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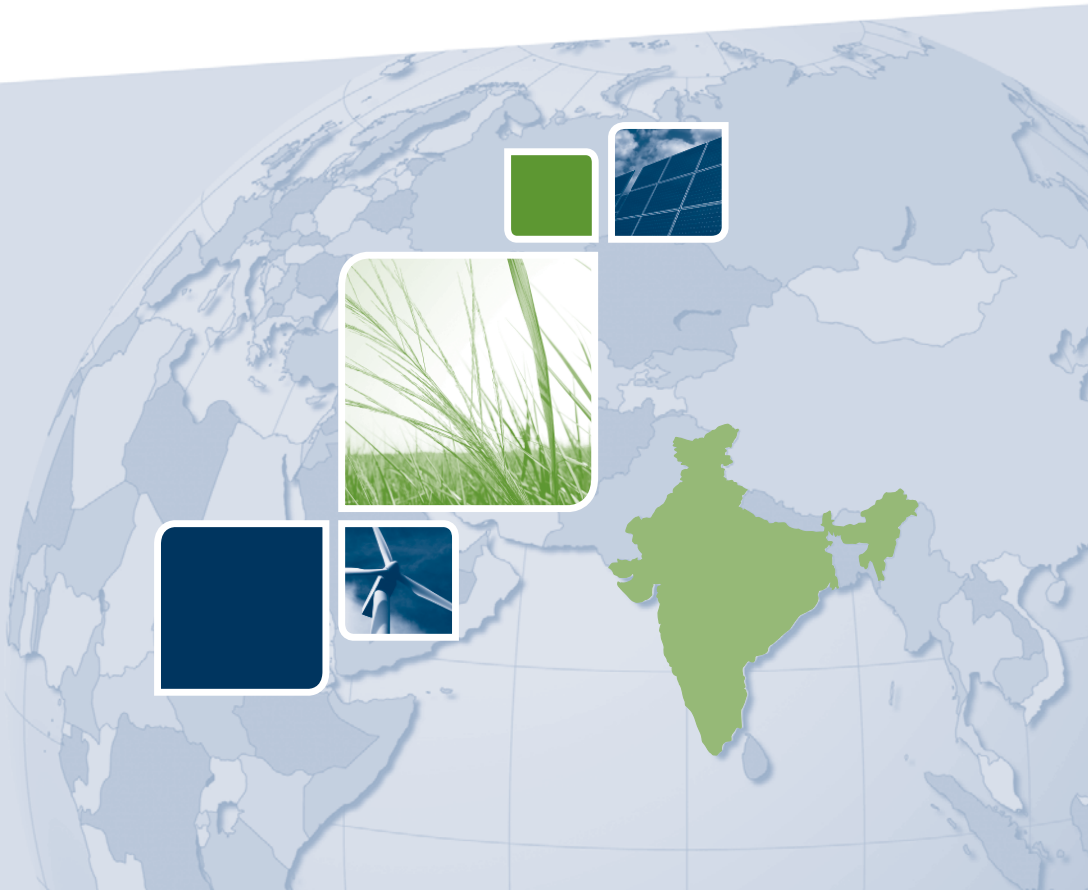
Clean Energy:
An Exporter's Guide to **India**



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Acronyms

ABS asset-backed securities
AC alternating current
ACEEE American Council for an Energy-Efficient Economy
ACORE American Council on Renewable Energy
ADB Asian Development Bank
AEE Association of Energy Engineers
AESP Association of Energy Services Professionals
AFV alcohol fuel vehicle
ALM asset liability management
ANERT Agency for Non-Conventional Energy and Rural Technology
APEDA Arunachal Pradesh Energy Development Agency
APM administered pricing mechanism
APP Asia–Pacific Partnership on Clean Development and Climate
ASE Alliance to Save Energy
ASEAN Association of Southeast Asian Nations
ASTAE Asia Alternative and Sustainable Energy
ASTM American Society for Testing and Materials
bcm billion cubic meters
BEE Bureau of Energy Efficiency (India)
BERC Bihar Electricity Regulatory Commission
BHEL Bharat Heavy Electricals, Ltd.
BIPV building-integrated photovoltaics
BIS Bureau of Indian Standards
BOO build, own, operate
BOOT build, own, operate, and transfer
BOV battery-operated vehicle
BPL below poverty line
BREDA Bihar Renewable Energy Development Agency
BSES Brihanmumbai Suburban Electrical Supply
BT billion tons
CCF City Challenge Fund
CCI Controller of Capital Issues
CDM Clean Development Mechanism
CE European Conformity (French acronym)
CEA Central Electricity Authority
CER credits for emission reductions
CERC Central Electricity Regulatory Commission
CET clean energy technology
CFL compact fluorescent lighting
CHCP combined heat, cooling, and power
CH4 methane
CHP combined heat and power
CII Confederation of Indian Industry
CLASP Collaborative Labeling and Appliance Standards Program
CNG compressed natural gas
CO2 carbon dioxide
CPCB Central Pollution Control Board
CREDA Chhattisgarh State Renewable Energy Development
CVC Central Vigilance Commission
DC direct current
DFI development financial institution
DISCOM distribution company
DME di-methyl ether
DOC U.S. Department of Commerce
DOE Department of Environment (India)
DOP Department of Power (India)
DSM demand-side management
EC energy conservation
ECB external commercial borrowing
ECBC Energy Conservation Building Codes
ECO Energy Efficiency Commercialization Project
EE energy efficiency
EEB Bureau of Economic, Energy and Business Affairs (United States)
EEI energy efficiency indicator
EERE Office of Energy Efficiency and Renewable Energy (United States)
EIB European Investment Bank
EJ exajoule
EMCO energy management contract
EPC equipment procurement and construction
ESCO energy service company
ETC evacuated tube collectors
EV electric vehicle
EVA solid phase crystallization of Evaporated silicon
Ex-Im Export–Import Bank of the United States
FAS Foreign Agricultural Service (United States)
FDI foreign direct investment
FI financial institution
FYP Five-Year Plan
GATT General Agreement on Tariffs and Trade
GB Guojia Biaozhun
gce gram of coal equivalent
GDP gross domestic product
GEDA Gujarat Energy Development Agency
GEF Global Environment Facility
GENCO generation company (India)
GERC Gujarat Electricity Regulatory Commission
Gg gigagram
GHG greenhouse gas
GNP gross national product
GOI Government of India
GPV gas-powered vehicle
GRP glass fiber–reinforced plastic
GW gigawatt
GWe gigawatt electric
GWp gigawatt peak
HAREDA Haryana Renewal Energy Development Agency
HDFC Housing Development Finance Corporation Limited
HFC hydrofluorocarbon
HIT heterojunction with intrinsic thin layer
HT high-tension

HUDCO Housing and Urban Development Corporation (India)
IBRD International Bank for Reconstruction and Development
ICB international competitive bidding
IDBI Industrial Development Bank of India
IDFC Infrastructure Development Finance Company (India)
IEA International Energy Agency
IEC International Electrotechnical Commission
IFC International Finance Corporation
IFCI Industrial Finance Corporation of India
IFI international financing institution
IGCC integrated gasification combined cycle
IIFCL India Infrastructure Finance Company Limited
IL&FS Infrastructure Leasing & Financial Services Limited (India)
INR Indian National Rupees
IP intellectual property
IPA Indian Patent Act
IPP independent power producer
IPR intellectual property rights
IREDA Indian Renewable Energy Development Agency
ITA U.S. International Trade Administration
JAKEDA Jammu and Kashmir Energy Development Agency
JBIC Japan Bank for International Cooperation
JCF Japan Carbon Finance, Limited
JV joint venture
kgce kilogram of coal equivalent
kha kilohectare
KREDL Karnataka Renewal Energy Development Limited
kT kiloton
kV kilovolt
kW kilowatt
kWe kilowatt electric
kWh kilowatt hour
kWp kilowatt peak
LC letter of credit
LED light-emitting diode
LIC Life Insurance Corporation (India)
LNG liquefied natural gas
LOLP loss of load probability
LPG liquefied petroleum gas (Propane)
MANIREDA Manipur Renewable Energy Development Agency
mb/d millions of barrels per day
MEDA Maharashtra Energy Development Agency
MIGA Multilateral Investment Guarantee Agency
MJ megajoule
MMSCM million standard cubic meter
MNES Ministry of Non-conventional Energy Sources (India)
MNRE Ministry of New and Renewable Energy (India)
MoEF Ministry of Environment and Forests (India)
MoF Ministry of Finance (India)
MOP Ministry of Power (India)
MPUVNL Madhya Pradesh Urja Vikas Nigam Limited
MSIHC Manufacture, Storage, and Import of Hazardous Chemicals
mt million tons
MT magnetotelluric
mToe million tons of oil equivalent
MU million units
MW megawatt
MWe megawatt electric
MWeq megawatt equivalent
MWp megawatt peak
NABARD National Bank for Agriculture & Rural Development (India)
NAESCO National Association of Energy Service Companies
NB national competitive bidding
NBC National Building Code (India)
NCE non-conventional energy
NEDA Non-conventional Energy Development Agency (India)
NEDCAP Non-conventional Energy Development Corporation of Andhra Pradesh
NELP New Exploration and Licensing Policy (India)
NHPC National Hydroelectric Power Corporation (India)
N2O nitrous oxide
NOx nitrogen oxide
NREDA Nagaland Renewable Energy Development Agency
NREL National Renewable Energy Laboratory of the U.S. Department of Energy
NTPC National Thermal Power Corporation (India)
NUTP National Urban Transport Policy (India)
OECD Organization for Economic Co-Operation and Development
OFAC Office of Foreign Assets Control (United States)
OGL open general license
O&M operation and maintenance
OPIC Overseas Private Investment Corporation (United States)
PCF Prototype Carbon Fund
PDCOR Project Development Corporation (India)
PDD Project Design Documentation
PE private equity
PECVD plasma-enhanced chemical vapor deposition
PEMF Private Energy Market Fund LP
PEMFC proton exchange membrane fuel cell
PFC Power Finance Corporation (India)
PFDF Pooled Finance Development Fund (India)
PGC Power Grid Corporation (India)
PHWR pressurized heavy water reactor
PIS Patent Information System (India)
PNB Punjab National Bank
PPA power purchase agreement
PPP public–private partnership
PSU public–sector undertaking
PTC Power Trading Corporation (India)
PV photovoltaic
RBI Reserve Bank of India

R&D research and development
RE renewable energy
REC Rural Electrical Corporation (India)
REPS renewable energy portfolio standard
RGGVY Rajiv Gandhi Grameen Vidhyutikaran Yojana
RPS reserve energy portfolio standard
RSPM respirable suspended particulate matter
RTI Right to Information Act (India)
RVE Remote Village Electrification
SBA Small Business Administration (United States)
SBI State Bank of India
SEBI Securities and Exchange Board of India
SEFI Sustainable Energy Finance Initiative
SEK Svensk Exportkredit
SERC State Energy Regulatory Commission (India)
SHP small hydropower
SHS solar home system
SI solar ingot
SICLIP Swedish International Climate Investment Program
SIDBI Small Industries Development Bank (India)
SME small and medium enterprise
SO2 sulphur dioxide
SOE state-owned enterprise
SPCB State Pollution Control Board (India)
SPV solar photovoltaics
SRDA State Renewable Development Agency (India)
SWH solar water heating
TC-88 Technical Committee 88 of the IEC
tce tons of coal equivalent
TEDA Tamil Nadu Energy Development Agency
TERI Tata Energy Research Institute
toe tons of oil equivalent
TPES total primary energy supply
TRIPS Trade-related Aspects of Intellectual Property Rights
TüV Technische Überwachungsvereine (Germany standards/testing company)
TWh terawatt hour
UL Underwriters Laboratories
ULB urban local body
UNDP United Nations Development Program
UNICITRAL United Nations Commission on International Trade
UPS uninterruptible power supply
UREDA Uttranchal Renewable Energy Development Agency
URIF Urban Reform Incentive Fund
USAID U.S. Agency for International Development
USDA U.S. Department of Agriculture
USDOE U.S. Department of Energy
USTDA U.S. Trade and Development Agency
USTR U.S. Trade Representative
VAT value-added tax
VER Verified Emission Reduction
VSD variable-speed drive
W watt
WEEA World Energy Efficiency Association
WOFE wholly-owned foreign enterprise
Wp watt peak
WTG wind turbine generator
WTO World Trade Organization

Executive Summary

Introduction

This report is intended as a clean energy technology market overview for India, with two primary objectives: (1) to analyze the clean energy markets in India and (2) to identify opportunities for trade and investment through 2020. The report provides the following:

- An analysis of the existing infrastructure of clean energy technologies and market opportunities in India through 2020 including market forecasts, market drivers, cost data, and market segment analysis.
- A review of government policies for clean energy development in India.
- A detailed analysis of barriers and obstacles to clean energy technologies trade and investment in India.
- A definition of clean energy technologies for India.
- A review of resources available to U.S. businesses that wish to enter the Indian clean energy markets.

After a short introduction, Section 1 addresses clean energy technologies for India, including information on India's overall energy status, both current and projected; a market overview; identification of clean energy policies; trade and investment opportunities for U.S. firms; and barriers to clean energy market entry, development, and commercialization. This chapter also includes annexes on Indian policy-makers with authority over clean energy technologies. Section 2 provides definitions of the clean energy technologies addressed in the report.

Clean Energy Technology Defined

Clean energy technologies include renewable energy, hybrid and co-generation, and energy efficiency technologies for power generation; alternative fuels; and advanced technologies for transportation. They produce power for a wide range of applications using no fuel or less fuel than fossil-fuel-based technologies, produce no or fewer pollutants than conventional technologies and can use renewable energy sources, which, unlike fossil fuels, are not depleted over time. The renewable energy technologies considered in this report are biomass and biofuels, waste-to-energy, solar power, wind power, geothermal, hydropower, and ocean power.

Biomass consists of plant and plant-derived material. Sources include agricultural residues such as rice hulls, straw, bagasse from sugarcane production, wood chips, and coconut shells and energy crops such as sugarcane or switch grass. Biomass can be used directly for energy production or processed into fuels. Waste-to-energy technology converts energy from a waste source, such as a city's municipal waste system, farms, and other agricultural operations, or waste from commercial and industrial operations. Large-scale waste-to-energy systems can supply heat or electricity in utility-based electric power plants or district heating systems. Small-scale systems can provide heating or cooking fuel and electricity to individual farms, homes, and businesses.

Solar technologies convert light and heat from the sun into useful energy. Photovoltaic (PV) systems convert sunlight into electricity, and thermal systems collect and store solar heat for air and water heating applications. *Wind* power technology converts energy in the wind into useful power; the primary market for wind power technology is for wind turbines, which convert wind energy into electricity. *Geothermal* power is generated using thermal energy from underground sources, including steam, hot water, and heat stored in rock formations; various technologies are used to generate electricity. *Hydropower* is the conversion of energy embodied in moving water into useful power. Today, hydropower supplies about 19 percent of the world's electricity. Finally, *ocean power* technology makes use of energy in the ocean by converting it into electricity. This technology is still in the development phase,

Hybrid and co-generation power systems take advantage of the benefits of multiple technologies in a single, integrated system for power generation. Renewable-based hybrid power systems use combinations of wind turbines, PV panels, and small hydropower generators to generate electricity. Hybrid power systems typically include a diesel or other fuel-based generator (including biofuels) and may include batteries or other storage technology.

Co-generation systems, also called combined heat and power (CHP) systems, generate both electricity and useful heat. Conventional fossil-fuel-based electric power plants generate heat as a byproduct that is emitted into the environment; co-generation power plants collect this heat for use in thermal applications, thereby converting a higher percentage of the energy in the fuel into useful power. The most efficient conventional power plants have a typical fuel-to-electricity conversion factor of about 50 percent, while co-generation plants can achieve efficiencies of over 75 percent. Examples of thermal loads that can be served by a co-generation plant are: district heating systems that provide heat for towns and neighborhoods; industrial processes that require heat, such as paper mills; institutions such as prisons and hospitals; and wastewater treatment plants.

Energy efficiency (EE) involves replacing existing technologies and processes with new ones that provide equivalent or better service using less energy. EE results

in energy savings at the time that the energy service is provided. Energy service providers can also use load management to change the time that an energy service is delivered in order to reduce peak loads on an energy distribution system. Demand-side management uses both load management and EE to save the amount of primary energy required to deliver the energy service.

Almost half a billion vehicles on the world's roads contribute to half of the global oil consumption and generate about 20 percent of the world's greenhouse gases, including carbon monoxide, nitrous oxides, and particulates. *Transportation technologies* can help address these issues through the use of alternative fuels and advanced technologies. Alternative fuels for transportation include biodiesel, ethanol, natural gas, and propane. Advanced vehicle technologies include electric vehicles and hybrid electric vehicles, which offer air pollution improvements over average fossil fuel vehicles. Finally, mobile idle reduction systems and diesel engine retrofits can reduce the emissions of heavy-duty vehicles.

India: Energy Overview

Clean energy technologies have received unprecedented attention in the last few years in India as its energy demand grows every year. This is largely a result of India's economy, which has steadily advanced over the last 30 years, averaging a 7 percent per year growth since 2000. During 2004 and 2005, only China's economy grew faster. With 1.1 billion people, India is the world's second most populous country behind China and is expected to have the world's largest population by 2030. Further population increases and the country's continued economic growth are expected to increase India's energy demand from 537 million tons of oil equivalent (Mtoe) in 2005 to 770 Mtoe in 2015 and to 1,299 Mtoe by 2030.

Coal is the dominant fuel in India's energy mix, a condition that is expected to persist for at least the next 25 years. India has vast coal resources, but most are of low quality. Indigenous oil and gas reserves are in short supply while demand for oil almost quadrupled from 1980 to 2005. Oil imports are projected to increase even more going forward, leaving the country more vulnerable to international price spikes and potentially unreliable supplies. In 2005 India ranked fourth in energy consumption, after the United States, China, and Russia. By 2030, India is expected to surpass Russia and be the third-largest energy consumer.

Energy demand grew by 3.5 percent per year during the period 1990–2005. Supply has not kept up, and a deficit of 11,463 megawatt (MW), equivalent to 12.3 percent of peak demand, was recorded in peak hours in India during 2006. The states of Gujarat, Maharashtra, Meghalaya, Jammu and Kashmir, Punjab, and Madhya Pradesh recorded more than a 20 percent deficit in the availability of power during peak hours – a deficit that is expected to increase in the future. India has an installed base of about 124,287 MW of electricity as of the year 2006, which includes about 66 percent thermal energy (85 percent of which is coal based) followed by hydro with 26 percent, nuclear with 3 percent, and renewable energy with 5 percent. Of the current total installed renewable energy base, wind constitutes 69 percent, followed by small hydro (19 percent), biomass (co-generation, 11.5 percent), waste-to-energy (0.42 percent), and solar (0.03 percent).

Market assessments indicate that India could eventually be the largest renewable market in the world, given its abundance of renewable energy resources. The country has already developed electricity from small hydro, wind, and biomass (co-generation), but the contribution of waste-to-energy and solar energy is very small, while electricity generation from solar thermal, geothermal, and ocean power is non-existent. This is an indicator of the opportunity that is available in harnessing the full potential of these sectors.

Renewable Resources, Capacity, and Potential

India's renewable energy resource potential is significant, with wind energy, biomass, and small hydropower representing the technologies with the largest potential. Wind has been the most successful renewable resource to date and has the most potential going forward. Currently however only nine states use wind energy and they represent over 99 percent of the nation's total wind capacity. Assuming 20 percent grid penetration in the future and an increase in the availability of wind resources in certain provinces – most notably Maharashtra, Andhra Pradesha, Tamil Nadu, and Gujarat – wind could potentially account for up to 45,000 MW of energy per year. Since the total installed wind capacity in 2006 was only 5,341 MW, this represents a significant opportunity for American companies. The majority of wind resources are found in coastal states, where geographic and climatic conditions are favorable for wind farms.

The approximate potential for biomass utilization (largely co-generation) is estimated at about 22,000 MW. Waste-to-energy potential is approximately 2,700 MW. It has been estimated that India produces 139 million tons of surplus biomass every year, which can produce about 16,000 MW of electricity. Rajasthan, Punjab, Uttar Pradesh, Maharashtra, Madhya Pradesh, Haryana, and Gujarat account for 76 percent of the projected potential, and Rajasthan alone accounts for 25 percent of the total projected potential. The installed capacity of biomass power/co-generation increased from 381 MW in 2002 to 1,253 MW through September 2007. Andhra Pradesh, Karnataka, Tamil Nadu, and Uttar Pradesh account for 77 percent of the total installed capacity in the country. This trend is due to the availability of biomass and bagasse, which is used as raw material for electricity generation. Maharashtra and Uttar Pradesh are the two major bagasse-producing states, accounting for 57 percent of India's projected bagasse

potential (3,500 MW total). About 166 MW of renewable energy can be found in distributed non-grid connected generation in India

Ethanol and biodiesel have been identified as key focus areas by the Indian Government, though currently both are in the early stages of commercialization. In 2004, the government mandated a 5 percent blending of gasoline with ethanol, subject to certain conditions. In addition, an autonomous National Biodiesel Board was created to promote, finance, and support organizations that are engaged in oilseed cultivation and oil processing leading to biodiesel production. The state governments of Andhra Pradesh, Chhattisgarh, Gujarat, and Tamil Nadu have even created state biodiesel boards and are implementing buy-back schemes with farmers to promote additional biodiesel development. Private players are participating in the plantation phase of the biodiesel production chain in Tamil Nadu. In Gujarat, private companies are producing quality biodiesel that meets the American Society for Testing and Materials (ASTM) 16750 standard.

India has an estimated hydropower potential of 84,000 MW, of which 15,000 MW is from small hydropower (SHP). The Ministry of New and Renewable Energy (MNRE) has identified 4,227 potential SHP sites, which could account for 10,324 MW of potential energy. India had only 1,748 MW of installed SHP capacity in 2006, meaning the market for SHP is expected to increase substantially. The potential of this sector is however dependent on the availability of water resources, which are thus far abundant in a majority of states. In fact, of the 135,000 MW capacity addition requirement anticipated by the government, 35,500 MW are expected to come from hydropower. Toward this end, a 50,000-MW hydroelectric initiative was launched in 2003.

India also receives abundant solar radiation equivalent to over 5,000 trillion kilowatt hours (kWh) per year. The government has had a PV program in place for over two decades, yet the current installed capacity is just 3 MW, only a small proportion of the overall energy mix. PV systems are promoted primarily for rural and off-grid applications, consisting mainly of mini-grids, solar home systems, solar lanterns, and solar street lights. The overall solar water heater potential in India is estimated to be 140 million m^2 of collector area, of which about 1.9 million m^2 have been installed in buildings and in industry.

Energy Efficiency, Co-Generation, and Transportation

India's energy efficiency potential mostly comes from supply side high-efficiency, low-emission coal, thermal, or electric power generation. Transmission and distribution losses have been recorded to exceed 25 percent, indicating a potential market for firms able to reduce these inefficiencies. Industry has been a major target of the energy efficiency effort, as it accounts for 50 percent of the total commercial energy use in India. Six key industries—aluminum, cement, fertilizers, pulp and paper, petrochemicals, and steel—account for about two-thirds of total industrial energy use. The energy intensity in these industries is higher than in developed countries, mainly owing to obsolete and energy inefficient technologies. Nonetheless, energy efficiency in Indian industry has increased steadily. In cement, steel, aluminum, and fertilizers, the average energy consumption has been declining as a result of energy conservation in existing units and the development of efficient technologies. Energy efficiency in building and construction has not been the beneficiary of a concerted energy efficiency effort and needs to be assessed and targeted.

As of 2006, India had an installed capacity of 582 MW of bagasse co-generation, including grid and off-grid installations. By 2012, a total of 1,200 MW of installed cogeneration from bagasse is projected.

In transportation, the rapid growth in motor vehicle activity in India is contributing to high levels of urban air pollution, among other adverse socioeconomic, environmental, health, and welfare impacts. The demand for transport increased by 1.9 percent per year from 2000–2005, but is projected to double by 2015 and more than quadruple by 2030. The slow growth in demand for diesel to date may be due to improved efficiency of new cars and trucks and switching to compressed natural gas vehicles for public transportation in some major cities. However, like many developing countries, India lacks mandatory vehicle fuel efficiency standards. The Ministry of New and Renewable Energy is promoting several research, development, and demonstration projects including a demonstration project in battery-operated vehicles (BOVs), which help in conserving oil and curbing environmental pollutions. In addition, fuel cell–battery hybrid vehicles with domestically developed exchange membrane fuel cells of 10 kW have undergone field performance evaluation, which could lead to domestic production and wider applications of fuel cell systems across the country. Hydrogen fuel is expected to be a major alternative to fossil fuels for India's transport sector by 2020. Various laboratories in the country are developing different technologies for production, storage, and transportation.

Market Analysis

In India's 11th Five-Year Plan, the government aims to achieve a GDP growth rate of 10 percent and maintain an average growth of about 8 percent during the next 15 years. This growth will be highly dependent on the expansion of the country's energy consumption. Due to rapidly expanding demand for power, a capacity addition of over 100,000 MW is planned through 2011 and 2012. Though this is largely based on growth of thermal generation, the contribution of electricity from renewable sources is expected to increase, with wind energy continuing to lead the way. As Table A shows, India

needs 347,000 additional megawatts of energy through 2020, of which renewables can account for 24 percent of the needed capacity. One of the major requirements for developing this sector is the availability of cost-effective technologies and successful demonstrations.

Table A also shows the renewable energy targets in the 11th Five-Year Plan—which goes through 2012. These targets correspond to a need for massive investment in the clean energy sector in India. In fact, the projected addition of 15,000 MW from renewable energy could lead to $21 billion in investment over the next ten years.

The current capital cost of small hydro and wind in India is similar and ranges from $900–1300/kW and $950–1100/kW, respectively. Biomass is slightly less, at $800–1000/kW. Bagasse co-generation and biomass gasification range from $600–800/kW. PV is by far the highest at $5000–6500/kW. The delivery cost for all the above except for PV ranges from $0.045–7/kWh, with co-generation at the bottom of the range and wind at the top; PV is in the range of $0.19–40/kWh.

India currently manufactures wind generators with up to 1,650 kW of per unit capacity. To harness the projected wind potential, however, new technologies with higher capacities are needed in the country. India has a fairly developed capacity and technology for designing, constructing, and operating small hydropower plants. There has been continuous improvement with time in India's small hydro technology, with increasingly efficient and reliable domestic equipment. In addition, India has manufacturing facilities for equipment and components used in solar PV systems, though there is a need for megawatt-scale PV power-generating systems. A number of solar thermal applications have also been developed in India, which include water/air heating, cooking, drying of agricultural and food products, water purification, detoxification of wastes, cooling and refrigeration, heat for industrial processes, and electric power generation. Most of the solar thermal devices and systems are manufactured in India.

Manufacturing capability also exists in India for the equipment/machinery required in biomass projects. Biomass co-generation combustion technology is already in operation as well as atmospheric gasifiers, in which the country has significant experience and expertise. Thus, except for critical control equipment and high-efficiency turbines, most of the equipment can be procured from indigenous sources. India has limited local capacity for waste-to-energy technology, however, and large-scale operation of biomethanation, combustion/incineration, pyrolysis/gasification, landfill gas recovery, and other technologies requires import of design, engineering, and equipment.

Three major drivers exist for clean energy demand in India. First, the gap between existing electricity supply and demand is large and expected to grow. Second, the need to strengthen energy security has caused India to invest in wind, biomass, and hydropower generation as a way to diversify their energy portfolio. Third, fossil fuels imports are increasingly susceptible to price fluctuations and leave India vulnerable to supply insecurity; increasing dependence on indigenous and renewable resources is thus an attractive countermeasure.

India's environmental, social, and health concerns are serious—India is a top greenhouse gas (GHG) emitter in the world, with corresponding costs in health and productivity. Indoor air pollution in rural areas from reliance on biomass for cooking, for instance, causes serious health issues for women and children. Nonetheless, India enjoys significant resources for clean energy development including both human and ecological resources, and strong government support. These factors in themselves are important indicators of India's energy future.

Energy Policy

India's energy sector has undergone a significant renaissance over the last decade as a number of new policies have created both the institutions to promote clean technology development but also the momentum and government support needed to see projects through to completion. New policies include the National Environment Policy, which provides guidance on air pollution reduction, climate change, and GHG mitigation; promotion of clean technologies; and the measurement of efficiency per unit of economic output. The National Tariff Policy establishes power purchase tariffs for the State Electricity Regulatory Commissions. India's Ministry of New and Renewable Energy has issued a draft renewable energy policy that identifies the strategies for increased deployment of grid-connected renewable energy technologies. The country's Rural Electrification Policy goals include provision of access to electricity to all households by the year 2009.

The National Electricity Policy of 2005 stipulated that the energy intensity of GDP growth must be lowered through higher energy efficiency, and merged the Petroleum Conservation Research Association and the Bureau of Energy Efficiency to form an agency capable of moving

Table A. India's Renewable Energy Potential and Targets.

	POTENTIAL (MW)	INSTALLED CAPACITY AS OF MARCH 2007 (MW)	TARGET OF 11TH FIVE-YEAR PLAN (MW)
Small hydro	15,000	1,976	1,400
Wind	45,000	7,092	10,500
Solid biomass	19,500	569	500
Bagasse CHP	3,500	615	1,200
Waste-to-energy	1,700	43	400
Solar		3	50
Distributed RE power systems			950
Total	**84,700**	**10,298**	**15,000**

Source: Report of the Working Group on New and Renewable Energy for 11th Five-Year Plan.

energy efficiency investments forward. The newly created board set standards for labeling energy-intensive equipment created financial penalties for equipment that fails to meet minimum standards, and mandated the purchase of renewable-energy-based through competitive bidding.

As of March 2007, the conduct of energy audits has been made mandatory in large energy-consuming units in nine industrial sectors. These units, indicated as "designated consumers," are also required to employ "certified energy managers" and report energy consumption and energy conservation data annually. To achieve the potential of 15,000 MW of renewable energy within the 11th Five-Year Plan period, the proposed energy efficiency measures include forming industry-specific task forces, conducting energy audits among designated consumers, recording and publishing best practices per sector, developing energy consumption norms, and monitoring compliance with mandated provision by designated consumers. The program includes capacity building to train key personnel in energy efficiency measures and management.

Among the fiscal policies already in place are income tax holidays, accelerated depreciation, duty-free import of renewable energy equipment, capital subsidies and concessionary financing from the Indian Renewable Energy Development Agency, requirements for energy purchases by distribution companies, and exemptions from electricity taxes and sales taxes. In addition to these financial incentives, wind energy projects and equipment used in biomass/bagasse power generation can claim accelerated depreciation in the first year of the project. There is also a liberalized foreign investment approval regime to facilitate foreign investment and transfer of technology through joint ventures.

Opportunities for U.S. Clean Technology Firms in India

Opportunities for U.S. clean tech firms are numerous in India thanks to the scope of energy demand and the government's warm response to energy efficiency and renewable technologies. According to India's integrated energy policy, in order to deliver a sustained growth of 8 percent through 2031, India will need to expand its primary energy supply by at least three to four times and electricity supply by five to seven times its current consumption. As such, the power sector is expected to add over 150,000 MW over the next 15 years, of which at least 10 percent is expected to come from renewable energy technologies. Different states are in the process of issuing tariff orders for renewable energy electricity generation and specifying quotas for power from renewable energy in accordance with the Electricity Act of 2003. This government push can translate into major opportunities for foreign firms.

Other major government initiatives include an installment of 1 million household solar water heating (SWH) systems, rural electrification of 24,000 villages using renewable mini-grids, and deployment of 5 million solar lanterns and 2 million solar home lighting systems throughout the countryside. Investment opportunities are available for corporate users of power, long-term investors in power, promoters of clean power, and trading credits for emission reductions. Private-sector companies can set up enterprises to operate as licensee or generating companies. A foreign investor can enter into a joint venture not only for renewable energy devices/products but also for manufacturing renewable-energy-based power generation projects on a build, own, and operate basis.

At the sector level, small hydropower (SHP), wind, and solar energy offer the maximum scope for clean energy development. However, these sectors are relatively mature with significant local capacity; therefore, U.S. companies may face competition in these sectors. Geothermal and tidal energy sectors offer the advantages of early entry into the Indian market. Opportunities for U.S. firms include products, equipment, demonstrated technology, and project development in these sectors. There is a need to assess the potential of geothermal resources in India and to harness these resources for power generation and for direct heat applications for space heating, greenhouse cultivation, and cooking. The potential of tidal energy and harnessing it for power generation also needs to be assessed.

In general, a lack of technical expertise exists in installation, operations, maintenance, troubleshooting, and other aspects of clean energy implementation. Technological needs in the SHP sector include technology for direct-drive low-speed generators for low-head sources, technology for submersible turbo-generators, and technology for variable-speed operation. There is also a need for proven high capacity wind turbines, generally greater than 1-2 MW. In addition, there is a need for turbines adapted to low-wind regimes and improved design for rotor blades, gear boxes, and control systems. In the PV sector, there is demand for thin-film solar cell technology, technology for megawatt-scale power generation, and improvements in crystalline silicon solar cell/module technology. Building integration for PV and solar thermal systems is also an area of opportunity.

In bioenergy, opportunities are many and include development of megawatt-scale fluidized bed biomass gasifiers; development of poly-generation facilities for the production of liquid fuels, a variety of chemicals, and hydrogen in addition to power production; development of more efficient kilns for charcoal production and pyrolysis of biomass; and raising the system efficiency of small (up to 1 MW) combustion and turbine technologies. Biofuel needs include engine modifications for using more than 20 percent biodiesel as a diesel blend. There is a need for waste-to-energy technological development across the board, including the successful demonstration of biomethanation, combustion/incineration, pyrolysis/gasification, landfill gas recovery, densification, and pelletization. In the nascent geothermal and ocean power

sectors, there is a need for technology suppliers, equipment manufacturers, and project developers. Finally, energy-efficiency service companies and energy efficiency equipment suppliers for buildings and industries could be extremely profitable.

Barriers for U.S. Firms

Given the existing market conditions in India, U.S. firms may encounter challenges in the areas of competition from local suppliers and equipment manufacturers in the SHP, wind, and solar energy sectors. In addition, there appears to be a lack of coordination and integration of renewable energy and energy efficiency policies across broader development issues, including a disconnect between Indian government ministries, states, and sub-sectors. Policies are often unclear and inconsistent and distortions may arise because of uneven price settings across and within sub-sectors. The enforcement of the legal restrictions has also been a significant barrier to participation in the renewable energy market. Issues include informal governance based on social relationships and reciprocity that arises from a complex legal process and the lack of legal enforcement. Regulatory issues such as time delays, complexity in the permitting and sitting of projects pose, and the lack of monitoring of legal and financial disclosures are present additional barriers.

Conclusion

Clean energy technologies have moved to the forefront of India's energy infrastructure and investments opportunities. This is driven by the need to enhance energy security and fuel diversity, meet increasing energy needs in an environmentally sustainable manner, and advance economic and social development, all while reducing poverty and sustaining economic growth. Though barriers exist from a technology, policy, and investment perspective, India promises to be one of the largest markets for clean energy, and U.S. companies have a significant role to play in both trade and investment. The advantages of the Indian clean energy technology market include a strong industrial base and fast-growing economy; availability of skilled, relatively cheap labor; one of the world's largest renewable energy programs; the world's only dedicated federal ministry to support renewable energy (MNRE) and the only government financial institution exclusively supporting renewable energy and energy efficiency (Indian Renewable Energy Development Agency—IREDA). These are buttressed by a favorable government policy environment, low inflation and moderate tax rates, and a strong and growing carbon finance market.

By 2012—the completion of the 11th Five-Year Plan—the Indian Government has set a goal for at least 10 percent of power generation to come from renewable energy sources, with a 4–5 percent share in the electricity mix. Presently at over 10,000 MW of installed capacity, renewable energy is projected to reach over 24,000 MW by 2012. India's rich renewable energy resource endowment provides opportunities across a spectrum of technologies—biomass, solar PV, solar thermal, wind, hydropower, solid and industrial waste-to-energy, geothermal, and tidal energy. The prospects for U.S. firms are encouraging, including research, development, and demonstration; technical collaborations; product and equipment sales; project design, development, and promotion; power generation and production; operational and maintenance (O&M); project monitoring; carbon finance/trading; and consulting services. U.S. firms should find ample opportunity to enhance their competitive market position in this rapidly expanding marketplace.

Introduction

Purpose

The report's objectives are twofold: (1) to analyze the clean energy market in India and (2) to identify opportunities for trade and investment through 2020.

Approach

The report provides the following:

- An analysis of the existing infrastructure of clean energy technologies and market opportunities in India through 2020. This includes market forecasts, market drivers, cost data, and market segment analysis.
- A review of government policies for clean energy development in India.
- A detailed analysis of barriers and obstacles to clean energy technologies trade and investment in India.
- A definition of clean energy technologies for India.
- A review of resources available to U.S. businesses that wish to engage in clean energy trade and investment in India.

Methodology

Both primary and secondary data sources were used in the preparation of this report. These included:

India Resources

- Annual reports from relevant ministries at the national level and, where available, at the state levels;
- List of relevant agencies, areas of operation, and contact details;
- Policy documents (e.g., India's Electricity Act 2003, India's New and Renewable Energy Policy Statement 2005) as well as documents stating quotas, tax requirements, procurement requirements, foreign investment policy, and master plans for technology development in different sectors;
- Statistical documents containing installed capacity, energy balance, consumption, etc.;
- Five-Year Plans and ministerial long-term development plans; Annual Reports of relevant corporations;
- Data related to financial markets in India.

U.S. Government Sources

- U.S. Department of Commerce;
- U.S. Department of Energy, including the National Renewable Energy Laboratory, Energy Information Agency, and Office of Energy Efficiency and Renewable Energy;
- U.S. Agency for International Development (India);
- U.S. Trade and Development Administration;
- Export–Import Bank of the United States;
- Asia–Pacific Partnership on Clean Development and Climate.

International Institutions

- Asian Development Bank;
- World Bank;
- International Energy Agency.

Trade, Industry, and Sector Associations; Business Counsels

- Interviews conducted with key trade associations, including the Indian Confederation of Indian Industry (CII);
- Interviews with the United States–India Business Council;
- Documents from the American Council on Renewable Energy (ACORE).

Transmission and Distribution Agencies, Manufacturers, Generators

- Annual Reports from various industry leaders operating in India;
- Annual Reports of major electricity generators in India.

Organization of the Report

The remainder of this report is organized as follows:

- Section 1 provides a market overview for India. This chapter includes information on India's overall energy status, both current and projected; a market overview; identification of clean energy policies; trade and investment opportunities for U.S. firms; and barriers to clean energy market entry, development, and commercialization. The chapter also includes annexes on key Indian policy-makers with authority over clean energy technologies and information on the renewable energy industry in India.
- Section 2 provides a definition of clean energy technologies addressed in the report. This chapter includes energy efficiency, distributed generation, combined heat and power, wind, solar photovoltaics, solar thermal, small hydropower, biomass, biofuels, waste-to-energy, geothermal, and ocean energy technologies.
- Appendix A provides a compendium of trade and investment resources for U.S. clean technology firms. Contact information for individual organizations is also included.
- Appendix B provides a directory of sustainable energy-financing sources. This directory is synthesized from the on-line resource available at www.sef-directory.net/, which is maintained by the Sustainable Energy Finance Initiative, a joint initiative of the United Nations Environment Program and the Basel Agency for Sustainable Energy.


India
National Capital
Raipur City
International Boundary
State/Territory Boundary
Punjab State/Territory Name
Goa, Daman & Diu; Dadara & Nagar Haveli;
and Pondicherry; are centrally administered territories.
Parts of Kashmir in Pakistan and China claimed by India.
300 km
0
300 Miles
AFGHANISTAN
PAKISTAN
CHINA
NEPAL
BHUTAN
BANGLADESH
MYANMAR
SRI LANKA
Arabian Sea
Bay of Bengal
Andaman and Nicobar Islands
Srinagar
Leh
Jammu and Kashmir
Jammu
Himachal Pradesh
Amritsar
Simla
Chandigarh
Punjab
Haryana
Delhi
New Delhi
Uttar Pradesh
Rajasthan
Jaipur
Agra
Kanpur
Lucknow
Allahabad
Patna
Bernares
Bihar
Sikkim
Gangtok
Siliguri
Arunachal Pradesh
Itanagar
Ledo
Dispur
Assam
Nagaland
Kohima
Shillong
Meghalaya
Imphal
Manipur
Agartala
Tripura
Aizal
Mizoram
Asansol
West Bengal
Jamshedpur
Calcutta
Kandla
Gandhinagar
Ahmadabad
Bhopal
Jabalpur
Madhya Pradesh
Gujarat
Baroda
Veraval
Diu
Daman
Dadra and Nagar Haveli
Bombay
Maharashtra
Poona
Nagpur
Raipur
Cuttack
Bhubaneswar
Puri
Orissa
Vishakhapatnam
Hyderabad
Andhra Pradesh
Goa
Panaji
Mormugao
Guntakal
Karnataka
Bangalore
Mangalore
Madras
Pondicherry
Cuddalore
Calicut
Tamil Nadu
Kerala
Madura
Trivandrum
Kavaratti Island
Port Blair

Section 1: India

Chapter 1: India's Energy Status

India is the world's fourth-largest economy, after the United States, China, and Japan. India's economy has grown steadily over the last 30 years, averaging 7 percent annually since 2000. During 2004 and 2005, only China's economy grew faster.[1] India is now home to approximately 1.1 billion people—constituting roughly 17 percent of the world's population—and is the world's second most populous country. By 2030, India is expected to overtake China and have the world's largest population.

Energy Supply and Demand

Due primarily to the projected increase in population and the country's continued economic growth, primary energy demand in India is expected to increase from 537 Mtoe in 2005 to 770 Mtoe in 2015 and to 1,299 Mtoe by 2030 (see Table 1.1). Over the period 1990–2005, demand grew by 3.5 percent per year.

As indicated by the above table, coal is expected to remain the dominant fuel in India's energy mix over the next 25 years. Demand for oil will steadily increase to a projected 328 mToe by the year 2030, still one-half the projected demand for coal. Other renewables, mostly wind power, are projected to grow 12 percent per year, albeit from a relatively low baseline. Nuclear and hydropower supplies grow in absolute terms, but they make only a minor contribution to primary energy demand in 2030—3 percent in the case of nuclear and 2 percent for hydropower.

As shown in Table 1.2, demand for oil in India almost quadrupled from 1980 to 2005, with consumption in 1980 in the amount of 0.7 mb/d, increasing to 2.6 mb/d in

Table 1.1: Indian Primary Energy Demand in the Reference Scenario (mToe)

	1990	2000	2005	2015	2030	2005–2030*
Coal	106	164	208	330	620	4.5%
Oil	63	114	129	188	328	3.8%
Gas	10	21	29	48	93	4.8%
Nuclear	2	4	5	16	33	8.3%
Hydro	6	6	9	13	22	3.9%
Biomass	133	149	158	171	194	0.8%
Other renewables	0	0	1	4	9	11.7%
Total	**320**	**459**	**537**	**770**	**1299**	**3.6%**
Total excluding biomass	*186*	*311*	*379*	*599*	*1105*	*4.4%*

Source: International Energy Agency, World Energy Outlook 2007: China and India Insights (Paris, France: OCED/IEA, 2007).

Table 1.2: Key Energy Indicators for India

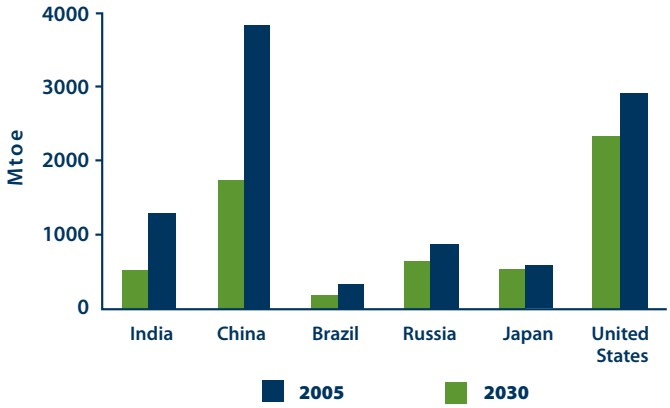
	1980	1990	2000	2005
Total primary energy demand (Mtoe)	209	320	459	537
Oil demand (mb/d)	0.7	1.2	2.3	2.6
Coal demand (Mtoe)	75	152	235	297
Gas demand (bcm)	1.4	11.9	25.4	34.8
Biomass and waste (Mtoe)	116	133	149	158
Electricity output (TWh)	119	289	562	699
TPES/GDP (index, 2005 = 100)	163	142	120	100
Total primary energy demand per capita (toe)	0.30	0.38	0.45	0.49
CO2 emissions per capita (tonne)	0.43	0.69	0.95	1.05
Oil imports	0.5	0.6	1.6	1.8
Electricity demand per capita (kWh)	174	341	553	639

Source: International Energy Agency, World Energy Outlook 2007: China and India Insights (Paris, France: OCED/IEA, 2007, p. 444).

2005.[2] These increasing oil imports have left the country more vulnerable to international price spurts and potentially unreliable supplies. Likewise, gasoline demand spiked from 1.4 bcm in 1980 to 34.8 bcm in 2005, a growth of over 2,000 percent.

Figure 1.1 shows in 2005 India ranked fourth in world energy consumption, after the United States, China, and Russia. By 2030, however, India is expected to surpass Russia and become the third-largest energy consumer in the world, after China and the United States.

Figure 1.1: Primary Energy Demand in Selected Countries in the Reference Scenario



Source: International Energy Agency, *World Energy Outlook 2007: China and India Insights* (Paris, France: OCED/IEA, 2007).

As of 2006, India had an installed 124,287 MW base of electricity. Thermal energy (coal, oil, and diesel) contributes 66 percent of the total, followed by hydro (26 percent), renewable energy (5 percent), and nuclear (3 percent). The regional split is roughly equal. Southern India contributes 29 percent of the country's installed capacity, the western region 28 percent, northern India 27 percent, and eastern India 16 percent. The installed electricity generation capacity in India by state is listed in Table 1.3.

India's Energy Deficit

The state-by-state peak demand, supply, and deficit for 2006 are shown in Table 1.4. As the table indicates,

With GDP per capita rising by about 5.4% per year in 2000-2005 and expected to grow by 6.4% in 2005-2010, the potential for energy demand growth in India is enormous. But there are challenges. India has vast coal resources, but most of them are of low quality. Indigenous oil and gas reserves are in short supply. Energy imports are growing. Renewable energy holds promise, but, with the exception of traditional biomass and hydropower, its use is very limited today.

World Energy Outlook, 2007

Table 1.3: Installed Electricity Generation Capacity (MW) in India During 2006

STATE/ UNION TERRITORY / CENTRAL SECTOR	HYDRO	%	COAL	%	
Northern region					
Chandigarh	0	0	0	0	
Delhi	0	0	320	34.32	
Haryana	946.64	37.07	1602.50	62.76	
Himachal Pradesh	323.00	86.78	0	0	
Jammu and Kashmir	309.15	6138	0	0	
Punjab	2470.52	52.39	2130.00	45.17	
Rajasthan	1008.84	26.72	2420.00	64.09	
Uttar Pradesh	518.60	10.78	4280.00	88.98	
Uttarakhand	986.93	96.79	0	0	
Central sector	4108.00	28.45	6840.00	4737	
Private sector	390.20	61.73	0	0	
Subtotal	**11061.88**	**32.77**	**17592.50**	**52.11**	
Western region					
Chhattisgarh	125.00	8.86	1280.00	90.72	
Dadra and Nagar Haveli	0	0	0	0	
Daman and Diu	0	0	0	0	
Goa	0	0	0	0	
Gujarat	745.00	12.91	4429.00	76.76	
Madhya Pradesh	1573.17	42.01	2157.50	57.61	
Maharashtra	2777.66	27.26	6425.00	63.06	
Central sector	1000.00	12.58	4360.00	54.83	
Private sector	460.50	7.61	2290.00	37.84	
Subtotal	**6681.33**	**19.02**	**20941.50**	**59.63**	
Southern region					
Andhra Pradesh	3582.61	51.63	2952.50	42.55	
Karnataka	3376.20	61.50	1470.00	26.78	
Kerala	1807.60	86.47	0	0	
Puducherry	0	0	0	0	
Tamil Nadu	2145.85	32.43	2970.00	44.89	
Central sector	0	0	8090.00	86.80	
Private sector	55.45	0.93	510.00	8.56	
Subtotal	**10967.71**	**30.09**	**15992.50**	**43.88**	
Eastern region					
Bihar	44.90	7.14	553.50	88.02	
Jharkhand	130.00	9.33	1260.00	90.38	
Orissa	1923.93	82.04	420.00	17.91	
Sikkim	32.00	69.41	0	0	
West Bengal	161.70	4.44	3305.00	90.84	
Private sector	0	0	1441.38	99.50	
Central sector	204.00	2.92	6682.50	95.79	
Subtotal	**2496.53**	**15.15**	**13662.38**	**82.91**	
Northeastern region					
Arunachal Pradesh	18.50	30.74	0	0	
Assam	2.00	0.33	330.00	55.25	
Manipur	1.50	2.95	0	0	

	GAS	%	OIL	%	TOTAL THERMAL	%	NUCLEAR	%	RENEWABLE ENERGY SOURCES	%	TOTAL
	0	0	2	100	2	100	0	0	0	0	2
	612.4	65.68	0	0	932.4	100	0	0	0	0	932.4
	0	0	3.92	0.15	1606.42	62.91	0	0	30	0.01	2553.36
	0	0	0.13	0	0.13	0.03	0	0	49.08	13.19	372.21
	175.00	34.74	8.94	1.77	183.94	36.52	0	0	10.59	2.10	503.68
	0	0	0	0	2130.00	47.03	0	0	115.25	2.44	4715.77
	113.80	3.01	0	0	2533.80	67.10	0	0	233.29	6.18	3775.93
	0	0	0	0	4280.00	88.98	0	0	11.40	0.24	4810.00
	0	0	0	0	0	0	0	0	32.77	3.21	1019.70
	2311.99	16.01	0	0	9151.99	6338	1180.00	8.17	0	0	14439.99
	0	0	0	0	0	0	0	0	241.91	38.27	632.11
	3213.19	**9.52**	**14.99**	**0.04**	**20820.68**	**61.68**	**1180.00**	**3.50**	**694.59**	**2.06**	**33757.15**
	0	0	0	0	1280.00	0.90	0	0	6.00	0.43	1411.00
	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0.05	100.00	0.05
	478.72	830	17.28	0.30	4925.00	8536	0	0	99.73	1.73	5769.73
	0	0	0	0	2157.50	57.61	0	0	14.51	39	3745.18
	912.00	8.95	0	0	7337.00	72.01	0	0	74.76	0.73	10189.42
	1292.00	16.25	0	0	5652.00	71.08	1300.00	1635	0	0	7952.00
	2398.00	39.62	0.20	0	4688.20	77.46	0	0	903.78	14.93	6052.48
	5080.72	**14.47**	**17.48**	**0.05**	**26039.70**	**74.15**	**13000**	**3.7**	**1098.83**	**3.13**	**35119.86**
	272.30	3.92	0	0	3224.80	46.47	0	0	131.46	1.89	6938.87
	0	0	127.92	2.33	1597.92	29.11	0	0	515.31	3.39	5489.43
	0	0	234.60	11.22	234.60	11.22	0	0	48.12	2.30	2090.32
	32.50	1000.00	0	0	32.50	100.00	0	0	0	0	32.50
	431.00	6.51	0	0	3401.00	51.40	0	0	1069.85	16.17	6616.70
	350.00	3.76	0	0	8440.00	90.56	880.00	9.44	0	0	9320.00
	2348.70	39.41	576.80	9.68	3435.50	57.65	0	0	2468.75	41.42	5959.70
	3434.50	**9.42**	**393.32**	**2.58**	**20366.32**	**55.88**	**880.00**	**2.41**	**4233.49**	**11.62**	**36447.52**
	0	0	0	0	5553.50	88.02	0	0	30.40	4.83	628.80
	0	0	0	0	1260.00	90.38	0	0	4.05	0.29	1394.05
	0	0	0	0	420.00	17.91	0	0	1.30	0.06	2345.23
	0	0	5.00	10.85	5.00	13.19	0	0	9.10	19.74	46.10
	100.00	2.75	12.06	0.33	3417.06	93.92	0	0	59.70	1.64	3638.46
	0	0	0.14	0.01	1441.52	99.51	0	0	7.12	0.49	1448.64
	90.00	1.29	0	0	6772.50	97.08	0	0	0	0	6976.50
	190.00	**1.15**	**17.20**	**0.10**	**13869.58**	**84.17**	**0**	**0**	**111.67**	**0.68**	**16477.78**
	0	0	15.88	26.39	15.88	26.39	0	0	25.80	42.87	60.18
	2444.50	40.93	20.69	3.46	595.19	99.65	0	0	0.11	0.02	597.30
	0	0	45.41	89.28	45.41	89.28	0	0	3.95	7.77	50.86

a 11,463 MW deficit was recorded in 2006, equivalent to 12.3 percent of peak demand. Gujarat, Maharashtra, Meghalaya, Jammu and Kashmir, Punjab, and Madhya Pradesh recorded more than a 20 percent deficit in availability of power during peak hours. Goa, Daman and Diu, Chandigarh, Dadra and Nagar Haveli, Puducherry, and Damodar Valley Corporation recorded negligible peak-hour deficits in electricity. However, all other states also noted electricity deficits during peak hours. At the regional level, the eastern region recorded the least peak-hour deficits, while the western region recorded most.

Electricity supply and demand scenarios for national, regional, and state levels are summarized in Table 1.5. This table indicates that a deficit of 52,938 million units (MU), equivalent to 8.4 percent of demand, was recorded in 2006. Maharashtra, Meghalaya, Jammu and Kashmir, and Uttar Pradesh each recorded more than a 15 percent deficit in availability of power during 2006. Except for Puducherry, all states and union territories recorded overall deficits in availability of electricity. At the regional level, the southern region recorded the

Table 1.3: Installed Electricity Generation Capacity (MW) in India During 2006 (continued)

STATE/ UNION TERRITORY / CENTRAL SECTOR	HYDRO	%	COAL	%	
Meghalaya	185.52	98.12	0	0	
Nagaland	25.50	83.14	0	0	
Tripura	16.00	10.78	0	0	
Mizoram	4.05	6.08	0	0	
Central sector	860.00	69.64	0	0	
Private sector	0	0	0	0	
Subtotal	**1113.07**	**46.30**	**330.00**	**13.73**	
Islands					
Andaman and Nicobar Islands	5.25	10.39	0	0	
Lakshadweep	0	0	0	0	
Private sector	0	0	0	0	
Subtotal	**5.25**	**6.51**	**0**	**0**	
All India	**32325.77**	**26.01**	**68518.88**	**55.13**	

Source: TERI Energy Data and Yearbook 2006.

Table 1.4: Peak Supply and Demand Scenario Over 2006

STATE/SYSTEM/REGION	PEAK DEMAND (MW)	PEAK MET (M W)	SURPLUS/ DEFICIT (MW)	(%)
Chandigarh	240	240	0	0
Delhi	3722	3600	-122	-3.3
Haryana	4333	3931	-402	-9.3
Himachal Pradesh	788	749	-39	-4.9
Jammu and Kashmir	1600	1225	-375	-23.4
Punjab	7731	6158	-1573	-20.3
Rajasthan	5588	4850	-738	-13.2
Uttar Pradesh	8175	6588	-1587	-19.4
Uttarakhand	991	857	-134	-13.5
Northern region	**28154**	**25200**	**-2954**	**-10.5**
Chhattisgarh	2133	1857	-276	-12.9
Gujarat	9783	7610	-2173	-22.2
Madhya Pradesh	6558	5136	-1422	-21.7
Maharashtra	116069	12360	-3709	-23.1
Daman and Diu	223	223	0	0
Dadra and Nagar Haveli	387	387	0	0
Goa	368	368	0	0
Western region	**31772**	**25257**	**-6515**	**-20.5**
Andhra Pradesh	8999	8542	-457	-5.1
Karnataka	5949	5558	-391	-6.6
Kerala	2623	2578	-45	-1.7
Tamil Nadu	9375	8297	-1078	-11.5
Puducherry	251	251	0	0.00
Southern region	**24889**	**23,372**	**-1517**	**-6.1**
Bihar	1314	1116	-198	-15.1
Damodar Valley Corporation	1531	1531	0	0.00

	GAS	%	OIL	%	TOTAL THERMAL	%	NUCLEAR	%	RENEWABLE ENERGY SOURCES	%	TOTAL
	0	0	2.05	1.08	2.05	1.09	0	0	1.51	0.80	189.08
	0	0	2.00	6.52	2.00	6.52	0	0	3.17	10.34	30.67
	127.50	85.94	4.85	3.27	132.35	89.21	0	0	0.01	0.01	148.36
	0	0	51.86	77.86	51.86	77.84	0	0	10.71	16.08	66.62
	375.00	30.36	0	0	375.00	30.36	0	0	0	0	1235.00
	24.50	93.87	0	0	24.50	93.87	0	0	1.60	6.13	26.10
	771.50	**32.09**	**142.74**	**5.94**	**1244.24**	**51.75**	**0**	**0**	**46.86**	**1.95**	**2404.17**
	0	0	40.05	79.23	40.05	79.23	0	0	5.25	10.39	50.55
	0	0	9.97	100.00	9.97	100.00	0	0	0	0	9.97
	0	0	20.00	99.16	20.00	99.16	0	0	0.17	0.84	20.17
	0	**0**	**70.02**	**86.78**	**70.02**	**86.78**	**0**	**0**	**5.42**	**6.72**	**80.69**
	12689.91	**10.21**	**1201.75**	**0.97**	**82410.54**	**66.31**	**3360.00**	**2.70**	**6190.86**	**4.98**	**124287.17**

Table 1.4: Peak Supply and Demand Scenario Over 2006 (continued)

STATE/SYSTEM/REGION	PEAK DEMAND (MW)	PEAK MET (M W)	SURPLUS/ DEFICIT (MW)	(%)
Jharkhand	669	623	-46	-6.9
Orissa	2437	2396	-41	-1.7
West Bengal and Sikkim	4790	4644	-146	-3
Eastern region	**10161**	**9677**	**-484**	**-4.8**
Arunachal Pradesh	75	73	-2	-2.7
Assam	733	679	-54	-7.4
Manipur	113	109	-4	-3.5
Meghalaya	280	205	-75	-26.8
Mizoram	76	72	-4	-5.3
Nagaland	90	87	-3	-3.3
Tripura	171	155	-16	-9.4
Northeastern region	**1385**	**1192**	**-193**	**-13.9**
All India	**93255**	**81792**	**-11463**	**-12.3**

Source: www.cea.nic.in/power sec-reports/executive summary/2006 04/22-23.pdf

least deficit, while the western region recorded the highest. The deficit is expected to increase in the future considering the future demand scenarios described in subsequent sections

Power Development Scenario in the 11th Five-Year Plan: 2007–2012[3]

The Fifth National Power Plan (2007–2012) prepared by the Central Electricity Authority (CEA) reports that India needs an installed capacity of 212,000 MW and a system reliability level of less than 1 percent loss of load probability (LOLP) by the end of the 11th Five-Year Plan. The primary resources for electric power generation to meet this projected installed capacity have been identified as hydro, fossil fuel (coal, lignite, oil, and natural gas), and nuclear energy. It is predicted that the contribution from renewable sources such as wind, biomass, and tidal energy will increase to meet much of the projected increase in demand. The Working Group on Power, constituted by the Planning Commission, had planned a 41,110 MW capacity addition during the 10th Five-Year Plan, comprising 14,393-MW of hydro power, 25,417-MW of thermal, and 1,300-MW of nuclear. Out of the total thermal capacity of 25,417 MW, the contribution of coal/lignite-based capacity had been predicted to be 20,053 MW. For the 11th plan, CEA has identified a capacity addition requirement

Table: 1.5: Overall Supply and Demand Scenario Over 2006

REGION	REQUIREMENT (MU)	AVAILABILITY (MU)	SURPLUS/ DEFICIT (MU)	DEFICIT (%)
Chandigarh	1260	1258	-2	-0.2
Delhi	21602	21281	-321	-1.5
Haryana	23791	21631	-2160	-9.1
Himachal Pradesh	4302	4258	-44	-1
Jammu and Kashmir	9268	7672	-1596	-17.2
Punjab	35682	32591	-3091	-8.7
Rajasthan	32052	30879	-1173	-3.7
Uttar Pradesh	55682	44033	-11649	-20.9
Uttarakhand	5155	5008	-147	-2.9
Northern region	188794	168611	-20183	-10.7
Chhattisgarh	13012	12540	-472	-3.6
Gujarat	57137	52436	-4701	-8.2
Madhya Pradesh	36846	31619	-5227	-14.2
Maharashtra	102765	84117	-18648	-18.1
Daman and Diu	1346	1323	-23	-1.7
Dadra and Nagar Haveli	2539	2531	-8	-0.3
Goa	2338	2338	0	0.00
Western region	215983	186904	-29079	-13.5
Andhra Pradesh	53030	52332	-698	-1.3
Karnataka	34601	34349	-252	-0.7
Kerala	13674	13578	-96	-0.7
Tamil Nadu	54194	53853	-341	-0.6
Puducherry	1678	1678	0	0.00
Southern region	157177	155790	-1387	-0.9
Bihar	7955	7218	-737	-9.3
Damodar Valley Corporation	10003	9891	-112	-1.1
Jharkhand	4033	3868	-165	-4.1
Orissa	15208	15010	-198	-1.3
West Bengal and Sikkim	25148	24719	-429	-1.7
Eastern region	62347	60706	-1641	-2.6
Arunachal Pradesh	208	206	-2	-1
Assam	4051	3778	-273	-6.7
Manipur	510	489	-21	-4.1
Meghalaya	1382	1144	-238	-17.2
Mizoram	230	216	-14	-6.1
Nagaland	408	389	-19	-4.7
Tripura	745	666	-79	-10.6
Northeastern region	7534	6888	-646	-8.6
All India	**631757**	**578819**	**-52938**	**-8.4**

Source: www.cea.nic.in/power-sec-reports/executive-summary/2006 04/22-23.pdf Power Development Scenario in the 11th Five-Year Plan: 2007–20121
Note: MU is million unit, where one unit = 1 kWh.

of 67,439 MW, comprising 23,358-MW hydro, 38,166-MW thermal, and 5,915-MW nuclear. Out of the total thermal capacity of 38,166 MW, the coal/lignite-based capacity had been predicted to be 30,411 MW.

Power Development Scenario Beyond the 11th Five-Year Plan: 2012--2020

CEA has estimated a capacity addition requirement of 135,000 MW for 2012–2020. The breakdown of this

requirement has been estimated to be 35,500-MW hydro, 10,000-MW nuclear, and 89,500-MW thermal (including 6,500-MW gas-based plants). The coal-based capacity requirement has been projected at 83,000 MW during this period. Any shortfall in achieving the hydro capacity would be supplemented by additional coal projects. Keeping in view the huge power generation capacity requirement to be added during the 11th and 12th Five Year Plans, an urgent need has been identified to develop large-scale thermal power plants in an environmentally friendly manner. To achieve this mix and to accelerate hydropower development, a 50,000-MW hydroelectric initiative was launched in 2003 and the Nuclear Power Corporation has plans to add 20,000 MW of additional nuclear power between 2012–2020.

Power Development Scenario: 2020 and Beyond

It has been estimated that the primary energy intensity in India will fall 1.2 percent annually based on GDP estimates. By extrapolating historical electricity intensity through 2022 and accounting for the expected 1.2 percent annual reduction in primary energy intensity, the growth rates of the primary energy and electrical energy have been estimated in Table 1.6 and represent a significant challenge to Indian power generation.

Growth rates in per capita electricity generation should reach 5,300 kWh per year by 2052 and total about 8,000 TWh. This would correspond to an installed capacity of roughly 1,300 gigawatts (GWe). Given this, annual primary energy consumption should increase to 117 exajoules (EJ) by 2052.

Table 1.6: Annual Primary and Electricity Growth Rate (%)

PERIOD	PRIMARY ENERGY	ELECTRICITY
2002–2022	4.6	6.3
2022–2032	4.5	4.9
2032–2042	4.5	4.5
2042–2052	3.9	3.9

Current Status of Indian Clean Energy Technology

Renewable Energy

Renewable energy resources are abundant in India, including hydropower, solar, wind, biomass, and waste-to-energy. Table 1.7 presents the assessed potential for renewable energy development, estimated at 84,776 MW – this excludes solar and large hydropower. The breakdown indicates wind energy, biomass, and small hydropower constitute 97 percent of the total projected potential. Wind energy alone accounts for 54 percent followed by biomass/co-generation and small hydropower.

Table 1.8 provides a breakdown of installed renewable capacity by resource. As noted, the total installed capacity as of May 2007 was 10,297 MW, up from 3,241 MW in 2001. Wind constitutes 69 percent of the total, followed by small hydro (19 percent), biomass (co-generation, 11.5 percent), waste-to-energy (0.42 percent), and solar (0.03 percent).

Table 1.8 also demonstrates India's need to develop alternative forms of renewable energy and diversify its energy portfolio even further. The contributions of waste-to-energy and solar-energy, for instance are considerably less than their potential indicates. Solar thermal, geothermal, and tidal energy are virtually non-existent, an indicator of the significant potential these sectors have for development.

A breakdown of distributed renewable energy is provided in Table 1.9. As indicated, 166 MW equivalent renewable

Table 1.7: Renewable Energy Development Potential in India.

SOURCE	POTENTIAL
Small hydropower	15,000 MW
Wind power	45,195 MW
Biomass power/ co-generation	21,881 MW
Solar	4-6 kWH/m2/day
Waste-to-energy	2,700 MW
Total	**84,776 MW (excluding solar)**

Source: Government of India Ministry of New and Renewable Energy http://mnes.nic.in/

Table 1.8: Total Installed Capacity Based on Different Renewable Energy Sources from 2001–2007

RENEWABLE ENERGY SOURCE	TOTAL INSTALLED CAPACITY (MW)						
	2001	2002	2003	2004	2005	2006	2007
Hydro	1,341	1,423	1,463	1,603	1,693	1,747	1,976
Wind	1,626	1,867	2,483	2,980	3,595	5,342	7,092
Solar PV	2	2	2	3	3	3	3
Solar thermal	0	0	0	0	0	0	0
Biomass	273	358	468	613	727	797	1,184
Waste-to-energy	15	17	25	42	47	35	43
Geothermal	0	0	0	0	0	0	0
Tidal/ocean	0	0	0	0	0	0	0
Total	**3,241**	**3,650**	**4,441**	**5,240**	**6,065**	**7,995**	**10,297**

Source: Government of India, Annual Reports of Ministry of New and Renewable Energy, 2000–2001 to 2006–2007.

energy exists in distributed (non-grid-connected) sectors. Biomass-gasifier-based renewable energy contributes 52 percent, followed by 36 percent from biomass (co-generation) and 12.2 percent from waste-to-energy. These figures again indicate the lack of a mature market and demonstrate the potential opportunity for American firms.

Wind

Statewide gross and technical wind power potential is given in Table 1.10. The technical potential has been estimated by assuming 20 percent grid penetration, which would increase with the augmentation of grid capacity in certain states. Table 1.10 indicates that Maharashtra, Andhra Pradesh, Tamil Nadu, and Gujarat are the leading states, with 62 percent of the projected "technical" potential.

Table 1.11 shows India had 5,341 MW of installed electricity capacity from wind energy as of March 2006. Nine states accounted for 99 percent of the installed capacity in the country. Tamil Nadu accounted for 54 percent of wind generation, while Maharashtra accounted for 18.7 percent of installed capacity in India. Most of states enjoying wind power generation – 70 percent -- are located in coastal areas with geographic and climatic conditions favorable for wind farms.

Table 1.9: Breakout of Distributed Renewable Energy

BIOMASS POWER / CO-GEN. (NON-BAGASSE)	59.00 MW
Biomass gasifier	86.53 MWeq
Waste-to-energy	20.21 MWeq
Total	**165.74 MWeq**

Source: Government of India Ministry of New and Renewable Energy http://mnes.nic.in/

Solar PV and Solar Thermal

India receives abundant solar radiation equivalent to over 5,000 trillion kWh per year. The daily average solar energy incident varies from 4–7 kWh per square meter depending upon the location. A government-supported program for PV has existed for two decades, but the current installed capacity equals only 3 MW, a small proportion of the country's total energy mix. PV systems are promoted primarily for rural and off-grid applications, consisting largely of mini-grids, solar home systems, solar lanterns, and solar street lights.

The overall solar water heater potential in India is estimated to be 140 million square meters of collector area, of which about 1.9 million square meters have been installed in buildings and in industry – 99 percent of the potential is therefore undeveloped.

Table 1.10: Wind Power Potential in India, by State

STATE	GROSS POTENTIAL (MW)	TECHNICAL POTENTIAL (MW)
Andhra Pradesh	8,257	2,110
Gujarat	9,675	1,900
Karnataka	6,620	1,310
Kerala	875	610
Madhya Pradesh	5,500	1,050
Maharashtra	3,650	3,060
Orissa	1,700	1,085
Rajasthan	5,400	1,050
Tamil Nadu	3,050	2,150
West Bengal	450	450
Total	**45,177**	**14,775**

Source: Confederation of Indian Industry, "Background Paper," 1st India Clean Tech Forum, August 3, 2007.

Table 1.11: Break-out of Installed Base of Electricity Generation from Wind Energy, by State, in 2006

STATE	31 MARCH 2006		
	DEMONSTRATION PROJECTS	PRIVATE PROJECTS	TOTAL CAPACITY
Andhra Pradesh	5	116	121
Gujarat	17	322	338
Karnataka	7	578	586
Kerala	2	0	2
Madhya Pradesh	0.6	40	40
Maharashtra	8	993	1001
Rajasthan	6	352	358
Tamil Nadu	19	2873	2894
West Bengal	1	0	1
Others	2	0	3
Total	**69**	**5271**	**5341**

Source: TERI Energy Data and Yearbook 2006.
Note: Numbers may not add exactly owing to independent rounding.

Bioenergy

Statewide biomass potential is presented in Table 1.12. India produces 139 million tons of surplus biomass every year, amounting to 16,000 MW of electricity. Rajasthan, Punjab, Uttar Pradesh, Maharashtra, Madhya Pradesh, Haryana, and Gujarat account for 76 percent of the projected potential, with Rajasthan alone accounting for 25 percent of the total projected potential.

Bagasse-based co-generation potential is presented in Table 1.13. Maharashtra and Uttar Pradesh, the two major bagasse-producing states, account for 57 percent of the total projected potential. In 2006, India had 582 MW of installed bagasse co-generation (grid and off-grid); projections through 2012 call for 1,200 MW installed.

Based on COGEN Europe[4] and Tata Energy Research Institute (TERI) estimates, the total combined heat and power (CHP) potential in India is over 10,000 MW, 61 percent from non-sugar-based industries. These estimates are based on internal heat-to-power ratios, which would meet the plant's energy requirements and still meet the production capacities of the various industry categories. The prominent industry categories are paper, cotton textile, caustic soda, fertilizers, iron and steel, refineries, rice mills, man-made fibers, cement, sulfuric acid, and aluminum.

Table 1.13: Bagasse-based Co-Generation Potential in India, by State

STATE	POTENTIAL (MW)
Maharashtra	1000
Uttar Pradesh	1000
Tamil Nadu	350
Karnataka	300
Andhra Pradesh	200
Bihar	200
Gujarat	200
Punjab	150
Others	100
Total	**3500**

Source: Confederation of Indian Industry, "Background Paper," 1st India Clean Tech Forum, August 3, 2007.

Table 1.12: National Biomass Power Estimation, by State

STATE	AREA (KHA)	CROP PRODUCTION (KT/YEAR)	BIOMASS GENERATION (KT/YEAR)	BIOMASS SURPLUS (KT/YEAR)	POWER POTENTIAL (MWE)
Andhra Pradesh	2,540.2	3,232.0	8,301.7	1,172.8	150.2
Assam	2,633.1	6,075.7	6,896.3	1,398.4	165.5
Bihar	5,833.1	13,817.8	20,441.8	4,286.2	530.3
Chhattisgarh	3,815.5	6,142.8	10,123.7	1,907.8	220.9
Goa	156.3	554.7	827.2	129.9	15.6
Gujarat	6,512.9	20,627.0	24,164.4	7,505.5	1,014.1
Haryana	4,890.2	13,520.0	26,160.9	9,796.1	1,261.0
Himachal Pradesh	710.3	1,329.2	2,668.2	988.3	128.0
Jammu and Kashmir	368.7	648.7	1,198.7	237.7	31.8
Jharkhand	1,299.8	1,509.0	2,191.2	567.7	66.8
Karnataka	7,277.3	38,638.5	23,766.8	6,400.6	843.4
Kerala	2,041.7	9,749.7	9,420.5	5,702.6	762.3
Madhya Pradesh	9,937.0	14,166.9	26,499.6	8,033.3	1,065.4
Maharashtra	15,278.3	51,343.3	36,804.4	11,803.9	1,585.0
Manipur	72.6	159.4	318.8	31.9	4.1
Meghalaya	0.8	14.0	42.0	8.4	1.1
Nagaland	27.1	87.6	149.2	27.2	3.1
Orissa	2,436.6	3,633.3	5,350.4	1,163.4	147.3
Punjab	6,693.5	27,813.7	46,339.8	21,267.0	2,674.6
Rajasthan	12,537.5	93,654.8	204,887.6	35,531.1	4,595.0
Tamil Nadu	2,454.0	24,544.6	15,976.6	6,658.7	863.7
Uttar Pradesh	12,628.2	46,800.8	50,416.7	11,725.9	1,477.9
Uttaranchal	66.4	135.8	159.9	51.6	6.6
West Bengal	5,575.6	21,062.8	23,316.0	2,959.7	368.3
Total	**105,786.8**	**399,262.1**	**546,422.6**	**139,355.8**	**17,981.8**

Source: Government of India Ministry of New and Renewable Energy http://mnes.nic.in/

State-based waste-to-energy potential is presented in Table 1.14. Maharashtra, Uttar Pradesh, Karnataka, Tamil Nadu, and West Bengal account for more than 53 percent of the projected waste-to-energy potential.

The statewide list of commissioned biomass power/co-generation projects as of September 30, 2007, is given in Table 1.15. As shown, the installed capacity of biomass power/co-generation has tripled from 381 MW in 2002 to 1,253 MW in 2007. Andhra Pradesh, Karnataka, Tamil Nadu, and Uttar Pradesh account for 77 percent of the total installed capacity, due to the availability of biomass and bagasse.

Small Hydro

Statewide small hydropower potential in India is provided in Table 1.16. India has an estimated hydropower potential of 84,000 MW, 15,000 MW from SHP. The Ministry of New and Renewable Energy (MNRE)[5] has identified 4,227 potential small hydropower sites accounting for 10,324 MW in potential projects amounting to 25 MW. The remaining potential sites are under study. Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Arunachal Pradesh have 52 percent of the projected SHP potential.

As Table 1.17 demonstrates, 1,748 MW of installed small hydropower (SHP) operated in India in 2006. Karnataka and Maharashtra accounted for 17 and 11 percent of the total, respectively. The states of Punjab, Andhra Pradesh, Himachal Pradesh, and Jammu and Kashmir together accounted for more than 17 percent of installed capacity. The potential of this sector is dependent on available water resources, which are abundant in the majority of states.

Since India needs 347,000 MW of additional capacity through 2020 of which renewable energy can contribute 24 percent. Major requirements for developing this sector include continued technology improvements, cost reductions, and successful demonstrations.

Table 1.14: Waste-to-Energy Potential in India, by State

STATE	LIQUID WASTE (MW)	SOLID WASTE (MW)	TOTAL (MW)
Andhra Pradesh	16	107	123
Delhi	20	111	131
Gujarat	14	98	112
Karnataka	26	125	151
Maharashtra	37	250	287
Tamil Nadu	14	137	151
Uttar Pradesh	22	154	176
West Bengal	22	126	148
Other	55	349	404
Total	**226**	**1,457**	**1,683**

Source: Confederation of Indian Industry, "Background Paper," 1st India Clean Tech Forum, August 3, 2007.

Table 1.16: Small Hydropower Potential in India, by State

STATE	NUMBER OF SITES	TECHNICAL POTENTIAL (MW)
Andhra Pradesh	286	255
Arunachal Pradesh	492	1,059
Himachal Pradesh	323	1,625
Jammu and Kashmir	201	1,207
Karnataka	230	653
Kerala	198	467
Madhya Pradesh	85	336
Maharashtra	234	599
Tamil Nadu	147	339
Uttarakhand	354	1,478
Uttar Pradesh	211	267
Other States	1,466	2,039
Total	**4,227**	**10,324**

Source: Confederation of Indian Industry, "Background Paper," 1st India Clean Tech Forum," August 3, 2007.

Table 1.15: List of Commissioned Biomass Power/Co-generation Projects (MW), by State

STATE	UP TO MARCH 31, 2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	TOTAL
Andhra Pradesh	101.20	58.85	37.70	69.50	12.00	22.00	33.00	334.25
Chhattisgarh	11.00	—	—	—	16.50	85.80	17.50	130.80
Gujarat	0.50	—	—	—	—	—	—	0.50
Haryana	4.00	—	—	2.00	—	—	—	6.00
Karnataka	75.60	33.78	26.00	16.60	72.50	29.80	8.00	262.28
Madhya Pradesh	0.00	—	1.00	—	-—	—	—	1.00
Maharashtra	24.50	—	—	11.50	—	40.00	19.50	95.50
Punjab	12.00	10.00	—	—	6.00	—	—	28.00
Rajasthan	0.00	—	7.80	—	7.50	8.00	—	23.30
Tamil Nadu	106.00	—	44.50	22.50	—	42.50	12.00	227.50
Uttar Pradesh	46.50	—	12.50	14.00	48.50	—	22.00	143.50
Total	**381.30**	**102.63**	**129.50**	**136.10**	**163.00**	**228.10**	**112.00**	**1252.63**

Source: Ministry of Non-conventional Energy Sources, Annual Report 2005/06 (New Delhi, India).

Energy Efficiency

The most important supply-side efficiency prospects are high-efficiency, low-emission coal thermal electric power generation and reductions in losses in electricity distribution. The National Thermal Power Corporation (NTPC), for example, envisions a 660-MW green-field project employing supercritical steam parameters. A USAID-funded feasibility study of an integrated gasification combined cycle (IGCC) demonstration project estimated a 200-MW demonstration plant could be constructed for $2,000/kW.

Currently, 25 percent of Indian power is lost through transmission and distribution losses alone. A reduction of 5 percent of these losses could result in significant augmentation of the electricity supply. Industry represents 50 percent of the total energy consumption and is a major target of the energy efficiency effort. Six key industries—aluminum, cement, fertilizers, pulp and paper, petrochemicals, and steel—account for two-thirds of the nation's total industrial energy use. The energy intensity in these industries is higher than in developed countries, mainly due to obsolete and energy inefficient technologies, which have not been retrofitted with higher efficiency products. Nonetheless, recently energy efficiency in Indian industry has increased steadily. In the cement, steel, aluminum, and fertilizer industries, average energy consumption has declined as these industries

Table 1.17: Installed Base of Electricity Generation from Small Hydro, by State, in 2006

STATE/UNION TERRITORY	POTENTIAL		EXISTING PROJECTS		ONGOING PROJECTS	
	NUMBER OF SITES	CAPACITY (MW)	NUMBER OF SITES	CAPACITY (MW)	NUMBER OF SITES	CAPACITY (MW)
Andhra Pradesh	286	254.63	57	178.81	9	13.9
Arunachal Pradesh	492	1059.03	62	34.30	52	51.42
Assam	90	148.90	3	2.11	7	26.00
Bihar	92	194.02	5	45.90	9	14.00
Chhattisgarh	174	179.97	4	11.00	2	8.00
Goa	3	2.60	1	0.05	—	—
Gujarat	290	156.83	2	7.00	—	—
Haryana	22	30.05	5	62.70	—	—
Himachal Pradesh	323	1624.78	53	119.08	10	52.50
Jammu and Kashmir	201	1207.27	30	109.74	7	7.31
Jharkhand	89	170.05	6	4.05	8	34.85
Karnataka	230	625.61	53	300.63	22	112.74
Kerala	198	466.85	14	84.62	7	57.75
Madhya Pradesh	85	336.33	8	41.16	3	24.20
Maharashtra	234	599.47	27	207.08	5	25.75
Manipur	96	105.63	8	5.45	3	2.75
Meghalaya	98	181.50	3	30.71	9	3.28
Mizoram	88	190.32	16	14.76	3	15.50
Nagaland	86	181.39	8	20.47	6	12.40
Orissa	161	156.76	6	7.30	7	40.92
Punjab	78	65.26	24	113.40	6	26.35
Rajasthan	49	27.26	10	23.85	—	—
Sikkim	68	202.75	12	35.60	5	15.20
Tamil Nadu	147	338.92	12	77.70	2	7.90
Tripura	8	9.85	3	16.01	—	—
Uttarakhand	354	1478.24	76	75.45	37	23.01
Uttar Pradesh	211	267.06	8	21.50	1	3.60
West Bengal	145	182.62	20	92.30	7	5.80
Andaman and Nicobar Islands	6	6.40	1	5.25	—	—
Total	**4404**	**10,450.35**	**537**	**1,747.98**	**227**	**585.13**

Source: Ministry of Non-conventional Energy Sources, Annual Report 2005/06 (New Delhi: MNES, Government of India, 2006).

have placed a higher importance on conservation and the installation of state-of-the-art technology. Latent potential in the building and construction sectors however remains significant and should be addressed going forward.

Fuel-based Energy Sources

Table 1.18 depicts the present status of fuel-based resources. The estimated domestic mineable coal resources are 38 billion tons (BT), and the estimated hydrocarbon reserves are 12 BT. These reserves together may provide 1,200 EJ of energy. To meet the projected demand, India needs to develop all options, including efficient use of known fossil reserves, competitive importation of energy, hydro potential both large and small, and non-fossil resources including both nuclear and non-conventional energy sources.

Clean Transportation Technology

The rapid growth in motor vehicle activity in India is contributing to high levels of urban air pollution, among other adverse socioeconomic, environmental, health, and welfare impacts. The demand for transport increased by 1.9 percent per year from 2000 to 2005, but is projected to double by 2015 and more than quadruple by 2030. The slow growth in demand for diesel to date may be due to improved efficiency of new cars and trucks and switching to compressed natural gas vehicles for public transportation in some major cities. However, like many developing countries, India lacks mandatory vehicle fuel efficiency standards.[6]

The Ministry of New and Renewable Energy is promoting several research, development, and demonstration projects including a demonstration project in battery-operated vehicles (BOVs). Under the program a central subsidy is provided for the purchase of the BOVs through renewable energy development agencies. In addition, fuel cell–battery hybrid vehicles with indigenously developed exchange membrane fuel cells of 10 kW have undergone field performance evaluation. Efforts made are expected to lead to the indigenous production and wider applications of fuel cell systems in the country. Various laboratories are developing different technologies for production, storage, and transportation including hydrogen fuel, which some argue has the potential to replace fossil fuels as early as 2020.[7]

Table 1.18: Fuel-based Energy and Electricity Resources

	AMOUNT	THERMAL ENERGY			ELECTRICITY POTENTIAL
		EJ	TWh	GW/year	GWe/year
Fossil					
Coal	38 BT	667	185,279	21,151	7,614
Hydrocarbon	12 BT	511	141,946	16,204	5,833
Non-fossil					
Nuclear					
Uraniummetal	61,000 T				
In PHWRs		28.9	7,992	913	328
In fast breeders		**3,699**	**1,027,616**	**117,308**	**42,231**
Thoriummetal	225,000 T				
In breeders		13,622	3,783,886	431,950	155,502

Chapter 2: Market Analysis

Clean energy technologies in India, including renewable energy and energy efficiency, have received unprecedented attention in the last few years as the country's energy demand grows each year. Increased use of clean energy technologies will help mitigate concerns that often accompany rapid economic development in areas that are already resource constrained—such as poor air quality, desertification, dependence on imported fuel, and exponential growth in demand.

Renewable Energy

There is a need for massive investment in the Indian renewable energy sector. Table 1.19 provides the renewable energy targets under the 11th Five-Year Plan, as well as associated outlays for grid-connectivity and distributed power generation. The total investment required to meet the 15,000 MW goal would be about $19.5 billion, 19 times the proposed budgetary support. This includes 1,000 MW targeted from distributed renewable power systems with an outlay of $531.6 million and $6.3 million for performance testing. The detailed breakout is given below.

The Electricity Act of 2003 included a renewable portfolio standard, building on the precedent of those states that had already set targets of 5–10 percent to be realized by 2010. These targets virtually ensure a guaranteed market for renewable energy technologies in the country. While the target set out in the 10th Five-Year Plan for installed capacity is 3,075 MW, the actual achievement is likely to be in excess of 6,000 MW.

Wind Energy

Individual wind turbine capacity has increased from 55 kW in the mid-1980s to 2,000 kW today. India already manufactures wind electric generators with up to 1,650 kW per unit capacity domestically and their expertise in the subject continues to grow. Enercon (India) Ltd., Vestas RRB India Ltd., and Suzlon Energy Ltd lead the industry, but a full list of electric generators installed through 2006, by manufacturer, is provided in Annex 1, as well as a listing of wind turbine manufacturers.

To harness the projected potential, new technologies with higher capacities are needed in the country. These technologies may include wind power systems greater than 1–2 MW, wind machines for low-wind regimes, and better designs for rotor blades, gear boxes, and control systems.

Small Hydro

India has a fairly developed capacity for designing, constructing, and operating small hydropower plants. A list of small hydropower turbine/equipment manufacturers in India is provided in Annex 1.

Small hydro technology has improved steadily over time and is now more efficient, reliable, and automatic compared with several years ago. Some of the new technological advances include the replacement of mechanical governing systems by electronic governors and analogue controls by digital systems. The projects are now

Table 1.19: Potential Targets and Associated Investments Required to Meet the Targets

PROGRAM COMPONENT	PHYSICAL TARGET (MW)	PROPOSED OUTLAY ($ MILLION)	INVESTMENT REQUIREMENT ($ MILLION)
Wind power	10,500	18.9 *	15,530
Small hydro	1,400	177.2	2,070
Co-generation Biomass power	1,200 500	151.8 50.6	1,106 492
Urban waste-to-energy	200	37.9	295
Industrial waste-to-energy	200	18.9	
Subtotal (A)	14,000	455.6	
Solar power (grid-interactive/distributed generation)	50	50.6**	
Distributed RE power systems (excluding solar)	950	481	
Subtotal (B)	1,000	531.6	
Total (renewable power) (A+B)	15,000	987.3	
Performance testing	–	6.32	
Grand total	**15,000**	**993.6**	**19,493**

Source: Report of the Working Group on New and Renewable Energy for 11th Five Year Plan.
* For demonstration projects in states where there is sizable potential but where no commercial activity has commenced.
**Subsidy limited to $265.8 per household. Investment required is dependent on subsidy, which varies during the annual budget of thegovernment of India.

completely automatic from start to grid synchronization. The concept of remotely operating projects and Supervisory Control and Data Acquisition systems have been introduced in this sector. Apart from improvement in equipment designs, there is a need to improve/standardize civil design and hydraulic structures to reduce construction time. The areas of technological interventions include development of direct-drive low-speed generators for water sources with low heads; standardized control and monitoring hardware packages; submersible turbo-generators; compact equipment, which requires the laying of few cofferdams; appropriate turbine design suitable to electrical output below 1 MW; variable-speed operation (optimal use of low- and variable-head sites); flexible small hydro turbines for very low heads (<2.5 m); and adaptation of high-pole permanent magnet excitation generators to SHP.

Solar Photovoltaics

India has manufacturing facilities for equipment and components used in solar photovoltaic (PV) technology. The list of solar cell and module manufacturers in India is provided in Annex 1. New technologies are still needed however. These include the development of polysilicon and other materials, device fabrication processes and improvements in crystalline silicon solar cell/module technology, and thin-film solar cell technology (based on amorphous silicon films; cadmium telluride films and copper indium diselenide thin films; and organic, dye-sensitized, and carbon nano tubes). There is also a need for megawatt-scale solar PV power-generating systems.

Solar Thermal Technology

A number of solar thermal applications have been developed in India, which include water/air heating, cooking, drying of agricultural and food products, water purification, detoxification of wastes, cooling and refrigeration, heat for industrial processes, and electric power generation. Most of the solar thermal devices and systems are manufactured in India. Evacuated tube collectors (ETC) used in one of the configurations of solar water heating systems are imported and marketed in the country by the solar thermal industry.

Annex 1 provides a listing of solar cooker manufacturers, ETC suppliers and manufacturers, and Flat Plate Collector–based solar water heating systems, driers, air heating, and solar steam-generating systems in India. The major opportunities for American firms are solar thermal (high-temperature) power generation systems and energy efficient buildings utilizing solar energy concepts.

Bioenergy

Manufacturing capability exists in India for the equipment/machinery required to establish and operate biomass projects. Biomass combustion technology using co-generation is in operation in industries throughout the country. India also has significant experience and technology in atmospheric gasifiers, where biomass is converted into producer gas via gasification. With the exception of some critical control equipment and high-efficiency turbines, most of the equipment can be procured from domestic sources. A number of large manufacturers have established capabilities for manufacturing spreader-stoker-fired, traveling grate/dumping grate boilers; atmospheric pressure fluidized bed boilers; and circulating fluidized bed boilers. Almost all combinations—condensing, single-extraction/double-extraction condensing, back pressure, etc.—are available in the country with full after-sales service guarantees. There is a well-established capability and capacity for the manufacture of related equipment in the bioenergy field, including harvesters, balers, briquetting equipment, handling and firing equipment, and pollution control systems. Annex 1 provides the list of companies in the areas of gasifier manufacturing, plasma arc technology, pyrolysis/gasification technology, and biogas burners.

Some of the new areas where technical expertise is required include:

- Development of megawatt-scale fluidized bed biomass gasifiers, hot-gas clean-up systems, and optimum integration of the system following the principles of IGCC.
- Development of poly-generation facilities for the production of liquid fuels, development of a variety of chemicals and hydrogen in addition to power production through IGCC, and establishment of the concept of a biorefinery.
- Increase in the efficiency of atmospheric gasification to 25–30 percent along with cooling systems, complete tar decomposition, and safe disposal of wastes in commercial production.
- Increase in the system efficiency of small (up to 1 MW) combustion and turbine technologies to 20 percent or more.
- Design and development of high-rate anaerobic co-digestion systems for biogas and synthetic gas production.
- Development of gasifier systems based on charcoal/pyrolysized biomass.
- Development of efficient kilns/systems for charcoal production/pyrolysation of biomass.
- Design and development of engines, Stirling engines, and micro-turbines for biogas, producer gas, and biosyngas.
- Design and development of direct gas-fired absorptive chillers, driers, stoves, etc., and improvement in biomass furnaces, boilers, etc.
- Engine modifications for using more than 20 percent biodiesel as a blend with diesel.
- Development of second-generation bioliquid fuels and related applications.
- Diversification of feedstocks to utilize alternate biomass wastes along with cattle dung for setting up household biogas plants.
- Methods for sustaining biogas production during winter months.

- Development of biogas micro-turbines and engines.
- Local power grids compatible with dual fuel engines and gas engines/turbines.
- Removal of hydrogen sulfide from biogas produced in night soil-based biogas plants.
- Additional treatment methods for effluent from night soil-based biogas plants.

Waste-to-Energy

The technological options available for waste-to-energy projects include biomethanation, combustion/incineration, pyrolysis/gasification, landfill gas recovery, densification, and pelletization. However, India has limited local capacity in these technology areas. The large-scale operations of any of these technologies require import of design, engineering, and equipment. There is also a need to demonstrate the usefulness of these technology options throughout the country.

The list of suppliers of these waste-to-energy technologies in India is given in Annex 1. It should be noted, however, that the majority of these suppliers are dealers, franchisees, and/or licensees of technology suppliers outside India.

Geothermal Energy

There is a need to assess the potential of geothermal resources in India and to harness these resources for power generation to be used in space heating, greenhouse cultivation, and cooking. Past projects undertaken by the MNRE have demonstrated the applications of geothermal fluids for small-scale power generation and in poultry farming and greenhouse cultivation. Magnetotelluric (MT) investigations to delineate sub-surface, geo-electric structures and evaluate their geothermal significance have been carried out by the National Geophysical Research Institute in the Tatapani geothermal area in Chhattisgarh, the Puga geothermal area, and the Ladakh region of Jammu and Kashmir. Similar studies are in progress for geothermal fields in the states of Surajkund in Jharkhand and Badrinath-Tapovan in Uttarakhand and in the Satluj-Beas and Parvati Valleys in Himachal Pradesh. The National Hydroelectric Power Corporation (NHPC), with the support from the Indian Government, prepared a feasibility report for development of geothermal fields in Puga, the Ladakh region of Jammu and Kashmir, and the Tatapani geothermal field in the Surguja district of Chhattisgarh. Currently, there is no technology supplier for geothermal energy harnessing/equipment manufacturing in India.

Ocean Energy

The potential of ocean and tidal energy for power generation in India has yet to be assessed. Some potential sites for tapping tidal energy have been identified in the Gulf of Kuchch and Gulf of Cambay in Gujarat and the Delta of the Ganga in the Sunderbans region in West Bengal. A detailed project report for the proposed 3.65-MW tidal power project at Durgaduani/Sunderbans, West Bengal, has been prepared by the West Bengal Renewable Energy Development Agency and is being updated by the NHPC. Currently, there is no technology supplier for tidal energy harnessing/equipment manufacturing in India.

Key Market Drivers

A number of market drivers are spurring the development of clean energy markets in India. These include:

- Existing and projected gaps in the electricity supply.
- Increasing fuel importation to augment the electricity supply, thereby increasing dependence on imported resources.
- Rising prices of fossil-fuel-based energy delivery (prices reached $100/barrel in January 2008).
- Projected potential of locally available renewable energy resources and the need for energy portfolio diversity.
- Favorable policy environment to promote the use of clean energy technologies (national, state, local) and improved investment climate.
- Expanded financial support for renewable energy and energy efficiency from local and international financial institutions, multilateral agencies, donor organizations, and others.
- Growing carbon credit markets, including the Clean Development Mechanism (CDM) and voluntary markets.
- Existence of local capacities/capabilities to harness the clean energy sector and relatively inexpensive local labor supplies.
- Growing environmental, social, and health concerns over fossil fuel development.

At present, India is the fourth-largest greenhouse gas (GHG) emitter in the world, ranking second only to China as the fastest growing GHG emitter.[8] India is also a major emitter of methane and nitrous oxide, and has exceeded its national ambient air quality standards in eight major cities. There is thus a major need for the development of clean energy options in the country.

Policy Drivers

According to India's integrated energy policy, sustained growth of 8 percent through 2030 will require primary energy supply to increase three to four times and electricity supply by five to seven times compared to current consumption. If no alternative arrangements are made to reduce the consumption of coal, an annual coal requirement is expected to be 2,040 mt by 2010, which will lead to a substantial increase in GHG emissions. The power sector is expected to add over 150,000 MW in the next 15 years, of which at least 10 percent is expected to come from renewable energy technologies.

Implementation of Section 86(1)(e) of the Electricity Act of 2003 and Section 6.4(1) of the National Tariff Policy

is underway. Different states are in the process of issuing tariff orders for renewable energy-based electricity generation and specifying quotas/shares for power from renewable energy in accordance with the provisions of the Electricity Act. For example, the Maharashtra Electricity Regulatory Commission (MERC) has stipulated the minimum percentage targets (3 percent for FY 2006–2007, 4 percent for FY 2007–2008, 5 percent for FY 2008–2009, and 6 percent for FY 2009–2010) for procuring electricity generated from eligible renewable energy sources. Similar orders have been issued by other states, based on the potential resources available in their respective states.

Other major renewable energy initiatives include: (1) installation of 1 million household solar water heating systems, (2) electrification by renewable mini-grids of 24,000 villages without electricity, (3) deployment of 5 million solar lanterns and 2 million solar home lighting systems, and (4) establishment of an additional 3 million small biogas plants.

The integrated Indian energy policy set the ambitious goal of a 25 percent reduction in energy intensity from current levels. Within mining, electricity generation, transmission and distribution, water pumping, industrial production processes, building design, construction, heating, ventilation, air conditioning, lighting, and household appliances, energy efficiency can play a key role. Nearly 25,000 MW of capacity creation through energy efficiency in the electricity sector alone have been estimated in India. The energy conservation potential for the economy as a whole has been assessed at 23 percent, with maximum potential in the industrial and agricultural sectors. The target areas identified by the Board of Energy Efficiency (BEE) in which to achieve energy efficiency include:

- Indian industry program for energy conservation;
- Demand-side management;
- Standards and labeling program;
- Energy efficiency in buildings and establishments;
- Energy conservation building codes;
- Professional certification and accreditation;
- Manuals and codes;
- Energy efficiency policy research program;
- School education;
- Delivery mechanisms for energy efficiency services.

A financial requirement of about $162 million has been projected for the 11th Five-Year Plan for energy-efficiency-related initiatives. A number of pilot and demonstration projects have been taken up for load management and energy conservation through reduction of transmission and distribution losses in the system. In the area of building energy efficiency, building plans will not be approved by local authorities unless they comply with the Energy Conservation Building Codes (ECBCs) after 2009. The ECBCs will make it mandatory for buildings not to exceed 140 kilowatt/hour per square meter annually.

Ethanol and biodiesel have likewise been identified as key focus areas, with both at the early stages of commercialization. In 2004, the government of India (GOI) mandated a 5 percent blending of petrol with ethanol, subject to certain conditions. An autonomous National Biodiesel Board is being created to promote, finance, and support organizations that are engaged in the field of oilseed cultivation and oil processing leading to biodiesel production.

Cost Analysis

Tables 1.20 and 1.21 below provide the current costs of renewable energy technologies in India, as well as their market value—derived from the current costs—as of March 2007.

The existing market figure of $13,366 million given in Table 1.21 is based on estimating the value of the total investments in the installed capacity in each subsector, which has been estimated at today's costs per megawatt of installed capacity. It must be noted that these capacities have been installed over the last two decades, and, thus, this is a reflection of the value of investment in renewable energy at today's cost. At least 60 to 70 percent of the installed assets would have been depreciated by over 60–80 percent, and some would also have been upgraded with refurbishments or even replaced. If one assumes 80 percent depreciation, then the true value of the market is about $4 to $5 billion at the end of 2007. By 2012—the

Table 1.20: Cost of Clean Energy Technologies in India

TECHNOLOGY	CAPITAL COSTS (MILLION $/MW)	UNIT COSTS ($/KWH)
Small hydropower	1.27–1.53	0.038–0.064
Wind power	1.02–1.27	0.051–0.076
Biomass power	1.02	0.064–0.089
Bagasse co-generation	0.89	0.064–0.076
Biomass gasifier	0.48–0.51	0.064–0.089
Solar photovoltaics	0.66–0.69	0.382–0.509
Waste-to-energy	0.64–2.55	0.064–0.191

Source: Planning Commission (Integrated Energy Policy; http://planningcommission.nic.in/reports/genrep/intengpol.pdf)

Table 1.21: Market Value of CETs as of March 2007

	INSTALLED CAPACITY MARCH 2007 (MW)	VALUE OF INVESTMENT (MILLION $)
Small hydro	1,976	2,964
Wind power	7,092	8,865
Solar PV (home lighting)	86	366
Solid biomass	569	569
Bagasse CHP	615	538
Waste-to-energy	43	65
Total		**13,366**

Source: Based on government projections and reports of the GOI's Planning Commission.

completion of the 11th Five-Year Plan—the GOI has mandated that 10 percent of the nation's power supply comes from renewable energy sources, resulting in a 4–5 percent share of the electricity mix. As a result, the current 10,000 MW of installed renewable capacity is projected to reach 24,000 MW by 2012. This should translate from the current CET market size to more than $21 billion by 2012, in a best case scenario. Even under the realistic assumption of just a 50 percent capacity addition in the renewable and energy efficiency sub-sectors by 2012, the estimated market size would be $11 billion by 2012.

No figures for export of CET are available for India as of early 2008. However, according to Indian Government sources, only solar photovoltaic components are exported from India. Wind energy equipment manufactured in India is not exported as it supplies the domestic market. Domestic SHP turbines and biomass gasifiers manufactured in India are also used in-country.

Chapter 3: Clean Energy Policies

The market potential of clean energy technologies, including renewable energy and energy efficiency, can be realized by enabling policy and regulatory frameworks supported by an adequate institutional structure. Over the last decade, the government of India (GOI) has prepared a road map for economic development by opening up different sectors of the economy. In particular, the energy sector has witnessed substantial regulatory reforms, liberalization, and a number of new policy initiatives, followed by the creation of new institutions to support these developments. In this context, the following sections describe the key policies, laws, decrees, plans, institutional structure, and policy drivers impacting U.S. energy companies wishing to do business in India, as well as potential opportunities posed by policy interventions.

Key Policies, Laws, Decrees, and Plans

India's policy framework and developmental plans are formulated by the national government. The state governments align their policies and development plans as the national policy framework and action plans mandate. In the area of clean energy, there is no single over arching policy of the government of India and thus state governments are forced to develop often ad hoc policies based on patchwork policies, laws, decrees, and plans. Many of these are shown Table 1.22.

Salient features of the above policies, in the context of renewable energy and energy efficiency, are outlined below.

Rural Electrification Policy

- Goals of the Rural Electrification Policy include provision of access to electricity to all households by the year 2009, quality and reliable power supply at reasonable rates, and minimum lifeline consumption of one unit per household per day by 2012.
- For villages/habitations where grid connectivity would not be feasible or cost effective, off-grid solutions based on stand-alone systems may be taken up for the supply of electricity. Where these also are not feasible, and if the only alternative is to use isolated lighting technologies, solar photovoltaics may be adopted.

National Electricity Policy of 2005

Lowering the energy intensity of GDP growth through higher energy efficiency is critical to meeting India's energy challenge and ensuring its energy security. Some of the key provisions are provided below:

- Policy measures for improving energy efficiency include:
- Merging the Petroleum Conservation Research Association and the Bureau of Energy Efficiency (BEE) into an autonomous statutory body under the Energy Conservation Act, independent of other energy ministries and separately funded by the government of India.
- Making the expanded BEE responsible for accelerating efficiency improvements in energy-consuming appliances,

Table 1.22: Summary of India's Clean Energy–related Policies

YEAR	TITLE	MAIN THRUST
Major Policies		
2006	Rural Electrification Policy	Establishes a national goal for universal access, assigns responsibilities for implementation, and creates new financing arrangements.
2006	National Environment Policy	Provides guidance on air pollution reduction, climate change and GHG mitigation, and CDM; promotes clean technologies, environmental resource usage, and efficiency per unit of economic output.
2006	National Urban Transport Policy	Encourages integrated land use and transportation planning in cities.
2006	National Tariff Policy	Provides guidance on establishing power purchase tariffs by State Electricity Regulatory Commissions.
2006	MNRE (Draft) R&D Policy	Establishes resource requirements for the 11th Five-Year Plan.
2006	MNRE (Draft) Renewable Energy Policy	Identifies the strategies for increased deployment of grid-interactive RE technologies.
2005	National Electricity Policy	Provides guidelines for accelerated development of the power sector.
Major Acts		
2003	Electricity Act	Legislates a comprehensive reform and liberalization process for the power sector.
2001	Energy Conservation Act	Provides the legal framework and institutional arrangements for embarking on a national energy efficiency drive.
1986	Environment (Protection) Act	Provides broad objectives, goals, and guidance for environmental compliance.

equipment, and vehicles through schemes such as the "Golden Carrot" incentives.
- Implementing energy efficiency standards and labeling of energy-using equipment, using financial penalties if equipment fails to meet minimum energy performance standards.
- Establishing benchmarks for energy consumption in energy-intensive sectors.
- Increasing gross efficiency in power generation, including improvements of 10 percent in existing generation and 5–10 percent in new plants, and promoting urban mass transport, energy efficient vehicles, and freight movement by railways.
- Progressively increasing the share of electricity from non-conventional sources. This requires that each state regulatory authority create a renewable energy portfolio standard (RPS) for the transmission and distribution companies serving their jurisdictions.
- Distribution companies are directed to purchase power from renewable energy sources through a competitive bidding process at a preferential price fixed by the regulatory commission.

Tariff Policy of 2006

Salient features of the tariff policy include:

- As per Section 86(1)(e) of the act, the appropriate commission shall fix a minimum percentage for purchase of energy from renewable sources, taking into account availability of such resources in the region and its impact on retail tariffs.
- It will take some time before non-conventional technologies can compete with conventional sources in terms of cost of electricity. Therefore, procurement by distribution companies shall be done at preferential tariffs determined by the appropriate commission. This procurement should be done using competitive bidding. In the long term, these technologies will need to compete with other sources in terms of full costs.
- The Central Commission should lay down guidelines within three months for pricing non-firm power,[9] especially from non-conventional sources, to be followed in cases where such procurement is not through competitive bidding.

National Urban Transport Policy

The National Urban Transport Policy (NUTP) of the Ministry of Urban Development promotes integrated land use and transport planning in cities. It focuses on greater use of public transport and non-motorized modes of transportation by offering central financial assistance. The policy incorporates urban transportation as an important parameter at the urban planning stage.

Renewable Energy Policy

The Ministry of New and Renewable Energy has prepared a draft R&D policy (December 12, 2006)[10] based on resource requirements estimated for the 11th Five-Year Plan. The MNRE has also prepared a draft renewable energy policy, which identifies the strategies for increased deployment of grid-connected RE technologies. The renewable energy policy statement is available in Annex 3. These policies have yet to be approved.

The Electricity Act of 2003

The Electricity Act of 2003 combines the various provisions of: (a) The Indian Electricity Act, 1910; (b) The Electricity (Supply) Act, 1948; and (c) The Electricity Regulatory Commissions Act, 1998. This was necessitated by the rapid developments in the electricity sector mainly in the areas of reforms, regulation, and technology development. The act recognizes the role of renewable energy technologies for supplying power to the utility grid as well as in stand-alone systems. Some of the important provisions in the act in this regard include:

- As per Section 3(1), the central government shall from time to time prepare the national electricity policy and tariff policy, in consultation with the state governments and the authority for development of the power system, based on optimal utilization of resources, such as coal, natural gas, nuclear substances or materials, hydro, and other renewable sources of energy.
- As per 1.0.2.2 Section 4, the central government shall, after consultation with state governments, prepare a national policy permitting stand-alone systems (including those based on renewable energy and other non-conventional energy sources for rural areas).
- As per Section 61(h), the appropriate commission shall, subject to the provisions of this act, specify the terms and conditions for the determination of tariffs and, in so doing, shall be guided by the promotion of co-generation and generation of electricity from renewable sources of energy.
- As per Section 86(1)(e), one of the functions of the state regulatory commission is to promote co-generation and generation of electricity through renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any persons and also specify, for purchase of electricity from such sources, a percentage of the total consumption of electricity in the area of a distribution licensee. Section 86(1)(e) also makes it mandatory for distribution companies to buy a certain percentage of the total energy consumption from renewable sources of energy. The State Energy Regulatory Commissions (SERCs) have been given the responsibility of determining this percentage or a quota for renewable power.
- As per Section 6, appropriate government endeavors are required to extend the electricity supply to villages and hamlets.

- As per Section 14, there is no requirement for a license if a person intends to generate and distribute electricity in rural areas.

The Energy Conservation Act of 2001

The Energy Conservation Act of 2001 includes the promotion of energy efficiency and energy conservation in the country to make power available to all Indian citizens by 2012. In this context, the Energy Conservation Act of 2001 was passed and BEE set up to carry out the various functions it envisioned. The act provides the legal framework, institutional arrangement, and a regulatory mechanism necessary to promote energy efficiency in the country.

Legal Framework for Environmental Compliance

The legal framework required for ensuring environmental compliance for a clean energy project has been briefly described in terms of "basic" requirements and "others." The basic requirements need to be met in order to obtain "Consent to Establish" and "Consent to Operate." Other requirements refer to with the use of hazardous chemicals for storage as well as planning, construction, and implementation of a project.

Plans, Guidelines, Codes, and Other Policies

The National Building Code of India (NBC) provides guidelines for regulating building construction across the country and serves as a model code for all agencies involved in building. It contains administrative regulations; development control rules and general building requirements; fire safety requirements; stipulations regarding materials, structural design, and construction (including safety); and building and plumbing services.

In March 2007, the conduct of **energy audits** was made mandatory in large energy-consuming units in nine industrial sectors. These units, indicated as "designated consumers," are also required to employ "certified energy managers" and report energy consumption and energy conservation data annually. **Energy Conservation Building Codes (ECBCs)** have been prepared for each of the six climatic zones of India. The ECBCs provide minimum requirements for energy efficient design and construction of commercial buildings, including air conditioning, lighting, electric power and distribution, and service water heating and pumping. Some of the short/long-term measures undertaken and/or proposed by BEE to catalyze energy efficiency are given below:

- Energy conservation—complete pilot phase of program for energy efficiency in government buildings and prepare action plan for wider dissemination and implementation.
- Energy audit of government buildings including complete energy audits for nine government buildings. Legal performance contract agreements, payment security mechanisms, bid selection, and evaluation criteria are provided to all building owners to support implementation.
- Capacity building among departments to upgrade energy efficiency programs—BEE will train core group members to implement energy efficiency in buildings.
- Priority measures including forming industry-specific task forces, specifying more industries as designated consumers, conducting energy audits among designated consumers, recording and publicizing best practices (sector-wise), developing energy consumption norms, and monitoring compliance with mandated provisions by designated consumers.

Over 700 **CDM projects** have been approved by the India CDM National Designated Authority, and about 240 of these have been registered by the CDM Executive Board. The registered projects have already resulted in over 27 million tons of certified CO2 emissions reductions and have directed investment in renewable energy projects by reducing the perceived risks and uncertainties of these new technologies, thereby accelerating their adoption.

The MNRE has prepared a **renewable energy plan and a national master plan** for development of waste-to-energy. In addition, the government of India adopted the **Biodiesel Purchase Policy** in 2005. This policy mandates oil marketing companies to purchase biodiesel from registered suppliers at a uniform price to be reviewed every six months. Some public sector oil companies are already experimenting with various mixes of biodiesel in state transport buses and are in discussions with the automobile industry to share results.

The National Auto Fuel Policy of 2003 provides a road map for achieving various vehicular emission norms over a period of time and the corresponding requirements for upgrading fuel quality. While it does not recommend any particular fuel or technology for achieving the desired emission norms, it suggests that liquid fuels should remain the primary auto fuels throughout the country and that the use of CNG/LPG should be encouraged in cities affected by higher pollution levels so as to enable vehicle owners to have the choice of the fuel and technology combination.

The Working Group for the 11th Five-Year Plan on Coal[11] has identified the need for energy efficiency and demand-side management. This has emerged from the various supply scenarios and is underlined by rising energy prices. The average gross efficiency of generation from coal power plants is 30.5 percent. The best plants in the world operate with supercritical boilers and obtain gross efficiencies of 42 percent. It should be possible to get gross efficiency of 38–40 percent at an economically attractive cost for all new coal-based plants. This alone could reduce the coal requirement by 111 mToe of coal (278 mt of Indian coal). The working group therefore has prioritized the development of high-efficiency coal-fired technologies, stating that all new thermal power plants should be commissioned with a certified fuel conversion efficiency of at least 38–40 percent. Power plants operating at a smaller plant load factor are required to undertake

comprehensive renovation and modernization of units/technology and, wherever possible, old plants should be replaced by higher-capacity ultra-mega power plants with supercritical technology.

The Department of Electronics and Telecommunication has proposed a special incentive package scheme to encourage investments in semi-conductor fabrication and other micro- and nano- technology manufacturing industries in India. In addition, the national and state-level industry associations have been working with the central and state governments to promote a range of policies for sustainable participation in the country's economic development.

In April 2005, the Ministry of Power introduced the **Rajiv Gandhi Grameen Vidhyutikaran Yojana (RGGVY)** Program, which aims at providing electricity in all villages and habitations by 2009. Under RGGVY, the electricity distribution infrastructure establishes a Rural Electricity Distribution Backbone with at least a 33/11-kilovolt (kV) sub-station, a Village Electrification Infrastructure with at least a distribution transformer in a village or hamlet, and stand-alone grids where grid supply is not feasible. This infrastructure should cater to the requirements of agriculture and other activities in rural areas including irrigation pump sets, small and medium industries, khadi and village industries, cold chains, healthcare and education, and communication technologies. This would facilitate overall rural development, employment generation, and poverty alleviation. Up to 90 percent of the subsidies toward capital expenditure will be provided through the Rural Electrification Corporation Limited (REC), which is a nodal agency for implementation of this program. Electrification of unelectrified below-poverty-line households will be financed with 100 percent capital subsidies at $38.00 per connection in all rural habitations. The Management of Rural Distribution is mandated through franchises, but the services of the Central Public Sector Undertakings are available to assist states in executing rural electrification projects.

Chapter 4: Opportunities for U.S. Firms in India

The geographical region, type of opportunity, and policy drivers associated with each technology are identified below. At the sector level, small hydropower, wind, and solar energy offer maximum scope for clean energy development. These sectors are relatively mature and significant local industries already exist. On the other hand, geothermal and tidal energy technologies are nascent and offer important early entry advantages to U.S. companies.

Renewable Energy Technology

Geographically, major opportunities by sector are provided in Table 1.24 below.

Specific subsectors, which offer opportunities for U.S. companies, are listed in Table 1.25.

Table 1.24: Clean Technology Opportunities by Sector

SECTOR	GEOGRAPHIC OPPORTUNITY
Small hydropower	Himachal Pradesh, Uttarakhand, Jammu and Kashmir, and Arunachal Pradesh
Wind energy	Maharashtra, Andhra Pradesh, Tamil Nadu, and Gujarat
Solar	All over India
Bioenergy	Rajasthan, Punjab, Uttar Pradesh, Maharashtra, Madhya Pradesh, Haryana, and Gujarat
Waste-to-energy	Maharashtra, Uttar Pradesh, Karnataka, Tamil Nadu, and West Bengal
Geothermal	Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and Chhattisgarh
Tidal	Gulf of Kuchch and Gulf of Cambay in Gujarat and the Delta of the Ganga in the Sunderbans region in West Bengal.
Energy efficiency	All over India

Energy Efficiency

Opportunities for U.S.-based organizations (based on proposals by the BEE) include:

- About $12 million has been allocated by BEE for development of five-year energy efficiency action plans by state-level agencies. These plans will propose interventions, which will be implemented using national/state-level funding, as well as funds from the private sector.
- BEE has requested proposals from national/international consulting organizations to assist the agency in the preparation of bankable proposals in the area of agricultural demand-side management (DSM) (pumping efficiency) for all the states within two years.
- BEE has requested proposals from national/international consulting organizations to assist the agency in the preparation of bankable proposals and to develop projects in the area of municipal DSM for all the states within two years.
- BEE has requested proposals from national and international consulting organizations to assist in the promotion of compact fluorescent lighting (CFL) and to claim certified emission reduction credits (CERs) through CDM projects.
- The State of Uttar Pradesh has solicited an expression of interest from agencies to implement CFL usage under a public–private partnership (PPP) model, where the operator can claim benefits from CERs.
- The State of Gujarat has solicited proposals for implementing municipal DSM by ESCOs.

Table 1.26 is an energy efficiency opportunity matrix prepared on the basis of policy-level attributes and geographical area of implementation.

Other Opportunities

The state governments of Andhra Pradesh, Chhattisgarh, Gujarat, and Tamil Nadu are promoting biodiesel production, including the development of state biodiesel boards and farmer buy-back schemes. In both Tanil Nadu and Gujarat, private companies are producing quality biodiesel that meets the American Society for Testing and Materials (ASTM) 16750 standard.

Incentives

An addition of 15,000 renewable MW over the next decade most likely equates to a $21 billion Indian market for renewable technologies. Renewable energy is already often competitive with conventional power sources due to fiscal policies and incentives and has been strengthened recently with the creation of a renewable portfolio standard. Income tax holidays, accelerated depreciation, duty-free imports, capital subsidies, and concessionary financing, and exemptions from electricity taxes and sales taxes all bolster this emerging market. Table 1.27 provides a summary of these incentives.

The National Electricity Policy of 2005 and Electricity Act of 2003 have given a clear mandate to the State Electricity Regulatory Commissions to promote renewable energy, including fixing a share for renewable energy–based electricity. Presently the investment decisions from a policy perspective are based on the following: buy-back tariffs, wheeling charges, whether banking of power is allowed or not, and whether third-party sales are allowed or not. The present status of issuing tariff orders and specifying quotas for renewable energy procurement in major Indian states is summarized in Table 1.28. This table also shows the attractiveness of the various states for renewable energy.

Most of these states have also specified the purchase tariff for procurement of power from different renewable energy–based projects. These tariffs have been designed on the basis of cost of generation, assuming 14–16 percent returns on equity by investors. Yet because the resource, generation, and costs of a given project vary by state, purchase tariffs also vary. The purchase tariffs for renewable energy projects in different states are presented in Table 1.29.

Fiscal and Financial Incentives

There are no direct financial incentives or subsidies for grid-connected power generation projects based on renewable energy sources. However, an interest subsidy is provided through IREDA. Present applicable interest rates for grid-connected renewable energy power generation are shown in Table 1.30.

Table 1.26: Energy Efficiency Opportunities

ATTRIBUTES	GEOGRAPHICAL AREA/ STATES
Agricultural DSM	National level
Municipal DSM	
Building energy efficiency	
Policy implementation (budget/ organization set-up/action plans)	Haryana, Gujarat, Maharashtra, Tamil Nadu, Kerala, Karnataka, Delhi

Table 1.25: Specific Technology Opportunities for U.S. Firms in India

SECTOR	TECHNOLOGY OPPORTUNITY
Small hydropower	▸ Technology for adaptation of high-pole permanent magnet excitation generators to SHP. ▸ Technology for low-speed generators (direct-drive low-speed generators for low heads). ▸ Technology for submersible turbo-generators. ▸ Technology for appropriate turbine designs suitable to electrical output below 1 MW. ▸ Technology for variable-speed operation (optimal use of low- and variable-head sites) . ▸ Technology/ projects for flexible small hydro turbines for very low head (<2.5 m).
Wind energy	▸ Latest technologies with higher capacities are needed. These technologies may include wind power systems greater than 1–2 MW. ▸ Wind machines for low-wind regimes and better designed rotor blades, gear boxes, and control systems.
Solar	▸ Technology for polysilicon and other materials. ▸ Technology for device fabrication processes and improvements in crystalline silicon solar cell/module technology. ▸ Thin-film solar cell technology (based on amorphous silicon films; cadmium telluride films and copper indium diselenide thin films; organic, dye-sensitized, and carbon nano tubes). ▸ Technology for megawatt-scale solar photovoltaic power-generating systems. ▸ Technology for solar thermal (high-temperature) power generation systems and energy efficient buildings utilizing solar energy concepts.
Bioenergy	▸ Development of megawatt-scale fluidized bed biomass gasifiers, hot-gas clean-up system, and optimum integration of the system following the principles of IGCC. ▸ Development of poly-generation facilities for the production of liquid fuels, variety of chemicals and hydrogen in addition to power production through the IGCC route, and establishing the concept of a biorefinery. ▸ Raising efficiency of atmospheric gasification to 25–30% along with cooling systems, complete tar decomposition, and safe disposal of wastes in commercial production. ▸ Raising system efficiency of small (up to 1 MW) combustion and turbine technologies to 20% plus. ▸ Design and development of high-rate anaerobic co-digestion systems for biogas/synthetic gas production. ▸ Development of gasifier systems based on charcoal/pyrolyzed biomass. ▸ Development of efficient kilns/systems for charcoal production/pyrolyzation of biomass. ▸ Design and development of engines, Stirling engines, and micro-turbines for biogas/producer gas/biosyngas. ▸ Design and development of direct gas-fired absorptive chillers, driers, stoves, etc., and improvement in biomass furnaces, boilers, etc. ▸ Engine modifications for using more than 20% biodiesel as a blend with diesel. ▸ Development of second-generation bioliquid fuels and related applications. ▸ Diversification of feed stocks to utilize alternate biomass wastes along with cattle dung for setting up household biogas plants. ▸ Methods for sustaining biogas production during winter months. ▸ Development of biogas micro-turbines and engines. ▸ Local power grids compatible with dual fuel engines and gas engines/turbines. ▸ Removal of hydrogen sulfide from biogas produced in night soil-based biogas plants. ▸ Additional treatment methods for effluent from night soil- based biogas plants.
Waste-to-energy	▸ Technology and successful demonstration of biomethanation, combustion/incineration, pyrolysis/ gasification, landfill gas recovery, densification, and pelletization.
Geothermal	▸ Technology supplier/equipment manufacturer/project developer for geothermal energy harnessing.
Tidal	▸ Technology supplier/equipment manufacturer/project developer for harnessing tidal energy.
Energy efficiency	▸ ESCOs, energy efficiency equipment for buildings/ industries.

In addition, wind energy projects and the equipment used in biomass/bagasse power generation can claim accelerated depreciation benefits in the first year of the project, providing a tax benefit for investors.

Table 1.27. Incentives for the Promotion of CETs

NO.	SECTOR	INCENTIVES/ SUBSIDIES/TARIFFS/QUOTAS
1.	All RE projects	Customs duty for RE projects under 50 MW fixed at 20% ad valorem. Central sales tax exemption. Minimum purchase rates of $0.057 per unit of electricity.
2.	SHP	10.75% interest rates (interest rate subsidy).
		Fifteen states—Andhra Pradesh, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand, and West Bengal—have declared buy-back tariffs from SHPs.
		Thirteen states—Andhra Pradesh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh, and West Bengal—have declared quotas for purchase of power from SHP.
3.	Wind power	10.25% interest rates (interest rate subsidy).
		Eight states—Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, and Tamil Nadu—have declared buy-back tariffs.
		Tax holidays for wind power generation projects. 80% accelerated depreciation on the equipment during the first year. Concessions on customs and excise duties. Liberalized foreign investment procedures. Preferential tariffs for wind power.
4.	Biomass/ bagasse/ co-generation	10.75% interest rate (interest rate subsidy) for biomass.
		11.25% interest rate (interest rate subsidy) for bagasse.
		Twelve states—Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh—have declared buy-back tariffs for bagasse.
		MNRE provides interest subsidies for co-generation projects. In addition, it provides capital subsidies to bagasse-based co-generation projects in cooperative with public sector sugar mills. State governments also provide various fiscal and financial incentives.
		MNRE provides subsidies for installation of biomass gasifier systems. Financial incentives valued at $30,000 per 100 kWe are provided for 100% producer gas engines, with biomass gasifier systems for both off-grid and grid-interactive applications. 80% depreciation on equipment during first year.
		Five-year tax break with 30% exemption for projects with power purchase agreement.
5.	Energy from urban and industrial waste	The 12th Finance Commission has recommended that at least 50% of the grants provided to ULBs through states should be utilized to support the cost of collection, segregation, and transportation of waste.
6.	Solar PV systems	Implementation of the water pumping program was continued through the state nodal agencies and IREDA. A subsidy is provided under the scheme at $75 per watt of SPV array used, subject to a maximum of about $1,200 per system.
	Solar water heating systems	GOI, through MNRE, has provided various interventions in terms of subsidies and other fiscal benefits to promote solar water heating systems.
7.	Renewable energy technologies for distributed generation	MNRE provides financial assistance for meeting up to 90% of the project costs and for comprehensive maintenance for periods up to 10 years.

Table 1.28: Status of Specified Quotas for Renewable Energy Procurement, by State

STATE	QUOTA/RENEWABLE PURCHASE OBLIGATION	TIME PERIOD
Andhra Pradesh	Minimum 5% of total energy consumption (of this, 0.5% is to be reserved for wind)	2005–2006, 2006–2007, & 2007–2008
Gujarat	Minimum 1% of total energy consumption	2006–2007
	Minimum 1% of total energy consumption	2007–2008
	Minimum 1% of total energy consumption	2008–2009
Himachal Pradesh	Minimum 20% of total energy consumption	2007–2010
Haryana	Up to 2% of total energy consumption	2006–2007
	Up to 2% of total energy consumption	2007–2008
	Up to 2% of total energy consumption	2008–2009
	Up to 2% of total energy consumption	2009–2010
Karnataka	Minimum 5% and maximum of 10% of total energy consumption	
Kerala	Minimum 5% of total energy consumption (of this, 2% from SHP, 2% from wind, and 1% from all other noncon-ventional (NCE) sources)	2006–2009
Madhya Pradesh	Minimum 0.5% of total energy consumption including third-party sales from wind energy	2004–2009
Maharashtra	Minimum 3% of total energy consumption	2006–2007
	Minimum 5% of total energy consumption	2007–2008
	Minimum 5% of total energy consumption	2008–2009
	Minimum 5% of total energy consumption	2009–2010
Orissa	3% (for wind and SHP)	2007–2008
Rajasthan	Minimum 4.88% of total energy consumption	2007–2008
	Minimum 6.25% of total energy consumption	2008–2009
	Minimum 7.45% of total energy consumption	2009–2010
	Minimum 8.50% of total energy consumption	2010–2011
	Minimum 9.50% of total energy consumption	2011–2012
Tamil Nadu	Minimum 10% of total energy consumption	2006–2009
Uttar Pradesh	5% of total energy consumption	—
West Bengal	Minimum: 1.9%	2006–2007
	Minimum: 3.8%	2007–2008

Sources: Regulations of different State Electricity Regulatory Commissions.

Table 1.30: Interest Rates of IREDA for Different Power Generation Technologies

RENEWABLE ENERGY SOURCE	INTEREST RATE (%)
Biomass	10.75
Bagasse co-generation	11.25
Small hydro	10.75
Wind	10.25

Source: Financing guidelines, IREDA. www.ireda.in

Table 1.29: Purchase Tariffs for Renewable Energy Projects by State (in dollars)

STATE/UNION TERRITORY	WIND POWER	SMALL HYDROPOWER	BIOMASS POWER
Andhra Pradesh	0.085 Fixed for 5 years	0.068 (2004–2005)	0.066 (2005–2006) Esc. at 0.01 for 5 years
Arunachal Pradesh	—	—	—
Assam	—	—	—
Bihar	—	—	—
Chhattisgarh	—	—	0.068 (2005–2006)
Gujarat	0.085 Fixed for 20 years	—	0.075 No esc.
Haryana	—	0.056 (1994–1995)	0.101 biomass 0.094—co-generation Esc. at 0.02 (base 2007–2008)
Himachal Pradesh	—	0.063	—
Jammu and Kashmir	—	—	—
Jharkhand	—	—	—
Karnataka	0.086 Fixed for 10 years	0.073	0.069—co-generation 0.072—biomass Esc. at 0.01 for 10 years (base year 2004–2005)
Kerala	0.079 Fixed for 20 years	—	0.0708 (2000–2001) Esc. at 0.05 for 5 years
Madhya Pradesh	0.100–0.083	0.056	0.084–0.130 Esc. at 0.03–0.08 for 20 years
Maharashtra	0.088 Esc. at 0.15 per year	0.0569 (1999–2000)	0.077—co-generation 0.077–0.086—biomass Esc. at 0.01 for 13 years
Manipur	—	—	—
Meghalaya	—	—	—
Mizoram	—	—	—
Nagaland	—	—	—
Orissa	—	—	—
Punjab	—	0.069 (1998–1999)	0.076 (2001-2002) Esc. at 0.03 for 5 years limited to 0.0348
Rajasthan	0.073 Esc. at 0.05 for 10 years	0.069 (1998–1999)	0.091–0.100 Water—air cooled
Sikkim	—	—	—
Tamil Nadu	0.068 (fixed)	—	0.069 (2000–2001)* Esc. at 0.05 for 9 years
Tripura	—	—	—
Uttar Pradesh	—	0.056	0.072—existing plants 0.075—new plants Esc. at 0.04 per year

Source: Government of India Ministry of New and Renewable Energy www.mnes.nic.in
Notes: * Rs. 2.48 per unit at 0.05 escalation for nine years (2000–2001) for off-season power generation using coal/lignite (subject to ceiling of 0.90 of high-tension (HT) tariff).
Policies for wheeling/ banking/ third-party sale vary from state to state.
Esc. = Escalation.

Chapter 5: Investment and Financing of Clean Energy

Investment and financing of clean energy technologies including renewable energy and energy efficiency can occur through a favorable investment and business environment supported by an adequate institutional structure. In the case of India, the business and investment climate has improved significantly in the last decade. The following section describes these changes.

Foreign Investment Policy for Renewables

Foreign investors can enter joint ventures with an Indian partner for financial and/or technical collaboration and also for the establishment of renewable energy projects. There is a liberalized foreign investment approval regime to facilitate foreign investment and transfer technology through joint ventures. Proposals with up to 74 percent foreign equity participation qualify for automatic approval and full foreign investment as equity is permissible with the approval of the Foreign Investment Promotion Board but the GOI encourages foreign investors to create renewable energy–based power generation projects on a public–private partnership basis.

Funding and Financial Mechanisms, Capital Markets, and Financial Institutions

Currently, government funding drives the financing of clean energy projects at three levels—national, state, and local (municipal). Other sources of finance include capital markets, financial institutions (national and international), and private sector finance.

Central Government

The government is responsible for policy and regulatory frameworks related to financing. The Ministry of Finance (MoF), with the help of the planning commission, is responsible for planning the budget and allocating funds to the various ministries. It provides equity for project agencies, offers guarantee mechanisms, funds programs for capacity building, promotes fiscal incentives, and fuels bond markets with government borrowing. The budgets of the line ministries have been growing during the past few years. For example, MNRE's budget increased from $39 million in 2005–2006 to $75 million in 2006–2007. These line ministries are providing financial assistance for states and districts (and organizations within them), both directly and through various programs.

State Government

The central government, together with multilateral agencies, is funding a large number of environmental projects at the state level. In many cases the states are expected to match contributions with state funding.

Local Government

Municipalities are often funded through grants, funding from the central government via state governments, state government grants, and local revenues generated through local taxes. Urban Local Bodies (ULBs) traditionally suffer from a lack of funds; typically, they receive only about 40 percent of their state funding share. This is due to deductions by state governments for items such as overdue power charges and loan payments, which result from a general lack of revenue generation. In addition, ULBs lack a system to identify and track income and expenditures.

Access to capital markets is an important way to bolster the finances of ULBs. Some of the key features in this type of financing are shown below:

- Municipal development funds have been established to enhance the viability of local development projects. Funds are often created through collaborations between an international firm a local counterpart, and the local government.
- Establishment of the City Challenge Fund (CCF), the Urban Reform Incentive Fund (URIF), and the Pooled Finance Development Fund. Presently, URIF targets selected reforms but does not finance specific infrastructure investments. CCF was designed to provide investment funding coupled with specific city-level reforms. Discussions are underway concerning integration of URIF and CCF into an Urban Infrastructure Development Fund, a much bigger fund that could provide funding to states to support large infrastructure projects. The flow of funds to the states would be linked with reforms.
- Resources have been mobilized through taxable bonds and tax-free bonds. However, only financially strong, large municipalities are in a position to directly access capital markets. For smaller ones, pooled financing is an option. The Tamil Nadu Urban Development Fund in an example of pooled financing, the objective is to fund urban infrastructure projects including water supply, sewage, and solid waste management.

Capital Markets

A vibrant, well-developed capital market has been shown to facilitate investment and economic growth. India's debt and equity markets were equivalent to 130 percent of the GDP at the end of 2005. This impressive growth, starting from just 75 percent in 1995, suggests growing confidence in market-based financing. At nearly 40 percent of GDP, the size of India's government bond segment is comparable to many other emerging market economies, and India boasts a dynamic equity market. The sharp rise in India's stock markets since 2003 reflects its improving macroeconomic fundamentals.

India's debt markets are divided into two segments: corporate and government. The government bond segment is the larger and more active of the two, with issuers comprising the central government (which accounts for 90 percent of the total) with the remainder from state governments. The corporate bond market consists of Public Sector Undertakings (PSUs), corporate bodies, financial institutions, and banks. PSU bonds far outweigh the size of private corporate bonds, reflecting a number of factors, including regulatory requirements for private issues.

India's financial market began its transformative path in the early 1990s. The banking sector witnessed sweeping changes, including the elimination of interest rate controls, reductions in reserve and liquidity requirements, and an overhaul in priority sector lending. Its market infrastructure has advanced while corporate governance has progressed faster than in many other emerging market economies. The seamless move toward shorter settlement periods has been enabled by a number of innovations. The introduction of electronic transfer of securities brought down settlement costs markedly and ushered in greater transparency, while "dematerialization" instituted a paper-free securities market. Innovative products such as securitized debt and fund products based on alternative assets are starting to break ground. Asset-backed securities (ABSs) are the predominant asset class in India's securitized segment. The ABS market has risen exponentially since 2002, in tune with the sharp growth in credit since that time. In 2005, India's ABS market volume was roughly $5 billion, making it the fourth largest in the Asia–Pacific region.

At the institutional level, the Securities and Exchange Board of India (SEBI) was established in 1992 with a mandate to protect investors and improve the micro-structure of capital markets. The repeal of the Controller of Capital Issues (CCI) in 1992 removed the administrative controls over pricing of new equity issues. Competition in the markets increased with the establishment of the National Stock Exchange in 1994, leading to a significant rise in the volume of transactions and to the emergence of new important instruments in financial intermediation. The Reserve Bank of India (RBI) has maintained its role as the government's debt manager and regulator of government-issued papers.

Development Financial Institutions and Commercial Banks

Development financial institutions (DFIs) at central, state, and municipal levels; provident funds; commercial banks; and export credit agencies provide funding for infrastructure projects. These agencies provide loans, work as financial intermediaries, arrange loans from other sources, provide guarantees, and assume advisory roles. DFIs usually provide the greatest portion of financing for large-scale projects.

Apart from debt, some of the DFIs also invest in equity. Among the types of financing available, project financing dominates the sector because of the capital-intensive nature and long gestation periods. Corporate financing is generally provided in low-risk projects with prominent corporate entities. Hybrid finance through equity/quasi-equity is occasionally provided. Bond financing is used by established infrastructure companies or authorities with the backing of central and state governments.

The major domestic DFIs operating in the clean energy sector in India are:

- Industrial Finance Corporation of India (IFCI);
- Industrial Development Bank of India (IDBI);
- Life Insurance Corporation (LIC);
- Small Industries Development Bank (SIDBI);
- Infrastructure Development Finance Company (IDFC);
- Housing and Urban Development Corporation (HUDCO);
- India Infrastructure Finance Company Ltd (IIFCL);
- L&T Finance;
- Infrastructure Leasing & Financial Services Limited (IL&FS);
- Indian Renewable Energy Development Agency Ltd (IREDA);
- National Bank for Agriculture & Rural Development (NABARD).

The power sector is the preferred investment for infrastructure financers, followed by roads and ports. In the

Financing Renewable Energy and Energy Efficiency in India

The potential offered by Indian capital markets for the financing of renewable energy and energy efficiency projects is enormous. In contrast to the government bond market, the size of the corporate bond market (i.e., corporate issuers plus financial institutions) remains very small, amounting to just $16.8 billion, or less than 2 percent of GDP at the end of June 2006. A well-developed corporate bond market would give companies greater flexibility to define their optimum capital structure. Structured finance offers immense potential. Securitization is an attractive growth segment in India's debt markets. The market is still in its nascent stages, where current activities primarily occur between banks, non-bank financial institutions, and asset reconstruction companies through private placements. Paving the way for a secondary market is the implementation of the proposed changes to the Securities Contracts Regulation Act, which would reclassify securitized debt as true marketable securities.

waste management sector, active players are HUDCO, L&T Finance, and IL&FS. The majority of DFIs are gearing to become universal banks, which allows them to access low-cost savings and offer more flexibility in terms of loan types and tenors. IREDA is a specialized DFI providing soft loans for renewable energy and energy efficiency projects. IREDA has been a major funder of wind projects since its inception. However, due to depreciation allowances and other incentives, wind power projects have become viable investments by commercial banks. Currently, IREDA's focus has shifted mostly to financing small hydropower projects, an area that is currently financed by just two commercial banks. IREDA provides financing for projects, equipment, and manufacture of equipment.

Commercial banks are increasing their exposure to infrastructure. The major banks are the State Bank of India (SBI) and its associates, ICICI Bank, Punjab National Bank (PNB), Canara Bank, Union Bank of India, Allahabad Bank, and Corporation Bank. Due to the increased involvement of commercial banks, the need for DFIs is likely to diminish. The contribution of mutual funds and pension funds in lending for renewable energy projects has yet to mature.

International Financial Institutions (IFIs)

Major financial institutions that are involved in clean energy and related activities are shown in Table 1.31.

International Finance Corporation (IFC). The IFC is a private sector lending division of the World Bank Group, which fosters sustainable economic growth in developing countries by financing private sector investment, mobilizing capital in international markets, and providing advisory services to businesses and governments. Infrastructure projects are central to IFC's investment strategy with investments in power generation (including renewable energy), distribution, transmission, and energy efficiency projects. Additionally, IFC is associated with green-field projects, corporate loans, acquisition finance, and refinancing.[12]

IFC South Asia has a $1.6 billion lending portfolio covering India, Sri Lanka, the Maldives, Bhutan, and Nepal. India alone accounts for three-fourths of this portfolio. IFC's South Asia portfolio includes:

- One-third in financial markets [ICICI, Housing Development Finance Corporation (HDFC), Shrey International];
- One-third in general manufacturing (medium and large enterprises);
- One-third in infrastructure and agribusiness (power transmission and water utilities).

IFC has recently ventured into development-based lending focused on sub-national lending to municipalities for purposes of improving energy, water, and solid waste management by municipal corporations. This represents a new and risky area for IFC, where there is no sovereign guarantee.

Asian Development Bank (ADB). According to the ADB, the bank "extends loans and provides technical assistance to its developing member countries for a broad range of development projects and programs. It also promotes and facilitates investment of public and private capital for economic and social development."[13] ADB emphasizes the acceleration of renewable energy and energy efficiency in its developing member countries, including India. In the clean energy area, ADB supports capacity building, institutional development, policy and regulatory activities, and project development. The ADB has committed $1 billion per year for renewable energy and energy efficiency over the next few years. Of special note are its efforts to catalyze local financing institutions and the private sector to participate in the delivery of clean energy services and to include modern energy access. ADB's private sector operations department has also made equity investments in several funds targeting clean energy. ADB is financing a number of clean energy–related projects in India, including energy efficiency, CDM projects on the supply and demand sides, urban infrastructure projects, hydro-electric projects, and transportation services.

USAID. USAID's work on energy development in India dates back to the 1980s and focuses on three areas: building regulatory capacity at the state level in order to implement sector reform, asset-based reform and commercial capacity building focused on utilities, and relating public policy (e.g., the Electricity Act of 2003 and the Energy Conservation Act of 2001) to business policy via practical ways to overcome market and institutional barriers. USAID has promoted new concepts in energy efficiency in both industries and buildings. The major program on energy

Table 1.31: Summary of Major Donors' Clean Development Activities

	DEMAND-SIDE EE	SUPPLY-SIDE EE	RENEWABLE ENERGY	CLEAN FOSSIL FUELS	CLEAN TRANSPORT
IFC	√				√
ADB	√	√	√		√
USAID	√	√	√	√	√
World Bank	√	√	√		√
Ex-Im		√	√	√	√

Source: USAID ECO–Asia Clean Development and Climate Program, 2006.

efficiency is the Energy Conservation and Commercialization ECO (Energy Efficiency Commercialization Project) III project.

World Bank. The World Bank has invested significant resources into energy efficiency projects including coal-fired power generation through rehabilitation [$45 million GEF, $157 million International Bank for Reconstruction and Development (IBRD)].[14] The World Bank is also supporting energy efficiency improvements in the urban sector. The Second Renewable Energy Project being implemented supports both renewable energy and energy efficiency. The project provides a financial intermediation loan of $200 million to IREDA, which will be lent to private companies to finance numerous small renewable energy projects. Sub-projects will be primarily for electricity generation and will include biomass power generation; co-generation at sugar refineries; and small hydropower, windmill power, solar PV power, and solar thermal projects. The project also includes a technical assistance component, which involves training and capacity building of energy managers, bankers, and the building sector. Further, it supports demonstration projects in the building sector. A new programmatic CDM effort with $75 million in GEF financing for India has also been launched by the World Bank.

Private-Sector Participation

The private sector is involved in implementation of Build, Own, Operate, and Transfer (BOOT) and Build, Own, and Operate (BOO) Projects. These models are actively followed in the small hydropower sector as evidenced in Uttarakhand, where clear guidelines have been defined by the government. The GOI is also promoting public–private partnerships (PPPs) in infrastructure development, including waste- to-energy and solid waste management. PPP projects with at least 51 percent private equity receive support from this facility through viability gap funding, reducing the capital cost of projects and making them attractive for private sector investment. Viability gap funding can take various forms, including capital grants, subordinated loans, O&M support grants, and interest subsidies. The total government support required by the project must not exceed 20 percent of the project cost. The projects may be proposed by any public agency at the central or state level, the ULB that owns the underlying assets, or a private agency, with sponsorship from the relevant central or state government agency. The government has also set up a special-purpose vehicle—India Infrastructure Finance Company Limited (IIFCL)—to meet the long-term financing requirement of potential investors involved in PPPs. The majority of companies involved in PPPs to date have been mostly domestic. This trend indicates the increasing participation of domestic companies and paves the way for foreign companies to enter through either joint ventures or equity participation.

Several development agencies and Indian financial institutions have already joined with state governments to promote environmental infrastructure development and facilitate private participation. Examples from the urban infrastructure sector include the Tamil Nadu Urban Development Fund, the Project Development Corporation (PDCOR) in Rajasthan, and iDeck in Karnataka. Fifty-Five ULBs have invited some form of private participation in solid waste management. Currently, most waste-to-energy projects are heavily dependent on subsidies provided by MNRE and financial institutions such as HUDCO.

Business Environment

The business environment in the context of clean energy can be explained in terms of subsidies and partially controlled regimes regulating the fossil-fuel-based energy supply.

Coal

Coal pricing has been decontrolled, but wholesale restructuring of the coal sector is still being debated. Coal continues to be included in the Essential Commodities Act of 1955 but can be freely imported under open general license (OGL). The pricing of coal was fully deregulated after the updated Colliery Control Order of 2000 went into effect on January 1, 2000. Since then, coal prices have been fixed on a cost-plus basis.

Oil, Gas, and Natural Gas

Crude oil prices have also been deregulated, allowing domestic exploration and production companies to negotiate with the refiners on the price of crude oil. The GOI has successfully implemented a new exploration licensing policy and now allots both national and international companies exploration blocks. With the dismantling of administered pricing mechanisms (APM) in April 2002, prices of petroleum products were linked to international markets. Since then, some of the trends that have emerged include:

- Petroleum products except diesel, kerosene, and liquefied petroleum gas (LPG) are governed by international prices.
- The government decreased the customs duty on petrol and diesel from 10 to 7.5 percent.
- The government has encouraged the import of liquefied natural gas (LNG) by placing it under the OGL list and permitting 100 percent foreign direct investment (FDI).
- There is no uniform method for determination of gas prices. With deregulation of the gas market, both market-determined and administered pricing coexist in the sector. Gas sold by national oil companies from the pre–New Exploration and Licensing Policy (NELP) blocks is under APM prices. In June 2006, under APM the revised prices for these categories were Rs 3840/million standard cubic meters (MMSCM) for general consumers and Rs 2304/MMSCM for northeast consumers. The gas produced under the NELP blocks

can be sold at market-determined prices. These prices are decided on the basis of the production-sharing contracts and the gas sales agreement.

Biodiesel

Since January 1, 2006, public sector oil companies are mandated to purchase biodiesel. Twenty purchase centers have been identified where companies can purchase biodiesel that meets the standards prescribed by the Bureau of Indian Standards. The initial purchase price is about $6 per liter, which may be reviewed by the companies every six months.

Ethanol

The Indian Oil Corporation Ltd. has finalized a deal to source ethanol from sugar mills at $0.47 per liter ex-distillery, which was calculated on the basis of bids quoted.

Clean Energy

The broad policy framework for financing clean energy is formulated by the central government and is implemented at the state level by nodal agencies. Each state provides token or matching contributions to facilitate clean energy project development and implementation. The Electricity Act of 2003 mandates that the SERCs promote generation of electricity from non-conventional sources by providing suitable measures for connectivity with the grid and sale of electricity to any person and also by specifying, for purchase of electricity from such sources, a percentage of the total consumption of electricity in an area. Thirteen states have determined quotas for procurement of renewable energy as shown in Table 1.27. SERCs are now determining preferential tariffs for renewable electricity. Sixteen states have policies in place for private sector participation. The tariff policy has entrusted responsibility to the SERCs to lay down guidelines for pricing non-firm power, especially from non-conventional energy sources.

Tariffs

Fifteen states—Andhra Pradesh, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand, and West Bengal—have declared buy-back tariffs from SHPs. Eight states—Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, and Tamil Nadu—have issued orders for determining tariffs from wind power. Finally, 12 states—Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, and Uttar Pradesh—have issued orders for determining tariffs from biomass.

Financing and Subsidies

Financing and subsidies are available for all the sectors of clean energy. Descriptions for each sector of clean energy are given below.

Small Hydropower

Currently, most SHP capacity additions are being achieved through private investment. State Nodal Agencies for renewable energy provide assistance for obtaining necessary clearances in allotment of land and potential sites. The MNRE has been providing subsidies for public sector as well as private sector SHP. For the private sector, the subsidy is released to the participating financial institution after successful commissioning and commencement of commercial generation from the project. The subsidy is provided as an offset against the term loan provided to the developer. To ensure quality, equipment used in projects is required to meet international standards. Projects are also required to be tested for performance by an independent agency in order to receive the subsidy. Various financial institutions, namely, IREDA, Power Finance Corporation (PFC), and the REC, provide loan assistance for setting up small hydropower projects. In addition to these agencies, loans are also available from IDBI, IFCI, ICICI, and some nationalized banks.

Wind Energy Systems

Several financial and fiscal incentives are available to wind energy systems, including:

- Tax holidays for wind power generation projects;
- Eighty percent accelerated depreciation on the equipment during the first year;
- Concessions on customs and excise duties;
- Liberalized foreign investment procedures;
- Preferential tariffs for wind power.

Major national financial institutions such as IDBI, ICICI, REC, and PFC also finance wind power projects.

Bagasse-based Co-generation

MNRE provides interest subsidies for co-generation projects. In addition, it provides capital subsidies to bagasse-based co-generation projects in cooperative with public sector sugar mills. State governments also provide various fiscal and financial incentives.

Biomass Gasifiers

MNRE provides subsidies for installation of biomass gasifier systems. Financial incentives valued at $30,000 per 100 kWe are provided for engines using 100 percent producer gas, with biomass gasifier systems for both off-grid and grid-interactive applications.

Energy from Urban and Industrial Waste

The 12th Finance Commission has recommended that at least 50 percent of the grants provided to ULBs through states should be utilized to support the cost of collection, segregation, and transportation of waste. This will facilitate operation of waste-to-energy projects.

Solar Photovoltaic Systems

Implementation of the water pumping program was continued through the state nodal agencies and IREDA. A subsidy is provided under the scheme at $75 per watt of solar PV (SPV) array used, subject to a maximum of about $1,200 per system.

Solar Water Heating Systems

Considering the vast potential and resource availability, the GOI, through MNRE, has provided various programs in terms of subsidies and other fiscal benefits to promote solar water heating systems.

Renewable Energy Technologies for Distributed Generation

To meet the electricity needs of villages, the Remote Village Electricification (RVE) Program utilizes solar, biomass, small hydro, wind, and hybrid combinations for decentralized and distributed generation of power and supply of electricity locally. Under the program, MNRE provides financial assistance for meeting up to 90 percent of the project costs and for comprehensive maintenance for periods up to 10 years. The Rural Electrification Corporation and the RVE Program of MNRE are the two national-level schemes that complement each other in achieving national electrification targets.

Effects of Financial Incentives of Clean Tech Costs

The effect of the incentives and tax regimes on the capital costs and delivered costs of renewable energy from various sources is provided in Table 1.32.

Table 1.33 below shows that, in general, the loan disbursements by IREDA have been declining since 2001, although in 2006–2007 there was an increase. Even in 2006, however, the share of IREDA financing was less than in 2001. This is an indicator that other mainstream financial institutions (FIs) have started financing renewable energy projects, and their share is increasing. This is the result of two factors: (1) interest rates now offered by IREDA at the same rate as those offered by other FIs meaning the market is beginning to decrease the risk associated with renewable projects, and (2) renewable power generation is now seen as a mature sector in India. These new FI loans are typically based on a number of traditional issues like strong project sponsorship, appropriate contractual structure, proven track record of equipment suppliers, appropriate fuel supply agreements, cost competitiveness and project viability on a stand-alone basis, and adequate mitigation of off-take, payment risk.

General financing trends of renewable energy and energy efficiency projects currently emerging from the commercial banks can be summarized as follows:

- High debt/equity ratio of about 2:1.
- Increasing trend of financing on a non-recourse/limited recourse basis. This is attributed to the evolution of the contractual framework in implementing renewable energy projects.
- Long project implementation period of two to four years. This implies a delay in equity returns and a moratorium period for principal repayment.
- Longer repayment period (10–15 years) of maturity of debt.

The above trends indicate that, though commercial banks have started offering loans for renewable energy projects, the market for renewable energy investments must to continue to evolve.

Environment Related to Procurement and Contracts

Financing instruments facilitating export and import trade are quite developed at both the national and the state levels, where instruments such as letters of credit (LCs), security deposits, and bank guarantees are extensively used during export and import of services and products. Standard contractual guidelines formulated by the GOI have evolved over many years and have been modified since liberalization started in the early 1990s. These are also applicable for renewable energy and energy efficiency projects.

Procurement of services and products in specialized sectors follows open international and national competitive bidding (ICB/NB) procedures at both the national and the state levels. Increasing participation of international firms is an indicator of transparent procurement practices. Procurement by national and

Table 1.32: Cost of Renewable Power Generation, 2005

TYPE	CAPITAL COST ($/KW)	DELIVERY COST (CENTS/KWH)
Small hydro	900–1300	5–6
Wind energy	950–1100	6–7
Biomass power	800–1000	5–6
Bagasse co-generation	600–800	4.5–5.5
Biomass gasification	600–800	5–6
Solar PV	5000–6500	19–40

Source: MNRE, 2005.

Table 1.33: Annual Loan Disbursements by IREDA (million $)

	2001	2002	2003	2004	2005	2006
Wind energy	75.4	31.3	30.9	24.1	14.0	73.9
Small hydro	20.4	19.9	31.4	19.1	17.5	20.7
Bagasse co-generation	41.9	28.9	37.2	6.6	6.5	1.7
Solid biomass	31.4	23.1	25.0	9.2	7.9	78.7
Waste-to-energy	0.2	2.7	7.5	0.5	0.5	0.00

Source: Government of India, Annual Reports of Ministry of New and Renewable Energy, 2000–2001 to 2006–2007.

state governments through bidding procedures is subject to standard guidelines set by the Central Vigilance Commission (CVC), an independent national agency responsible for checking corruption in the procurement process. Recent implementation of the Right to Information (RTI) Act at both the national and the state levels has further assisted in ensuring transparency in procurement.

Increasing implementation of projects under public–private partnerships—with developed concession/revenue-sharing contractual agreements and securitization of payments through escrow accounts—is an indicator of the developing market. Standardization due to experience in developing and implementing power purchase agreements (PPAs) is another indicator. In addition, performance guarantees and liquidated damages are now being included in the standard contractual mechanism, as is an arbitration clause that takes recourse to the United Nations Commission on International Trade (UNICITRAL) or other international mechanisms, to provide a safeguard mechanism. ESCO financing is yet to emerge owing to scattered and unconsolidated energy efficiency markets. However, it is expected to evolve in future years as the efficiency market is more consolidated.

Increasing non-recourse financing through project financing is seen in the renewable energy sector. The major characteristics and stakeholders of this type of financing are given below:

- **Sponsors/Equity Investors:** Project sponsors generally hold at least 51 percent of the equity component either directly or indirectly. If the sponsor is holding less than 50 percent, then other investors are equipment procurement and construction (EPC)/O&M contractors/fuel suppliers and/or other investors seeking sufficient return.
- **Lenders:** Lenders often require project sponsors to have a strong track record in implementing similar renewable energy projects.
- **Power Off-taker/Purchaser:** The banks require a significant portion of power be tied up through a long-term PPA, while a certain portion is kept for merchant sale. This will further evolve as the recently constituted national-level power exchange starts functioning.
- **Fuel Supplier (not applicable in the case of wind energy and small hydropower projects):** The Fuel Supply Agreement provides the contractual basis for the supply of fuel to the power project. "Take or Pay" contracts provide a degree of comfort level to lenders for mitigating the risk of fuel supply and fluctuation in fuel prices.
- **Equipment Procurement and Construction (EPC) Contractor:** The lenders require EPC contracts to be awarded to reputable firms with successful track records to a more manageable risk.
- **Operation and Maintenance (O&M) Contractor:** The capability, capacity, and reputation of the O&M contractor are very important and will be evaluated by bankers.

Patent Enforcement

In India, patent legislation is governed by the Patent Act of 1970, which provides for the enforcement of patents by way of lawsuits for infringement. In dealing with these suits, the Indian courts follow the traditional principles and procedures of civil litigation. However, after enforcement of the Trade-related Aspects of Intellectual Property Rights (TRIPs) Agreement [the intellectual property component of the Uruguay round of the General Agreement on Tariffs and Trade (GATT) Treaty] since 1995, various methods have been adopted to improve the enforcement measures with regard to patents. The differences between TRIPs and the Indian Patent (IPA) Act of 1970 are provided in Table 1.34.

- Subsequent to its obligations under the TRIPs Agreement, the Indian Parliament introduced various amendments in the Patent Act and the corresponding Patent Rules in 2002 (also in 2005 and 2006).

According to the amendment, the defendant in a suit for infringement would be expected to prove his innocence rather than the plaintiff proving his guilt.

Institutional Changes

The government is also revamping the Offices of the Controller General of Patents, Designs, and Trademarks. Modernization and computerization are being carried out in the patent offices, speeding up the legal process. The patent offices are being upgraded with the use of the Patent Information System (PIS), based in Nagpur. This new patent law has brought the Indian patent regime further in line with international norms. The changes provide new and powerful incentives for investment,

Table 1.34: Differences Between TRIPs and the Indian Patent Act (IPA)

TRIPS	IPA
Grant of patent prescribes three conditions; if satisfied, both process and product patents to be granted in all industries. Duration of patent is uniform, a 20-year duration.	Only permits process patents for food, medicines, drugs, chemicals, micro-organisms, and seeds. Duration of patent is five years from date of sealing or seven years from date of patent.
For compulsory patents, license can be given only in the case of national emergency.	For compulsory patents, an application can be made after three years from grant of patent.
For life-form patents, patenting of micro-organisms and non-biological, and micro-biological processes is required.	For life-form patents, patenting of life forms or farming techniques Is prohibited.
Onus of proof is on the infringer or the defendant.	Onus of proof lies on the patentee or applicant.

both foreign and domestic. The operation of the patent offices in handling patent applications has also been improved. A patent can now be granted in less than three years, as opposed to an average of five to seven years just a few years ago.

Enforcement Measures Available under the Indian Law

The patentee may file an action for patent infringement in either a District Court or a High Court. Whenever a defendant counterclaims for revocation of the patent, the suit along with the counter claims is transferred to a High Court for the decision. Because defendants invariably counterclaim for revocation, patent infringement suits are typically heard by a High Court only. According to patent law in India, the High Court may allow the patentee to amend the application in order to preserve the validity of the patent. In such an event, the applicant must give notice to the Controller, who may be entitled to appear and be heard and shall appear if so directed by the High Court.

If a patentee is successful in proving its case of patent infringement and if the defendant does not comply with the judgment, a petition for contempt of court can be filed. Contempt of court is a criminal offense, while patent infringement is a civil offense. In the event of contempt of court, Indian law provides for imprisoning the authorized person(s) of the defendant. It is also possible to obtain a preliminary injunction, although the above-noted judicial backlog should be considered. The basis upon which a preliminary injunction will be granted is whether the plaintiff shows a prima facie case and also whether the balance of "convenience" is in the plaintiff's favor. However, an important consideration before enforcing a patent in India is to ensure the patentee has worked the invention directly or through its licensees in India.

Current Trends in Clean Energy Financing

Investment opportunities for renewable energy and energy efficiency are available for corporate users of power, long-term investors in power, promoters of clean power, and potential pollution traders or CER traders. Private sector companies can set up enterprises to operate as licensee or generating companies. A foreign investor can enter into a joint venture not only for renewable energy devices or products, but also for manufacturing renewable energy–based power generation projects on a build, own and operate basis. Investors are required to enter a power purchase agreement with the affected state. Various chambers of commerce and industry associations in India provide guidance to the investors in finding appropriate partners.

In addition, it is possible to set up a manufacturing plant as a 100 percent export-oriented unit (EOU). Generally, these are permitted import of raw materials and components duty free and are eligible to sell up to 20 percent of their production in domestic markets.

Table 1.35 above provides an overview of emerging trends in renewable energy financing. Other considerations in terms of investment opportunities include:

Table 1.35: Emerging Trends in Renewable Energy Financing

Existing Approach	Emerging Trends
Conventional lending through debt and equity	**Financing through:** Subordinated debt Private equity (PE) funds Insurance companies
Debt through rupee term loans	**Inflows through:** External commercial borrowings External credit agencies Multilateral lending agencies
Limited exit options for lenders	"Buy-out" clause in concession agreement
Difficult risk mitigation mechanism	Innovative financial engineering for risk mitigation

- The MNRE is promoting medium, small, mini-enterprises, and micro-enterprises for manufacturing various types of renewable energy systems and devices.
- No clearance is required from the Central Electricity Authority (CEA) for power generation projects up to $25 million.
- A five-year tax holiday is allowed for renewable energy power generation projects. A customs duty concession is available for renewable energy spare parts and equipment, including those for machinery required for renovation and modernization of power plants.
- Opportunities exist for enhancing manufacturing capacity of different end-use applications of renewable energy technologies through low-cost, proven devices and systems produced on a mass scale.
- Opportunities exist for Indian companies in joint ventures in the production and services related to wind electric equipment, particularly investment in power generation, as developers/project promoters and consultants and in O&M, monitoring, and inspection.
- Financial assistance exists for innovative demonstration projects for generation of power from municipal solid waste and for selected industrial waste.
- Financial assistance is available for up to 50 percent of the incremental cost for generation of power from biogas.
- A number of companies have entered into joint ventures with leading global PV manufacturers. There are no specific conditions laid down by MNRE for the formation of joint ventures. General conditions established by the Ministry of Industry, Secretariat for Industrial Approvals, and the RBI are applicable for this sector.

Chapter 6: Barriers to Clean Energy Trade and Investment for U.S. Firms

Although clean energy technologies are a strong and growing industry in India, a number of barriers continue to stymie the competitiveness of American companies.

Policy Barriers

Perceived Lack of Coordination/Integration of Policy. India has a centralized energy sector that is dominated by state-owned enterprises. In this context, there appears a perceived lack of coordination/integration regarding renewable energy and energy efficiency policies that applies across Indian government ministries, states, and sub-sectors. Policies are often unclear and inconsistent between local and central government agencies and across line ministries charged with creating and implementing policies related to renewable energy, energy efficiency, power, and climate change. Further, there is a lack of clear and consistent long-term policy.

Market Distortions of Fossil Fuels versus Renewables. The major distortions are lack of accounting for externalities (both environmental and socioeconomic) in conventional fossil fuels, price distortions, uneven subsidies and tax structures, and capital cost accounting versus life-cycle accounting. Some distortions may arise due to uneven price setting across and within sub-sectors, lack of price level guarantees, and lack of price rationalization.

Weak or Unclear Legal/Regulatory Environment. The enforcement of the legal and regulatory environment in India is a significant barrier for private sector participation in the renewable energy market. Informal governance based on social relationships and reciprocity emerges from a long and complex legal process and lack of legal enforcement. Regulatory issues such as time delays and complexity in the permitting and sitting of projects pose additional legal and regulatory hurdles. The legal and financial disclosures made by firms are not monitored as there are few robust established or enforced systems for monitoring systems in place. This gap in monitoring systems creates a lack of credibility for potential joint ventures, mergers and acquisitions, and investment inflows. In general, renewable energy policy targets are not mandatory (and thus carry no penalty) and are not enforceable from a regulatory perspective.[15]

Confusion in Implementation of Renewable Energy Projects/Need for Standardization. There is considerable confusion at the state level regarding implementation of the Electricity Act and requirement for a renewable energy portfolio standard to be institutionalized by each SERC. In some states the RPS is higher, while in others there are preferences for specific types of renewable energy. In most states there are price differentials in the power purchase tariffs that each distribution licensee must follow when meeting their RPS. Given these differentials, there is a need for minimum standardization in setting the power purchase price.

Lack of Policy Guidelines for Waste-to-Energy Projects. In waste-to-energy projects, there is lack of clear policy guidelines from state governments with respect to allotment of land, supply of garbage, power purchase arrangements, and evacuation facilities.

Lack of Strategic Review of Energy Efficiency at the National and State Levels. In the energy efficiency sector, there is a lack of strategic review to assess priorities for initiatives on energy efficiency development in the future. There thus appears to be a lack of focus for sustained, multi-year attention on the implementation of the policy initiatives and market-oriented investment mechanisms that can provide the most significant energy efficiency contributions. A long-term strategy with prioritized areas of intervention will lead to future investment pipelines. At the sub-national level, most of the state-designated agencies for energy efficiency have been formed fairly recently. They therefore lack capacity and infrastructure to develop state-level action plans for future implementation, and, as a result, no areas for energy efficiency interventions have been prioritized in the states.

Investment Barriers

Investment barriers include a general lack of access to affordable capital, the reasons for which are described below:

Payment Security. During the early to mid-1990s, a number of U.S. companies encountered difficulties recovering their costs of investment in power plants in India owing to non-payment. Most resulted in divestment and bankruptcy. At that time there was a sovereign guarantee in place by the government of India that in the event of default by any of the payees, the GOI would step in and ensure that the payments were made by the government. This policy is no longer in place. The act in force at the time was the Electricity Act of 1948. At the time the state electricity board was the sole purchaser of all electricity generated.

Since that time, regulatory commissions have been established through the Regulatory Commissions Act of 1998, which gave state and central regulatory commissions the power to set tariffs and make clear distinctions between the state (as the owner of the assets) and the companies (those who operated the assets). The states were requested to issue policy directions on tariffs, but the final tariff was set up by the regulatory commissions at the state and central levels.

The Electricity Act of 2003 deregulated the generation, transmission, and distribution of electricity and opened access universally. The act removed the obligation of power companies to sell all their electricity to monopolistic state-owned utilities and allowed them to sell power to any entity anywhere in India. Because there are now several generation and distribution entities at the central and state levels, the generators can also decide to sell the electricity to any of these entities.

Following the enactment of the Electricity Act, power trading companies and power exchanges have been created to sell excess power throughout the country. Credit rating agencies are now independently rating utilities and state electricity boards, on the basis of which financial institutions invest in the projects. The entire securitization is now based on market risk resulting in a more fluid, economically beneficial situation for the sale of electricity.

Project Developer Risks. Due to the higher ratio of initial capital costs to operating costs for many renewable energy projects, there is a need for longer-term financing instruments at affordable rates. As most of these projects are small scale, they often do not attract commercial financing structures for a number of reasons. First, projects are predominantly balance sheet funded based on the creditworthiness and strength of the borrower rather than on merits of the project. Second, borrowers are typically exposed to unlimited personal liability, if they are able to obtain the required financing. And third, renewable energy technologies are often new to project developers and sponsors, and this lack of experience can lead to higher completion and operational risk, further reducing the creditworthiness of the potential borrower, resulting in higher transaction costs.

Financiers' Unfamiliarity. Banks often provide funding to their existing customers on the basis of past relationships, trust, and credit history. They are typically hesitant to extend financing to new and unfamiliar clients. This occurs because of the weak regulatory environment and lack of legal enforcement, where they have no firm guarantee of legal recourse. Further, the type of projects tends to be newer to banks and financiers, leading to higher-risk perceptions and hesitation to extend debt to clients without a credible and established relationship.

Lack of Equity. Domestic and international venture capital and private equity investors have comparatively little expertise in investing in the Indian clean energy sector. Therefore, small-scale renewable energy project sponsors lack sufficient personal funds to invest as equity in the project or as collateral for banks to extend credit. Start-up and early-stage growth capital therefore often comes from project sponsors or developers and their acquaintances, limiting the amount of capital and creating informal governance mechanisms.

Lack of Long-term Loans. Long-term loans have not been made available to renewable energy projects because banks face a mismatch in asset liability management (ALM). Financial institutions such as insurance companies or pension funds that do not face ALM issues are not very active in the area of infrastructure financing thanks to limited institutional capabilities.

Limited Reach of Bond Market. Bond markets, which offer long-term loans at fixed rates, actively trade in government securities and AAA-rated companies. The secondary markets have very limited liquidity for other securities, thereby offering major constraints to finance projects through bonds.

Consumer Finance. On the consumer side, Indian retail finance and microfinance are in their infancy. The initial capital cost to install renewable energy systems is often prohibitive without tailored finance packages, which currently do not exist. Due to the distributed nature of end-users of distributed generation technologies, they often reside outside of the formal credit system, thus creating creditworthiness issues at the consumer level.

Constraints in External Commercial Borrowing (ECB) for Debt. The major constraints in availing ECBs include refinancing of rupee term loans by ECBs, absence of ECBs having tenor beyond five to seven years, inflexibility to prepay loans beyond $400 million, and the inability of Indian banks to act as financial intermediaries for ECB.

There are a number of financial risks and uncertainties associated with renewable energy, such as the intermittent nature of renewable energy generation, early-stage technology performance, reliable off-take, consistent policy, and expertise at the management and implementation levels. Due to insufficient returns on investment from gaps in policy implementation, immature market conditions, and uncompensated risks, there is a lack of appropriate and much needed risk management instruments to offset traditional project risks. Further, insurance is not currently offered for non-performance, technical failure, or indemnity, and no risk premium has yet been built into financial mechanisms or pricing structures.

Market distortions and uneven fiscal incentives are significant barriers to commercial viability of renewable energy adoption and development. The government continues to support fossil fuels with subsidies, regulations, and laws that benefit conventional energy generation. The major consumer of coal is the power sector, which is heavily regulated and cannot raise electricity tariffs in tune with increases in fuel costs. As a consequence, coal prices have not been allowed to change freely in order to protect the power sector from potential high fuel prices. The fear of rising electricity generation costs and a resultant hit to the economy has made deregulation difficult in practice. This situation highlights the inherent

problems in the pricing and regulation of the coal sector in India, the complexities caused by a non-transparent subsidy to the power sector, and an imposed monopoly in the mining sector. At the time of dismantling of the APM, it was thought that subsidies on kerosene and LPG would be gradually phased out. However, after four years of dismantling, the subsidies on kerosene and LPG continue to exist.

Additional reasons for higher RE project costs include the following:

- Failure to account for environmental and socioeconomic externalities in the price of conventional fossil fuel energy sources.
- Non-recognition of RE portfolio value in price stability.
- Subsidies and tax structures on fossil fuels, which make energy portfolios heavily biased toward conventional forms of energy.
- Energy generation project costs are often viewed in cost-per-unit basis ($/MW installed) rather than on a life-cycle accounting basis, which includes initial cost, fuel cost, operation and maintenance cost, equipment lifetime, and decommissioning cost.

Carbon finance uncertainty also presents a barrier to American firms. Renewable energy projects have the *potential* to create a substantial revenue stream through Clean Development Mechanism (CDM) credits issued under the Kyoto Protocol. India has registered roughly 35 percent of all global CDM projects, a market that is very likely to grow. If a post-2012 agreement on climate change can be reached, carbon credits will become an even more financially rewarding venture.

Patent enforcement should also be considered a challenge for foreign firms, who generally lack the understanding of Indian legal structure and judicial precedent. These features include: no time frame prescribed for legal recourse; no criminal remedy available for infringement of patents, as opposed to that of copyrights, etc; and a backlog of patent applications.

Conclusion

Today, India is one of the fastest growing markets for clean energy technologies, offering a number of advantages that include:

- A strong industrial base and fast growing economy;
- Availability of skilled, relatively cheap labor;
- One of the world's largest renewable energy programs;
- A dedicated federal ministry to support renewable energy (MNRE) and the only government financial institution exclusively supporting renewable energy and energy efficiency (IREDA);
- A vast, untapped consumer base;
- Favorable government policy environment (national and state);
- Low inflation and moderate tax rates;
- Financial and fiscal incentives;
- Diversified domestic and international financing sources;
- A strong and growing carbon finance market.

By 2012—the completion of the 11th Five-Year Plan—the GOI has targeted 10 percent power generation from installed capacity to come from renewable energy sources, with a 4–5 percent share in the electricity mix. This should translate into a seven-fold market increase for renewable power generation – from $3 billion today to more than $21 billion by 2012. Even under the realistic assumption of 50 percent growth, the market would be $11 billion by 2012. India's rich renewable energy resource endowment provides opportunities across a spectrum of technologies—biomass, solar PV, solar thermal, wind, hydropower, solid and industrial waste-to-energy, geothermal, and tidal energy – that incentivize foreign investment and foreign expertise.

Further, a $2 billion market for energy efficiency technologies is anticipated, targeting energy-intensive industries such as cement, aluminum, fertilizers, pulp and paper, petrochemicals, and steel. India offers a number of prospects for U.S. firms, including research, development, and demonstration; technical collaborations; product and equipment sales; project design, development, and promotion; power generation and production; O&M; project monitoring; carbon finance/trading; and consulting services. Opportunities for foreign investors include equity participation in joint ventures with Indian partners, foreign direct investment, technology transfer, and establishment of manufacturing facilities or power projects.

Though barriers exist from technology, policy, and investment perspectives, India promises to be one of the largest markets for clean energy in the future, and U.S. companies have a significant role to play in both trade and investment in this rapidly expanding marketplace.

Annex 1. Major Market Players in India

Wind Electric Generators Installed in India, by Manufacturer

MANUFACTURER	RATING (KW)	NUMBERS	CAPACITY (IN MW)
ABAN–Kenetech	410	231	94.71
AMTL–Wind World	220	2	0.44
	250	328	82
	500	3	1.5
BHEL	55	16	0.88
	200	17	3.4
BHEL Nordex	200	79	15.8
	250	184	46
C-WEL	250	57	14.25
	600	2	1.2
Danish Windpower	150	12	1.8
Das Lagerwey	80	9	0.72
	250	284	71
Elecon	200	1	0.2
	300	51	15.3
	600	5	3
Enercon	230	451	103.73
	330	38	12.54
	600	681	408.6
	800	435	348
GE Wind Energy	1500	12	18
Himalaya	140	4	0.56
	200	24	4.8
JMP-Ecotecnia	225	10	2.25
Kirloskar–WEG	400	8	3.2
Micon (Pearl)	90	99	8.91
Mitsubishi	315	6	1.89
Nedwind-Windia	250	4	1
	500	20	10
	550	35	19.25
NEG Micon	750	674	505.5
	950	54	51.3
	1650	137	226.05
NEPC India	225	957	215.325
	250	16	4
	400	7	2.8
	750	12	9
NEPC-Micon	55	14	0.77
	110	2	0.22
	200	50	10
	225	589	132.53
	250	528	132
	400	121	48.4
	600	2	1.2
Pegasus	250	9	2.25
Pioneer Asia	850	35	29.75
Pioneer Wincon	110	10	1.1
	250	260	65
	755	1	0.76
REPL-Bonus	55	22	1.21
	100	1	0.1
	320	60	19.2
RES-Advanced Wind Turbine	250	80	20
Sangeeth–Carter	300	25	7.5
Suzlon	270	2	0.54
	350	836	292.6
	600	15	9
	1000	81	81
	1250	1255	1568.75
	2000	1	2
Tacke	250	4	1
	600	21	12.6
	750	1	0.75
Textool-Nordtank	300	65	19.5
	550	5	2.75
TTG/Shriram EPC	250	230	57.5
Vestas–RRB	55	31	1.71
	90	21	1.89
	100	5	0.5
	200	56	11.2
	225	735	165.375
	500	562	281
	600	65	
Wind Master	200	1	0.2
Windmatic	55	30	1.65
Wind Power	330	29	9.57
TOTAL		10825	5340.96

Source: http://mnes.nic.in/

Hydropower Manufacturers

SHP Turbine/Equipment Manufacturers

NAME AND ADDRESS	TELEPHONE	FAX
M/s Bharat Heavy Electricals Ltd. Piplani, Bhopal–462022	0755 546100, 540200	0755 540425
M/s Bharat Heavy Electricals Ltd. Hydropower Commercial Integrated Office Complex Lodi Road New Delhi–100 003	011 4698167, 4618215	011 4626555, 4618837
M/s Boving Fouress (P) Ltd. Plot No. 7, KIADB, Industrial Area Bangalore–562114	08111 71263, 71455	08111 71399, 080 8395176
M/s VA Tech. Escher Wyss Flovel Ltd. 13/1, Mathura Road Faridabad–121 003	011 274319	0129 274320
M/s Jyoti Ltd. Industrial Area, P.O. Chemical Industries, Vadodara–390003	0265 380633, 380627, 381402	0265 380671, 381871
M/s Steel Industrials Kerala Ltd. Silk Nagar, Athani P.O., Trissur Kerala–680771	048795 7335, 7360, 7735	0487 40451 Public Call Office, 048795 7732
M/s The Triveni Engg. Works Ltd. D-196, Okhla Industrial Area, Phase-I New Delhi–110020	6811878, 6812930, 6819015	011 6819857, 6818216
M/s Kirloskar Bros. Ltd. Udyog Bhawan, Tilak Road, Pune–411002	0212 453455	0212- 32780, 434198, 431156
M/s HPP Energy (India) Pvt. Ltd. F-85 East of Kailash New Delhi–110 065	6289017/18/20/16	011 6289019, 6192787
M/s Alstom Projects Pvt. Ltd. Chandiwala Estate Maa Anand Mai Ashram Marg, Kalkagi New Delhi–110 019	011 251811100, 011 26826180	
Flovel Energy Private Ltd. 14/3, Mathura Road Faridabad–121 003	0129 4088800, 2252803	
Schneider Electric India Pvt. Ltd. A-29, Mohan Cooperative Indl. Estate Mathura Road, New Delhi–110 044	011 41590000, 41678011	
Voith Siemens Hydro Pvt. Ltd. Hydropower Generation 201, 1st Floor, Okhla Industrial Estate, Phase-III New Delhi–110 020	011 51615385, 51615389	
Ushamil Hydro System (P) Ltd. A-292, Mahipalpur Extn., NH 8 New Delhi–110 037	011 30623740-47	

Wind Energy Manufacturers

Wind Turbine Manufacturers

NAME AND ADDRESS	TELEPHONE	FAX
M/s Enercon (India) Ltd. "Enercon Tower" A-9, Veera Industrial Estate Veera Desai Road, Andheri–400053	022 66924848	022 67040473
M/s Pioneer Winco Private Ltd. 30/1A, Harrington Chambers, 2nd Floor "B" Block Abdul Razaq, 1st Street, Saidapet Chennai–600095	044 24314790	044 24314789
M/s Shriram EPC Limited 9, Vanagaram Road, Ayanambakkam Chennai–600095	044 26533313	044 26532780
M/s Sothern Wind Farms Limited No. 15, Soundarapandian Salai, Ashok Nagar Chennai–600083		
M/s Pioneer Wincon Private Ltd. 30/1A, Harrington Chambers, 2nd Floor "B" Block Abdul Razaq, 1st Street, Saidapet Chennai–600015	044 24314790	044 24314789
M/s Shriram EPC Limited 9, Vanagaram Road, Ayanambakkam Chennai–600095	044 2653313	044 6532780
M/s Southern Wind Farms Limited No. 15, Soundarapandian Salai Ashok Nagar Chennai–600083	044 39182618	044 39182636
M/s Suzlon Energy Ltd. 5th Floor, Godrej Millenium 9, Koregaon Park Road Pune–411001	020 40122000	020 0122100
M/s Vestas RRB India Limited No. 17, Vembuliamman Koli Street K. K. Nagar (West) Chennai–600078	044 23641111	044 23642222
M/s Vesta Wind Technology India Private Limited [formerly M/s NEG Micon (India) Private Ltd.] 289, Old Mahabalipuram Road, Sholinganallur Chennai–600119	044 24505100	044 24505101
M/s Vestas PRB India Limited No. 17, Vembuliamman Koli Street Kk. K. Nagar (West) Chennai-–600078	044 23641111	044 23642222

Solar Energy Manufacturers

Bureau of Indian Standard (BIS)–certified Solar Cookers Manufacturers

NAME AND ADDRESS	TELEPHONE	FAX
M/s Universal Engineers Enterprises Garg Bhavan, Prince Road Gandhi Nagar, Moradabad (U. P.)	0591 2493619	0591 2499768
M/s Rural Engineering School Rojmal, Tal.: Gadhada (SN) District Bhavnagar–364750 Gujarat	02847 294127	02847 253535
Khadi Gramodhyog Prayog Samiti Gandhi Ashram Ahmedabad–380 027	Cell: 9825484275, 9879784255	079 27552469
Sayala Taluka Khadi Gramodyog Seva Mandal Motiram Building, below SBS Service Branch, Phulchhab Chowk Rajkot–360 001	Tel: 0281 2477226 Cell: 09825074591	

Other Known Manufacturers of Solar Cookers

NAME AND ADDRESS	TELEPHONE	FAX
M/s J. N Enterprises F-12, Navin Shahdara, Delhi	Cell: 2350859119	
M/s Vishvakarma Solar Energy Co. G. T. Road, Phillour, District Jallandhar, Punjab	01826 22523, 01826 22217	
M/s Fair Fabricators 142, Tilak Nagar, near Post Office Indore–452 018	Cell: 9425316707	0731 2491488
M/s Rohtas Electronics 15/268-B, Civil Lines, Kanpur–208001	0512 2305564	0512 2305390
M/s Rural Engineering School Rojmal, Tal.: Gadhada (SN) District Bhavnagar–364750, Gujarat	02847 294127	02847 253535
M/s Usha Engineering Works 40-A, Trunk Road, Madanur–635804 Vellore District, Tamilnadu	04174 73613	
M/s Geetanjali Solar Enterprises P/14, Kasba Industrial Estate Phase-I, E. M. Bye Pass P.O. East Kolkata Township Kolkata–700107	033 24420773, 24424027	033 24420773

List of Eligible Manufacturers/Suppliers Evacuated Tube Collector–based Solar Water Heating Systems

NAME AND ADDRESS	TELEPHONE	FAX
M/s Solar Hitech Geysers No. 4, Sri Krishna Behind Bhima Jyothi LIC Colony West of Chord Road Bangalore560 079		080 23223152, 23221511
M/s Photon Energy Systems Ltd. Plot No. 775-K, Road No. 45, Jubilee Hills Hyderabad–33	Cell: 9246333624	
M/s Sudarshan Saur Shakti Pvt. Ltd. 5, Rarak Colony, opposite Ramakrishna Mission Ashrama, Beed By-pass, Aurangabad–431 005	2376610 Cell: 9225303600	0240 2376609
M/s Venus Home Appliances (P) Ltd. Mangammal Salai, 5/54 A Senthilampannai Village Pudukottai P.O. Tuticorin District Tamil Nadu	0461 2271891	0461 2271890
M/s Twincity Sunlife 7, Ready Money Terrace, 167 Dr. A. B. Road, Worli Mumbai–400 018	022 24954596, 24939644	022 24939644
M/s Kiran Lab Plast 23, Vallabh Nagar, Malegaon Road Dhule–424001 (Maharashtra)	2562 233261	2562 233262
M/s Nutech Solar Systems Pvt. Ltd. #391/32, 12th Main, Dr. Rajkumar Road 6th Block, Rajajinagar Bangalore–560 010	080 23356789 Cell: 09448674998	080 23115802
M/s G. P. Tronics Pvt. Ltd. 502, Kamalalaya Center (5th Floor) 156A Lenin Sarani Kolkata–700 013	033 22150301 Cell: 9831848002	
M/s Mamata Energy Plot No. 858, Kothari Industrial Estate Behind Hutch Tower, Rakanpur Santej Road Santej–382 721 (Gujarat)	2764 394984	2764 268328
M/s Jay Industries D-64, Miraj MIDC Miraj–416 410 (Maharashtra), District Sangli		
M/s Hykon India (P) Ltd. Hykon House, Ikkanda Warrier Road Thrissur–1 (Kerala)	0487 2444163, 2444183	
M/s Tyche Peripheral Systems Ltd. Tyche House, 13-6-536/A/26 Lakshminagar Colony, Mehdipatnam Hyderabad–500028 (AP)	040 23525436, 23525437, 30903627	040 23525403
M/s EMMVEE Solar Systems Pvt. Ltd. #55, "Solar Tower," 6th Main, 11th Cross Lakshmaiah Block, Ganganagar Bangalore–560 024	080 23337428	080 23332060
M/s Natural Energy Systems 5/51, Punjabi Bagh New Delhi–110 026	Cell: 9811104818	011 42463235
M/s ECON Appliances Pvt. Ltd. 85, MG Road, Camp, Pune–411 001	020 26331016/17	020 26331191
M/s Arsh Electronics (P) Ltd. 224, Surya Niketan, Vikas Marg Extn Delhi–110 092	011 22374859	011 22379973

List of Eligible Manufacturers/Suppliers Evacuated Tube Collector–based Solar Water Heating Systems (continued)

NAME AND ADDRESS	TELEPHONE	FAX
M/s Bhambri Enterprises 794, Joshi Road, Karol Bagh New Delhi	011 23541114, 55388606 Cell: 9811759494	
M/s V. Guard Industries Pvt. Ltd. 44/875, Little Flower Church Road Kaloor, Cochin–682017 (Kerala)	0484 2539911, 2530912	0484 2539958
M/s Solanand Solar Systems Khera Chowk, Railway Road Ambala City–134 003	Cell: 9215627335	0171 556035
M/s Ados Electronics Pvt. Ltd. 1/30, Main Vikas Marg, Lalita Park Laxmi Nagar, Delhi–110 092	Tel: 011 22463701, Cell: 9811194519	
M/s Hiramrut Energies Pvt. Ltd. Plot No. 148 & 127, GIDC-II Jamwadi, N.H. 8-B Gandal–360311, District Rajkot (Gujarat)	02825 224824, 224272	02825 240472
M/s Vijaya Industries Katapady–574 105, Udupi District, Karnataka	0820 2557127 Cell: 9448377327	0820 2557327
M/s Phoenix Import & Exports 51, Deshmukh Colony, Sadar Bazar Satara–415 001 (Maharashtra)	02162 230383 Cell: 09422038284, 09423864592	
M/s Aurore Systems Auroshilpam, Auroville–605 101 (Tamil Nadu)	0413 2622749, 2622168, 2622277	0413 2622057
M/s Kraftwork Solar Pvt. Ltd. "Adithya" 29/2862 Near Gandhi Square, Poonithura Kochi–682 038	0484 2707339, 2707228	0484 2707228
M/s Shriram Green Tech 5th Floor, Akashdeep Bldg. 26A Barakhamba Road New Delhi–110 001	011 23312267	011 23313494
M/s Patory Export Import Pvt. Ltd. A-301, Ansal Chamber-1 3, Bhikaji Cama Place New Delhi–100 066	011 51661341, 26175759	
M/s Marc Solar, Jyoti Stem Industries 5, Fatima, Nilayam, HASSS Building Behind Arch-Bishop's House, S. D. Road Secunderabad–500 1003	040 27801293, 66311292	
M/s Savemax Solar Systems (P) Ltd. Jayprabha, Jadhavnagar, Vadgaon Bk. Pune–411 041	09822846201	020 24358613/8781
M/s Tata BP Solar India Ltd. 78, Electronics City Hosur Road, Bangalore–560 100	080 22358465, 51102577	
M/s K. S. Industries 195 R. M. T. Bunglow Road Sai Nagar Industrial Estate (post), Coimbatore–641 021 (Tamil Nadu)	0422 2673319,Cell: 9894111935	
M/s Rashmi Industries No. 60 & 61, Begur Road Hongasandra, Bangalore–560 068	080 25734114/15	
M/s Hira Merica Industries Welcome Plaza, S-551, School Block-II, Shakarpur Delhi–110 092	011 22481802, 22483768	

List of Eligible Manufacturers/Suppliers Evacuated Tube Collector–based Solar Water Heating Systems (continued)

NAME AND ADDRESS	TELEPHONE	FAX
M/s Kotak Urja 311, Lotus House, 33A V Thackersey Marg, New Marine Lines Mumbai–400 020	022 22092139/41	
M/s Orange Impex No. 22, 1st Floor, Prestige Point, 283 ShukrawarPeth, behind Telephone Exchange Bajirao Road Pune–411 022	020 30421001	

List of Bureau of Indian Standards–approved Manufacturers of Flat Plate Collector–based Solar Water Heating Systems

NAME AND ADDRESS	TELEPHONE	FAX
Andhra Pradesh		
Photon Energy Systems Limited Plot No. 46, Anrich Industrial Estate, IDA Bollarum, Medak Andhra Pradesh–502325	08458 279512	08458 279842
Sun-tech Solar Systems Plot No. 1-9-382/13/2, 26/06/2008 1st Floor, Lalitha Complex, near Navkiran Industrial Estate, Kushaiguda Hyderabad–500062	040 32904766	040 27138634
Sri Sundaram Solar Solutions 8-2-70, Harshavardhan Colony Old Bowenpally, Secunderabad Hyderabad District	040 27953661 Cell: 9949057469	
Shri Shakti Alternative Energy Limited F-8, Sie, 08/10/2008 City: Balanagar, Hyderabad Andhra Pradesh–500037	23770511 Cell: 9440409677	23770513
Sca GreenTtechnologies Plot No. 22 & 31, Survey No. 247 Subashnagar, Jeedimetla Hyderabad–500055	040 55996519	
Chandigarh		
Inter Solar Systems Pvt. Ltd. 901, Industrial Area Phase II Chandigarh–160002	0172 5085281	
Surya Shakti 739 Industrial Area, Phase II Chandigarh–160002	2653299	
Delhi		
Maharishi Solar Tecnology (P) Ltd. A-14, Mohan Co-operative Industrial Estate, Mathura Road New Delhi–110044	011 26959529, 30881700	011 26959669
Gujarat		
Sintex Industries Ltd. (Plastic Division), near Seven Garnala Kalol, Gandhinagar District Gujarat–382721	02764 24301 to 24305	02764 20385
NRG Technologists Private Limited Plot No. 989/6, GIDC Industrial Estate Makarpura Baroda, Gujarat–390010	0265 2642094, 2656167	0265 2642094, 2656167

List of Bureau of Indian Standards–approved Manufacturers of Flat Plate Collector–based Solar Water Heating Systems (continued)

NAME AND ADDRESS	TELEPHONE	FAX
Warm Stream Near Baroda Electric Meters Ltd. Vallabh Vidya Nagar,Anand, District: Kheda, Gujarat–388121	02692 232309, 231316	236478
Solar Energy Service A/4/2, 02/08/2008 Operative Industrial Estate, B.I.D.C. Gorwa Vadodara–390016	02667 264239	
Himachal Pradesh		
Solchrome Systems India Limited 61, Sector-5, Parwanoo Solan District, Himachal Pradesh	01792 232572	
Karnataka		
Sundrop Solar Systems 44/2A, Industrial Estate Opp Gangadhareshwara Kalyana Mantapa NH 7, Bellary Road, Hebbal Bangalore–560024	23620077 Cell: 9844068721	
Sudhanva Industries 65/18, 1st Main, 0 7/08/2008 1st Cross, Andrahalli Main Road Hegganahalli Bangalore –560091	28366832 Cell: 9845313912	
Kinara Power Systems and Projects Pvt. Ltd. Unit 2, 10, 10th Cross Patel Channappa Indl Estate Andrahalli Main Road, Peenya 2nd Stage Viswaneedum Post Bangalore–560091	28365944	
Om Shakthi Industries No. 2 S. T. Narayana Gowda Industrial Estate, Sri Gandha Nagar, Doddanna Industrial Estate Near Peenya II Stage Bangalore–560091	28362967, 56982645 Cell: 9448062867	
Sabha Solar Energy 3/1 behind Balaji Petrol Bunk 2nd Cross, Lakshmaiah Block Ganganagar Bangalore–560032		
Velnet Non-conventional Energy Systems (P) Ltd. No. 120, Bhadrappa Layout Ring Road, Nagashettyhalli Bangalore–560094	23418630, 23417940, 23512799 Cell: 9844050723	
Enolar Systems 45/29-1, Gubbanna Industrial Estate 6th Block, Rajajinagar Bangalore–560010	23355333, 23385500	23355333
Divya Industries No. 814, Chowdeshwari Nagar Laggere Main Road Laggere, Peenya Post Bangalore–560058	8398471	
Shringar Egineering & Energy System Pvt. Ltd., No. 93, 7th Main, 3rd Phase, Peenya Industrial Area Bangalore–560058	28398197	

List of Bureau of Indian Standards–approved Manufacturers of Flat Plate Collector–based Solar Water Heating Systems (continued)

NAME AND ADDRESS	TELEPHONE	FAX
Perfect Solar Bangalore Pvt. Ltd. No. 16 Byraveshwara Industrial Estate Andrahalli Main Road, Peenya 2nd Stage Bangalore	28362515/1129 Cell: 9845106037	28362515
Vijaya Industries 166/2 Katapady District Udupi, Karnataka Pin: 574105	0820 2557127, 2557327	2557700
Sunrise Solar Pvt. Ltd. B-4, Jayabharat Industrial Estate Yeshwanthpur Bangalore–560022	23328533, 23523644	23425115
Sustainable Power Developers India Pvt. Ltd. 604/677, Magadi Road P&T Layout Road, Sunkadakatte Bangalore–560079	23580066, 23581154	
Tata BP Solar India Ltd. Plot No. 78, Electronic City Phase–1 Hosur Road Bangalore–560100	080 56601300	080 28520972, 8520116
Emmvee Solar Systems Pvt. Ltd. Survey No. 13/1 Bellary Road Jala Hobli Sonnapanahalli Bettahalsur Post Bangalore–562157		
Kotak Urja Pvt. Ltd. 378 10th Cross, 4th Phase Peenya Industrial Area Bangalore–560058	28363330, 28362136	28362347
Sun Zone Solar Systems ¼, Balagangadhara Nagar Mallathahalli, behind Sanford College Bangalore–560056	23282145, 23214777 Cell: 56979935	
Anu Solar Power Pvt. Ltd. 248 3rd Cross, 8th Main, 3rd Phase Peenya Industrial Area Bangalore–560058	28394259, 28393913, 28396001	
Nuetech Solar Systems Pvt. Ltd. P. B. No. 9167, B. M. Shankarappa Industrial Estate Sunkadakatte Vishwaneedam Post, Magadi Main Road Bangalore–560091	080-23483766, 23481905	080 23281730
Vishwa Solar System Shed No. SM 19, KSSIDC Industrial Area Manipal, District Udupi Karnataka–576119	0820 2522791, 2571323	
Dheemanth Industries 35, behind Check Post Kamakshipalya Layout Bangalore–560079	23489377, 2342617	
Technomax Solar Devices Pvt. Ltd. No. 21/B, 4th Main, 1st Cross Industrial Suburb Yeshwanthpur Bangalore–560022	3418723	

List of Bureau of Indian Standards–approved Manufacturers of Flat Plate Collector–based Solar Water Heating Systems (continued)

NAME AND ADDRESS	TELEPHONE	FAX
Digiflic Controls (India) Pvt. Ltd. SIT 2E8/03/2008 No. 9, 2nd Cross, Rajagopala Nagar Main Road Bangalore–560058	080 28366839	080 28362689
Rashmi Industries 60 & 61 Begur Road Hongasandra Village Bangalore–560068	25732309, 4114,4115	25732309
Solar Energizers P. Ltd. 36/3, 1st Cross, Pukhraj Layout Bannerghatta Road, Adugodi Bangalore–560030	22245481	22225804
Navodaya Solaris No. 66, 2nd Main, Ramakrishnappa Building Ranganathpura, Magadi Road Bangalore–560079	23589736 Cell: 9448532177	
Nucifera Renewable Eergy System Raghavendranagar, behind Devanur Church Nalanda Convent Parallel Road Tumkur–572102	0816 290142	0816 254585
Maharashtra		
Bipin Engineers (P) Ltd. S. No. 143, Vadgaon Dhairy Pune-Sinhagad Road Pune–411041		
Sudarshan Saur Shakti Pvt. Ltd. K-240, MIDC Waluj Aurangabad District Pin: 431136		
The Standard Products Mfg. Co. G-13/8, MIDC, Taloja Industrial Area, Taloja Raigarh District Pin: 410208	27402228	
Skylark Thermal Energy Systems Sr. No. 36/2, Dhandekar Estate Kondhwa Budruk Pune Pin: 411048		
Solar Energie Technik Ltd. Urja Centre, Gat. No. 2329 Ganga Retreat Road Wagholi Pune–412207	27052205/07	27052625
Jain Irrigation Systems Ltd. Jain Agri Park, Jain Hills, P.O. Box No. 72 Shirsoli Road Jalgaon Pin: 425001	0257 250011/22	0257 251111/22
Solar Product Company S. No. 166, Vadgaon Dhayari, Nanded Phata Pune-–411041		
Kaushal Solar Equipments P. Ltd, S. No. 44 Warje Malewadi Pune–411029		

List of Bureau of Indian Standards–approved Manufacturers of Flat Plate Collector–based Solar Water Heating Systems (continued)

NAME AND ADDRESS	TELEPHONE	FAX
Solar Vision Agro Industries B-44/2, Gokul, Shirgaon MIDC Kolhapur Pin: 416234	2672745	
Machinocraft S. No. 1, Ambegaon (BK) Katraj-Dehu Road Bypass Pune–411 046	020 24317400, 30910794, 9822441250	020 24317400
Savemax Solar Systems Pvt. Ltd. S. No. 42/2B, Plot No. 26 Khadi Machine Road Vadgaon Budruk Pune–411041		
Standard Engineering Company 131/7B, Hadapsar Indl Estate Pune–411013		
Akson`s Solar Equipments Pvt. Ltd. Gat. No. 213 (old 1005) Village Rajewadi, Taluka Khandala City: Satara		
Merloni Termosanitari (I) Ltd. 265/274-376, at Post Kharabwadi Chakan, Taluka Khed District Pune Pin: 410501		
Jay Industries Plot No. D-64 MIDC, Miraj Sangli–416410		
Tmilnadu		
Goodsun Industries SF. 206, Perks Campus Rajalakshmi Mills Road, Upplipalayam Coimbatore–641015	0422 2592171, 2592158, 2590937	0422 2590937
Sunlit Solar Energy (P) Ltd. SF. No. 5071, 2/08/2008 Pachapalayam Road Arasur, Coimbatore–641 407 Coimbatore District Tamil Nadu–641607	6571745 Cell: 9842216190	
Cascade Helio Termics Limited No. 355/2, Abbas Garden Road Luna Nagar Coimbatore–641025	0422 2400254, 2401576	0422 2400347
Uttaranchal		
Bharat Heavy Electricals Limited Rudrapur–263153 DistrictUdham Singh Nagar Uttaranchal–263153	05944 43415, 43724, 43725	05944- 3605

List of Known Manufacturers/Suppliers/Institutions Involved in Installation of Flat Plate Collector–based Solar Driers/Air Heating Systems

NAME AND ADDRESS	TELEPHONE	FAX
M/S Planters Energy Network (PEN) No. 5, Powerhouse Street N.R.T. Nagar Theni–625531 Tamilnadu	04546 255272, 255271	04546 255271
M/S NRG Technologies 989/6, GIDC Estate, Makarpura Vadodara–390010	0265 2642094	0265 2642094
M/S Kotak Urja Pvt. Ltd. No. 378, 10th Cross, 4th Phase Peenya Industrial Estate Bangalore–560 058	080 23560456 7	23562233
Sardar Patel Renewable Energy Research Institute Post Box No. 2, Vallabh Vidyanagar–388120 Gujarat	02692 231332, 235011	02692 37982
Northern India Textile Research Association Sector-23, Raj Nagar Ghaziabad–201002	91 4783586, 4783592	9 4783596

List of Known Manufacturers/Suppliers/Institutions Involved in Installation of Solar Steam Generating Systems

NAME AND ADDRESS	TELEPHONE	FAX
M/s. Gadhia Solar Energy Systems (P) Ltd. Plot No. 86, OLD GIDC Gundlav, Valsad–396 035, Gujarat		02632 236703
Project Co-ordinator Solar Steam Cooking System Brahamakumari Ashram Mount Abu, Rajasthan	02974 237049, 238788	02974 238951, 238952
M/s Solar Alternatives St. Mary's Church Compound Phulwari Sharif, Patna–801505	0612 254487	227903
M/s Sharada Inventions 94/1, MIDC Satpur Nashik–422007	0253 2352444, 2353844	0253 2353853
M/s Supreme Rays Solar Systems 8, Kumbhar Building, behind Tekwade Petrol Pump, Opp. Akashwani, Hadapsar Pune–411028	020 26995588, 26996688	020 26980155
Unison Technologies Pvt. Ltd. No. 6, Ist Floor, Kodava Samaja Building Ist Main, Vasanthnagar Bangalore–560052	080 2355238, 30909193	080 22289294

Solar Cell and Module Manufacturers in India

NAME AND ADDRESS	TELEPHONE	FAX
Ammini Solar Pvt. Ltd. Plot No. 33–37 KINFRA Small Industries Park St. Xaviers College PO Trivandrum–695 582	04712705588	04712705599
Bharat Electronics Limited 116/2, Race Course Road Jalahalli, Bangalore–560015	080 25039300	080 25039305
Bharat Heavy Electricals Ltd. Electronics Division Post Box No. 2606 Mysore Road Bangalore–560 026	08026998553	080 26744904, 26740137
Central Electronics Ltd. 4, Industrial Area Sahibabad–201 010 U. P.	01202895151	01202 895148/42
EMMVEE Solar Systems Pvt. Ltd. 55, 6th Main, 11th Cross Lakshmaiah Block Ganganagar Bangalore–560024	080 23337427/28	080 23332060
Kotak Urja Pvt. Ltd. 378, 10th Cross 4th Phase, PIA Bangalore 560058 Karnataka, India	08028363330	08028362347
Maharishi Solar Technology Pvt. Ltd. A-14, Mohan Cooperative Industrial Estate Mathura Road New Delhi–110 044	011 26959800, 26959701	011 26959 669
Microsol Power P Ltd. 605, 6th Floor Sapthagiri, SP Road Begumpet Hyderabad	04027766917	040 27730546, 04027766916
Moser Baer Photovoltaic Ltd. 43B, Okhla Industrial Estate New Delhi–110020	11 41635201 07, 91 11 26911570 74	11 41635211, 91 11 26911860
Photon Energy Systems Plot No. 775 –K Road No. 45 Jublee Hills Hyderabad–560 033	04055661337/1338/1339	04055661340
Premier Solar Systems (P) Ltd. 41 & 42, Sri Venkateswara Cooperative Indl. Estate Balanagar Hyderabad–500 037		040 2271879
Rajasthan Electronics & Instruments Ltd. 2, Kanakpura Industrial Area, Sirsi Road, Jaipur –302 012	01412203038	0141 2202701, 0141-2352841

Solar Cell and Module Manufacturers in India (continued)

NAME AND ADDRESS	TELEPHONE	FAX
M/s Sun Times E-3, Lajpat Nagar–II New Delhi–110 024		011-26839444
Tata BP Solar India Ltd. Plot No. 78 Electronic City, Hosur Road Bangalore–560100	08022358465	08028520972, 28520116
Titan Energy Systems Ltd. 16, Aruna Enclave Trimulgherry, Secunderabad– 500015 Andhra Pradesh, India	04027791085, 0402-779-0751	040-2779 5629
USL Photovoltaics Pvt. Ltd. 1/473 Avinashi Road Neelambur Coimbatore 641 014 India	04222627851	04222628504
Udhaya Energy Photovoltaics (P) Ltd. 1/279Z, Mudalipalayam Arasur Post Coimbatore – 641 407		
Webel SL Energy Systems Ltd. Plot No. N1 Block GP, Sector V Salt Lake Electronic Complex Kolkata 700 091	03323578840	033-23573258
XL Telecom Ltd. 335 Chandralok Complex SD Road Secunderabad, Andhra Pradesh 500003	04027849094	04027840081

Waste-to-Energy Technology Suppliers

Waste-to-Energy Technology Providers/Suppliers in India

NAME AND ADDRESS	TELEPHONE	FAX
Biomethanation Technology		
M/s ENKEM Engineers Pvt. Ltd. 824, Poonamalle High Road Kilpauk (near KMC) Chennai–600010	044 26411362, 26428992	044 26411788
M/s Mailhem Engineers Pvt. Ltd. 14, Vishrambag Society Senapati Bapat Road Pune–411 016	020 24002285	020 25659857
M/s REVA Enviro Systems Pvt. Ltd. 3, Suyog Nagar, Ring Road Nagpur–440 015	0712 2743123, 2743124	0712 2743120
M/s Linde Process Technologies India Ltd. 38, Nutan Bharat Society, Alkapuri Vadodara–390 007	0265 2336319, 2336196	0265 2335213, 2313629
M/s Hydroair Tectonoics Pvt. Ltd. 401, "Devavrata," Sector-17 Vashi, Navi Mumbai–400 705	022 27892813/68/95	022 27893892
M/s Chemtrols Engineering Ltd. Amar Hill, Saki Vihar Road Powai, Mumbai–400 072	022 28575089, 28570557	022 28571913

Waste-to-Energy Technology Suppliers

Waste-to-Energy Technology Providers/Suppliers in India

NAME AND ADDRESS	TELEPHONE	FAX
M/s Degrimont India Ltd. Water and the Environment D-43, South Extension - II New Delhi–110 049	011 26481191, 26481192	011 26228782
M/s Global Environmental Engg. Ltd. 1233/C, K. G. Mansion Opp. Hotel Kohinoor Executive Apte. Road, Pune–411 004	0212 2327876, 2328007	0212 2328441
M/s UEM India Limited D-19, Kalkaji New Delhi–110 019	011 26447825, 26421634	011 26239801
Plasma Arc Technology		
M/s SELCO International H. No:1-10-74, R K Apartments Ashok Nagar Hyderabad–550 020		040 27650114
M/s Shriram Energy Systems Ltd. 7-1-29, United Avenue (North End) G1 B–Block Ameerpet Hyderabad–500016, Andhra Pradesh	040 23739552	040 237 39551
Pyrolysis/Gasification Technology		
M/s Terrasafe Technologies (P) Ltd. J12 Basement, Saket New Delhi–110017	011 26533471/72, 26535062	011 26520514
M/s Global Enviro Plasma Technologies Dhruv International Pvt. Ltd. 306 Akashdeep Building 26-A Barakhamba Road New Delhi–110001		
M/s Shri Damodar Synthetics Ltd. G-1, Nahar & Seth Industrial Premises Near P&G Plaza, Chakala Road Andheri (East) Mumbai–400 099	022 28366419, 28366420, 28365997	022 28252713
M/s Batliboi Environmental Engineering Ltd. Batliboi House, Govandi (W) Mumbai–400 043	022 25587421, 25583031	022 25566677, 25566949
Biogas Engine Supplier		
M/s Green Power International (P) Ltd. B-46, Ist Floor, Kalkaji New Delhi–110019	011 26447526, 26447527	011 26447525
M/s Guascor S.A. (Spain) M/s APE (India) Ltd. 19 Community Center, East of Kailash, New Delhi–110 065	011 26443889, 26420938	011 26470867
M/s Cogen India Engineering Pvt. Ltd. 5, Saraswati Heights 759/39, Deccan Gymkhana Pune–411004	020 25676435/6	020 25675824
M/s. Greaves Ltd. Disel Engines Unit Chinchwad, Pune–411019	020 27472101, 27473569	020 27472276

Biomass Technology Manufacturers

Manufacturers of Biogas Burners

NAME AND ADDRESS
M/s. Sunflame Industries (P) Ltd. Shed No. 2, Plot No. 58 P.O. Amar Nagar Faridabad–121 003
Ms. Gas & Chemical Industries (P) Ltd. Works: 14/1 Mathura Road Faridabad–121 003
M/s. Sweet Home Appliances Pvt. Ltd. 3-E/16, B. P. N. I. T. Faridabad–121 001
M/s. Associated Engineering Works Tanuku–534 211 (AP)
M/s. Agriculture Associates Station Road, Alwar (Rajasthan)
M/s. Rupak Enterprises 1/46 Vishwas Nagar, Shahdra Delhi–110 032
M/s. Mech-Ci-Co. 1-7, GIDC Industrial Township Vatwa, Ahmedabad–382 445

List of Gasifier Manufacturers in India

NAME AND ADDRESS	TELEPHONE	FAX
M/s Ankur Scientific Energy Technologies Pvt. Ltd. Near Old Sama Jakat Naka Vadodara–390008	793098, 794021	0265 794042
M/s Cosmo Powertech Pvt. Ltd. Devpuri Near Jain Public School Dhamtari Road Near Raipur–492015	0771 5011262	0771 5010190
M/s Netpro Renewable Energy (India) Ltd. 139/B, 10th Main, Rajmahal Vilas Extension Bangalore–560080	080 3613585, 3613457	080 3611584
Energreen Power Limited No. 1 Ashre 4B 2nd Street, Nandanam Extension Chennai–600035	044 24321339, 52111348	044 24321339
Rishipooja Energy & Engineering Company M. G. College Road Gorakhpur–273001 (U. P.)	0551 340612, 339475	
Bioresidue Energy Technology Private Ltd. S-2, Dig Vijay Apartment, 1st Cross Ganesha Block , Sultanpalya R. T Nagar P.O. Bangalore–560032	080 3431533	080 3534503

Annex 2. Indian Policy-makers with Authority over Clean Energy Technologies

Institutional Structure at National and State Levels

At the national level, the government of India is assisted by the planning commission and line ministries to formulate policies related to clean energy. The institutional structure is shown in Figure 1.2.[16]

Among the line ministries, the Ministry of Power (MOP), MNRE, and Ministry of Environment and Forests (MoEF) are the major agencies for formulating policies and action plans related to clean energy. The Central Electricity Regulatory Commission (CERC), Central Electricity Authority (CEA), and BEE assist MOP to formulate policies and action plans. Utilities and public sector entities such as NTPC Ltd., the National Hydroelectric Power Corporation (NHPC), the Power Grid Corporation (PGC), the Power Finance Corporation (PFC), the Rural Electrification Corporation (REC), and the Power Trading Corporation (PTC) implement action plans at the national level. BEE implements action plans with the help of state nodal agencies. State-level renewable energy development agencies assist MNRE to implement policies and action plans at the state level. IREDA assists MNRE and state nodal agencies in project development and financing of renewable energy programs.

The Central Pollution Control Board assists MoEF to formulate policies, rules, regulations, guidelines, and action plans related to the environment and pollution control at the national level. The State Pollution Control Boards (SPCBs) are responsible for ensuring compliance during project inception, construction, and implementation. MoEF also functions as a nodal ministry for CDM projects in India. Other line ministries such as the Ministry of Coal, Ministry of Petroleum and Natural Gas, and Department of Atomic Energy support clean energy programs peripherally. The Ministry of Petroleum and Natural Gas promotes clean energy through the promotion of CNG, LPG, and end-use energy efficiency in oil-fired equipment such as boilers and furnaces. The Ministry of Coal promotes clean technologies for coal production, coal gasification, and coal bed methane. A compendium of key government and state agencies is provided in Annex 2, which includes contact information.

The Ministry of Finance provides support for clean energy by determining tax benefits in the overall assessment of excise duties, central taxes, and provision of tax exemptions and fiscal incentives for clean technologies. The Department of Science and Technology provides support for clean energy by providing funds to technology development projects for clean energy. The Ministry of Rural Development is responsible for developing biodiesel projects across the country. The Ministry of Small-Scale Industries promotes clean technologies in small-scale industry sectors. Each of these ministries/departments has its own budget line for supporting clean technologies in its respective unit. Most of the funds pertain to demonstration units, with commercial funding for projects coming from the financial institutions as a part of the credit lines established for the purpose. In addition, there are individual ministries/departments dealing with steel, mines, pharmaceuticals and fertilizers, which have their own components of energy conservation and clean technologies as a part of their mandates.

At the state level, the policy and regulatory framework related to clean energy is implemented by the institutional structure shown in Figure 1.3. This consists of the State Electricity Regulatory Commission (SERC), the Department of Power (DOP), the State Renewable Development Agency (SRDA), and the Department of Environment (DOE). At the state level, the DOP implements policies and action plans through state utilities (generation, transmission, and distribution) and the electrical inspectorate, while the DOE implements

Figure 1.2: Institutional Framework at the National Level

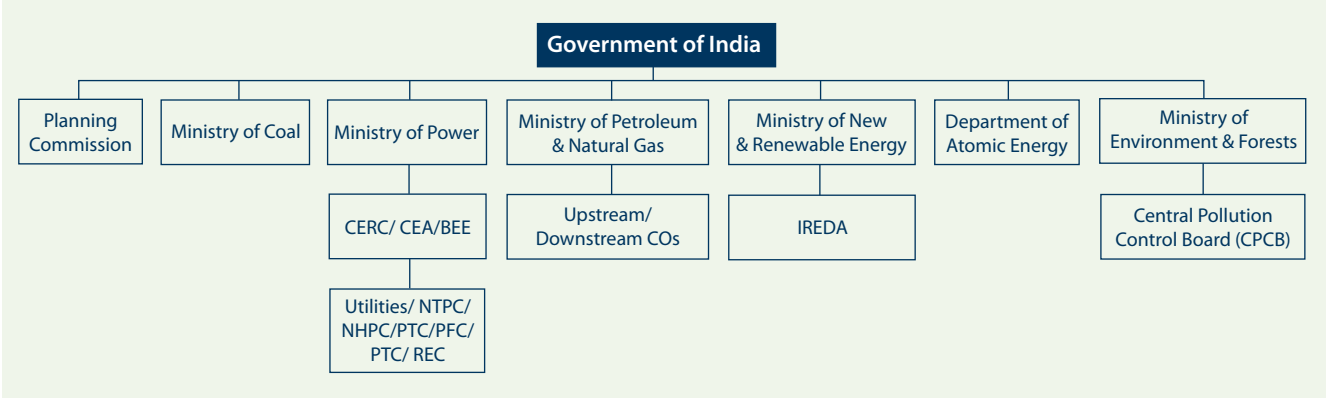
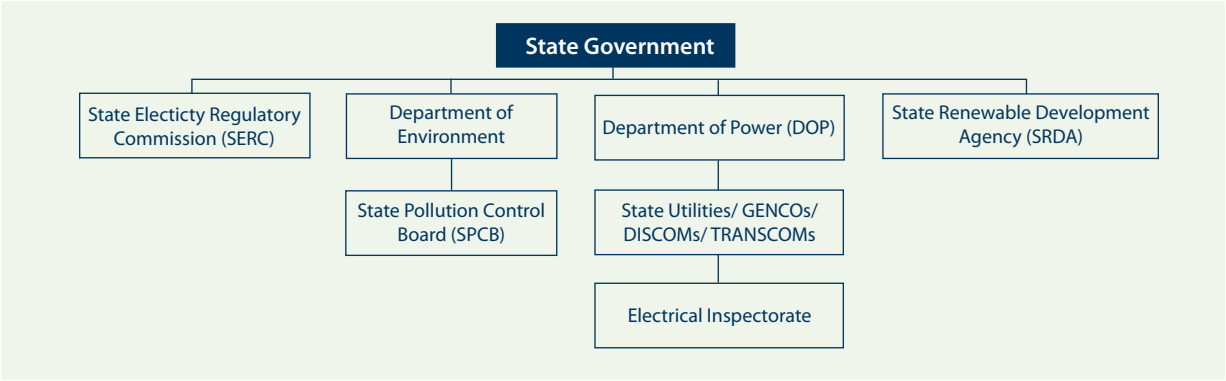


Figure 1.3: Institutional Framework at the State Level



policies and action plans for the environment and pollution control through the State Pollution Control Board (SPCB). SRDAs implement policies and action plans related to renewable energy. In some states and union territories, renewable energy falls under the jurisdiction of the DOP. The SRDAs also serve as nodal agencies for implementing energy efficiency policies and action plans as per the Energy Conservation Act.

The institutional structure by state/union territory is provided in Table 1.36. This table shows the regulatory

Table 1.36: Institutional Structure by State/Union Territory

	SERC	DOP	SRDA	NODAL AGENCY FOR ENERGY EFFICIENCY	DOE/SPCB
Andhra Pradesh	√	√	√	√	√
Arunachal Pradesh		√	√	√	√
Assam	√	√	√	√	√
Bihar	√	√	√	√	√
Chhattisgarh	√	√	√	√	√
Goa		√	√		√
Gujarat	√	√	√	√	√
Haryana	√	√	√	√	√
Himachal Pradesh	√	√	√	√	√
Jammu and Kashmir	√	√	√		√
Jharkhand	√	√	√	√	√
Karnataka	√	√	√	√	√
Kerala	√	√	√	√	√
Madhya Pradesh	√	√	√	√	√
Maharashtra	√	√	√	√	√
Manipur		√	√		√
Meghalaya		√	√	√	√
Mizoram		√	√	√	√
Nagaland		√	√	√	√
Orissa	√	√	√	√	√
Punjab	√	√	√	√	√
Rajasthan	√	√	√	√	√
Sikkim		√	√	√	√
Tamil Nadu	√	√	√	√	√
Uttarakhand	√	√	√	√	√
Tripura	√	√	√	√	√
Uttar Pradesh	√	√	√	√	√

Table 1.36: Institutional Structure by State/Union Territory (continued)

	SERC	DOP	SRDA	NODAL AGENCY FOR ENERGY EFFICIENCY	DOE/SPCB
West Bengal	√	√	√	√	√
Union Territories					
Andman and Nicobar Islands		√			√
Chandigarh		√			√
Delhi	√	√	√	√	√
Lakshadweep		√			√
Puducherry		√	√	√	√

commissions, nodal agencies for energy efficiency, nodal agencies for renewable energy, and nodal agencies for pollution control in all the states that are implementing policies and action plans related to clean energy.

An Overview of Central Government Agencies

An overview of central government agencies is provided in Table 1.37. This compendium gives the names of respective ministries, agencies, and public sector undertakings that are responsible for implementation of policies and action plans at national levels. The three ministries covered are the Ministry of Power, Ministry of New and Renewable Energy, and Ministry of Environment and Forests. The Ministry of Power is supported by the Central Electricity Regulatory Commission, the Central Electricity Authority, and the Bureau of Energy Efficiency to draft and implement policies. NTPC Ltd. and the National Hydroelectric Power Corporation Ltd. are thermal and hydropower-generating utilities. The Power Finance Corporation Ltd. and the Rural Electrification Corporation Ltd. are the financial institutions operating under the Ministry of Power. The Indian Renewable Energy Development Agency is a financial institution under the Ministry of New and Renewable Energy with a mandate to finance renewable energy and energy efficiency projects in India. The Ministry of Environment and Forests is supported by the Central Pollution Control Board to frame environmental policies, guidelines, and standards in India.

Overview of State/Union Territory Government Agencies

A compendium of state/union territory government agencies is provided in Table 1.38. This compendium provides the name of the state and the names of key agencies followed by the addresses of the ministry/department of power, electricity regulatory commission, utility, environment/pollution control agency, and the state nodal agency for renewable energy and energy efficiency.

Table 1.37: Compendium of Central Government Agencies

AGENCY	CONTACT DETAILS/ ADDRESS
Ministry of Power Government of India	Shram Shakti Bhavan, Ministry of Power, Government of India New Delhi–110001 Tel: 011 23710271, 23711316; fax: 011 23721487
Central Electricity Regulatory Commission	Central Electricity Regulatory Commission, Core 3, 6/7th Floors SCOPE Complex, 7 Institutional Area, Lodi Road, New Delhi–110 003 Tel: 011 24361145, 24360216 Fax: 011 24360010
Central Electricity Authority	SEWA Bhawan, R. K. Puram, New Delhi–110 066 Tel: 011 26102583; fax: 011 26109212
Bureau of Energy Efficiency	4th Floor, SEWA Bhawan, R. K. Puram, New Delhi–110 066 Tel: 011 26179699; fax: 011 26178352
NTPC Ltd.	NTPC Limited, NTPC Bhawan, SCOPE Complex, 7 Institutional Area Lodhi Road, New Delhi–110003 Tel: 011 24360100; fax: 011 24361018
National Hydroelectric Power Corporation Ltd.	NHPC Office Complex, Sector 33, Faridabad–121 003 Haryana Tel: 91 129 2258331 Fax: 0129 2277941, 2278012
Power Finance Corporation Ltd.	Power Finance Corporation Ltd., "Urjanidhi," 1 Barakhamba Lane, Connaught Place, New Delhi–110 001 Tel: 11 23456000; fax: 011 23412545
Rural Electrification Corporation Ltd.	Core- 4, SCOPE Complex, 7, Lodhi Road New Delhi–110003 Tel: 011 24365161; fax: 011 24360644
Ministry of New and Renewable Energy Government of India	Ministry of New and Renewable Energy Block-14, CGO Complex, Lodhi Road, New Delhi–110 003 Tel: 011 24361298, 24360707 Fax: 011-24361830
Indian Renewable Energy Development Agency Limited	India Habitat Centre Complex, Core-4A, East Court, 1st Floor Lodi Road, New Delhi–110 003 Tel: 011 24682214 21; fax: 011 24682202
Ministry of Environment and Forests Government of India	Ministry of Environment and Forests, Paryavaran Bhavan CGO Complex, Lodhi Road, New Delhi–110 003 Tel: 011 24361669, 24360605, 24360570, 24360519, 24361147 Fax: 011 24362746
Central Pollution Control Board	Parivesh Bhawan, CBD-cum-Office Complex, East Arjun Nagar Delhi–110 032 Tel: 011 22307233; telefax 22304948

Table 1.38: Compendium of State/Union Territory Government Agencies

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Andhra Pradesh	Principal Secretary (power)	Energy Department, Government of Andhra Pradesh Hyderabad–500001 Telfax: 040 23455452, 23453305
	Andhra Pradesh Electricity Regulatory Commission	4th and 5th Floors 11-4-660, Singareni Bhavan Red Hills Hyderabad–500 004 Tel: 23397381, 23397399, 23397556, 23397656, 23390970, 23390971, 23391973, 23378646 Fax: 23397378, 23397489
	Andhra Pradesh Power Generation Corporation Ltd.	Vidyut Soudhan, Hyderabad–500 082 Tel: 040 3317643, 3702571 Fax: 040 3317643
	Andhra Pradesh Transmission Corporation Ltd.	Vidyut Sudhan, Hyderabad–82 Tel: 3317657 Fax: 040 3320565
	Andhra Pradesh Pollution Control Board	Paryarana Bhawan, A-3, Industrial Area, Sanathnagar Hyderbabad–500 018 Andhra Pradesh
	Non-conventional Energy Development Corporation of Andhra Pradesh (NEDCAP) Ltd.	5-8-207/2 Pisgah Complex Nampally Hyderabad–500 001 Tel: 040 23201172 (O) (office) Fax: 040 23201666
	Non-conventional Energy Development Cooperation of Andhra Pradesh Ltd. (NEDCAP) (state nodal agency for energy efficiency)	5-8-207/2, Pisgah Complex Nampally, Hyderabad–500 001 Tel: 23201172 (O)
Arunachal Pradesh	Secretary, Department of Power	Block No. 11, Civil Secretariat, Itanagar–791 111 Tel: 0360 2216485; fax: 2291598
	Arunachal State Pollution Control Board	Government of Arunachal Pradesh, Office of the Principal Chief and Secretary (E&F) Conservator of Forests Itanagar–791111, Arunachal Pradesh
	Arunachal Pradesh Energy Development Agency	Urja Bhawan Tadar Tang Marg Post Box No. 141 Itanagar–791111 Tel: 0360 211160, 216937 (O); fax: 0360 214426
	Arunachal Pradesh Energy Development Agency (APEDA) (state nodal agency for energy efficiency)	Urja Bhawan, TT Marg Post Box No. 141 P.O. Itanagar–791 111, District Papum Pare Arunachal Pradesh Tel: 0360 2211160; fax: 0360 2214426

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Assam	Principal Secretary (power)	Energy, Assam Secretariat, Government of Assam Dispur–781005 Tel: 0361 2261120, 2262674; fax: 0361 2540314
	Assam Electricity Regulatory Commission	ASEB Campus, Dwarandhar G. S. Road, Sixth Mile Guwahati–781022 Tel: 0361 2234442 Fax: 0361 2234473
	Assam State Electricity Board	Bijulee Bhawan, Paltan Bazar Guwahati–781001 Tel: 540311, 541088 Fax: 0361 41090
	Assam Pollution Control Board	Bamunimaidan Guwahati–781021 Assam Tel: 91 361 2652774, 2550258 Fax: 91 361 2550259
	Assam Energy Development Agency	Co-operative City Bank Building, U. N. B. Road, Silpukhuri Guwahati–781 003 Tel: 0361 2662232, 2664415; fax: 0361 2668475
	Chief Electrical Inspector-cum-Adviser (state nodal agency for energy efficiency)	Chief Electrical Inspector-cum-Adviser Government of Assam Pub-Sarania Road Guwahati–781 003 Assam Tel: 0361 2529611
Bihar	Principle Secretary (power)	Government of Bihar, Patna 800008 Tel: 0612 2225412; fax: 0612 2232852
	Bihar Electricity Regulatory Commission (BERC)	Ground Floor, Vidyut Bhawan-II, B. S. E. B. Campus Jawahar Lal Nehru Marg (Bailey Road), Patna–800021 Bihar Tel: 0612-5526749, 2205488, 2205489 Fax: 0612-2205488
	Bihar State Electricty Board	Vidyut Bhawan, Bailey Road, Patna–800001 Telefax: 0612 2224534
	Bihar State Pollution Control Board	Beltron Bhawan, 2nd Floor, Lal Bhadur Shastri Nagar Patna–800 023, Bihar Tel: 0612 2281250 Fax: 0612 2291709
	Bihar Renewable Energy Development Agency	1st Floor, Sone Bhawan, Virchand Patel Marg Patna–800 001 Tel: 0612 2233572; fax: 0612 2228734
	Bihar Renewable Energy Development Agency (BREDA) (state nodal agency for energy efficiency)	1st Floor, Sone Bhawan, Birchand Patel Marg Patna–800 001 Tel: 0612 2233572

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Chhattisgarh	Secretary Energy	Government of Chattisgarh, Raipur Tel: 0771 5080962; fax: 0771 2221960
	Chhattisgarh State Electricity Regulatory Commission	Civil Lines, G. E. Road, Raipur (C.G.) Pin: 492001 Tel: 91 771 4073555; fax: 4073553
	Chhattisgarh State Electricity Board	Dangania, C. S. E. B. P.O. Sundar Nagar, Raipur 492013 Tel: 2242345, 4066900 Fax: 4028882
	Chattisgarh Environment Conservation Board	Nanak Nivas, Civil Lines Raipur–492001 Chattisgarh Tel: 0771 2425523; fax: 0771 2425586
	Chhattisgarh State Renewable Energy Development Agency	MIG/A-20 A/1 Sector 1, Shankar Nagar Raipur Tel: 0771-2426446; fax: 5066770
	Chhattisgarh State Renewable Energy Development (CREDA) (state nodal agency for energy efficiency)	Department of Energy, Government of Chhattisgarh MIG/A-20/1, Sector-1, Shankar Nagar Raipur (C.G.)–492 007 Tel: 0771 4066770; fax: 0771 4066771
Goa	Secretary (power)	Electricity Department, Government of Goa, Panaji–403001 Tel: 0832 2419416; fax: 0832 2419624
	Office of Chief Electrical Engineer	Electicity Department, Government of Goa, Vidyut Bhawan Third Floor, Panaji, Goa Tel: 0832 2426022, 2426421
	Goa State Pollution Control Board	1st Floor, Dempo Tower EDC Patto Plaza, Panaji, Goa. Pin: 403 001 Tel: +91 0832 2438528, 2438567, 2438550 Fax: 0832 2438528
	Goa Energy Development Agency	DST&E Building, 1st Floor, Saligo Plateau Opp. Seminary Saligao, Bardez, Goa–403511 Tel: 0832 271194
Gujarat	Principal Secretary	Energy Department, Government of Gujarat, Sachivayalay Block No. 5, Gandhinagar 382010 Telefax: 079 23250797
	Gujarat Electricity Regulatory Commission (GERC)	Viniyamak Bhawan, C- Block, Shivalik Malviya Nagar, New Delhi Telefax: +91 11 26673608
	Gujarat Electricity Board	Sardar Patel Vidyut Bhawan, Race Course Vadodara–390 007 Tel : 0265 338299 Fax: 0265 337918
	Gujarat Pollution Control Board	Paryavaran Bhavan, Sector 10A Gandhinagar–382 010, Gujarat Tel: 079 23222095, 23222096, 23222756 Fax: 079 23232156, 23222784, 23232161
	Gujarat Energy Development Agency (GEDA)	4th Floor, Block No. 11 and 12, Udyog Bhawan, Sector 11 Ghandhi Nagar–382017 Tel: 079 23247086/89/90 Fax: 079 23247097
	Gujarat Energy Development Agency (GEDA) (state nodal agency for energy efficiency)	Surajplaza-II, 2nd Floor Sayajigunj, Vadodara–390 005, Gujarat Tel: 0265 2362066; fax: 0265 2363120

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Haryana	Secretary Power	Government of Haryana, Chandigarh Tel: 0172 2713453: fax: 0172 2745279
	Haryana Electricity Regulatory Commission	Bays 33–36, Sector 4, Panchkula–134112, Haryana Tel: +91 172 2582531; fax:+91 172 2572359 EPABX: 2563052, 2572298, 2582532
	Haryana Vidyut Prasaran Nigam Ltd.	Shakti Bhawan Sector No. 6, Panchkula Tel: 0172 740188 Fax: 5611931–38
	Haryana State Pollution Control Board	C-11, Sector-6, Panchkula Tel: 0172 2581005/006
	Haryana Renewal Energy Development Agency (HAREDA)	SCO 48, Sector 26 Chandigarh–160 019 Tel: 0172 2791917, 2790918, 2790911; fax: 0172 2790928
	Renewable Energy Department, Haryana (state nodal agency for energy efficiency)	S. C. O. No. 48, Sector-26 Madhya Marg, Chandigarh–160 026 Tel: 0172 2791917: fax: 0172 2790928
Himachal Pradesh	Principal Secretary	Department of Power, Government of Himachal Pradesh Shimla–171002 Tel: 0177 262 1859; fax: 0177 2621154
	Himachal Pradesh Electricity Regulatory Commission	Keonthal Commercial Complex, Khalini Shimla–171 002 Himachal Pradesh Tel: + 91 177 2627262, 2627263 Fax: +91 177 2627162
	Himachal Pradesh State Electricity Board	Vidyut Bhawan, Shimla–4 Tel: 0177 213563 Fax: 0177 258984
	Himachal Pradesh State Environment Protection and Pollution Control Board	Paryavaran Bhawan, Phase-III New Shimla–171 009 H. P.
	HIMURJA	HIMURJA, SDA Complex Kasumpti, Shimla–171009 Tel: 0177 2620365 Fax: 0177 2620365
	Himachal Pradesh State Electricity Board (state nodal agency for energy efficiency)	Vidyut Bhawan Shimla-171004 (HP) Tel: (O) 0177 2655007; cell: 9816393156
Jammu and Kashmir	Principal Secretary, Power Department	Government of Jammu Kashmir, New Secretariat Jammu–180 001 Tel: 0191 2546715, 0191 2520864, 0194 2452236 Fax: 0194 2452352, 0191 2545447
	J&K State Electricity Regulatory Commission	PDC Complex, Ashok Nagar Satwari, Jammu Tel: 0191 2457899; fax: 0191 2454420
	Jammu and Kashmir State Pollution Control Board	Sheikhul Alam Campus, behind Government Silk Factory Rajbagh, Srinagar (April–Oct.) 0191 572961 Parivesh Bhawan Forest Complex, Gandhi Transport Nagar (Nawal), Jammu (November–March)
	Jammu and Kashmir Energy Development Agency (JAKEDA)	12 BC Road, Jammu–180001 Tel: 0191 546495; fax: 2546495

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Jharkhand	Secretary (energy)	Government of Jharkhand, Nepal House, Ranchi Tel: 0651 2490053; fax: 0651 2491002
	Jharkhand State Electricity Regulatory Commission	2nd Floor, Rajendra Jawan Bhawan-cum-Sainik Bazar Main Road, Ranchi–834001 Tel: 0651 2330923, 2330763, 2330761, 2330926
	Jharkhand State Electricity Board	Engineering Building, HEC, DHURWA, Ranchi–834004 Tel: 0651 2403807, 2403809
	Jharkhand State Pollution Control Board	T. A. Building, HEC P.O. Dhurwa Ranchi–834004, Jharkhand Fax: 0651 5004123
	Jharkhand Renewable Energy Development Agency	328 B, Road No. 4, Ashok Nagar, Ranchi–834 002 Tel: 0651 2246970; fax: 0651 2240665
	Chief Engineer-cum-Chief Electrical Inspector (state nodal agency for energy efficiency)	Energy Department, Government of Jharkhand Ranchi–834 001 Tel: 0651 2490053; fax: 0651 2491002
Karnataka	Principal Secretary	Energy Department, Government of Karnataka, Sachivalaya II Bangalore–560001 Tel: 080 22034648; fax: 080 22353952
	Karnataka Electricity Regulatory Commission	6th and 7th Floors, Mahalaxmi Chambers # 9/2, M. G. Road, Bangalore–560 001 Tel: +91 080 25320213, 25320214; fax: 25320338
	Karnataka Power Transmission Corporation Ltd.	Corporate Office, Cauvery Bhawan, Banglore–560 009 Tel: 080 2214234
	Karnataka Power Corp. Ltd.	No. 82, Shakthi Bhawan, Race Course Road, Banglore–560 001 Telefax: 080 2252144
	Karnataka State Pollution Control Board	#49, Parisara Bhavan Church Street, Bangalore-01 Karnataka Tel: 080 25581383, 25589112, 25586520
	Karnataka Renewable Energy Development Agency Ltd.	No. 19, Maj. Gen. A. D. Loganadan, INA Cross, Queen's Road Bangalore–560 052 Tel: (O) 080 22282220; fax: 080 22257399
	Karnataka Renewal Energy Development Limited (KREDL) (state nodal agency for energy efficiency)	No. 19, Maj. Gen. A. D. Loganadhan, INA Cross Queen's Road, Bangalore–560 052, Karnataka Tel: (O) 080 22282220, 22208109, 22282221
Kerala	Principle Secretary	Government of Kerala, Power Department, Secretariat Thiruvananthpuram Tel: 0471 2327979; fax: 0471 2725482
	Kerala Electricity Regulatory Commission	30, Belheven Gardens, Kawdiar P.O. Thiruvananthapuram–695003 Tel: 0471 2725951, 2725952, 2725964
	Kerala State Electricity Board Engineers Association	Engineers House, TC 26/1300, Panavila, Trivandrum–695001 Tel: 0471 2330696; fax: 0471 2330853
	Kerala State Pollution Control Board	Housing Board Complex, Chakkorathukulam Kozhikode–673 006 Tel: 0495 2300745
	Agency for Non-conventional Energy and Rural Technology (ANERT)	Pattom P.O., Pb no.1094, Kesavadasapuram Thiruvananthapuram–695 004 Tel: 0471 2440121, 2440122, 2440124; fax: 0471 2449853
	Energy Management Center (state nodal agency for energy efficiency)	Thycaud P.O., Thiruvananthapuram–695014 Kerala Tel: 0471 2323329, 2115043, 2323363

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Madhya Pradesh	Principal Secretary	Government of Madhya Pradesh, Energy Department Bhopal–462001 Tel: 0755 2442055; fax: 0755 2441462
	Madhya Pradesh Electricity Regulatory Commission	"Metro Plaza," 3rd and 4th Floors, E-5 Arera Colony Bittan Market, Bhopal–462 016 Tel: 0761 2430183
	Madhya Pradesh Electricity Board	Shakti Bhawan, Jabalpur–482 008 Tel: 0761 313251 Fax: 0761 311565
	Madhya Pradesh Pollution Control Board	Madhya Pradesh Pollution Control Board, Bhopal Tel: 0755 2469180; fax: 0755 2463742, 2469180
	MP Urja Vikas Nigam Ltd.	Urja Bhawan, Main Road No. 2 Shivaji Nagar, Bhopal–462016 Tel: 0755 2556245, 2553595; fax: 0755 2556245
	M.P.Urja Vikas Nigam Limited (MPUVNL) (state nodal agency for energy efficiency)	Urja Bhavan, Shivaji Nagar Bhopal, Madhya Pradesh Tel: (O) 0755 2556526, 2553595, 2767270 Fax: 0755 2553122
Maharashtra	Principal Secretary (energy)	Mantralaya, Government of Maharashtra, Mumbai–400001 Tel: 022 22026767; fax: 022 22820474
	Maharashtra Electricity Regulatory Commission	World Trade Centre, Center No. 1, 13th Floor, Cuffe Parade Colaba, Mumbai–400005 Tel: 091 22 22163964/65/69; fax: 022 22163976
	Maharashtra State Electricity Board	Plot No. G-9, "Prakashgad" Bandra (East) Mumbai–400 051 Tel: 022 2619400; fax: 022 26443749
	Maharashtra Pollution Control Board	Kalpa Taru Point, 3rd and 4th Floors Opp. Cine Planet, Sion Circle, Mumbai–400 022 Tel: 022 24014701, 24010437 Fax: 022 24024068
	Maharashtra Energy Development Agency (MEDA)	S. No. 191/A, Phase 1, 2nd Floor, MHADA Commercial Complex Opp. Tridal Nagar, Yerawada Pune–411 006 Tel: 020 26615354; fax: 020 26615031
	Maharashtra Energy Development Agency (MEDA) (state nodal agency for energy efficiency)	MHADA Commercial Complex, 2nd Floor, Opp. Tridal Nagar Yerwada, Pune–411 006, Maharashtra Tel: (O) 020 26615354, (D) 020 26614393, 26614403
Manipur	Principal Secretary, Department of Power	Government of Manipur, Manipur Secretariat Imphal–795 001 Tel: 0385 2220964; fax: 0385 222629
	State Electricity Regulatory Commission	Not yet formed
	Chief Engineer (power) Office of the Chief Engineer (power) (generation, transmission, distribution, state nodal agency for energy efficiency)	Secretariat: Electricity Department Government of Manipur, Keisampat, Imphal–795001 Manipur Tel: 0385 2220050; fax: 0385 2220143
	Manipur Renewable Energy Development Agency (MANIREDA)	Department of Science, Technology Minuthong Hafiz Hatta Imphal–795001 Tel: 385 441086; fax: 91 385 224930
	Environment and Ecology Wing	Department of Environment and Forests Government of Manipur Porompat Imphal East–795001 Tel: 0385 221537, 222629

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Meghalaya	Secretary (power)	Energy Department, Government of Meghalaya, Shillong Tel: 0364 2222016
	State Electricity Regulatory Commission	Formed but at inception stage
	Meghalaya State Electricity Board	Meghalaya State Electricity Board Lum Jingshai, Short Round Road Shillong, Pin: 793001 Meghalaya Tel: 0364 2590610, 2590742, 2590710, 2591843, 2591259 Fax: 0364 2590355
	Meghalaya Pollution Control Board	ARDEN, Lumpyngndad Meghalaya
	Meghalaya Non-conventional and Rural Energy Development Agency	Lower Lachaumiere, Opp. P&T Dispensary, near BSF Camp Mawpat Shillong–793 012 Telefax: 0364 2537343
	Senior Electrical Inspector (state nodal agency for energy efficiency)	Horse Shoe Building, Lower Lachumiere Shillong–793 001, Meghalaya Tel: (O) 25007556, (R) 2537722 (residence); cell: 9863049159
Mizoram	Secretary (power)	Government of Mizoram Aizwal–796 001 Tel: 0389 2325653, 2322776; fax: 0389 2318572
	State Electricity Regulatory Commission	Not yet formed
	Power and Electricity Department (state nodal agency for energy efficiency)	Power and Electricity Department, Government of Mizoram Treasury Square, Aizawl–796001, Mizoram Tel: 0389 2322848; fax: 0389 2320862
	Mizoram State Pollution Control Board	M. G. Road, Khatla, Aizawl–796001, Mizoram Tel: 0389 323439
	Zoram Energy Development Agency	H/No.A/4, Muol Veng, Chaltlang, Aizawl, Mizoram–796007 Tel: 0389-2350664, 2350665; fax: 323185
Nagaland	Secretary (power)	Government of Nagaland, Kohima–797001 Tel: 0370 270110; fax: 0370 2220110
	State Electricity Regulatory Commission	Not yet formed
	Department of Power	"Electricity House," Department of Power Government of Nagaland, Kohima–797001, Nagaland
	Nagaland Pollution Control Board	Office of the Chairman, Signal Point Dimapur–797112, Nagaland Tel: 03862 245726 Fax: 03862 245727
	Nagaland Renewable Energy Development Agency (NREDA) (renewable energy and state nodal agency for energy efficiency)	NRSE Cell Rural Development Department Nagaland Secretariat, Kohima, Nagaland Telefax: 0370 241408

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Orissa	Secretary Power	Department of Power, Government of Orissa Bhubaneswar–751001 Tel: 0674 2536960; fax: 0674 2394950
	Orissa Electricity Regulatory Commission	Bidyut Niyamak Bhavan, Unit-VIII, Bhubaneswar–751 012 Tel: 0674-2396117, 2393097, 2391580, 2393606 Fax: 0674 2393306, 2395781
	Orissa Hydropower Corporation Ltd.	Orissa State Police Housing and Welfare Corp. Building Vanivihar, Square, Bhubaneswar–751 022 Tel: 0674 400050; fax: 0674 415402
	Grid Corporation of Orissa	Vidyut Bhawan Janpath, Bhubaneswar–751 007 Tel: 0674 410098, 413396; fax: 0674 41904
	Central Electricity Supply Utility of Orissa	2nd Floor, IDCO Tower, Janpath, Bhubaneswar–751022 Phone: 0674 2545681, 2541727 Fax: 0674 2543125
	Orissa State Pollution Control Board	A-118, Nilakantha Nagar Unit-VIII, Bhubaneswar–751012, Orissa Tel: 0674 2564033 Fax: 0674 2562822, 2560955
	Orissa Renewable Energy Development Agency	S-59, Mancheswar Industrial Estate Bhubaneswar–751 010 Tel: (O) 0674 2580660; fax: 0674 2586368
	Superintending Engineer (electrical) (REPO and projects) (state nodal agency for energy efficiency)	EIC (Elecy)-cum-P. C. E. I., Orissa Unit-V, Bhubaneswar–1, Orissa Tel: 0674 2394873; fax: 0674 2391255, 2391024
Punjab	Secretary of Power	Department of Power, Government of Punjab, Chandigarh Tel: 0172 2741524; fax: 0172 2741554
	Punjab State Electricity Regulatory Commission	SCO: 220-221, Sector 34-A, Chandigarh PABX: 0172 2645164 65 66 Fax: 0172 2664758
	Punjab State Electricity Board	The Mall, Patiala–147 001 Tel: 0175 214927, 212005; fax: 0175 213199
	Punjab Pollution Control Board	Vatavaran Bhawan, Nabha Road, Patiala–147 001 Punjab Tel: 0175 2215793, 2215802
	Punjab Energy Development Agency	Plot No. 1-2, Sector 33-D Chandigarh–160 036 Tel: 0172 663392, 663328, 663382 Fax: 0172 2646384, 2662865
	Punjab Energy Development Agency (state nodal agency for energy efficiency)	Solar Passive Complex Plot No. 1–2, Sector 33-D Chandigarh (U.T.)–160 034 Tel: 0172 2663328, 2663382; fax: 0172 2662865

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Rajasthan	Secretary (energy)	Government of Rajasthan, Jaipur–302001 Tel: 0141 2227400; fax: 0141 2227635
	Rajasthan Electricity Regulatory Commission	Shed No. 5, Vidhyut Bhawan, Vidhyut Marg, Jyoti Nagar Jaipur–302 005 Tel: 0141 2741181, 2741016; fax: 0141 2741018
	Rajasthan State Electricity Board	Vidyut Bhawan, R. C. Dave Marg, Jaipur–302 005 Tel: 0141 740118; fax: 0141 740168
	Rajasthan Pollution Control Board	Rajasthan Pollution Control Board, 4, Institutional Area Jhalana Doongri, Jaipur EPBX: 0141 2700601, 2701801, 2711263, 2707938, 2704581, 2711329; fax: 0141 2710647, 2709980
	Rajasthan Renewable Energy Corporation Limited	E-166, Yudhister Marg, C-Scheme Jaipur–302 001 Tel: 0141 2225898, 2228198; fax: 0141 2226028
	Rajasthan Renewable Energy Corporation (state nodal agency for energy efficiency)	E-166, Yudhishthar Marg C-Scheme, Jaipur–302 001, Rajasthan Tel: 0141 2225859, 2228198, 2221650; fax: 0141 2226028
Sikkim	Secretary, Department of Power	Government of Sikkim, Gangtok–737101 Tel: 03592 2202028, 2202244 Fax: 03592 222927
	Sikkim State Pollution Control Board/ Department of Forests, Environment and Wildlife	Government of Sikkim, Deorali–737102 Tel: 03592 281778, 281385; fax: 03592 281778
	Sikkim Renewable Energy Development Agency (renewable energy and state nodal agency for energy efficiency)	Department of New and Renewable Energy Sources Government of Sikkim, Tashiling Secretariat, Annex- I Gangtok–737 101 Tel: 03592 22659; fax: 03592 22245
Tamil Nadu	Secretary of Power	Government of Tamil Nadu, Secretariat, Chennai Telefax: 044 25671496
	Tamil Nadu Electricity Regulatory Commission	No. 18, 3rd Main Road, Seethammal Colony, Alwarpet Chennai–600 017 Tel: 044 24359215, 24342037; fax: 044 24354982
	Tamil Nadu Electricity Board	N. P. K. R. R., Maaligai, Electricity Avenue, 800 Anna Salai Chennai–600 002 Tel: 044 8251300, 8544528 Fax: 044 8521210
	Tamil Nadu Pollution Control Board	No. 76, Mount Salai, Guindy, Chennai–600 032 Tel: 044 22353134, 22353141; fax: 22353155
	Tamil Nadu Energy Development Agency (TEDA)	EVK Sampath Building, Maaligal, 5th Floor Chennai–600 006 Tel: 044 28224832 Fax: 044 28236592, 28222971
	Electrical Inspectorate Department, Government of Tamil Nadu (state nodal agency for energy efficiency)	Thiru Vi. Ka. Industrial Estate Guindy, Chennai–600 032 Tel: 044 22342915 (D), 22342227, 22343184, 22342796 Fax: 044 22349036

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Uttarakhand	Principal Secretary of Energy	Government of Uttarakhand, Secretariat, Dehradun–248001 Tel: 0135 2712018; fax: 0135 2712077
	Uttarakhand Electricity Regulatory Commission	Institution of Engineers (I) Building, 1st Floor Near ISBT, Majra, Dehradun (UA) Tel: 0135 2641119; fax: 2643755
	Uttarakhand Power Corporation Limited	Urja Bhawan, Kanwali Road, Dehradun Uttarakhand–248006 Tel: 0135 2763672–75
	Uttarakhand Jal Vidyut Nigam Ltd.	Maharani Bagh, G. M. S. Road Dehradun–248006 Uttarakhand Tel: 0135 2523100, 2763508, 2763808; fax: 0135 2763507
	Uttaranchal Pollution Control Board	E-115, Nehru Colony, Hardwar Road Dehradun–248 011, Uttarakhand Tel: 0135 2668922 Fax: 0135 2668092
	Uttranchal Renewable Energy Development Agency (UREDA)	Energy Park Campus, Industrial Area, Patel Nagar Dehradun–248001 Tel: 0135 2521387, 2521386; fax: 0135 2521553
	Office of Electrical Inspector, Government of Uttaranchal (state nodal agency for energy efficiency)	Panchayat Ghar, Bari Mukhani Near Heera Convent School Haldwani, Nainitall Tel: (O) 05946 262839; fax: 05946 261913
Tripura	Secretary, Power Department	Government of Tripura, Agartala–799 001 Tel: 0381 2324185
	Chairman, Tripura Electricity Regulatory Commission	Tripura Electricity Regulatory Commission, Agartala Tel: 0381 2326372
	Tripura State Electricity Corporation Ltd.	Bidyut Bhavan, North Banamalipur, Agartala–799001, Tripura
	Tripura State Pollution Control Board	Vigyan Bhawan, Kunjaban Agartala (W)–799 006, Tripura Telefax: 0381 225421
	Tripura Renewable Energy Development Agency	Vigyan Bhawan, 2nd Floor Pandit Nehru Complex West Tripura, Agartala–799 006 Tel: (O) 0381 225421; fax: 0381 225900
	Chief Engineer (electrical) (state nodal agency for energy efficiency)	Chief Engineer (Electrical) Government of Tripura Department of Power Tripura, Agartala
Uttar Pradesh	Principal Secretary (energy)	Government of Uttar Praesh, Bapu Bhawan Lucknow–226001 Tel: 0522 2238244; fax: 0522 2237922
	Uttar Pradesh Electricity Regulatory Commission	IInd Floor, Kisan Mandi Bhawan, Gomti Nagar, Vibhuti Khand Lucknow–226010 Tel: 0522 2720426; fax: 0522 2720423
	UP Power Corporation Limited	Shakti Bhawan, 14 Ashok Marg, Lucknow–226 001 Tel: 0522 226736; fax: 0522 211169
	Kanpur Electricity Supply Company Limited	14/71, Civil Lines, KESA House, Kanpur–208001 P. B. No. 141 Telegram: KESCo; tel: 0512 2530890 Fax: 0512 2530010
	Uttar Pradesh Pollution Control Board	IIIrd Floor PICUP Bhavan, Vibhuti Khand, Gomti Nagar Lucknow–226020 UP tel: 0522 2720381, 2720681; fax: 0522 2720764
	Non-conventional Energy Development Agency (NEDA), U. P.	Vibhuti Khand, Gomti Nagar Lucknow–226 010 Tel: 0522 2720652; fax: 0522 2720779, 2720829
	Non-conventional Energy Development Agency (NEDA) (state nodal agency for energy efficiency)	Vibhuthikahand Gomtinagar Lucknow–226 016 Telefax: 0522 2720829, 2235503

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
West Bengal	Secretary (power)	Government of West Bengal, Kolkata–700001 Tel: 033 22481267; fax: 033 22438379
	West Bengal Electricity Regulatory Commission	Poura Bhavan (3rd Floor), Block-FD, 415-A,Bidhannagar Kolkata–700106 Tel: 033 23592189, 033 23593397; fax: 033 23593397
	West Bengal State Electricity Board	Vidyut Bhawan, DJ Block Sector-II, Salt Lake Calcutta–700 091 Tel: 033 3591915, 3371550 Fax: 033 3591954
	West Bengal Pollution Control Board	Paribesh Bhavan, 10A, Block-L.A., Sector III, Salt Lake City Calcutta–700 098 Tel: 1 800 345 3390 (toll free)
	West Bengal Renewable Energy Development Agency	Bikalap Shakti Bhawan, Plot- J-1/10, EP & GP Block Salt Lake Electronics Complex, Sector- V Kolkata–700091 Tel. 033 3575038, 3575348 (O); fax: 033 3575037, 3575347
	West Bengal State Electricity Board (state nodal agency for energy efficiency)	Bidyut Bhawan, 7th Floor, Block-DJ, Sector II Bidhanagar (Salt Lake), Kolkata–700 091, West Bengal Tel: 033 23591915, 23371150
Union Territories		
Andman & Nicobar Island	Commissioner Secretary	Department of Power, Andaman and Nicobar Administration Port Blair–744101 Tel: 03192 232479; fax: 03192 235412
	Superintending Engineer, Electricity Department, A&N Administration (electricity generation, transmission and distribution, and nodal agency for energy efficiency)	Electricity Department, A&N Administration Vidyut Bhawan, Port Blair–744 101 Tel: (O) 03192 232404
	The Principal Chief Conservator of Forests	Department of Environment and Forest, Andaman and Nicobar Islands, Van Sadan, Haddo P.O. Port Blair–744102 Tel: +91 3192 233321; fax: +91 3192 230113
Chandigarh	Superintending Engineer (electricity/electrical) (state nodal agency for energy efficiency)	Room No. 523, 5th Floor Deluxe Building, U. T. Sectt. Sector 9-D, Chandigarh–160 009 Tel: (O) 0172 2740475
	Chandigarh Pollution Control Committee	Chandigarh Administration, Additional Town Hall Building IInd Floor, Sector 17-C, Chandigarh–160 017
Delhi	Principal Secretary (power)	Government of NCT of Delhi, I P State, New Delhi Tel: 011 23392047, 23215198; fax: 011 23234640
	Delhi Electricity Regulatory Commission	Viniyamak Bhawan, C- Block, Shivalik Malviya Nagar, New Delhi Telefax: +91 11 26673608
	Delhi Vidyut Board	Shakti Bhawan, Nehru Place, New Delhi–110 019 Tel: 011 6484833, 6484802 Fax: 011-6460942
	BSES Rajdhani	A-1/27, Safdarjung Enclave, New Delhi–110029
	Delhi Pollution Control Committee	4th Floor, I. S. B. T. Building Kashmere Gate Delhi–110006
	Delhi Transco Ltd.	EE & REM Center Delhi Transco Ltd. 2nd Floor, SLDC Building, Minto Road New Delhi–110002 Tel: 011 23234994; fax: 23231886
	CMD, Delhi Transco Limited (state nodal agency for energy efficiency)	Principal Secretary (Power) Shakti Sadan, Kotla Road New Delhi–110 002

Table 1.38: Compendium of State/Union Territory Government Agencies (continued)

STATE	COMMISSION / BOARD / AGENCY	CONTRACT DETAILS
Lakshadweep	Secretary (power)	Union Territory of Lakshadweep, Kavaratti via Cochin–682555 Tel: 04896 262256; fax: 04896 262184
	Executive Engineer (generation, transmission, distribution, renewable sources of energy, and nodal agency for energy efficiency)	Department of Electricity, Kavaratti–Lakshadweep–682555 Telegram: POWERLAK Tel: +91 4896 262127, 262363, 262156 Fax: +91 4896 262936
	Secretary Environment	Union Territory of Lakshadweep Kavaratti–682 555 Tel: +91 4896 262896, 262598, 262592
Puducherry	Principal Secretary (power)	Department of Power, Chief Secretariat, Puducherry–60500 Telefax: 0413 2334448
	Superintending Engineer-I (head of department)	Department of Electricity, Government of Puducherry Puducherry Tel: (O) 0413 233 4277; fax: 0413 233 1556
	The Puducherry Power Corporation	10, Second Cross, Jawahar Nagar, T. R. Pattinam Nagore Main Road, Boomianpet, Karaikal–609606 Puducherry–605005 Tel: 0413 2204043, 2204688 Tel: 04368233287, 233988 (PBX) Fax: 0413 2202971
	The Project Director Renewable Energy Agency of Pondicherry (state nodal agency for energy efficiency)	No. 10, Second Main Road Elango Nagar Puducherry–11 Fax: 0413 2337575
	Director/ Member Secretary	Department of Science, Technology and Environment IIIrd Floor, PHB Building, Anna Nagar, Puducherry–5 Tel: 0413 2201256; fax: 0413 2203494

Section 2: Clean Energy Technologies Defined

This report covers clean energy technologies (CETs) including renewable energy technologies, energy efficiency, hybrids and cogeneration, and clean transportation technologies. CETs are more environmentally friendly than traditional, fossil fuel-based technologies. CETs can either use natural resources such as sunlight, wind, rain, tides, geothermal heat, and plants, which are naturally replenished, and/or use processes to use energy more efficiently.

CETs include renewable energy, hybrid and cogeneration, and energy efficiency technologies for power generation and alternative fuels and advanced technologies for transportation. This chapter presents an overview of these technologies.

Renewable Energy Technologies

Renewable energy technologies considered in this report include biomass and biofuels, waste-to-energy, solar power, wind power, geothermal, hydropower, and ocean power.

Biomass

Biomass consists of plant and plant-derived material. Sources of biomass include agricultural residues such as rice hulls, straw, bagasse from sugarcane production, wood chips, and coconut shells and energy crops such as sugarcane or switch grass. Biomass can be used directly for energy production or processed into fuels. Examples of biomass fuels are liquid and gel fuels including oil and alcohol and pelletized biomass for gasification and combustion. Liquid biomass–derived fuels can be used as substitutes for or additives to fossil fuels.

Although the conversion of biomass into energy results in the release of carbon into the atmosphere, biomass-based energy is considered to be carbon neutral because of the carbon sequestered by plants during the growth of the biomass material. For biomass resources to be renewable, their cultivation must be managed carefully to ensure sustainable harvesting and land use. The use of biomass for energy production can result in competition with food crops, either directly, when food crops themselves are used for energy production, or indirectly, when land and water that would be used to grow crops is used instead for energy crops.

Biomass technologies include equipment for industrial processes that produce heat and steam; electrical power generation through combustion, liquefaction, or gasification; and transportation fuels such as ethanol and biodiesel. Biomass is converted into energy through one of two pathways: thermochemical and biochemical. Thermochemical conversion occurs by combustion, gasification, or pyrolysis. Biochemical conversion results from anaerobic digestion or fermentation. The energy products produced from these biomass conversion processes are electricity, heat, and biofuels.

TEXTBOX 2.1: BIOMASS ENERGY RESOURCES.

Solid biomass: Wood, vegetal waste (including wood waste and crops), conventional crops (oil and starch crops), charcoal, animal wastes, and other wastes (including the biodegradable fraction of municipal solid wastes) used for energy production.

Liquid biofuels: Biodiesel and bioethanol (also includes biomethanol, bio-oil, and biodimethylether).

A) **Biodiesel:** Biodiesel can be used in pure form or may be blended with petroleum diesel at any concentration for use in most modern diesel engines. Biodiesel can be produced from a variety of feedstocks, such as oil feedstock (rapeseed, soybean oils, jatropha, palm oil, hemp, algae, canola, flax, and mustard), animal fats, or waste vegetable oil.

B) **Bioethanol:** The largest single use of ethanol is as a fuel for transportation or as a fuel additive. It can be produced from a variety of feedstocks such as sugarcane, corn, and sugar beet. It can also be produced from cassava, sweet sorghum, sunflower, potatoes, and hemp or cotton seeds or derived from cellulose waste.

Biogas: Methane and carbon dioxide produced by anaerobic digestion or fermentation of biomass, such as landfill gas and digester gas.

Combustion

Direct combustion is a widely used process where biomass is converted into useful power through exposure to high temperatures. Heat from the process can be used to produce steam, which in turn can drive a turbine to generate electricity. Depending on the combustion process, various pre-treatment steps such as sizing (shredding, crushing, and chipping) and drying are required. The heating value and moisture content of the biomass determine the efficiency of the combustion process. Drying prior to the combustion process (e.g., with waste heat) helps to lower the moisture content and raise the heating value to acceptable levels.

Gasification

In the gasification process, biomass is thermochemically converted into gaseous fuel by means of partial oxidation of the biomass at high temperatures. This process requires less oxygen than combustion. In addition to the gaseous fuel, gasifiers produce heat and ash. To maximize the efficiency of gasification-based systems, beneficial uses should be developed for all three products.

The main processes of a gasification plant are fuel feeding, gasification, and gas clean-up. Fuel feeding prepares and introduces the feedstock into the gasifier. The gasifier converts the feedstock into a fuel gas containing carbon monoxide, hydrogen, and methane. In the gas clean-up process, harmful impurities are removed from the fuel gas to allow for safe usage in gas-burning engines or turbines.

Pyrolysis

Pyrolysis is also a thermochemical conversion process that converts biomass into liquid, solid, and gaseous substances by heating the biomass to about 500 degrees Celsius in the absence of air. The pyrolysis process includes feedstock preparation and the application of liquid and char for heat production. Alternative technologies include rapid thermal processing and the vacuum pyrolysis process. The latter involves the thermal decomposition of matter under reduced pressure for conversion into fuels and chemicals. Fast pyrolysis refers to the rapid heating of biomass in the absence of oxygen. Feedstocks for the pyrolysis process include forestry residue (sawdust, chips, and bark) and by-products from the agricultural industry (bagasse, wheat straw, and rice hulls).

Fermentation

Anaerobic digestion is a type of fermentation that biochemically converts organic material, especially animal waste, into biogas that consists mainly of methane and carbon dioxide and is comparable to landfill gas. The biomass is converted by bacteria under anaerobic conditions—without oxygen present. Biogas plants consist of two components: a digester (or fermentation tank) and a gas holder. The digester is a cube- or cylinder-shaped waterproof container with an inlet into which the fermentable mixture is introduced in the form of liquid slurry.

Fermentation of sugars is a biochemical process that entails the production of ethanol (alcohols) from sugar crops (sugarcane, beet) or starch crops (maize, wheat). The biomass is ground and the starch is converted by enzymes and bacteria into sugars. Yeast then converts the sugars into ethanol. Pure ethanol can be obtained by distillation; the remaining solids can be used as cattle feed. In the case of sugarcane, the remaining bagasse can also be used as fuel for boilers or electricity generation processes. These multiple applications allow ethanol plants to be self-sufficient and even to sell surplus electricity to utilities.

Bioethanol is primarily produced by fermentation of sugarcane or sugar beet. A more complex and expensive process involves producing bioethanol from wood or straw using acid hydrolysis and enzyme fermentation. Production of bioethanol from corn is a fermentation process, but the initial processing of the corn requires either wet or dry milling. Residues from corn milling can be used or sold as animal feed. Bioethanol from wheat requires an initial milling and malting (hydrolysis) process.

Biofuels

As defined by the United Nation's, "there are various pathways to convert feedstock and raw materials into biofuels. First-generation biofuel technologies, such as the fermentation of plant sugars or the transesterification of plant oils, are well established. Second-generation biofuel technologies include, among others, acid hydrolysis of wood chips or straw for bioethanol. The technology for extracting oil from oilseeds has essentially remained the same for the last 10 to 15 years."[17] Biodiesel production is a relatively simple process. However, economic small-scale production of biodiesel still requires sufficient feedstock, some equipment, capital, and skills.

While many of the above conversion processes are accomplished on a large scale, new and emerging technologies make it possible to produce electricity, heat, and fuels on a smaller scale and with modular systems. These technologies are being developed for off-grid applications and at an economic scale suitable for developing countries. An example of a modular biopower system [50 kilowatts electric (kWe)] is pictured above.[18]

Where biomass is produced in conjunction with agriculture for food production, it represents an additional value stream. Biofuels are produced in many countries, albeit in varying quantities and at different costs. Liquid biofuels have the potential to provide communities in developing countries with multiple energy services such as electricity for lighting, small appliances, and battery charging; income generation and educational activities; and pumping water, cooking, and transportation.

Waste-to-Energy

Waste-to-energy technology produces energy from waste, such as waste from a city's municipal waste system, farms and other agricultural operations, or commercial and industrial operations. Large-scale waste-to-energy systems can supply heat or electricity in utility-scale electric power plants or district heating systems. Small-scale systems can

provide heating or cooking fuel and electricity to individual farms, homes, and businesses.

In incineration systems, waste is converted into useful energy through combustion. Modern incineration plants include materials separation processes to remove hazardous or recyclable materials from the waste stream before it is incinerated. Improvement in combustion processes and emissions controls minimizes the emission of particulate matter, heavy metals, dioxins, sulfur dioxide, and hydrochloric acid associated with waste combustion. Incineration plants emit fewer air pollutants than coal-fired plants but more than gas-fired plants. While Denmark and Sweden are leaders in the use of incineration technologies for energy generation, other European countries and Japan use the technology as a primary waste-handling system.

Landfill gas systems collect landfill gas for use in boilers, process heaters, turbines, and internal combustion engines, thereby reducing direct emissions of methane and other gases into the atmosphere or displacing the use of fossil fuels for power generation. Landfill gas contains varying amounts of methane and other gases, depending on the type of deposited waste and the characteristics of the landfill. Landfill gas can be piped directly to nearby buildings and used in boilers for heat or industrial processes or used in on-site electric generation plants that can supply electricity to the landfill itself, nearby industries, or to the electric power grid. The amount and type of waste in a landfill, its size, extent of landfill operating activity, and proximity to energy users are all factors that affect a landfill gas project's viability. Environmental precautions to minimize the emission of air pollutants are necessary to meet environmental regulations.

Anaerobic digester systems convert animal and human waste into methane and carbon dioxide, which can be used in turbines and internal combustion engines in electric power plants. Municipal waste treatment plants and confined animal feeding operations can be sources of waste for the digesters. Converting the waste into electricity reduces air and water pollution and the costs associated with processing the waste.

Other new and emerging waste-to-energy technologies use thermal and chemical conversion processes to convert solid waste into fuels.

Solar Power

Solar power is energy from the sun. Solar technologies convert light and heat from the sun into useful energy. Photovoltaic (PV) systems convert sunlight into electricity. Thermal systems collect and store solar heat for air and water heating applications. Concentrating solar power systems concentrate solar energy to drive large-scale electric power plants. Solar power systems produce little or no emissions and have a minimal impact on the environment.

Photovoltaics

PV power systems convert light from the sun into electricity. PV cells are devices made of semiconducting materials similar to those used in computer chips. When these devices are connected to an electrical circuit and exposed to light, they release electrons that flow through the circuit, creating an electric current. PV panels, shown above,[19] are devices that contain a varying number of PV cells and convert sunlight into direct current (DC) electricity. PV panels are typically incorporated into systems that combine batteries and electronic control equipment to provide full-time DC and/or alternating current (AC) power. Typical applications include lighting, electronics, telecommunications, and small-scale water pumping.

Solar Thermal

Solar thermal technology uses flat and concentrating absorbers that collect heat energy from the sun for such processes as crop drying, food processing, water and space heating, industrial process heat, and electricity generation.

Solar water heating systems, such as the ones pictured in China's Yunnan Province,[20] consist of a solar collector and a storage tank. The collector is typically a rectangular box with a transparent cover, through which pipes run, carrying water that is heated by the sun. The pipes are attached to an absorber plate, which is painted black to absorb the heat. As the sun's heat warms the collector, the water is heated and passed to the storage tank, which stores the hot water heated for domestic use. As explained by the National Renewable Energy Laboratories, "Solar water heating systems can be either active or passive. Active systems rely on pumps to move the liquid between the collector and the storage tank, while passive systems rely on gravity and the tendency for water to naturally circulate as it is heated. Simpler versions of this system are used to heat swimming pools."[21]

Solar heating systems to dry food and other crops can improve the quality of the product while reducing waste. Solar driers outclass traditional open-air drying and have lower operating costs than mechanized fuel-based driers. The three types of solar driers are natural convection, forced convection, and tent driers. In natural convection driers, air is drawn through the dryer and heated as it passes through the collector, then partially cooled as it picks up moisture from the product drying. The flow of air is caused by the lighter warm air inside the dryer moving toward the cooler outside air. In forced convection, a fan is used to create the airflow, reducing drying time by a factor of 3 and the area of collector required by up to 50 percent. A photovoltaic panel can be used to generate electricity for the fan. Tent driers combine the drying chamber and collector and allow for a lower initial cost. Drying times are not much lower than for open-air drying, but the main purpose is to provide protection from dust, dirt, rain, wind, and predators; tent driers are usually used for fruit, fish, coffee, or other products for which wastage is otherwise high.

Passive Solar

Passive solar systems integrate solar air heating technologies into a building's design. Buildings are designed with materials that absorb or reflect solar energy to maintain comfortable indoor air temperatures and provide natural daylight. Floors and walls can be designed to absorb and retain heat during warm days and release it during cool evenings. Sunspaces operate like greenhouses and capture solar heat that can be circulated throughout a building. Trombe walls are thick walls that are painted black and made of a material that absorbs heat, which is stored during the day and released at night. Passive solar designs can also cool buildings, using vents, towers, window overhangs, and other approaches to keep buildings cool in warm climates.

Other Solar Technologies

Solar technologies can be used for residential, commercial, and industrial applications. Commercial and industrial applications can include air preheating for commercial ventilation systems, solar process heating, and solar cooling. A solar ventilation system can preheat the air before it enters a conventional furnace, reducing fuel consumption. Solar process heat systems provide large quantities of hot water or space heating for industrial applications. A typical system includes solar collectors that work with a pump, a heat exchanger, and one or more large storage tanks. Heat from a solar collector can also be used for commercial and industrial cooling of buildings, much like an air conditioner but with more complex technology.

Concentrated solar power systems focus sunlight on collectors that serve as a heat source to produce steam that drives a turbine and electricity generator. Concentrating solar power systems include parabolic-trough, dish-engine, and power tower technologies. Parabolic-trough systems concentrate the sun's energy through long rectangular, u-shaped mirrors, which are tilted toward the sun and focus sunlight on a pipe, heating the oil in the pipe and then using it in a conventional steam generator to produce electricity. Dish-engine systems use a mirrored dish similar to a satellite dish, which collects and concentrates the sun's heat onto a receiver, which in turn absorbs the heat and transfers it to fluid within the engine. The heat causes the fluid to expand against a piston or turbine to produce mechanical power, which is then used to run a generator to produce electricity. Power tower systems use a large field of mirrors to concentrate sunlight onto the top of a tower, where molten salt is heated and flows through a receiver. The salt's heat is used to generate electricity through a conventional steam generator. Because molten salt efficiently retains heat, it can be stored for days before being converted into electricity and ensures power production on cloudy days and after the sun has set.

Wind Power

Wind power technology converts energy in the wind into useful power. Historically, wind power technology was used for mechanical applications such as grain milling and water pumping and is still used for such purposes. Today, the primary market for wind power technology is for wind turbines, which convert wind energy into electricity.

Wind power for electricity generation is the fastest growing segment of the power sector, driven by the low cost of electricity generation, short project development and construction times, and government policies favoring clean and renewable energy technologies. The world's approximately 74,000 megawatts (MW) of installed wind capacity meet about 1 percent of the total global electricity demand. In the United States, as of December 2007, total installed wind capacity was approximately 14,000 MW, with an additional 5.7 MW under construction. Wind power accounts for about 20 percent of Denmark's electricity production, 9 percent of Spain's, and 7 percent of Germany's.

According to a recent study,[22] India and China alone are expected to add 36,000 MW of wind power capacity by 2015, representing over 80 percent of the Asian wind market during that period. Market growth in those countries is being driven by the growth of independent power producers (IPP) in India and by electric utilities in China. Major wind turbine manufacturers, including Vestas, GE, Suzlon, Gamesa, and Nordex, are establishing manufacturing facilities in India and China on the basis of strong market

growth for their products in those countries. Suzlon, an Indian wind manufacturing company, is also active in the global wind market, including Europe and North America, as both an equipment supplier and project developer.

Large wind power generating plants, often called wind farms, can be integrated into agricultural and other land uses; a wind farm in Hawaii is shown at right.[23] Wind farms typically use tens to hundreds of wind turbines rated between 600 kilowatts (kW) and 5 MW and produce between 50 and hundreds of megawatts of electric power. In some countries, especially Denmark, Germany, and the United Kingdom, interest in offshore projects is increasing. In these projects, turbines are installed in the shallow waters of coastal areas, where they are exposed to the strong prevailing coastal winds and can be located close to large load centers.

Medium-sized turbines, between 10 and 600 kW, are used in distributed energy applications, supplementing or replacing grid power on farms and other commercial or industrial sites. Small wind turbines, in the 100 watt (W) to 10 kW range, are suitable for household, water pumping, or village power applications.

Conventional horizontal-axis wind turbines for electricity generation consist of a rotor, nacelle, tower, and foundation. The rotor consists of wind-spun blades that drive a gearbox and electric generator in the nacelle, which is located at the top of the tower. (Some turbine designs do not include a gearbox.) The tower and foundation support the nacelle and rotor at a height above the ground where winds are strong. Other wind turbine designs include vertical-axis turbines and small turbines designed for urban use.

Geothermal

Geothermal power is generated using thermal energy from underground sources. Different technologies are used to generate electricity using geothermal resources, which include steam, hot water, and heat stored in rock formations. Dry steam power plants use geothermal steam directly to drive a turbine and electric generator. Water condensed from the process is pumped underground and turned back into steam. Flash steam plants generate power by releasing hot water from underground pressurized reservoirs to drive turbines in an electric power plant. Both types of steam power plants release small amounts of gases and steam into the atmosphere.

Binary-cycle plants have no gas emissions and operate by passing hot water from a geothermal source through a heat exchanger, where heat from the water is transferred into a fluid that drives a turbine for electricity generation. Binary-cycle plants are more efficient than dry steam or flash steam systems and are the preferred technology for projects currently in the planning phase.

Geothermal energy was first used for electric power in Italy in the early 18th century. Geothermal resources are found worldwide in areas where geothermal energy is accessible at shallow levels. Areas with usable geothermal resources include the western United States, the southwestern coast of South America, a few areas in Europe and East Africa, and a significant portion of the Asia–Pacific region. New developments in geothermal power technology will use heat from hot, dry rock formations in and beneath the earth's crust.

Hydropower

Hydropower is the conversion of energy embodied in moving water into useful power. People have been harnessing the power of water for thousands of years for irrigation and operation of mechanical equipment and more recently for electricity generation. In fact, hydroelectric power now supplies about 19 percent of the world's electricity. In the United States, hydropower accounts for only 7 percent of the total electricity production, but over 70 percent of the total installed renewable energy capacity. Most industrialized nations have developed their hydropower potential, but undeveloped resources remain in countries such as China, India, Brazil, and regions of Africa and Latin America. In some countries with access to large untapped hydro resources, the resources are located far from electric load centers, posing a problem for transmission of electricity over long distances. Solving this technological problem and providing efficient transmission of electric power from off-grid hydropower plants is a major opportunity for investment and leadership in many countries around the world.

Hydropower plants are a clean, emission-free source of electricity. The natural hydrological cycle replenishes the resource, but also making it vulnerable to droughts. Competition for scarce water resources for agriculture, recreation, and fishing can affect the availability of water for power production. However, the potential for small hydro project development for rural electrification remains high in countries with concentrations of rural populations living near rivers and streams.

Large hydropower plants with capacities in the tens of megawatts are typically impoundment systems and require a dam that stops or reduces a river's flow to store water in a reservoir. Penstocks carry water from the reservoir to water turbines, which in turn drive electric generators. Impoundment systems offer the advantage of controlled power output and other benefits such as water recreation associated with reservoirs, irrigation, and flood control. However, dams negatively impact fish populations by interfering with migration patterns. Water quality both in the reservoir and downstream of the dam can be affected by changes in water flow and dissolved oxygen levels. Large new hydropower projects often require planning to remove communities from areas that will be flooded after

a dam is built and other measures to manage environmental impact. Recent research has also raised concern about the possible effect of large reservoirs on atmospheric concentrations of greenhouse.

Small hydropower plants, such as the one shown at right,[24] with capacities ranging from a few kilowatts to several megawatts, are typically diversion systems, which divert some water from a river through a canal or penstock to a turbine. Small hydropower plants can provide electricity for isolated rural populations. These systems range in size from household-sized systems to ones that can supply power to entire villages and commercial or industrial loads. Diversion systems, also called run-of-river systems, do not require dams or reservoirs, are suitable for small hydropower projects, and have less impact on the environment. Small hydropower projects are being aggressively developed as part of rural electrification programs; in some cases innovative financing approaches are used in countries such as India, Sri Lanka, and Nepal.

Pumped storage systems require two reservoirs at different heights. They pump water during periods of low electric demand between the two heights and release water from the upper reservoir during periods of high demand.

Ocean Power Technology

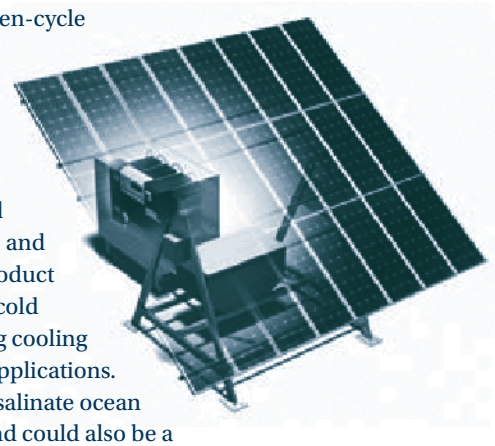
Ocean power technology makes use of energy embodied in the ocean by converting it into electricity. Some systems convert the energy in moving ocean water into electricity,

using either the vertical motion of waves or the horizontal motion of ocean currents. Other systems use temperature differences at different levels of the ocean to generate electricity. Ocean power technology is in the research and development stage, with several commercial prototypes being tested.

Tidal power technology converts the energy in tidal motion caused by the gravitational forces of the sun and moon on ocean water into electricity. Tidal stream systems operate similarly to wind turbines, using tidal turbines to convert energy in ocean currents into a rotational motion to drive turbines and power generators. Like wind turbines, tidal turbines can use horizontal-axis or vertical-axis machines. These systems rely on currents caused by ocean tides moving through and around obstructions such as entrances to bays and other geographical features. Tidal barrage systems are similar to hydropower dams, using differences in height of water on either side of a dam to generate electricity. Barrage systems use a dam-like structure and gates to store and release water as tides cause water levels to rise and fall.

Wave power technology extracts energy from the vertical motion of ocean water caused by waves. Wave power systems can be built offshore, in deep water typically far from coastlines or onshore in shallower water along the coast. Onshore systems show more promise because of their potential proximity to large load centers. Oscillating water column systems use rising and falling water caused by waves to compress and expand an air column in a vertical steel or concrete structure. The oscillating air pressure levels cause a turbine to spin, which drives an electric generator. Tapered channel systems use wave power to fill a raised reservoir with water, which is then allowed to flow through turbines. Pendulor wave systems consist of a rectangular structure with a hinged door that swings with the motion of waves. The swinging door operates a hydraulic pump that drives a turbine.

Ocean thermal energy conversion systems use temperature differences between warm surface water and cool deep water to convert a liquid into gas. The expanding gas drives a steam turbine and electric power generator. Closed-cycle systems circulate warm surface water through a heat exchanger where a fluid with a low boiling point is vaporized. A second heat exchanger condenses the vapor using cool deep water. Open-cycle systems use ocean water itself as the heat transfer fluid, boiling warm surface water in a low-pressure chamber. Water vapor drives a turbine and is condensed back into liquid using cool deep water. Hybrid systems use a combination of open- and closed-cycle arrangements. A by-product of ocean thermal energy systems is cold water, which can be used in building cooling systems, agriculture, and fisheries applications. Open- and hybrid-cycle systems desalinate ocean water in the vaporization process and could also be a source of fresh water. Ocean thermal energy conversion systems work in areas where the difference between the surface of the ocean and deeper water is about 20 degrees Celsius, which is often the case in tropical coastal areas.



As with other renewable energy technologies, ocean power technology projects are capital intensive, but typically have lower operating costs than fuel-based power technologies.

It should be noted that ocean power systems can impact migration patterns in ocean species and cause other environmentally troubling consequences. Systems employing barrages can cause silt buildup that affects tidewater and coastal ecosystems. These consequences can however be mitigated by careful selection of project sites.

Energy Efficiency

The efficiency of an energy conversion process is the ratio of the useful energy produced by the process to the amount of energy that goes into it. Primary energy is

fossil fuel, nuclear, hydroelectric, or renewable energy extracted for use in an energy conversion process. Secondary energy is a high-quality form of energy such as electricity or refined fuel that can be used to provide energy services. An energy service is an end use provided by a process or device that requires secondary energy. Useful energy is the energy that goes toward providing an intended energy service. For example, the light produced by a lighting application is useful energy, whereas the heat produced by the application is not. Energy efficiency can be measured at different points in the process of converting a fuel or other energy resource into an end-use energy service. Efficiency points include the following:

- Extraction efficiency is a measure of the amount of primary energy delivered to a power plant or refinery per unit of energy contained by the energy resource in the ground or atmosphere and required by the extraction process.
- Power plant or refinery conversion efficiency is the ratio of the quantity of secondary energy produced by a power plant, refinery, or other conversion facility to the quantity of primary energy required by the process.
- Transmission and distribution efficiency is the ratio of secondary energy delivered to an end-use facility to the quantity of that energy produced by the power plant or refinery.
- End-use efficiency is a measure of the quantity of useful energy provided by a device or process per unit of energy delivered to the device or process.

Some analyses of energy efficiency also include a measure of the actual need for the energy service. For example, an office building that provides lighting for an unoccupied room or a factory that runs electric machines after the needed process is complete would be less efficient than a building equipped with motion sensors that provide lights only when people are in a room or a factory that shuts down equipment not being used.

Energy efficiency measures involve replacing existing technologies and processes with new ones that provide equivalent or better energy service using less energy. The value of the saved energy typically covers the cost of deploying the new technologies and processes, especially when the increase efficiency occurs downstream in the conversion process. For example, improving the efficiency of a pumping system in an industrial facility by redesigning the circulation system to minimize friction in pipes will result in the need for a smaller motor to drive pumps, which in turn consumes less energy. The reduced electricity demand will result in reduced losses in the entire chain, from the generation plant through the distribution system.

Energy efficiency results in savings at the time the energy service is provided. Energy service providers can also use load management to change the time that an energy service is delivered in order to reduce peak loads on an energy distribution system. Demand-side management (DSM) uses both load management and energy efficiency to save the amount of primary energy required to deliver the energy service.

Energy savings provide several benefits. For energy consumers, benefits include reduced costs and reduced emissions; for energy service providers, efficiency reduces the need for (and cost of) fuel; and for governments and communities alike, efficiency reduces CO2 emissions and can help meet targets for global warming pollutants. Energy efficiency programs can reduce future investment requirements, enhance competitiveness by lowering input and operating costs, free up capital for other social and economic development priorities, and contribute to environmental stewardship objectives. It can also contribute to long-term resource planning and management, hedge fuel risks, and reduce operation and maintenance (O&M) costs. Energy efficiency programs promote improvement and investment in energy generation, delivery, end-use equipment, facilities, buildings, and infrastructure that increase useful energy output or services.

Combining energy efficiency and renewable energy policies maximizes the impact of energy policy on emission reductions. Reducing growth of energy demand allows low- or no-emission renewables to keep up with electric demand. Without coordination, new renewable capacity would be outstripped by increased demand, requiring increased fossil fuel capacity to meet the growth. A combined policy also takes advantage of the temporal synergy of the two approaches: Energy efficiency programs can meet shorter-term goals because efficiency measures can be implemented quickly and at relatively low cost. Renewable energy programs can meet longer-term goals, with new capacity coming on line as the efficiency programs achieve their goals.

Demand Side Management (DSM) is the practice of changing energy consumption patterns to reduce the need for new energy generation capacity. DSM can include energy efficiency programs, peak load reduction programs, real-time and time-of-use energy pricing, interruptible load tariffs, direct load control, and shifting demand from peak to off-peak periods.

Building codes provide guidelines for the construction industry to achieve energy-saving goals through improvements in lighting, heating, and cooling. Special programs promote the development of zero-energy buildings, which combine energy efficiency with energy production technologies to maximize the amount of a building's energy that it generates on site.

In the transportation sector, vehicle efficiency standards, public transportation programs, and urban planning minimize the consumption of transportation fuels while maintaining adequate levels of transportation services.

Industrial efficiency measures the decrease in energy

use and pollution in the industrial sector. Investment in efficient motor and pumping systems, combined heat and power, and distributed on-site energy generation results in long-term energy savings and can help industries compete while meeting environmental regulations.

Energy efficiency measures require capacity-building efforts to empower institutions and individuals to implement energy-saving programs and make energy-saving decisions. Examples of capacity building include establishing energy audit procedures and auditor training programs, developing systems to track energy consumption patterns and establish benchmarks, establishing energy management systems, creating certification systems for energy practitioners, developing energy management guidelines, and facilitating technology transfer.

Hybrids and Co-generation

Hybrid and co-generation power systems take advantage of the benefits of multiple technologies in a single, integrated system. Hybrid power systems use combinations of power generating technologies to generate electricity. Co-generation systems, also called combined heat and power (CHP) systems, generate both electricity and useful heat.

Hybrid Power System Technology

Renewable-based hybrid power systems use combinations of wind turbines, photovoltaic panels, and small hydropower generators to generate electricity. Hybrid power systems typically include a diesel or other fuel-based generator and may include batteries or other storage technology. A completely renewable hybrid power system might use a biofuel-based generator in place of a diesel or other fossil fuel generator. Hybrid power system applications are typically small to medium in scale (producing between 100 watt-hours and tens of megawatt-hours per day) and generate electricity for distributed power generation applications, in remote areas for village power, and for communications and military installations around the world.

Hybrid power system designers select technologies on the basis of the renewable resource available at a particular location to take advantage of resource complementarity. For example, a wind–solar hybrid system can make use of both solar and wind power in areas that experience windy periods at night after the sun has set. A solar–hydropower hybrid system would be appropriate at a location that is near a stream or river and has sunny weather during dry periods of the year when stream flow is low. In some cases, the renewable resource may complement varying availability of fossil fuel resources, such as in areas in the Arctic that experience high winds, when transportation of fuels to remote locations is difficult or impossible due to winter conditions.

Renewable penetration is a measure of the relative contribution of renewable and non-renewable resources in a hybrid power system that includes fossil-fuel-based generation. The simplest and therefore lowest-cost designs are low-penetration systems in which the renewable power components produce sufficient power to save up to 20 percent on fossil fuel consumption. Medium- and high-penetration systems can save up to 40 and 70 percent on fuel consumption, respectively, but are more costly to design and complex to operate because they require additional control equipment to ensure the system's stability.

Advanced hybrid power systems use new technologies for power generation, storage, and system control. New technologies for research and experimental hybrid power systems include natural gas turbines, fuel cells, advanced batteries, flywheels, and other technologies.

Examples of Hybrid Power Systems

Over 400 simple wind–solar–battery hybrid systems provide between 500 and 600 W of electric generation capacity for rural households in Inner Mongolia, China. Each system consists of a 300-W wind turbine and 100- to 200-W photovoltaic array that charges deep-cycle lead acid batteries.

Packaged hybrid power systems, such as the one shown at left,[25] produce power for communications applications, disaster relief, and emergency power and can also provide power for rural electrification and agricultural applications. The SunWize product shown here, can meet continuous loads of 100 to 350 W, equivalent to 2.4 to 8.4 kWh/day.

A final example is a wind–hydro–diesel hybrid system in Coyhaique, Chile, which was designed to provide over 15 percent of the regional capital's electricity needs and to displace about 600,000 liters of diesel fuel annually.

Co-generation System Technology

Conventional fossil-fuel-based electric power plants generate heat as a by-product that is emitted into the environment through gas flues, cooling towers, and by other methods. Co-generation power plants collect this heat for use in thermal applications, thereby converting a higher percentage of the energy in the fuel into useful energy. The most efficient conventional power plants have a typical fuel-to-electricity conversion factor of about 50 percent, while co-generation plants can achieve efficiencies of over 75 percent. Co-generation plants generate more useful power than conventional plants using the same amount of fuel and also produce less pollution per unit of useful energy.

Co-generation plants are most effective when located near a thermal load center. Examples of thermal loads that can be served by a co-generation plant are district heating systems that provide heat for towns and neighborhoods, industrial processes that require heat such as paper mills, institutions such as prisons and hospitals, and wastewater treatment plants.

Co-generation plants either primarily produce electric-

ity and collect exhaust heat from the electricity generation process (topping cycle plant) or primarily generate heat and use excess thermal energy to drive an electricity generating process (bottoming cycle plant). Co-generation plants can be large (greater than about 25 MW) and based on conventional natural gas turbines, combined-cycle natural gas turbines, or steam turbines. Smaller co-generation plants (25 kW to 25 MW) use reciprocating or Stirling engines to run an electric generator and collect the waste heat from the engine's exhaust system for thermal applications. These smaller plants can be fired by biomass or industrial and municipal waste. Very small co-generation plants (1–25 kW) for distributed energy applications use some of the heat from water or space heating systems to generate electricity for a single household or small business.

Clean Transportation Technologies

Alternative fuels for transportation include biodiesel, ethanol, natural gas, and propane. Biofuels produced from agricultural products are considered renewable fuels because they can be grown annually. Biofuels also produce fewer air pollutants when burned in vehicle engines. Advanced transportation technologies include electric vehicles, hybrid electric vehicles, mobile idle reduction systems, and diesel retrofits.

Biodiesel is a fuel derived from biomass that can be burned in diesel engines, including those in light- and heavy-duty diesel vehicles. Biodiesel can be used in all diesel vehicles and produces fewer emissions than fossil fuel diesel. Because biodiesel is produced from biomass, it can be considered a carbon-neutral fuel from a global warming perspective, although carbon emissions from the production and transportation of biodiesel contribute to its carbon footprint. Biodiesel fuel can easily be distributed through the existing fueling infrastructure.

Ethanol can be mixed with gasoline and used in vehicle engines designed to burn gasoline–ethanol mixtures. E85 fuel consisting of 85 percent ethanol and 15 percent gasoline can reduce air pollutant emissions and be used in vehicles with modified engines or with engines designed for use with ethanol fuel mixtures. Existing fueling stations can be modified to distribute ethanol-based fuels.

Compressed and liquefied natural gas (CNG and LNG) can be used in engines designed or modified for use with the fuels. Natural gas engines produce lower emissions than gasoline engines. Wide-scale use of natural gas as a transportation fuel requires adoption of the specialized vehicles by consumers and transportation companies and development of new fueling infrastructure. Propane (LPG) can be used in passenger and light-duty delivery vehicles and in forklifts and mowers. Propane costs vary from 5 to 40 percent less than gasoline and can result in reductions in air pollutants.

Electric vehicles are appropriate for neighborhood use. Using electricity in electric vehicles represents about a 30 percent reduction in fuel costs over conventional fuels. Using electricity from the conventional grid results in a 50 percent reduction in emissions compared to conventional fossil fuel vehicles.

Hybrid electric vehicle technology can be used in passenger and light-duty vehicles and in buses and trucks. Hybrid electric vehicles are more efficient than fossil-fuel-only vehicles and offer slight air pollution improvements over average fossil fuel vehicles. Plug-in hybrids offer an improvement over hybrid electric vehicles by allowing for some of the vehicle's energy to be supplied by the electric power grid and potentially by renewable energy sources. Because electric power tends to be cleaner than power from internal combustion engines, this approach can result in overall reductions in transportation-related pollution.

Fuel efficiency and air emissions for heavy-duty diesel vehicles can be improved with new technologies. Mobile idle reduction systems provide alternative power sources for use when trucks are idle but still require power for heating and cooling. Diesel engine retrofits including exhaust catalysts and filters reduce the emission of air pollutants.

Summary

This section has presented only a brief summary of the clean energy technologies included in this assessment report. There is a considerable wealth of information on these technologies and on the ongoing research and development of other alternative energy technologies from national laboratories such as the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy, as well as various renewable energy industry associations. Other resources for U.S. firms are included in Appendix A of this document.

Appendix A. Resources for U.S. Firms

The following table provides a compendium of trade and investment resources for U.S. clean technology firms, with a brief description of each resource. Contact information for individual organizations can be found by at each listed Web site. The provision of this list of resources does not constitute endorsement of any organization.

ORGANIZATION	WEB SITE	DESCRIPTION
A. U.S. GOVERNMENT		
U.S. Department of Commerce (DOC), International Trade Administration (ITA)	*www.trade.gov*	DOC/ITA participates in the development of U.S. trade policy, identifies and resolves market access and compliance issues, administers U.S. trade laws, and undertakes a range of trade promotion and trade advocacy efforts. ITA has more than 2,000 dedicated individuals posted at U.S. embassies and commercial offices around the world, including in China and India. ITA's lead business unit for trade promotion is the U.S. Commercial Service, which supports U.S. businesses through its global network of offices. The Commercial Service promotes the export of American goods and services worldwide and includes special programs for India and China. A resource guide for U.S. exporters to China, including a listing of legal services for China, is available at *www.buyusa.gov/china/en/contactchina.html*. The India site is available at *www.buyusa.gov/india/en/*. The U.S. Commercial Service offers four ways to grow international sales: world-class market research, trade events that promote products and services to qualified buyers, introductions to qualified buyers and distributors, and counseling through every step of the export process. For more information about how our worldwide network can help your company, call 1-800-USA-TRADE or contact our Export Assistance Centers. ITA's other business units include: Market Access and Compliance, which resolves market access issues, identifies and reduces trade barriers, and ensures that foreign countries are in compliance with trade agreements; Manufacturing and Services, which advocates policies to help U.S. companies be competitive at home and around the world and ensures industry's voice is reflected in policy development; and Import Administration, which administers various trade laws and monitors subsidies. ITA also has various resources to help in this fight including: one-on-one consultations with IPR trade specialists; IP attaches in China, Brazil, India, Russia, Thailand and Egypt to assist American businesses and actively engage with local IP agencies; the China IPR Advisory Program that provides U.S. companies a one-hour free legal consultation with a volunteer attorney experienced in IPR matters; IPR toolkits available online at *www.stopfakes.gov* containing detailed information on local IP laws and resources, as well as helpful local contact information in key foreign markets; free monthly China IPR Webinar series for U.S. industry; a hotline (1-866-999-HALT) answered by IPR experts to help businesses secure and enforce their IP rights; a Trade Fair IPR Initiative to promote protection of IP at domestic and international trade fairs; domestic outreach programs including a U.S. PTO China Roadshow; as well as a free, web-based IPR Module available at *www.stopfakes.gov* to help SMEs evaluate, protect, and enforce their IP both in the United States and overseas.

Export–Import Bank of the United States (Ex-Im Bank)	*www.exim.gov*	Ex-Im Bank is the official export credit agency of the United States. Ex-Im Bank's mission is to assist in financing the export of U.S. goods and services to international markets. Ex-Im Bank enables U.S. companies—large and small—to turn export opportunities into real sales helping to maintain and create U.S. jobs and contribute to a stronger national economy. Ex-Im Bank does not compete with private-sector lenders but provides export financing products that fill gaps in trade financing. Ex-Im Bank assumes credit and country risks that the private sector is unable or unwilling to accept and helps to level the playing field for U.S. exporters by matching the financing that other governments provide to their exporters. Clean energy is a priority for Ex-Im Bank, and the agency offers its most favorable terms for these technologies.
Overseas Private Investment Corporation (OPIC)	*www.opic.gov*	OPIC helps U.S. businesses invest overseas, fosters economic development in new and emerging markets, complements the private sector in managing risks associated with foreign direct investment, and supports U.S. foreign policy. Because OPIC charges market-based fees for its products, it operates on a self-sustaining basis at no net cost to taxpayers. OPIC has made clean energy investment a priority and offers favorable terms for these technologies.
U.S. Agency for International Development (USAID)	*www.usaid.gov*	USAID is an independent agency that provides economic, development, and humanitarian assistance around the world in support of the foreign policy goals of the United States. Currently, USAID is operational in India (but not China). In India, USAID works with local partners to increase viability in the power sector, conserve resources, and promote clean technologies and renewable energy. USAID facilitates sharing of energy and environment best practices between the United States and India and among South Asian countries.
US Department of Agriculture (USDA)	*www.usda.gov*	The Foreign Agricultural Service (FAS) of USDA works to improve foreign market access for U.S. products, build new markets, improve the competitive position of U.S. agriculture in the global marketplace, and provide food aid and technical assistance to foreign countries. FAS has the primary responsibility for USDA's international activities—market development, trade agreements and negotiations, and the collection and analysis of statistics and market information. It also administers USDA's export credit guarantee programs. USDA helps increase income and food availability in developing nations by mobilizing expertise for agriculturally led economic growth. USDA is also active in bioenergy development, domestically and overseas.

U.S. Department of Energy (USDOE)	*www.energy.gov*	USDOE is committed to reducing America's dependence on foreign oil and developing energy efficient technologies for buildings, homes, transportation, power systems, and industry. The Office of Energy Efficiency and Renewable Energy (EERE) seeks to strengthen America's energy security, environmental quality, and economic vitality in public–private partnerships that enhance energy efficiency and productivity; bring clean, reliable, and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life. EERE leads the federal government's research, development, and deployment efforts in energy efficiency. EERE's role is to invest in high-risk, high-value research and development (R&D) that is critical to the nation's energy future and would not be sufficiently conducted by the private sector acting on its own. Program activities are conducted in partnership with the private sector, state and local governments, USDOE national laboratories, and universities. EERE offers financial assistance for renewable energy and energy efficiency R&D. EERE also works with stakeholders to develop programs and policies to facilitate the deployment of advanced clean energy technologies and practices. EERE has bilateral agreements in clean energy with India and China and participates in the Asia–Pacific Partnership on Clean Development and Climate (APP) (see below).
U.S. Department of State (State)	*www.state.gov*	State is the lead U.S. foreign affairs agency, and the Secretary of State is the president's principal foreign policy adviser. The department advances U.S. objectives and interests in shaping a freer, more secure, and more prosperous world through its primary role in developing and implementing the president's foreign policy. The Bureau of Economic, Energy and Business Affairs (EEB) formulates and carries out U.S. foreign economic policy, integrating U.S. economic interests with our foreign policy goals so that U.S. firms and investors can compete on an equal basis with their counterparts overseas. It implements U.S. economic policy in cooperation with U.S. companies, U.S. Government agencies, and other organizations. State also manages U.S. embassies overseas and coordinates U.S. activities under the APP (see below).
U.S. Embassy in China	*http://beijing.usembassy-china.org.cn*	The embassy provides information on travel, doing business in China, an IPR toolkit (*http://beijing.usembassy-china.org.cn/ipr.html*), and other useful information for U.S. visitors to China. The U.S. Commercial Service has offices throughout China as well.
U.S. Department of Treasury (Treasury)	*www.treasury.gov*	The Office of Foreign Assets Control (OFAC) of Treasury administers and enforces economic and trade sanctions based on U.S. foreign policy and national security goals against targeted foreign countries, terrorists, international narcotics traffickers, and those engaged in activities related to the proliferation of weapons of mass destruction. OFAC acts under presidential wartime and national emergency powers, as well as authority granted by specific legislation, to impose controls on transactions and freeze foreign assets under U.S. jurisdiction.
U.S. Small Business Administration (SBA)	*www.sba.gov*	SBA's mission is to aid, counsel, assist, and protect the interests of small-business concerns; to preserve free competitive enterprise; and to maintain and strengthen the overall economy of our nation. SBA also helps small businesses to compete in the global marketplace.

U.S. Trade and Development Agency (USTDA)	*www.tda.gov*	USTDA's mission is to advance economic development and U.S. commercial interests in developing and middle-income countries. To this end, the agency funds various forms of technical assistance, investment analysis, training, orientation visits, and business workshops that support the development of a modern infrastructure and a fair and open trading environment. In carrying out its mission, USTDA gives emphasis to economic sectors that may benefit from U.S. exports of goods and services.
U.S. Trade Representative (USTR)	*www.ustr.gov*	USTR is an agency of over 200 people with specialized experience in trade issues and regions of the world. They negotiate directly with foreign governments to create trade agreements, resolve disputes, and participate in global trade policy organizations. They also meet with governments, business groups, legislators, and public interest groups to gather input on trade issues and explain the president's trade policy positions.
StopFakes	*www.stopfakes.gov*	International Trade Administration of the Department of Commerce manages StopFakes, which provides access to information on promoting trade and investment, strengthening the competitiveness of U.S. industry, and ensuring fair trade and compliance with trade laws and agreements.
B. Non–U.S. Government Organizations		
Alliance to Save Energy (ASE)	*www.ase.org/*	Programs in the United States and abroad (including China and India) conduct research, advise policy-makers, and educate decision-makers on energy efficiency issues. The China program educates manufacturers and government officials on efficient windows and other technologies. In India, ASE is working on municipal water delivery.
Amerex Brokers, LLC	*www.amerexenergy.com/*	A division of the GFI Group that operates markets in electrical power, natural gas, emission allowances, and renewable energy credits. Also provides energy procurement services to large commercial and industrial customers.
American Council for an Energy-Efficient Economy (ACEEE)	*www.aceee.org/*	Non-profit organization provides technical and policy assessments, policy support, business, and public interest collaborations. Organizes conferences and provides information dissemination through publications and education.
American Council on Renewable Energy (ACORE)	*www.acore.org/*	ACORE establishes collaborative research and communication among leaders of financial institutions, government, professional service providers, and others in the wind, solar, geothermal, biomass and biofuels, hydropower tidal and current energy, and waste energy industries. Organizes an annual international ministerial-level workshop on renewable energy in Washington, D.C.
Asia-Pacific Partnership on Clean Development and Climate (APP)	*www.asiapacificpartnership.org*	The APP is a Presidential initiative to accelerate the development and deployment of clean energy security, reduce harmful air pollution, and greenhouse gas (GHG) emissions intensity in the context of sustained economic growth. The United States, Australia, China, India, Japan, the Republic of Korea, and Canada (accounting for over half of the world's GHG emissions, energy consumption, GDP, and population) agreed to work together and the private sector to expand investment and trade in cleaner energy technologies. Led by the State Department, the APP is an industry-focused, technology-driven, results-oriented partnership. Through Activities like the Clean Energy Technologies Trade Mission to China and India, the Department of Commerce seeks to position U.S. companies to make commercial sales while removing obstacles that restrict the ability of U.S. companies to do business in partner countries.

Association of Energy Engineers (AEE)	*www.aeecenter.org/*	Non-profit society of energy professionals in 77 countries promotes interest in sustainable development. Publishes industry newsletters for facility managers, renewable energy developers, environmental managers, and energy service providers.
China Embassy in United States	*www.china-embassy.org/eng*	Provides information on China and its economy and trade, ministry information, and some policy documents.
Cultural Savvy	*www.culturalsavvy.com/*	Provides training and consulting services for international business travelers. Includes some on-line information.
E Source	*www.esource.com/*	For-profit company originally operated as a Rocky Mountain Institute project. E Source provides analysis of retail energy markets, services, and technologies to its members, which include electric and gas utilities, large corporate and institutional energy users, government agencies, energy service companies, manufacturers, consultants, and others in over 20 countries.
Evolution Markets	*new.evomarkets.com/*	Provides financial and brokerage services for the global green market and clean energy sector.
Intergovernmental Panel on Climate Change	*www.grida.no/climate/ipcc/tectran/index.htm*	This site provides an overview of methodological and technological issues in technology transfer, including financing and partnerships, and sectoral analyses.
International Cultural Enterprises, Inc.	*www.businessculture.com*	Publishes best-practice reports, audio guides, and Web-based reports on country-specific business practices, customs, negotiating tactics, communication, and other issues. Also provides cross-cultural training and consulting services.
National Association of Energy Service Companies (NAESCO)	*www.naesco.org/*	The energy service industry trade organization advocates for the delivery of cost-effective energy services, provides industry information and data, and helps establish industry standards.
Organization for Economic Co-operation and Development (OECD) Directorate for Financial and Enterprise Affairs	*www.oecd.org/*	The OECD Investment Committee provides guidelines for multinational enterprises covering business ethics and sustainable development. Also provides investment statistics and analysis and investment codes.
Organization for International Investment	*www.ofii.org/*	Represents interests of U.S. subsidiaries of companies headquartered abroad. Educates public and policy-makers about positive role U.S. subsidiaries play in U.S. economy and ensures that U.S. subsidiaries are not discriminated against in state or federal law. Provides peer-to-peer forums for U.S. subsidiaries.
Renewable Energy Access	*www.renewableenergyaccess.com*	Company directory is a searchable list of companies by function. Searching for financial services companies generates a list of clean energy finance companies worldwide.
RenewableEnergyStocks.com	*www.renewablenergystocks.com*	Provides information on renewable energy investing and links to renewable energy industry information.
The Association of Energy Services Professionals (AESP)	*www.aesp.org/*	Membership organization of electric and natural gas utilities, public benefits associations, regulatory and non-profit entities, vendors, manufacturers, and consulting firms provides professional development programs and networking opportunities and promotes knowledge transfer.
The Lett Group	*www.lettgroup.com/*	Trains executives and professionals in business etiquette, manners, and other skills using international protocol.

UNEP Sustainable Energy Finance Initiative	*www.sefi.unep.org/*	Provides financiers with tools and access to networks to foster investment in sustainable energy projects.
World Energy Efficiency Association (WEEA)	*www.weea.org/*	Assists developing and reindustrializing countries in assessing information on energy efficiency. Publications include best practices and case studies on energy efficiency projects, financing, and ESCOs. Also publishes directories of international energy organizations and companies.
World Trade Organization	*www.wto.org/*	The WTO site provides information on trade goods, rules, and regulations; intellectual property rights, including trade-related aspects of Intellectual Property Rights (TRIPS); accessions, government procurement, and other commerce and trade topics. Information on China and the WTO is available at *www.wto.org/english/thewto_e/countries_e/china_e.html*; information on India and the WTO is available at *www.wto.org/english/thewto_e/countries_e/india_e.htm*.

Appendix B. Sustainable Energy Finance Directory

This directory is synthesized from the on-line resources available at *www.sef-directory.net/*, which is maintained by the Sustainable Energy Finance Initiative (SEFI), a joint initiative of the United Nations Environment Program and the Basel Agency for Sustainable Energy. It has been updated as of late 2007.

Note that financing for clean energy technologies has increased significantly in the last few years. This directory provides information on a number of these sources based on information from SEFI but is not exhaustive.

Debt Capital				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
Asian Development Bank (ADB)	Debt, equity, fund development, risk mitigation	Member countries	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind Other activities: capacity building, institutional development, policy and regulatory activities, project development, and CDM support. ADB has committed $1 billion per year for renewable energy and energy efficiency over the next few years. Of special note are its efforts to catalyze local financing institutions and the private sector to participate in the delivery of clean energy services and to include modern energy access.	
DEG German Investment and Development Company	Debt capital	Public	Energy efficiency, bioenergy, Small hydropower	
E+Co	Debt capital	Multilateral, Bilateral, foundations, private sector	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind Also provides business planning support and seed capital	
European Investment Bank (EIB)	Debt capital	Capital markets	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	GEOGRAPHIC FOCUS	CONTACT
	West Asia, South Asia, Southeast Asia, East Asia	6 ADB Avenue, Mandaluyong City 0401 Metro Manila Philippines Tel: +632 632 4444 Fax: +632 636 2444 *information@adb.org* *www.adb.org*
	West Asia, East Asia, Southeast Asia, North Africa, Central and Eastern Europe, Central and South America, South Asia, Sub-Saharan Africa	CONTACT—China: DEG Representative Office Beijing Beijing Sunflower Tower, Suite 1110 No. 37 Maizidian Street Chaoyang District 100026 Beijing People's Republic of China Tel: +86 10 8527 5168 Fax: +86 10 8527 5170 *degbj@public3.bta.net.cn, stb@degchina.com* *www.deginvest.de/EN_Home/index.jsp* CONTACT—India: DEG Representative Office New Delhi 21, Jor Bagh New Delhi–110 003 India Tel: +91 11 2465 5138, 3012 Fax: +91 11 2465 3108 *deg@degindia.com www.deginvest.de/EN_Home/index.jsp*
	West Asia, North Africa, Central and South America, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	Hongcheng Plaza Building, Suite 1302 Qingnian Road Kunming 650021 Yunnan, China Tel: +86 871 312 0934 Fax: +86 871 310 0897 *EandCo.China@EandCo.net* *www.energyhouse.com*
	Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Sub-Saharan Africa	100 Boulevard Konrad Adenauer L-2950 LuxembourgLuxembourg Tel: +35 2 43791 Fax: +35 2 437704 *info@eib.org* *www.eib.org*

International Finance Corporation	Debt, equity, fund development, risk mitigation	IFC funds, GEF, other	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, among others	
Triodos Renewable Energy for Development Fund	Debt capital	Bilaterals, multilaterals, foundations, private sector	Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Sub-Saharan Africa	CONTACT—China Michael Ipson, Country Manager 15th Floor, China World Tower 2 China World Trade Center No. 1 Jian Guo Men Wai Avenue Beijing, China 100004 Tel: +86 10 5860 3000 Fax: +86 10 5860 3100 *mipson@ifc.org* *www.ifc.org/ifcext/eastasia.nsf/Content/China* Mario Fischel, General Manager Private Enterprise Partnership for China R. 2716, 27th Floor CCB Sichuan Building No. 88, Tidu Street Chengdu, Sichuan Province P. R. China, 610016 Tel: + 86 28 8676 6622 Fax: N/A *mfischel@ifc.org* *www.ifc.org/ifcext/eastasia.nsf/Content/China* Guwahati–781 005, Assam Tel: +91 361 2463 133 36 Fax: +91 361 2463 152 *SouthAsia@ifc.org* *www.ifc.org/India*	CONTACT—India New Delhi Paolo Martelli, Director, South Asia or Anil Sinha, General Manager, SEDF 50-M, Shanti Path, Gate No. 3 Niti Marg, Chanakyapuri New Delhi–110 021 Tel: +91 11 4111 1000 Fax: +91 11 4111 1001/02*SouthAsia@ifc.org* *www.ifc.org/ifcext/southasia.nsf/Content/India_overview* Mumbai Sujay Bose, Senior Manager Godrej Bhavan, 3rd Floor Murzban Road, Fort Mumbai–400 001, Maharashtra Tel: +(91 22 6665 2000 Fax: +91 22 6665 2001 *SouthAsia@ifc.org* *www.ifc.org/ifcext/southasia.nsf/Content/India_overview* Chennai Prasad Gopalan, Principal Investment Officer Giriguja Enclave, No. 56 2nd Floor, 1st Avenue Shanti Nagar, Adyar Chennai–600 020, Tamil Nadu Tel: +91 44 2446 2570 Fax: +91 44 2446 2571 *SouthAsia@ifc.org* *www.ifc.org/ifcext/India* Guwahati Sushanta Kumar Pal, Business Development Officer First Floor, Orion Place Next to Mizoram House Christian Basti, G S Road
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Sub-Saharan Africa	Utrechtseweg 60, P.O. Box 55 3700 AB Zeist The Netherlands Tel: +31 30 693 6500 Fax: +31 30 693 6566 *tredf@triodos.nl* *www.triodos.com* Team members Bob Assenberg Tel: +31 30 693 65 60 *bob.assenberg@triodos.nl*	Gerrit-Jan Brunink Tel: +31 30 693 65 78 *gerrit-jan.brunink@triodos.nl* Helena Korhonen Tel: +31 30 693 65 41 *helena.korhonen@triodos.nl* Martijn Woudstra Tel: +31 30 694 26 91 *martijn.woudstra@triodos.nl*

Verde Ventures, Conservation International	Debt capital		Energy efficiency	
World Bank	Loans, guarantees, analytic, and advisory services to developing countries	Member countries	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Private Equities				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
Actis Energy Fund	Private equities		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Al Tayyar Energy	Private equities		Bioenergy, small hydropower, solar (PV and thermal), wind	
Battery Ventures	Private equities	Limited partners	Energy efficiency, cleaner fuels, solar (PV and thermal), wind, fuel cells	

	Southeast Asia, Central and South America, Oceania, Sub-Saharan Africa	2011 Crystal Drive, Suite 500 Arlington, Virginia 22201 USA Tel: +1 703 341 2400, +1 800 406 2306 Fax: +1 703 553 0721 *verdeventures@conservation.org* *www.conservation.org/xp/verdeventures/*	
	West Asia, South Asia, Southeast Asia, East Asia	CONTACT—India Hema Balasubramanian *hbalasubramanian@worldbank.org* Sunita Malhotra *smalhotra@worldbank.org* Tel: +91 11 24617241	CONTACT—Washington, D.C. Junhui Wu 1818 H Street, N.W. Washington, D.C. 20433 USA Tel: +1 202 458 1405 Fax: +1 202 522 1648 *Jwu@worldbank.org*

	GEOGRAPHIC FOCUS	CONTACT	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Sub-Saharan Africa	CONTACT—China Benjamin Cheng, Investment Principle 712 China World Tower 2 No. 1 Jianguomenwai Street Chaoyang District Beijing 100004 People's Republic of China Tel: +86 10 6505 6655 Fax: N/A *bcheng@act.is* *www.act.is* CONTACT—India Bangalore Subba Rao Telidevara, Partner 15 Rest House Crescent Bangalore–560001 India Tel: +91 80 2555 0651 Fax: +91 80 2555 0592 *stelidevara@act.is* *www.act.is*	Delhi Steven Enderby, Partner NBCC Place, 1st Floor, East Tower Bhisham Pitamah Marg Pragati Vihar New Delhi–110003 India Tel: +91 11 4366 7000 Fax: +91 11 4366 7070 *senderby@act.is* *www.act.is* Mumbai JM Trivedi, Partner 704, 7 Floor Dalamal House Jamnala Bajaj Road Nariman Point Mumbai–400021 India Tel: +91 22 2281 6430 Fax: +91 22 2282 0737 *jtrivedi@act.is* *www.act.is*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Sub-Saharan Africa	Granville (Pete) Smith P.O. Box 757 Abu Dhabi United Arab Emirates Tel: +971-2-681-4004 Fax: +971 2 681 4005 *pete@altayyarenergy.com* *www.altayyarenergy.com*	
	South Asia, Southeast Asia, West Asia, North America, Western Europe	Ramneek Gupta *rgupta@battery.com* Mark Sherman mark@battery.com	

CDC Group PLC	Private equities	Private	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), Wind	
E+Co	Debt capital	Multilateral, bilateral, foundations, private sector	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
EnviroTech Financial, Inc.	Private equities		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Global Environment Fund	Private equities		Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Good Energies Inc.	Private equities	Private	Solar (PV and thermal), wind	
Jane Capital Partners LLC	Private equities		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
New Energies Invest AG (Bank Sarasin + Cie)	Private equities	Rights offering	Energy efficiency, bioenergy, small hydropower, solar (PV and thermal), wind, fuel cells	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Sub-Saharan Africa	6 Duke Street, St. James's London SW1Y 6BN United Kingdom Tel: +44 0 20 7484 7700 Fax: +44 0 20 7484 7750 *enquiries@cdcgroup.com* *www.cdcgroup.com*	930 Winter Street, Suite 2500 Waltham, Massachusetts 02541 USA Tel: +1 781 478 6600 Fax: +1 781 478 6601 *www.battery.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Sub-Saharan Africa	CONTACT—China Wu Jing, Investment Officer Laura Colbert, Communications Officer Zhu Xiaonan, Office Manager Hongcheng Plaza Building, Suite 1302 Qingnian Road Kunming 650021 Yunnan, China Tel: +86 871 312 0934 Fax: +86 871 310 0897 *EandCo.China@EandCo.net* *www.energyhouse.com*	CONTACT—Main Office Christine Eibs Singer 383 Franklin Street Bloomfield, New Jersey USA Tel: +1 973 680 9100 Fax: +1 973 680 8066 *chris@energyhouse.com* *www.energyhouse.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Gene Beck, President EnviroTech Financial, Inc. 333 City Boulevard West, 17th Floor Orange, California 92868-5905 USA Tel: +1 714 532 2731 Fax: +1 714 459 7492 *gbeck@etfinancial.com* *www.etfinancial.com*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Sub-Saharan Africa	1225 Eye Street N.W., Suite 900 Washington, D.C. 20005 USA Tel: +1 (02 789 4500 Fax: +1 202 789 4508 *info@globalenvironmentfund.com* *www.globalenvironmentfund.com*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Michael Ware 1250 24th Street, N.W., Suite 300 Washington, D.C. 20037, USA Tel: +1 202 466 0582 Fax: +1 202 466 0564 *www.goodenergies.com*	
	South Asia, Southeast Asia, East Asia, North America, Oceania	Neal Dikeman 505 Montgomery, 2nd Floor San Francisco, California 94111 USA Tel: +1 415 277 0180 Fax: +1 415 277 0173 *dikeman@janecapital.com* *www.janecapital.com*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Andreas Knörzer Elisabethenstrasse 62 CH-4002 Basel Switzerland Tel: +41 0 61 277 7477 *andreas.knoerzer@sarasin.ch* *www.newenergies.ch/index_ei.html*	

OCM/GFI Power Opportunities Fund	Private equities	Corporate pension funds, insurance companies, foundation endowments, etc.	Energy efficiency	
Private Energy Market Fund LP (PEMF)	Private equities	Private	Bioenergy, wind	
Robeco Milieu Technologies	Private equities	Private	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Sigma Capital	Private equities		Energy efficiency, bioenergy, small hydropower, solar (PV and thermal), wind	
Triodos International Fund Management BV	Private equities	Institutional and private investors	Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	11611 San Vicente Boulevard, Suite 710 Los Angeles, California 90049 USA Tel: +1 310 442 0542 Fax: +1 310 442 0540 *info@gfienergy.com* *www.gfienergy.com*
	South Asia, Southeast Asia, East Asia, West Asia, Central and Eastern Europe, Western Europe,	Gustaf Godenhielm (Tekniikantie 4 D) P.O. Box 92 02151 Espoo Finland Tel: +358 9 469 1208 Fax: +358 9 469 1207 *gustaf.godenhielm@pemfund.com* *www.pemfund.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Postbus 973 3000 AZ Rotterdam The Netherlands Tel: +31 10 224 12 24 Fax: +31 10 411 52 88 *info@robeco.nl* *www.robeco.nl*
	Southeast Asia, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe	Bruce Woodry, Chairman and CEO P.O. Box 1002 Harbor Springs, Michigan 49740 USA Tel: +1 231 526 9585 Fax: N/A *woodry@sigmacapital.net* *www.sigmacapital.net/*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Western Europe, Sub-Saharan Africa	Utrechtseweg 60, P.O. Box 55 3700 AB Zeist The Netherlands Tel: +31 30 693 6500 Fax: +31 30 693 6566 *tredf@triodos.nl* *.www.triodos.com* Team members Bob Assenberg Tel: +31 30 693 65 60 *bob.assenberg@triodos.nl* Gerrit-Jan Brunink Tel: +31 30 693 65 78 *gerrit-jan.brunink@triodos.nl* Helena Korhonen Tel: +31 30 693 65 41 *helena.korhonen@triodos.nl* Martijn Woudstra Tel: +31 30 694 26 91 *martijn.woudstra@triodos.nl*

UBS (Lux) Equity Fund Future Energy	Private equities		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Warburg Pincus Investment Consulting Company Ltd.	Private equities	Private	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Public Equities				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
New Alternatives Fund	Public equities	This is an open and mutual fund that seeks shareholders.	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—Beijing 1609 China World Tower 1 Jian Guo Men Wai Avenue Beijing 100004 People's Republic of China Tel: +86 10-6505 22 13,+86 10-6505 22 14, +86 10-6505 22 15 Fax: +86 10-6505 11 79 CONTACT—Shanghai Room 3407 Citic Square No. 1168 Nanjing Xi Lu Shanghai 200041 People's Republic of China Tel: +86 21 5292 55 55 Fax: +86 21 5292 55 52	CONTACT—India 2/F, Hoechst House Nariman Point Mumbai–400 021 India Tel: +91 22 281 4649, +91 22 281 4676 Fax: +91 22 230 9000, +91-22-281 4673 CONTACT—Main Office Gerhard Wagner, Socially Responsible Investments Analyst Gessnerallee 3 8098 Zurich Switzerland Tel: +41 1 235 55 52 Fax: +41 1 235 55 30 *gerhard.wagner@ubs.com* *www.ubs.com/swedenfunds.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—Beijing Beijing Representative Office 9th Floor, China World Tower 1 1 Jianguomenwai Avenue Beijing 100004 China Tel: +86 10 5923 2533 Fax: +86 10 6505 6683 *www.warburgpincus.com* CONTACT—Shanghai Shanghai Representative Office Unit 2201, Bund Center Office Tower No. 222 Yanan Road (East) Shanghai, 200002 China Tel: +86 21 6335 0308 Fax: +86 21 6335 0802 *www.warburgpincus.com*	CONTACT—India Mumbai Office 7th Floor, Express Towers Nariman Point Mumbai–400 021 India Tel: +91 22 6650 0000 Fax: +91 22 6650 0001 *www.warburgpincus.com* CONTACT—Main Office Almack House 28 King Street, St. James's London SW1Y 6QW United Kingdom Tel: +44 207 360 0306 Fax: +44 207 321 0881 *www.warburgpincus.com*

	GEOGRAPHIC FOCUS	CONTACT
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	150 Broadhollow Road, Suite 360 Melville, New York 11747 USA Tel: +1 800 423 8383 Fax: N/A *info@newalternativesfund.com* *www.newalternativesfund.com*

New Energy Fund LP	Public equities	High-net-worth individuals, family offices, foundations, and institutions	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	

Carbon Finance				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
Carboncredits.nl	Carbon finance		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Climate Change Capital	Carbon finance, equity, venture capital	Public, private	Energy efficiency, renewable energy	
CO2e	Other	Finance through sale of emissions credits	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa (This is a global fund, since it is a global phenomenon.)	527 Madison Avenue, 6th Floor New York, New York 10022 USA Tel: +1 212 419 3918 Fax: +1 212 419 3971 *www.newenergyfundlp.com*
	GEOGRAPHIC FOCUS	**CONTACT**
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, Oceania, Western Europe, Sub-Saharan Africa	Carboncredits.nl Juliana van Stolberglaan 3 The Hague The Netherlands Tel: +31 70 3735 495 Fax: +31 70 3735 000 *carboncredits@senternovem.nl* *www.carboncredits.nl*
	Global, active in China and India	CONTACT —London 3 More London Riverside London SE1 2AQ, London United Kingdom Tel: +44 0 20 7939 5000 Fax: +44 0 20 7939 5030 CONTACT—China Climate Change Capital 9/F China Life Tower 16 Chao Wai Da Jie Beijing 100020 Tel: +86 10 85253797 Fax:+86 10 85253197
	West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	CONTACT—India CantorCO2e India Private Limited 10th Floor, Raheja Chambers Free Press Journal Marg Nariman Point Mumbai–400 021 India Tel: +91 986 753 1203 Fax: N/A *mumbai@cantorco2e.com* *www.co2e.com* CONTACT—International Office 181 University Avenue, Suite 1500 Toronto, Ontario Canada M5H 3M7 Tel: +1 416 350 2177 Fax: +1 416 350 2985 *cdm@cantorco2e.com* *www.co2e.com*

EcoSecurities	Carbon finance	Public, private	Renewable energy, waste management, industrial efficiency.	
European Carbon Fund	Carbon finance		Energy efficiency, cleaner fuels, geothermal, solar (PV and thermal), wind	
IFC-Netherlands Carbon (CDM) Facility (INCaF)	Carbon finance		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, wind	
Japan Carbon Finance, Ltd. (JCF)	Carbon finance	Major Japanese private enterprises and policy-lending institutions	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
KfW Carbon Fund	Carbon finance		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Natsource	Carbon finance	Public, private	Energy efficiency, renewable energy	
Prototype Carbon Fund (PCF)	Carbon finance	Trust Fund administered by the World Bank	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	Global, including China and India	CONTACT—China Unit 708, China Resources Building 8 Jianguomen Bei Avenue Beijing, 100005 Tel: +86 10 6518 1081 Fax: +86 10 6518 1085 *china@ecosecurities.com*	CONTACT—International Office 181 University Avenue, Suite 1500 Toronto, Ontario Canada M5H 3M7 Tel: +1 416 350 2177 Fax: +1 416 350 2985 *cdm@cantorco2e.com* *www.co2e.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—China Li Chao Beijing Tel: +86 106 655 5735 CONTACT—Asia (w/o China) Anne Dargelos Tel: +33 01 58 55 66 28 CONTACT—Main Office Laurent Segalen Tel: +44 0 207 648 0118 Fax: +33 015 855 2965 *www.europeancarbonfund.com/*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Oceania, Sub-Saharan Africa	2121 Pennsylvania Avenue, N.W. Washington, D.C. 20433 USA. Tel: +1 202 473 4194 Fax: +1 202 974 4348 *carbonfinance@ifc.org* *www.ifc.org/carbonfinance*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, Oceania, Western Europe, Sub-Saharan Africa	1-3, Kudankita 4-chome Chiyoda-ku Tokyo 102-0073 Japan Tel: +81 3 5212 8870 Fax: +81 3 5212 8886 *jcf@jcarbon.co.jp* *www.jcarbon.co.jp/*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Palmengartenstrasse 5-9 60325 Frankfurt Germany Tel: +49 69 7431 4218 Fax: +49 69 7431 4775 *carbonfund@kfw.de* *www.kfw-foerderbank.de*	
	Global, including China and India	Natsource LLC 100 William Street, Suite 2005 New York, New York 10038 Tel: +1 212 232 5305 Fax: +1 212 232 5353	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, Oceania, Western Europe, Sub-Saharan Africa	1818 H Street, N.W. Washington, D.C. 20433 USA *helpdesk@carbonfinance.org* *prototypecarbonfund.org*	

Swedish International Climate Investment Program (SICLIP)	Carbon finance		Energy efficiency, bioenergy, wind	
Svensk Exportkredit (SEK)–Sweden	Export credits		Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
World Bank Carbon Finance	Carbon finance	Public, private	Energy efficiency, renewable energy	
Insurance				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
Aon Global Risk Consultants Ltd.	Insurance		Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Miller Insurance Group	Insurance		Wind	

	South Asia, Southeast Asia, East Asia, West Asia, Central and Eastern Europe, Central and South America, Sub-Saharan Africa	Kungsgatan 43 Box 310, SE-631 04 Eskilstuna Sweden Tel: +46 16 544 2241, +46 16 544 2043 Fax: +46 16 544 2099 *angela.kallhauge@stem.se, gudrun.knutsson@energimyndigheten.se* *www.energimyndigheten.se*
	West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	P.O. Box 16368, SE-103 27 Västra Trädgårdsgatan 11 B Stockholm Sweden Tel: +46 8 61 38 300 Fax: +46 8 20 38 94 *nfo@sek.se* *www.sek.se/*
	Global, including China, India	The World Bank Carbon Finance Unit 1818 H Street, N.W. Washington, D.C. Tel: +1 202 473 1000 *www.carbonfinance.org*

	GEOGRAPHIC FOCUS	CONTACT	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—China Richard Dong Aon Corporation Beijing Representative Office Room 1206 Capital Tower Beijing 6 Jia Jian Guo Men Wai Avenue Chaoyang District Beijing 100022 The People's Republic of China Tel: +86 10 6563 0671 Fax: +86 10 6563 0672 *richard_dong@aon-cofco.com.cn* *www.aon.com/as/en/china*	CONTACT—India Prabodh Thakker, Chairman 302 Dalamal House Jamnalal Bajaj Marg Nariman Point Mumbai–400 021 India Tel: +91 22 6656 0505 Fax: +91 22 6656 0506 *prabodh_thakker@aon-asia.com* *www.aon.com/as/en/india* CONTACT—Main Office Aon Limited, 8 Devonshire Square London EC2M 4PL United Kingdom Tel: +44 0 20 7623 5500 Fax: +44 0 20 7621 1511 *www.aon.co.uk*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Susanna Lam, Director Miller Insurance Services (Hong Kong) Ltd. Tel: +852 2525 6982 *susanna.lam@miller-insurance.com* *www.miller-insurance.com/China-Energy* David Horne, Director Energy Tel: +44 0 20 7031 2582 *david.horne@miller-insurance.com* *www.miller-insurance.com/China-Energy*	CONTACT—Main Office Dawson House 5 Jewry Street London EC3N 2PJ United Kingdom Tel: +44 0 20 7488 2345 Fax: N/A *info@miller-insurance.com* *www.aon.co.uk*

Multilateral Investment Guarantee Agency (MIGA)	Insurance		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Swiss Re	Insurance		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Other				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
Capital Equity Partners	Financial engineering and investment banking	Debt capital, private equities, public equities, funds of funds, carbon finance, export credits, insurance, private placements	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	1818 H Street N.W. Washington, D.C. 20433 USA Tel: +1 202 473 1000 Fax: +1 202 522 0316 *migainquiry@worldbank.org* *www.miga.org*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—China Eric Gao, Branch Manager Beijing Branch 23rd Floor, East Tower, Twin Towers No. B12, Jian Guo Men Wai Avenue Chao Yang District Beijing 100022 China Tel: +86 10 6563 8888 Fax: +86 10 6563 8800 *Eric_gao@swissre.com* *www.swissre.com* CONTACT—India Dhananjay Date, Managing Director 9th Floor, Essar House 11 K Khadye Marg Mahalaxmi Mumbai–400 034 India Tel: +91 22 6661 2121 Fax: +91 22 6661 2122 *Dhananjay_date@swissre.com* *www.swissre.com*	CONTACT—Asia–Pacific Headquarters Darryl Pidcock Hong Kong Branch 61/F Central Plaza 18 Harbour Road G.P.O. Box 2221 Wanchai, HK Hong Kong Tel: +852 2827 4345 Fax: +852 2827 6033 *Darryl_Pidcock@swissre.com* *www.swissre.com*

	GEOGRAPHIC FOCUS	CONTACT	
	West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	410 Park Avenue New York, New York 10022 USA Tel: +1 928 436 4212 Fax: +1 270 447 3738 *contact@capitalequitypartners.com* *www.capitalequitypartners.com*	Aiken Capital Partners +1 212 751 5007 Same address

The Global Environment Facility (GEF)	Grants to developing countries	Member governments	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Japan Bank for International Cooperation (JBIC)	Other	Japanese government		
Kreditanstalt fur Wiederaufbau (KfW Bankengruppe)	Small and medium enterprise (SME), project, and export finance	German government	SMEs, clean energy	

	Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Sub-Saharan Africa	CONTACT—China Guangyao Zhu, Director General (Political Focal Point) International Department Ministry of Finance Beijing 100820 People's Republic of China Tel: +86 10 6855 3101 Fax: +86 10 6855 1125 *www.gefweb.org* Jinkang Wu, Director (Operational Focal Point) Ministry of Finance International Financial Institution Division IV Department of International Affairs Beijing 100820 People's Republic of China Tel: +86 10 6855 3101 Fax: +86 10 6855 1125 *jk.wu@mof.gov.cn* *www.gefweb.org*	Sudhir Mital, Joint Secretary (Operational Focal Point) Ministry of Environment and Forests Room 414, Paryavaran Bhawan CGO Complex, Lodhi Road New Delhi–110 003 India Tel: +91 11 243 6 3956 Fax: +91 11 24 6 9192 *Mital_sudhir@nic.in* *www.gefweb.org* CONTACT—Main Office 1818 H Street, N.W., MSN G6-602 Washington, D.C. 20433 USA Tel: +1 202 473.0508 Fax: +1 202 522.3240, 3245 *secretariat@thegef.org* *www.gefweb.org*
	South Asia, Southeast Asia, East Asia	CONTACT—China 3131 31st Floor China World Trade Center, No. 1 Jian Guo Men Wai Avenue Beijing 100004 People's Republic of China Tel: +86 10 6505 8989, 3825, 3826, 3827, 1196, 1197 Fax: +86 10 6505 3829, 1198 *www.jbic.go.jp/english/* CONTACT—India Rajeev Singh, Deputy Secretary (Political Focal Point) Department of Economic Affairs Ministry of Finance Room N. 66-C, North Block New Delhi–110001 India Tel: +91 11 230 93881 Fax: +91 11 230 92477 *r_p_singh@nic.in* *www.gefweb.org*	CONTACT—India 3rd Floor, DLF Centre Sansad Marg New Delhi–110001 India Tel: +91 11 2371 4362, 4363, 7090, 6200 Fax: +91 11 2371 5066, + 91 11 2373 8389 *www.jbic.go.jp/english/* CONTACT—Main Office 4-1, Ohtemachi 1-chome, Chiyoda-ku Tokyo 100-8144 Japan Tel: +03 5218 3101 Fax: +03 5218 3955 *www.jbic.go.jp/english/*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Charlottenstrasse 33/33a 10117 Berlin Tel: +49 30 20264 0 Fax: +49 30 20264 5188 *www.kfw.de/EN*	

Chapter Notes

[1] International Energy Agency, *World Energy Outlook 2007: China and India Insights* (Paris, France: OCED/IEA, 2007).

[2] Ibid., p. 444.

[3] *http://planningcommission.nic.in/plans/planrel/11thf.htm*

[4] *www.cogen.org/*

[5] See *http://mnes.nic.in/prog-smallhydro.htm* for MNRE's small hydro-power programs.

[6] International Energy Agency, *World Energy Outlook 2007: China and India Insights* (OECD/IEA, 2007).

[7] From Ministry of New and Renewable Energy (*http://mnes.nic.in/*).

[8] *http://millenniumindicators.un.org/unsd/mdg/SeriesDetail.aspx?srid=749&crid=*

[9] Non-firm power: power or power-producing capacity supplied or available under a commitment having limited or no assured availability.

[10] */www.mnes.nic.in/r&d/om-rnd1006.pdf*

[11] *Report of the Working Group on Coal & Lignite for Formulation of Eleventh Five-Year Plan (2007-12)* (Government of India, Ministry of Coal).

[12] *http://www.fias.net/ifcext/pressroom/ifcpressroom.nsf/PressRelease?openform&AB056249554C36DF8525731B005BBA3E*

[13] *http://hdr.undp.org/en/humandev/links/*

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[15] Clean Technology AustralAsia, "Pursuing Clean Energy Business in India," a background paper, , June 2007.

[16] Prepared from *TERI Energy Data Directory and Yearbook 2005/06*.

[17] *http://www.un.org/esa/sustdev/csd/csd15/documents/csd15_bp2.pdf*

[18] Photo courtesy of U.S. Department of Energy/National Renewable Energy Laboratory (USDOE/NREL) (*www.nrel.gov*).

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[23] Photo courtesy of USDOE/NREL. (USDOE used to denote United States Department of Energy since DOE has been used already to refer to the Department of Environment)

[24] Photo courtesy of USDOE/NREL.

[25] See *www.sunwize.com/*.