into the grid, so that they receive retail prices for the excess electricity they generate. This encourages customer investment in distributed generation, including renewable energy.

vi) Stranded Costs

Lower electricity prices resulting from the pressure of competition reduce the ability of some utilities to recover old investments in relatively expensive generating technologies.

There is uncertainty about who should pay for these stranded costs - utility shareholders, ratepayers, or both.

vii) Renewable Energy

Sources of renewable energy are either continuously resupplied by the sun or tap inexhaustible resources. They include solar, geothermal, bioenergy, wind, and hydropower resources.

Renewable Portfolio Standard (RPS)
An RPS requires all sellers of electricity to cover a minimum percentage of their sales with electricity generated from renewable resources.

Green Power Marketing
"Green" power is electricity generated from environmentally preferable renewable sources. Industry restructuring makes it possible to sell green power in competitive electricity markets, catering to consumers preferences for cleaner energy sources.

d. Electricity Reliability

A stable and reliable electricity grid is the backbone of modern society. With the electricity industry being restructured, additional demands are being placed on the grid, making it even more important to maintain reliability standards.

II.1.3. RESIDENTIAL, COMMERCIAL AND INSTITUTIONAL BUILDINGS SECTOR[7]

This section addresses greenhouse gas emissions and emissions reduction opportunities for residential and commercial (including institutional) buildings, often called the residential and service sectors[8]. Carbon dioxide emissions from fossil fuel energy used directly or as electricity to power equipment and condition the air (including both heating and cooling) within these buildings is by far the largest source of greenhouse gas emissions in this sector. Other sources include HFCs from the production of foam insulation and for use in residential and commercial refrigeration and air conditioning, and a variety greenhouse gases produced through combustion of biomass in cookstoves.

Traditional Biomass Fuels. Biomass fuels are the main source of energy for over 90% of Cambodian households. Cambodia's biomass fuels are divided into firewood, charcoal, dung, and other biomass (including agricultural residue). Biomass is the cheapest and most accessible source of energy used for cooking. According to the IPCC, CO_2 emissions from biomass used as fuels are excluded from the total CO_2 emission figure. This is true as long as there is good biomass resource management, because biomass growth reabsorbs CO_2. It is therefore assumed that any CO_2 emissions from burning biomass are reabsorbed during plant growth. However, in order to assess the direction of the "net flux" of CO_2 emissions (a balance between emission and absorption), CO_2 emissions from biomass is included in the LUCF section. Non-CO_2 emissions (like N_2O and CH_4) are included since they are not reabsorbed by plant growth. Local calorific values recommended by the Ministry of Industry, Mines and Energy (Appendix 1.1.3) have also been used for converting the amount of biomass used in the energy sector to kilotonne of oil equivalent (ktoe) before converting to energy unit.

There are myriad opportunities for energy efficiency improvement in buildings. Most of these technologies and measures are commercialized but are not fully implemented in residential and commercial buildings, while some have only recently been developed and will begin to penetrate the market as existing buildings are retrofitted and new buildings are designed and constructed.

A recent study identified over 200 emerging technologies and measures to improve energy efficiency and reduce energy use in the residential and commercial sectors[9]. There are new developments out of many that could be cited:
integrated building design
reducing standby power losses in appliances and equipment
photovoltaic systems for residential and commercial buildings
distributed power generation for buildings

[7] Methodological and Technological Issues in Technology Transfer, A Special Report of IPCC Working Group III, IPCC, 2000
[8] Climate Change 2001: Mitigation, IPCC, 2001
[9] Nadel et al, 1998

II.1.3.1. Integrated Building Design
Integrated building design focuses on exploiting energy-saving opportunities associated with building siting as well as synergies between building components such as windows, insulation, equipment, and heating, air conditioning and ventilation systems. Average energy savings of about 30%-60% can be achieved in integrated building design for residential construction. Assuming an average savings of 40% for integrated building design, the cost of saved energy for residential and commercial buildings has been calculated to be around US$3/GJ (the average cost of energy in the US buildings sector is about US$14/GJ).

II.1.3.2. Reducing Standby Power Losses in Appliances and Equipment
Improving the energy efficiency of appliances and equipment can result in reduced energy consumption in the range of 10 to 70%, with the most typical savings in the 30% to 40% range. A number of residential appliances and electronic devices such as televisions, audio equipment, telephone answering machines, refrigerators, dishwashers, and ranges consume electricity while in a standby or off mode. These standby power losses are estimated to consume 12% of Japanese residential electricity, 5% of US residential electricity, and slightly less in European countries. The costs of key low-loss technologies, such as more efficient switch-mode power supplies and smarter batteries, are low and a recent study found that if all US appliances were replaced by units meeting the 1-watt target, aggregate standby losses would fall at least 70%, saving the USA over US$2 billion annually.

II.1.3.3. Photovoltaic Systems for Buildings
Photovoltaic systems are being increasingly used in rural off-grid locations, especially in developing countries, to provide electricity to areas not yet connected to the power infrastructure or to offset fossil fuel generated electricity.

II.1.3.4. Distributed Power Generation for Buildings
Distributed power generation relies on small power generation or storage systems located near or at the building site. Several small scale (below 500kW), dispersed power-generating technologies are advancing quite rapidly. These technologies include both renewable and fossil fuel powered alternatives, such as photovoltaics and microturbines. Moving power generation closer to electrical end-uses results in reduced system electrical losses, the potential for combined heat and power applications (especially for building cooling), and opportunities to better coordinate generation and end-use, which can together more than compensate for the lower conversion efficiency and result in overall energy systems that are both less expensive and emit less carbon dioxide than the familiar central power generating station.

In buildings, ***energy efficiency*** means using less energy for heating, cooling and lighting.

An important concept for energy efficiency in buildings is the ***building envelope***, which is everything that separates the interior of the building from the outdoor environment: the doors, windows, walls, foundation, roof and insulation. All the components of the building envelope need to work together to keep a building warm in the winter and cool in the summer. A house's insulation, for instance, will be less effective if the roof, walls, and ceiling allow air to leak in or allow moisture to collect in the insulation.

Residential Buildings

In the residential sector, GHG mitigation technologies can be divided into three groupings:
building envelope strategies
building equipment strategies
renewable energy strategies

Building envelope strategies

Building envelope strategies address the size, shape, orientation, and thermal integrity of the residential unit. Examples of mitigation technologies include increased wall and roof insulation, advanced window technologies, roof coatings, and reduced or controlled infiltration.

Windows
In the U.S., energy efficient windows are indicated by the **Energy Star** [R] label. Some of the information provided for energy efficient windows are ***solar heat gain coefficient or SHGC*** (roughly equivalent to the solar shading coefficient), ***U-value*** (which indicates how well the window insulates),

and ***visible transmittance*** (which indicates how well light passes through the window). High-tech efficiency options include windows with argon between the window panes and low-emissivity (low-e) coatings.

Insulation

There are many types of insulation available, and each has a different insulating properties, expressed as "R-values" per inch. The amount of insulation needed can be easily calculated using the recommended R-value, which varies depending on the location and the specific part of the house or commercial building.

Foundations and Basement Slabs

Insulating both foundations and basement slabs is important for energy efficiency. For new construction, pre-insulated and pre-cast foundation panels or insulating concrete forms can simplify the task while achieving superior performance.

Walls and Ceilings

When building new walls and ceilings, advanced framing techniques help to achieve energy efficiency. Framing can also be avoided entirely with Structural Insulating Panels (SIP), the latest technology for achieving highly insulating walls and ceilings. The prefabricated panels sandwich a foam core between two sheets of plywood and are manufactured to precise design specifications. Insulated concrete forms, previously used only for foundations, are now also being used to form insulated concrete walls.

Alternative Building Materials

A wide variety of alternative materials is now being used to construct buildings. Many have energy efficiency as well as environmental benefits. These materials include:

Adobe (clay and straw)
Straw Bale
Rammed earth
Tires and other recycled materials
Cool Roofing - white or reflective roofing helps reflect heat and keep buildings cool. In the U.S., roofing products have the Energy Star^{R} label.

Adobe (clay and straw) - The adobe is a brick, which is made from mud. The traditional (U.S.) adobe block is 10 in. thick. The ideal mix of materials is approximately 20% clay and 80% sand. These mixed with water and the mud is then poured into forms to shape the blocks. Straw is added to add strength and to avoid large cracks in the adobe bricks. The adobe requires less energy to produce compared to a concrete block. For the solar enthusiast the adobe is an ideal material because of its thermal mass _____.

Straw Bale - Straw bales offer excellent insulation. One California study indicated that such a "super insulated" straw bale home could save as much as 75% of heating and cooling costs. This translates to direct dollar savings for the homeowner, and a corresponding reduction in the use of fossil fuels and CO_2 emissions.

Construction costs can also be reduced when building with straw bales. Stacked like huge bricks, straw bale wall systems can be erected quickly without much building experience and few power tools. Building with bales can also reduce on cutting down trees by reducing lumber used in typical "stick frame" construction. Straw is available wherever grain crops are grown, and is annually renewable. It is considered an agricultural waste product, and in many parts of the world is simply burned in the fields.

Two types of bale wall systems are commonly built:

post and beam - In a "post and beam" building, a wood, steel or concrete framework is erected and bales are placed in the walls as insulation.

Load bearing straw bale systems can bear the weight of the roof, as evidenced by the historic Nebraska homes, which were all load-bearing. In this case, a top- plate is laid above the bale wall and secured to the foundation by metal rods and/or strapping. The roof is then attached to the top plate.

In either of the two types of bale wall systems, the bale courses are stacked in a "running bond", and pinned with rebar, wood, or bamboo stakes. For added strength, chicken wire is commonly wrapped inside and out, and sewn tight to the bales. Then an earth plaster or cement stucco is applied as a finish. However, bales will also hold plaster without wire mesh.

Those concerned with indoor air quality also appreciate straw bale buildings for their "breathability". A non-toxic product itself, bales allow a gradual transfer of air through a wall, bringing fresh air into your living environment, especially when combined with a natural plaster. Straw bales are sound proof.

Straw bales resist combustion and a plastered straw bale wall system easily passed a two-hour fire test. For liquid moisture, a proper foundation, roof, and finish plaster can make straw bale buildings last indefinitely.

Rammed earth - Rammed earth, an ancient building technique, may have originally been developed in climates where humidity and rainfall did not permit the production of soil block. Structures constructed of soil materials are durable, and are said to last more than 50 years. Desirable qualities for soil construction materials include: strength, low moisture absorption, limited shrink/swell reaction, high resistance to erosion and chemical attack. For soil block to cure uncovered, there must be at least 10 rain-free days. Soil mixtures for rammed earth are similar to those for soil block. Soils with high clay content may be more suitable for ramming, as they tend to crack in blocks when curing.

Rammed earth soil mixes must be carefully prepared by screening, pulverizing, and mixing. Pulverizing is important to ensure a uniform mix and to break up any clumps. The soil mix is then transported to the forms. Large quantities of soil must be moved and transported vertically for placement in the forms. This process is not the same as pouring concrete, because the material is not liquid. Traditionally, workers passed buckets of earth up to where it was needed. Hoists can also be used effectively for this task.

The form work for rammed earth must be stable and well-built in order to resist pressure and vibration resulting from ramming. In the ramming process, once a soil "lift" of 6 to 8 inches in thickness is in place, the soil is rammed. Ramming can be accomplished manually or mechanically. Manual ramming is an ancient technique using a large, specially shaped tool with a long handle called a rammer. Rammers weigh around 18 pounds, and have heads of wood or metal. Differently shaped heads are designed to perform ramming for various form shapes, especially for corners. Mechanical impact ramming uses pneumatic ramming machines.

Issues that need to be considered in Building Envelope:

Moisture and Air Leakage Control

Leakage of outside air into a building can be prevented with air infiltration barriers, also called air retarders. These often also serve as vapor barriers to control moisture and prevent its condensation on cold surfaces.

Thermal Bridges

Studs, sills, and other building components can potentially act as thermal bridges, conducting heat past a building's insulation.

Indoor Air Quality and Air Exchange

Highly insulated buildings can accumulate noxious gases if they are not ventilated well - a problem known as sick buildings. Technologies such as air-to-air heat exchangers help ventilate buildings with minimal energy loss.

Whole-Building Design

Whole-building design takes an integrative approach to building design so that all elements of the building help achieve an optimal energy performance. The building has to interact effectively with the outdoor environment - a concept known as climate-responsive architecture. A variety of design tools are available.

Landscaping for Energy Efficiency

Landscaping can improve a building's energy performance. Trees and bushes can provide shading or block a prevailing wind, as can earth berms.

Energy Programs for Low-Income Homeowners

Low-income homeowners need energy efficiency most of all, but many live in drafty, poorly insulated homes. In the U.S., State and federal weatherization programs help these homeowners reduce their energy costs; low income home energy assistance programs (LIHEAP) help low-income homeowners pay their energy bills.

<u>Building equipment strategies</u>
improve the space heating and cooling, lighting, cooking, refrigerators, water heating, clothes washing and drying, air conditioning and other household appliances used in homes. Examples include such advanced technologies as condensing furnaces, compact fluorescent lamps and advanced refrigerator compressors.

LIGHTING

Compact Fluorescent Lamps (CFLs) - CFLs use much less energy than incandescent bulbs and need replacing far less often, making them a cost-effective choice. CFLs have also been used effectively to replace halogen lights in torchieres. Although early CFLs had a stark light, the color rendering of newer CFLs is equal to or superior to incandescent light bulbs, producing full-spectrum lighting.

Sulfur Lamps - Sulfur Lamps are bright, long-lasting, energy-efficient light sources that are effective in commercial and industrial buildings.

LEDs - are low-energy light sources that can save energy in such applications as flat-panel displays, exit signs, and traffic lights.

Ballasts - are an essential part of fluorescent lamps, transforming standard voltages into the voltage needed for the lamp. Magnetic ballasts are now being phased out in favor of more energy-efficient electronic ballasts.

Reflectors - form the backing of fluorescent fixtures and other lamps. Improved reflectors for fluorescent fixtures can light an area better using fewer lamps.

Fiber Optics - have the advantage of carrying light around bends and corners with little loss in brightness. They can also be used to distribute light throughout a building from a central lighting source.

Task Lighting - Lighting is more efficient when it is applied directly to a task (for instance, a bright light over a desk) rather than illuminating the entire room at the same lighting level.

Lighting controls - controls such as photosensors, occupancy sensors, and timers can save energy by turning lights off when they are not needed.

SPACE HEATING AND COOLING

This section focuses on the energy-efficient heating and cooling of buildings, and includes two renewable energy sources that can heat or cool buildings: solar energy and geothermal heat pumps.

Thermostats and Control Systems

Technologies such as setback thermostats and intelligent building controls offer inexpensive energy savings.

Ventilation
Ventilation is the least expensive and most energy-efficient way to cool buildings. In some cases, natural ventilation will suffice, although it usually needs to be supplemented with fans or other forced ventilation. Homeowners might want to investigate whole-house fans.

Evaporative Coolers
In low-humidity areas, evaporating water into incoming air provides a natural and energy-efficient means of cooling. Evaporative coolers, also called swamp coolers, rely on this principal.

During summer, an evaporative cooler offers an energy-efficient, ozone-friendly way to further cool off your house. An evaporative cooler basically consists of a large fan and water-wetted pads. Fresh outside air is cooled by about 20 degrees as it is drawn through the wet pads and blown into the house. The cooler slightly increases the humidity of the entering air. This contrasts with air conditioners, which reduce humidity as they recycle the air in the house. The wetted pads on an evaporative cooler are fairly efficient air filters, trapping particles on their wet surfaces. The continuous wetting of the pads flushes the trapped particulates into the sump, where they are contained.

Evaporative coolers are relatively quiet, simple appliances, which use less than a quarter as much electricity as an air conditioner. Evaporative coolers cost approximately half as much to buy as an air conditioner of equivalent cooling capacity. Installation costs will be similar. Operating costs will be less than a fourth as much as an air conditioner.

Dessicant Cooling and Dehumidification
Dessicants absorb water and release it again when heated. Dessicants can provide dehumidification and can also extend the application of evaporative coolers into more humid climates.

Dessicant cooling systems are energy efficient, cost effective, and environmentally safe. They are used as stand-alone systems or with conventional air-conditioning to improve the indoor air quality of all types of buildings. In these systems, a desiccant removes moisture from the air, which releases heat and increases the air temperature. The dry air is cooled using either evaporative cooling or the cooling coils of a conventional air conditioner. The adsorbed moisture in the desiccant is then removed (the desiccant is regenerated to its original dry state) using thermal energy supplied by natural gas, electricity, waste heat, or the sun.

Dehumidifiers
Dehumidifiers with the Energy Star^{R} label are energy efficient.

Room and Central Air Conditioners
For whole house cooling, central air is more efficient, but if you only need to cool your bedroom, consider a room air conditioner instead. Choose an energy efficient central air conditioner or room air conditioner and be sure it has an ENERGY STAR^{R} label (for U.S. only). Other air conditioners use chlorofluorocarbons (CFCs) as a refrigerant. Because of environmental concerns, modern air conditioners use halogenated CFCs (HCFCs) or other CFC replacements.

Ice Storage Systems
These commercial building systems save money by using inexpensive off-peak power to produce ice, usually at night. The ice provides building cooling during the day and avoids taxing utilities during peak usage hours.

Air Exchange Systems
Technologies such as air-to-air heat exchangers help ventilate buildings with minimal energy loss.

Furnaces and Boilers

Appliances

In the U.S., the U.S. Department of Energy, energy efficient appliances have EnergyGuide label. Energy efficient refrigerators, dishwashers, and clothes washers have an ENERGY STAR[R] label.

- ***Refrigerators and Freezers***

Along with energy efficiency, the environmental impact should also be considered. Older models use chlorofluorocarbons (CFCs) as a refrigerant; newer models will use halogenated CFCs (HCFCs), which are more environmentally benign.

Clothes Washers
Water-saving, horizontal-axis washing machines, also called front-loading washing machines, save energy, water and money.

Television Sets, Set-top Boxes, VCRs, and Home Audio Products
These electronic goods often use energy when they are turned off. These standby losses - also called "leaking electricity"- are being reduced in some newer models.

Dryers, Dishwashers, Ovens and Stoves
There are also energy-efficient models of these appliances.

Water Heating

This section focuses on the energy-efficient heating of water. Two renewable energy sources that can heat water are discussed separately: solar energy and geothermal heat pumps.

Technologies for Water Heating:

Tank Water Heaters
Air-Source Heat Pumps
Tankless Water Heaters
Drainwater Heat Recovery

Tank Water Heaters
The standard form of water heating in the U.S., the tank water heater will use less energy if insulation is added, and the water temperature is reduced.

Air-Source Heat Pumps
Heat pumps are more energy efficient than standard electric or gas water heaters.

Tankless Water Heaters
Also called "demand" or "instantaneous" water heaters, tankless water heaters can save energy by eliminating the standby energy losses suffered by tank water heaters.

Drainwater Heat Recovery
Any hot water that goes down your drain carries away energy with it. Drainwater heat recovery systems save energy by using the heat in drains to preheat water coming into the water heater.

Solar Hot Water and Space Heating and Cooling

Solar hot water heaters use the sun to heat either water or a heat-transfer fluid in collectors. A typical system will reduce the need for conventional water heating by about two-thirds. High-temperature solar water heaters can provide energy-efficient hot water and hot water heat for large commercial and industrial facilities.

<u>The renewable energy strategies</u>
Include passive solar building designs and active solar water heater and space heating systems, ground-source heat pumps, daylighting strategies and photovoltaic systems.

Geothermal Heat Pumps
Geothermal heat pumps are viable nationwide in the U.S. They use the earth as a heat sink in the summer and a heat source in the winter, and therefore rely on the relative warmth of the earth for their heating and cooling production. Through a system of underground (or underwater) pipes, they transfer heat from the warmer earth or water source to the building in the winter, and take the heat

from the building in the summer and discharge into the cooler ground. Therefore, GHPs don't create heat; they move it from one area to another.

A GHP works much like the refrigerator in your kitchen, with the addition of a few extra valves that allow heat-exchange fluid to follow two different paths: one for heating and one for cooling. The GHP takes heat from a warm area and exchanges the heat to a cooler area, and vice versa. The beauty of such a system is that it can be used for both heating and cooling - doing away with the need for separate furnace and air conditioning systems - and for free hot water heating during the summer months.

The benefits of a GHP system:

Low energy use - GHPs use 25 to 50% less electricity than conventional heating or cooling systems.

Free or reduced-cost hot water - A device called a "desuperheater" transfers excess heat from the heat pump's compressor to the hot water tank. In the summer, hot water is provided free; in the winter, water heating costs are cut roughly in half.

Year-Round comfort - While producing lower heating bills, geothermal heat pumps are quieter than conventional systems and improve humidity control. These features explain why customer surveys regularly show high levels of user satisfaction, usually well over 90%.

Design Features - GHPs allow for design flexibility and can be installed in both new and retrofit situations. Because the hardware requires less space than that needed by conventional HVAC systems, the equipment rooms can be greatly scaled down in size, freeing space for productive use. GHPs usually use the existing ductwork in the building and provide simultaneous heating and cooling without the need for a four-pipe system.

Improved Aesthetics - Architects and building owners like the design flexibility offered by GHPs. Historic buildings like the Oklahoma State Capital and some Williamsburg structures use GHPs because they are easy to use in retrofit situations and easy to conceal, as they don't require cooling towers. GHP systems eliminate conventional rooftop equipment, allowing for more aesthetically pleasing architectural design and roof lines.

Low Environmental Impact - Because a GHP system is so efficient, it uses a lot less energy to maintain comfortable indoor temperatures. This means that less energy - often created from burning fossil fuels - is needed to operate a GHP. According to the EPA, GHPs can reduce energy consumption - and corresponding emissions - up to 44% compared to air-source heat pumps and up to 72% compared to electric resistance heating with standard air-conditioning equipment.

Low Maintenance
Zone heating and cooling
Durability
Reduced Vandalism

Solar Technologies

Photovoltaics (PV)
Photovoltaics solar cells, which directly convert sunlight into electricity, are made of semiconducting materials. The simplest cells power watches and calculators while more complex systems can light houses and provide power to the electric grid.

Passive Solar Heating, Cooling and Daylighting
Buildings designed for passive solar and daylighting incorporate design features such as large south-facing windows and building materials that absorb and slowly release the sun's heat. No mechanical means are employed in passive solar heating. Incorporating passive solar designs can reduce heating bills as much as 50%. Passive solar designs can also include natural ventilation for cooling.

Concentrating Solar Power

Commercial and Institutional Buildings

The commercial and institutional buildings include different building types, such as offices, retail stores, schools, hospitals, hotels, warehouses, theaters, and places of worships.

As with residences, the mitigation technologies for commercial buildings can be divided into three categories. ***Building envelope strategies*** vary, depending upon the size and type of building and the climate. Wall and roof insulation in important in many building types. Modern commercial office buildings have higher internal heat loads from equipment and people, decreasing the importance of insulation and raising the importance of window and glazing systems. ***Building equipment strategies*** emphasize heating and cooling, efficient lighting, energy management control systems, and office equipment efficiency. ***Renewable technology strategies*** include photovoltaics, active and passive systems and daylighting.

a. Building Envelope Strategies

(Refer to the Building Envelope Strategies under the Residential Buildings)

b. Building Equipment Srategies

Office Equipment

Most office equipment spends much of its time sitting idle. The energy used by this equipment while it waits in standby mode can be significant. ***Power management*** shifts office equipment into a low-energy mode when not in use for a period of time - some models even turn off. Office equipment with power management features often carries the ENERGY STAR^R (U.S.) label. Power management is available for the following types of equipment:

Computers
Monitors
Copiers
Printers
Scanners
FAX Machines
Multifunction devices

Building Electrical Equipment

Transformers - Energy-efficient transformers carry the ENERGY STAR^R label.
Motors - Energy efficient motors must be sized correctly and should incorporate advanced ***motor-controller*** technologies. ***Variable speed motors*** save energy in many applications.

c. Renewable Energy Strategies

Photovoltaics

Sunlight (solar energy) can be used to generate electricity, provide hot water, and to heat, cool, and light buildings. A solar or PV cell consists of semiconducting material that absorbs the sunlight. The solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. PV cells are typically combined into modules that hold about 40 cells. About 10 of these modules are mounted in PV arrays. PV arrays can be used to generate electricity for a single building or, in large numbers, for a power plant. A power plant can also use a concentrating solar power system, which uses the sun's heat to generate electricity. The sunlight is collected and focused with mirrors to create a high-intensity heat source. This heat source produces steam or mechanical power to run a generator that creates electricity.

Solar water heating systems for buildings have two main parts: a solar collector and a storage tank. Typically, a flat-plate collector - a thin, flat, rectangular box with a transparent cover - is mounted on the roof, facing the sun. The sun heats an *absorber plate* in the collector, which, in turn, heats the fluid running through tubes within the collector. To move the heated fluid between the collector and the storage tank, a system either uses a pump or gravity, as water has a tendency to naturally circulate as it is heated. Systems that use fluids other than water in the collector's tubes usually heat the water by passing it through a coil of tubing in the tank.

Many large commercial buildings can use solar collectors to provide more than just hot water. Solar process heating systems can be used to heat these buildings. A solar ventilation system can be used in cold climates to preheat air as it enters a building. And the heat from a solar collector can even be used to provide energy for cooling a building.

A solar collector is not always needed when using sunlight to heat a building. Some buildings can be designed for ***passive solar heating***. These buildings usually have large, south-facing windows. Materials that absorb and store the sun's heat can be built into the sunlit floors and walls. The floors and walls will then heat up during the day and slowly release heat at night - a process called *direct gain*. No mechanical means are employed in passive solar heating. Incorporating passive solar designs can reduce heating bills as much as 50%. Passive solar design can also include natural ventilation for cooling.

Many of the passive solar heating design features also provide *daylighting*, which is simply the use of natural sunlight to brighten up a building's interior.

Photovoltaic solar cells, which directly convert sunlight into electricity, are made of semiconducting materials. The simplest photovoltaic cells power watches and calculators and the like, while more complex systems can light houses and provide power to the electrical grid.

II.1.4. INDUSTRY

II.1.4.1. Industrial Processes

Data used in the assessment was obtained from the records of the Ministry of Industry, Mines and Energy and from selected factories. For example, for the cement factory, the emissions were determined using balanced chemical equations of the resources transformation process.

Cement Manufacturing. Carbon dioxide is produced during the production of clinker, an intermediate product from which cement is made. However, clinker statistics were not available in Cambodia and, as a result, cement production statistics were used. This does not compromise the accuracy of the emission estimates since there is a direct relationship between cement production and clinker production. Studies in most countries have indicated that the difference in emission estimates using clinker or cement data is very small.

*Sugar Manufacturing and Beer Brewing***.** In Cambodia, sugar is produced from sugar palm juice at a household level. The process involves evaporating water by burning wood fuel. The energy consumption in this process is reported in the energy sector. GHG emissions are also produced during the microbial fermentation process in the production of beer, wines and spirits. However, these activities are assumed to give zero net CO_2 emissions since the CO_2 emitted is assumed to be reabsorbed during crop growth.

Industry uses more than one-third of all the energy used in the United States. Most of the energy industry uses is supplied from natural gas and petroleum, with electricity coming in a distant third, followed closely by coal. Certain industries, for instance steel production, require a large amount of energy per unit of product, and are the best candidates on which to focus energy-efficiency efforts.

Creating industrial products is extremely energy intensive, so simple measures such as optimizing and maintaining equipment can save enormous amounts of energy. Recent technological advances in the design of boilers and furnaces allow them to operate at higher temperatures while using less energy. This technology is not only more efficient, but is also cleaner, releasing fewer emissions. Hotter furnaces have spurred the development of new materials that withstand hotter temperatures. These materials, called composites, are strong, light, and corrosion-resistant, so they are quite durable.

Motors to power pumps, fans and blowers, air compressors and dozens of other mechanical devices find use in nearly all types of industrial production. The most energy-efficient motors are equipped with controllers and variable speed drivers to help the motors match output with the energy necessary for the task. Some motors have motor coils made of superconducting materials, which greatly reduce energy loss.

The most energy-intensive industries are the aluminum industry, the agricultural industry, the chemical industry, the forest products industry, the glass industry, and the steel industry. In the aluminum industry, in addition to employing improved technology to increase the efficiency of production, the focus is on increasing the recycling of scrap and waste products. The chemical industry is also increasing the recovery and reuse of liquid and solid wastes, which reduces the use of raw materials, minimizes water use, and cuts down on waste disposal. Catalysts that lower the energy requirements for chemical reactions, and computer programs that model chemical behavior have increased efficiency in the chemical industry as well. Both the chemical and agriculture industries are not only using more efficient industrial processes to cut down on their energy use, but the purpose of these industries has begun shifting toward creating products from renewable forms of energy, such as crops, that can replace products traditionally made from petroleum.

The forest products industry generates more than half of its own energy by using its wood waste for fuel. Sustainable forest management practices, recycled paper products, and new bleaching agents help save energy and minimize environmental damage. In the glass industry, oxygen-fueled furnaces that use pure oxygen, in order to burn at higher temperature, and new heat-resistant materials have greatly increased energy-efficiency. (Even recycling glass requires melting it in a furnace.) In the metals industries, improvements in metal casting technologies have resulted in superior shaping, making it possible to eliminate steps in the production process, and steel makers are using technology that has improved the efficiency of blast furnaces and reduced nitrous oxide emissions.

Some industries can use their waste heat as power, which has tremendous potential for energy efficiency in industry. This is called combined heat and power systems, or cogeneration. Some CHP systems even generate more power that can be used on site, and in some cases this energy may be sold to a utility.

Technologies

Industry-Specific Technologies
Efforts to develop energy-efficient technologies are focused on the most energy-intensive industries, including agriculture, the aluminum industry, the chemical industry, the forest products industry, the glass industry, the metal casting industry, the mining industry, the petroleum industry and the steel industry. Much of the work in agriculture and the chemical industry focuses on producing bioproducts from agricultural crops.

The ***forest products industry*** is the third largest industrial consumer of energy, but it generates more than half of its energy needs using its woody waste products and other renewable sources of fuel. Under **forest management**, forest products obviously depend on the growth of trees. Sustainable forest management practices help keep the soil productive to maintain the long-term growth of forests**.** **Paper production** technologies emphasize the use of recycled forest products and the energy-efficient drying of paper. New bleaching agents and recycling technologies are also helping to save energy and minimize the environmental impacts from the bleach plants at paper mills.

Combined Heat and Power Systems
The onsite production of electricity is particularly attractive to industries that can also make use of the waste heat. Such combined heat and power (CHP) systems - also called cogeneration systems - achieve higher thermal efficiencies than stand-alone power plants.

Power Production
CHP systems use a wide variety of power production technologies, such as gas turbines, (including combined-cycle systems), microturbines, fuel cells, and reciprocating engines.

Issues
Distributed Generation
CHP is one form of distributed generation, in which power is generated close to where it is used, thereby reducing the strain on power transmission systems.

Power Marketing
For CHP systems that generate more power than is used onsite, the economics of the systems depend on the ability to market the power to other entities, such as utilities.

Electricity Industry Restructuring
States that have restructured their electric industries to allow competition maybe more amenable to buying power from CHP systems.

Motors
Motor-driven equipment accounts for 64% of the electricity consumed by U.S. industries. Energy-efficient motors can cut this energy use by at least 12%.

Steam Systems
Over 45% of all the fuel burned by U.S. manufacturers is consumed to raise steam. A typical industrial facility can realize steam savings of 20% by improving its steam system. Simple approaches to improving energy performance include insulating steam and condensate return lines, stopping any steam leaks, and maintaining steam traps. Condensate return to the boiler is essential for energy efficiency.

Compressed Air Systems
Optimization of compressed air systems can provide energy-efficiency improvements of 20-50%. Many industries use compressed air systems as power sources for tools and equipment used for pressurizing, atomizing, agitating, and mixing applications. Compressors using variable-speed drives are saving energy, while simple measures like detecting and fixing air leaks remain all-important.

Continuous Fiber Ceramic Composites (CFCC)
These composites are light, strong, corrosion resistant, and capable of performing in high temperature environments, without the brittleness of pure ceramics.

Combustion
Boilers and furnaces, rely on advanced burners to operate cleanly and efficiently. Emissions of pollutants such as nitrous oxides (NOx) are always of concern in combustion processes.

Sensors and Controls
All industrial systems rely on sensors and controls. Advanced sensors and control systems can allow processes to operate at their optimal conditions.

Issues

Industrial Energy Assessments
Just as homes need energy audits, industries need energy assessments to identify the areas they can focus on for energy savings.

Financing
A variety of financing sources are available to fund industrial energy efficiency improvements.

II.2. GREENHOUSE GAS MITIGATION TECHNOLOGIES, MEASURES AND POLICIES PRACTICED IN CAMBODIA

The following is a summary of technologies, measures and policies that are already available in Cambodia. It should be noted, however, that some of the technologies and measures, are implemented in a limited area only.

The main reference of this section is from the CCEAP report "Greenhouse Gas Mitigation Analysis - Energy and Transport". Recent updates were also incorporated in this section.

Power Generation
Use of renewable energy as fuel to produce electricity
Shift to cleaner fuel and energy efficiency in power generation
Electricity supply improvement
National Transmission System
Electricity trading with neighboring countries
Rehabilitation of the Electricity System
Provincial and Rural Electrification
Improvement in the Electricite du Cambodge (EDC)
Commercialization of the supply of electricity

Transport
Energy efficient transport
Improvement in road, airport, rail and water transport

Non-motorized vehicles

Walking and riding the bicycle and the cyclo[10], are still being practiced by some city dwellers and people in the rural areas. In Phnom Penh, distances can be reached by walking or riding in a bicycle or a cyclo.

Household
Energy efficient cook stove

Policies and Measures
Institutional, Legal and Regulatory Initiatives
Regulatory reform action - Establishment of a Power Sector Regulatory Framework
The Asian Development Bank's "Strategic Environmental Framework for the Greater Mekong Subregion (GMS)[11]: Integrating Development and Environment in the Transport and Water Resource Sectors"

II.2.1. POWER GENERATION

II.2.1.1. Use of renewable energy as fuel to produce electricity

Hydropower Plants
A study entitled "Cambodia's Power Transmission Plan and Rural Electrification" Strategy" was funded by the World Bank. Cambodia's Ministry of Industry, Mines and Energy is using this study as basis for their power generation planning.

II.2.1.2. Shift to cleaner fuel and energy efficiency in power generation

JICA's "Feasibility of a 180 MW Combined Cycle Gas Turbine Power Plant at Sihanoukville (2000)"
The Japan International Cooperation Agency (JICA) funded a study on the "Feasibility of a 180 MW Combined Cycle Gas Turbine Power Plant at Sihanoukville (2000)". This is scheduled to be established at Sihanoukville in 2007.

The European Commission (EC)-ASEAN program Cogen 3
The European Commission (EC)-ASEAN program Cogen 3, promotes the use of clean coal, gas and biomass as fuel to cogeneration power plants. Cogen 3 has a Cambodian Country Coordinating Team, Ta Prohm Consultants[12][13]. The programme's "Full Scale Demonstration Project (FSDP)"

II.2.1.3. Electricity supply improvement
The Second Five-Year Socioeconomic Development Plan (2001-2005) or SEDPII includes the following initiatives:
Rehabilitation of the 10 MW hydropower plant in Kampong Speu province and of the 115 kV transmission line to supply Kampong Speu town and Phnom Penh;
Implementation of the agreement to establish the HV 220 KV interconnection with Vietnam to supply Phnom Penh
Investigation of lower voltage cross-border transmission lines to supply towns close to the Thai and Vietnamese borders; and
Investigation of a 115 kV transmission line from Thailand to supply Serey Sisophon in Banteay Meanchey province, with possible later extension to Siem Reap and Battambang

The US$56.2 million investment program for the period 2001-2003 includes projects for extension of the power system, power rehabilitation in provincial towns, and rural electrification. The rehabilitation of Kirirom hydro plant is to be undertaken at a cost of US$26 million by the China Electric Power Technology Import and Export Corporation.

II.2.1.4. National Transmission System

---

[10] A cyclo is a carriage attached to a bicycle and driven by foot pedal. In Cambodia, the cyclo is pedaled by a cyclo driver, who charges 1,000 riels (equivalent to .25 US$) within short distances.
[11] The six countries of the GMS include Cambodia, Lao People's Democratic Republic (Lao PDR), Myanmar, People's Republic of China (PRC), Thailand and Viet Nam.
[12] Ta Prohm Consultants is a Cambodian firm, with email address: Taprohm_c@camnet.com.kh.
[13]

To meet the growth in demand, which is forecast to grow from 97 MW and 522 GWh in 1998 to 746 MW and 2634 GWh in 2016, the Royal Government has decided to develop a National Transmission System. This System will allow access to energy generated by efficient large-scale power stations to provincial centers and also allows Cambodia to access available hydroelectric sites inside Cambodia or in neighboring countries. It will significantly reduce reliance on imported oil for the energy generation and also the risks involved in oil transportation.

The total capital cost of transmission developments within the period (1999-2016) is about $365 million excluding contingencies. It is proposed that the transmission system be developed in three stages depending on the availability of funds. Details of this plan are in Attachment __.

A national transmission system can allow trading of electricity from systems that may have excess capacity, at a lower cost and may produce less GHG, for example, importing cheaper electricity from Vietnam. This transmission line can also be used to export electricity to Vietnam. In the case of large hydroelectric power plants, which are considered uneconomical if the demand is not enough to effect economies of scale, once connected to the grid, this project will be economically feasible. A new and efficient

II.2.1.5. Electricity trading with neighboring countries

The **transmission** planning includes the development of a national grid linking the larger generating units to population centers in phases. The first phase consists of construction of the southern grid of Phnom Penh-border of Vietnam, 220 kV transmission through Takeo with a branch link from Takeo to Sihanoukville through Kampot, and the northern grid, a 115 kV interconnection from Thailand to Banteay Mean Chey, Siem Reap and Battambang provincial towns, to benefit from regional power trade opportunities. The long-term development framework considered in the master plan allows for a better optimization of investment decisions with a view to reduce the cost of electricity to consumers.

II.2.1.6. Rehabilitation of the Electricity System

In 1990, the electricity system was virtually non-existent. The AUSAID, ADB, World Bank, and JICA provided funding and technical assistance to Cambodia to rehabilitate its electricity system.

II.2.1.7. Provincial and Rural Electrification

Strategies and Measures Proposed by the World Bank, Asian Development Bank, France and Japan

The World Bank, ADB, France and Japan, in consultation with the MIME Directorate of Electricity have proposed the following strategies and measures:
Increase coverage and reduce costs of electricity supply
Establish rational tariff structure
Seek strategic partners in order to increase and improve services and improve financial performance of utilities
Encourage competition and private participation by establishing an enabling environment
Privatization and/or concessioning of Electricite du Cambodge (EDC)

Programs Supported by the International Development Association

The International Development Association (IDA) supports the programs “Phnom Penh Power Rehabilitation”, “Rural Electrification Project”, “Country Framework Report on Private Participation in Infrastructure (PPI)” and “Rural and Provincial Infrastructure Operation”.

The World Bank Project “Cambodia: Rural Electrification and Transmission”
The primary objectives of the project are to reduce poverty and support the foundations for sustainable development in the long term. The project will seek to accomplish these objectives by (a) promoting rural development by providing the economic benefits of electricity; and (b) improving power sector efficiency , by consolidating the sector restructuring efforts, reducing electricity costs and removing infrastructure bottlenecks. The project has been broken down into four principal components: Rural Electrification, 230 kV and 115 kV Transmission; and Technical Assistance.

The **rural electrification** component will support a long-term effort to provide electricity to rural areas for direct and indirect contribution to economic development and poverty alleviation. This will be achieved by strengthening of the institutional framework, capacity building of the stakeholders, and improve the living situation

II.2.1.8. Improvement in the Electricite du Cambodge (EDC)

The Asian Development Bank established a training center, and funded two Technical Assistance: "Strengthening of the Institutional and the Legal Framework for the Energy and Minerals Sector (1994)" and the "Power Sector Manpower Development and Training (1994)". The World Bank provided funds for a one-year training program of EDC Executive Directors and senior staff. The Government of France funded a Technical Assistance and advisory services for planning, training, system losses and tariffs (2000).

II.2.1.9. Commercialization of the supply of electricity
Commercialization of Electricite du Cambodge (EDC) and Marketing Strategy
The Electricite de France (EDF) carried out a study to develop a marketing and a new tariff structure to achieve the new coomercial objectives. EDC and EDF have jointly developed a 1998-2000 marketing plan.

Commercialization of Provincial Electricity Supply
Senior staff of provincial electricity supply units commenced training in Business Management in January 2000. This is a first stage of a program to implement a sound commercial management structure for provincial electricity supplies.

II.2.2. TRANSPORT

II.2.2.1. Energy efficient transport

An extensive mass transport is part of the system proposed under the JICA study "Transport Master Plan of the Phnom Penh Metropolitan Area in the Kingdom of Cambodia".

II.2.2.2. Improvement in road, airport, rail and water transport

JICA study "Transport Master Plan of the Phnom Penh Metropolitan Area in the Kingdom of Cambodia"
JICA funded a study entitled "Transport Master Plan of the Phnom Penh Metropolitan Area in the Kingdom of Cambodia". The implementation period of this Master Plan is from 2001 to 2015, at an estimated cost of 57.4 million US$.

National Transport Policy of Cambodia[14]
In November 2001, the Asian Development Bank commissioned the ND Lea, in association with JOC, to undertake a Transport Sector Study for the Kingdom of Cambodia. The objective of the study was to develop an overall Transport Sector Policy and individual modal or sub-sector strategies aimed at promoting national economic growth and alleviating poverty. The development of the Transport Sector Policy and the modal strategies, was based upon a detailed review of the current status of the transport sector and an analysis of the forecast transport demand. Also assessed were issues and constraints, brought to light at the Inception Workshop held in January 2002 and at the sub-sector Focus Group Sessions convened between February and May 2002. Concurrent with these activities a review was undertaken of the legal framework within which the transport sector operates and the constraints therein identified.

A detailed review of the present institutional arrangements in the Ministry of Public Works and Transport was carried out in order to identify any institutional constraints, which were taken into account in the preparation of the Capacity Building Plan.

Based on a review of the current status of the development of the private sector in Cambodia, an overview of possible private sector participation in the transport sector was also carried out.

[14] Cambodia Transport Sector Study, Kingdom of Cambodia, Ministry of Public Works and Transport – ND Lea Consultants Ltd. in association with Japan Oversea Consultants (JOC) Co., Ltd., June 2002

Subsequently, following the development of the individual transport sub-sector strategies, areas of specific opportunity for private sector participation have been recommended.

The policy and strategies presented in this study are fully consistent with the long-term objectives of the Royal Government of Cambodia, as enunciated in the Second Five Year Socio-Economic Development Plan 2001-2005 (SEDPII), and provide an appropriate policy framework and specific sub-sector strategic direction to achieve the objectives therein.

City Officials Discuss Ways to Clear Sidewalk Nuisances and Make Phnom Penh's Streets More Pedestrian-Friendly[15]
Taking a stroll down a Phnom Penh street is not easy. The sidewalk is usually crowded with vendors and parked cars; some places are completely blocked off with ropes or chains, particularly near foreign embassies.

The governor said that the city needed to preserve sidewalks as a space reserved for walkers.

II.2.2.3. Non-motorized vehicles
Presently, there are still a number of cyclos plying around cities like Phnom Penh. There are also a number of people who walk, as some places around the city are still within walking distances.

II.2.3. HOUSEHOLD

II.2.3.1. Energy efficient cook stove
The project Cambodia Fuelwood Saving Project (CFSP) promoted the production and use of efficient fuelwood cookstoves.

The AusAID's Community Development Fund, CDF [16](which replaced the Small Activities Scheme) is funding a clay-pot stove fabrication in three rural Battambang villages. It is twice as efficient as the traditional clay-pot. The profits are used by the village committees both to upgrade production and provide income to 7,000 villagers. The project is partnered by the NGO "Solidarity Charity" who assists with production and administration.

II.2.4. POLICIES AND MEASURES

II.2.4.1. Institutional, Legal and Regulatory Initiatives

Establishment of the Electricity Authority of Cambodia (EAC), the Council for the Development of Cambodia (CDC), and the Law on Environmental Protection and Natural Resources Management (LEPNRM)

II.2.4.2. Regulatory reform action - Establishment of a Power Sector Regulatory Framework

Long-Term (1999-2016) Power Sector Strategy
The Royal Government of Cambodia formulated a policy to provide adequate energy throughout Cambodia at reasonable and affordable price and is determined to take accelerated action and initiative in making available the energy to the disadvantaged group of population. In order to achieve these objectives, the Royal Government has developed a long-term (1999-2016) Power Sector Strategy. This Strategy includes the development of **Power Generation and Transmission Master Plan** (to meet the growing demand of electric power of 746 MW in 2000-2016), **rural electrification** and **power sector reform**.

Power Generation and Transmission Master Plan
The **power generation development** planning consists of developing in stages a gas power plant in Sihanoukville, and hydropower resources in the western part of the country, which are listed as priority projects for private investment. The **transmission** planning includes the development of a national grid linking the larger generating units to population centers in phases. The long-term

[15] The Cambodia Daily, "Embassies and Vendors Cluttering Sidewalks", September 10, 2002
[16] Phnom Penh Post "Australia Day", January 18-31, 2002

development framework considered in the master plan allows for a better optimization of investment decisions with a view to reduce the cost of electricity to consumers.

Rural Electrification
The **rural electrification** program includes the development of renewable and other energy resources. Rural electrification systems involve grid extension and stand-alone systems (including mini-grid with diesel generator, micro-hydropower plant, or solar home system). The Government is promoting rural electrification development with consideration of creating a Rural Electrification Fund to subsidize part of the investment capital of private rural electricity enterprises in order to help lower the cost of electricity for rural households.

Power Sector Reforms
The Royal Government of Cambodia has also initiated **power sector reforms** to attract private investment. Electricite du Cambodge (EDC), a state-owned power utility has been commercialized and is now working as an autonomous legal entity since 1997. The Electricity Law of Cambodia is promulgated on February 2, 2001 and the Electricity Authority of Cambodia (EAC), an independent regulatory body, has been established. The main function of EAC is to: i) license and regulate the electricity services and ii) approve the electricity tariff on competitive approach. This will create the conditions to attract private investment in Cambodia.

II.2.4.3. The Asian Development Bank's (ADB) "Strategic Environmental Framework for the Greater Mekong Subregion (GMS): Integrating Development and Environment in the Transport and Water Resources Sectors"
The Strategic Environmental Framework (SEF) Project[17] was created to help the ADB make funding decisions about infrastructure projects in the GMS. It combines analytical, participatory and policy oriented processes into a strategic platform for guiding investment decisions in the transport, water resources development and environmental sectors in the GMS. Its ultimate goal is to ensure these investments are environmentally and socially sustainable, and that environmental and social aspects, as well as cumulative impacts, are considered at an earlier stage in the planning process than currently takes place.

The SEF software and databases can help decision-making more generally. They can help national level policy-makers to formulate better development plans and to understand their potential impacts; private sector entities to design more sustainable infrastructure projects; citizen groups, NGOs and local communities to access information needed for more effective participation in national and regional decision-making; academic scholars to research and analyze public interest issues; and regional associations and inter-governmental organizations to develop more integrated regional plans, provide more effective oversight and assessment and support more informed regional agreements.

II.3. EVALUATION OF MITIGATION OPTIONS

In the CCEAP report "GHG Mitigation Options in the Energy Sector" (an analysis of potential measures to abate the increase in greenhouse gas emission in Cambodia and the corresponding GHG reduction using the LEAP[18] program), the computer program LEAP was used to evaluate the reduction of GHG emission for each GHG mitigation option. In order to evaluate each mitigation option, data is needed. Presently, Cambodia's actual data for energy is only for 1995. From 1996 onwards, the data was just a projection from the 1995 actual data.

There is a need for actual data in order to evaluate the GHG mitigation options. If actual data is available until 2001, then the projections for 2002 onwards would be more reliable.

II.4. BARRIERS IN THE IMPLEMENTATION OF GHG MITIGATION TECHNOLOGIES, MEASURES, AND POLICIES IN CAMBODIA

II.4.1. TRANSPORT

[17] The Strategic Environmental Framework for the Greater Mekong Subregion – TA No. 5783 (the SEF Project) was executed by the ADB with co-financing by the Swiss Agency for Development and Cooperation (SDC), with consulting inputs from the Stockholm Environment Institute (SEI), in collaboration with the UNEP Regional Resource Center for Asia and the Pacific (UNEP PRC AP) and the Mekong River Commission (MRC).

[18] The LEAP 2000 is the Long-Range Energy Alternatives (LEAP) system, a scenario-based energy-environment modeling tool. This program is used to evaluate the GHG mitigation options considered for Cambodia. LEAP 2000 is a user-friendly software developed by the Stockholm Environment Institute (SEI) - Boston Center at the Tellus Institute.

II.4.1.1. Road Safety
Most drivers in Cambodia are reckless and are not aware of traffic rules and regulations. This fact is shown on the number of fatal and serious road accidents. In Phnom Penh alone, 63 people died and 572 injured in traffic accidents, for the period of January to June, 2002[19]. The municipal police reports that these accidents were caused by speeding, improper passing, driving in the wrong lane, drunken driving, unsafe vehicles and disregarding traffic signs. Most of the drivers are illiterate and could not read traffic signs.

II.4.1.2. Lack of facilities for bicycle riders
In Phnom Penh, the city has no facilities for bicycle riders, like a bicycle lane or bicycle boulevard (to avoid accidents), bike bridges, lighted cycle paths, bicycle parking lots (with provision to put a lock and chain to avoid theft), bicycle lockers and racks.

II.5. RECOMMENDATION

TRANSPORT

The activities under "The Study on the Transport Master Plan of the Phnom Penh Metropolitan Area in the Kingdom of Cambodia", funded by JICA, needs to be implemented.

Use of bicycles

There should be a traffic school for juveniles who violate bicycle laws and funds an on-road cycling course for all bicycle riders[20]. To encourage employees to cycle to work, building offices should provide secure bicycle parking and showers and lockers for employees.

[19] The Cambodia Daily, August 8, 2002
[20] Marcia D. Lowe, "Bicycles Can Replace Gasoline-Powered Cars", Worldwatch Paper 90, September 1989

REFERENCES

U.S. Department of Energy website

Opening Remarks of His Excellency Ith Praing, Secretary of State of Cambodia's Ministry of Industry, Mines and Energy (MIME), at the Cambodia Investment and Trade 2002 Conference, 16 May 2002.

Council for the Development of Cambodia, Cambodia Investment Board (CIB), Project Monitoring Department

IPCC Technical Paper 1: Technologies, Policies, and Measures for Mitigating Climate Change, November 1996

Marcia D. Lowe, "Bicycles Can Replace Gasoline-Powered Cars", Worldwatch Paper 90, September 1989.

Methodological and Technological Issues in Technology Transfer, A Special Report of IPCC Working Group III, IPCC, 2000

Climate Change 2001: Mitigation, IPCC, 2001

JICA, "Transport Master Plan of the Phnom Penh Metropolitan Area in the Kingdom of Cambodia", 2002

Cambodia Transport Sector Study, Kingdom of Cambodia, Ministry of Public Works and Transport – ND Lea Consultants Ltd. in association with Japan Oversea Consultants (JOC) Co., Ltd., June 2002

The Cambodia Daily, "Embassies and Vendors Cluttering Sidewalks", September 10, 2002

Phnom Penh Post "Australia Day", January 18-31, 2002

The Strategic Environmental Framework for the Greater Mekong Subregion – TA No. 5783 (the SEF Project) was executed by the ADB with co-financing by the Swiss Agency for Development and Cooperation (SDC), with consulting inputs from the Stockholm Environment Institute (SEI), in collaboration with the UNEP Regional Resource Center for Asia and the Pacific (UNEP PRC AP) and the Mekong River Commission (MRC), 2002.
The Cambodia Daily, August 8, 2002