US-INDIA DIALOGUE ON SUSTAINABLE ENERGY SECURITY

Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic Prosperity

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Foreword

For over a decade, the Council has invited key organizations and experts from industry and government to become directly involved in dialogues designed to identify concrete recommendations for increasing official governmental and industry cooperation on establishing a more secure and sustainable global energy future. In 2010, the Council in partnership with the Confederation of Indian Industry (CII) and the US India Business Council initiated a multi-year bilateral US-India Dialogue to cooperate on achieving a sustainable energy structure in India and the United States through an examination of policy and technology options and the legislative, regulatory and incentive structures required to transform the energy sector in both countries. These Track II discussions have been designed to result in policy and regulatory recommendations to governments and industry within both countries. The collaborative discussions involved a cross section of government, industry and non-governmental experts who indentified major challenges and opportunities for public/private cooperation between India and the United States.

The Council's initial engagements with India on energy issues were in the series of four dialogues entitled "Clean Air for Asia: China-India- Japan - United States Cooperation to Reduce Air Pollution in China and India" held between 2002 and 2005. The meetings focused on a broad range of subjects including developing an integrated approach to energy planning, strengthening government institutions, energy conservation and efficiency measures, electric power reform, and technical cooperation. The meeting held on March 17-19, 2010 in New Delhi reexamined many of the same subjects taking into account the many developments that have occurred over the past five years. There is now greater understanding of the limits on India's domestic energy resources and the urgency of dramatically expanding the availability of affordable energy to support economic development.

In the coming decades, India faces a huge gap between their desired level of energy supplies and the likely level of resources that will be available from both traditional fossil fuels and new renewable sources such as solar and wind. A rapid expansion of nuclear power and the establishment of a robust nuclear supply chain are seen as critical. However, understandable concerns over ensuring adequate compensation in the event of a major industrial accident given the public's experience with the Bhopal disaster in 1984 has lead to the passage of a Nuclear Liability Law that is likely to severely impede growth in nuclear power. Hopefully, steps can be taken to ameliorate the expected adverse affects of this legislation on industry suppliers' willingness to participate in projects.

This development makes it even more imperative that the ongoing discussions between the US and India lead to a very major and rapid development and deployment of numerous technologies across all energy sectors. The report recommends establishing an Umbrella Memorandum to incorporate the many different programs now being discussed. The two countries have historically had a very active set of programs to improve the utilization of coal in the power sector that should be expanded to incorporate a number of clean coal technologies and to identify geological potential for coal bed methane and for Carbon Capture and Storage. More recent programs related to energy efficiency, smart grids, bio-fuel, solar and wind need to be result in a significant expansion of specific development and deployment activities that build human capacities and increase the ties between Indian and US business.

The importance of avoiding investment barriers to foreign companies willing to participate in India's growing energy industries is viewed as essential to ensuring the energy sector becomes globally competitive. Foreign investment is seen as enabling a much more rapid introduction of cost competitive new technology. Simultaneously, intellectual property should be protected for both Indian and US products and processes.

The United States and India should also coordinate efforts to address several issues that will need multilateral cooperation to ensure greater global energy security. These include:

- Establishing formal participation of many of the major economies in the IEA to broaden access to global oil stocks in the event of disruptions.
- Encourage the widespread adoption of national legislation to support the Extractive Industries Transparency Initiative.
- Support international efforts to reduce energy subsidies, in both producing and consuming countries.
- Ensure greater transparency by establishing periodic producer/consumer dialogues on both pricing and the long-term availability of supplies and consuming country demand.

The ongoing Indian and US official dialogues to expand cooperation in the many areas that remains critical to India's economic prosperity and to the establishment of a sustainable and secure energy future remains a very significant initiative for both countries. The Atlantic Council will continue to support this official government initiative though ongoing Track II dialogues involving participants from government, business and NGO experts with our partners at the Confederation of Indian Industry and other non-for- profit organizations like the US India Business Council.

Fred Kempe
President and CEO
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Table of Contents

Chapter 1: Executive Summary

The world is at a critical junction in history that will shift the course of economic, social and political developments. The steps major economies take will have a profound impact on international developments and make increasing global cooperation on a number of issues crucial to the well-being of citizens throughout the world. The "US-India Dialogue on Sustainable Energy Security" was the latest effort by the Atlantic Council's Program on Energy and Environment to work with other leading policy institutions to identify the challenges of international cooperation to resolve the difficulties associated with providing the energy resources required to support growing and sustainable economic and social prosperity. The Council's activities are designed to provide non-partisan, pragmatic assessments and recommendations that recognize the need for international energy structures that support the worldwide physical supply security of environmentally responsible and affordable energy.

On March 16-18, 2010, the Atlantic Council and the Confederation on Indian Industry, with organizing support from the US India Business Council, held the *US-India Dialogue on Sustainable Energy Security*, a Track II dialogue. Participants in the workshop included government, industry and not-for-profit representatives from the US and India. The timing of these discussions was particularly appropriate as the United States and India are engaged in an ongoing multi -year process of expanding cooperation under the official "India-US Strategic Dialogues." The dialogue focused on understanding the issues India must resolve sustainably to ensure the availability, accessibility, and affordability of energy resources. In addition, the dialogue identified how India's energy sector needs to develop and deploy new technologies to overcome the limitations of existing energy resources. It also required an understanding of the structural changes needed to make India's energy markets responsive to the deployment of new technologies.

Both India and the United States are introducing many technologies and policies to reduce the growth in energy demand by improving energy efficiency. In the electric power sector, this involves introducing an array of "smart grid" technologies that integrate information technology with power systems to enable the more efficient and effective production, distribution, and consumption of power while supporting the expansion of renewables. To be successful, many businesses must be involved, including the information technology and computer industries, equipment and device manufacturers, construction companies, regulatory/standard-setting organizations, as well as the certification and inspection experts. The nurturing of knowledge and capabilities across international markets will enable a more efficient and effective dissemination of the system changes and technologies needed to transform the manner in which electricity is generated, delivered, and utilized.

During the worshop, further opening India's domestic markets to international expertise and capital was seen as critical to addressing the urgency with which the government feels compelled to expand the availability and accessibility of affordable energy. Historic lengthy transformations of industries and economic relationships are now being attempted in only a few decades. Moreover, the introduction of many new technologies will require complex market structure alterations, as well as integrated solutions involving many disciplines, advanced skill, and organizational capabilities.

Throughout the dialogue, numerous opportunities for increased collaboration between India and the United States were discussed. These proposals ranged from cooperation on global issues involving multilateral activities to bilateral agreements on the development of mutually beneficial critical technologies. In some instances, it will be appropriate to consider multinational efforts to develop some technologies as is already being done in a number of areas[1].

The US-India official discussions over the last year have resulted in a number on memoranda of understanding that identified opportunities for cooperation. Participants to the Track II workshop noted that the establishment of collaborative longer- term institutional arrangements to jointly develop new technologies should accelerate the development and deployment of necessary technologies through a greater leveraging of expertise. Such collaboration should lead to the joint ownership of resulting new technologies as well as enhance US-India cross border investment opportunities.

This report describes the major aspects of India's current strategies for addressing current energy shortages and for the future dramatic expansion of electric power and transportation fuels. The United States has been assisting India on energy matters for many years, particularly in efforts funded by USAID and through the Asia Pacific Partnership to improve coal technologies. With the recent initiation of the "India –US Strategic dialogue," the U.S. has extended bilateral assistance to support joint efforts on power and energy efficiency, oil and gas, civil nuclear, and new technologies and renewables. Participants present at the March dialogue were aware of these activities and were specifically asked to identify additional opportunities to expand cooperation in the areas already being officially discussed. Throughout the workshop, significant time was devoted to discussion among participants. The dialogue also widened the areas of potential cooperation to address:

- Broad strategic issues related to enhancing the physical security of energy supplies, particularly for oil and gas,
- National and state policies and programs to foster energy efficiency,
- Policies and challenges of accelerating rural development,
- Building human and organizational capacity to implement new technologies and systems,
- The potential to eliminate or reduce national barriers to sharing energy and environmental technologies,
- Challenges associated with implementing India's aggressive "National Energy Action Plan on Climate Change", and
- The challenge and potential of transforming the electric power system through the development and deployment of "smart grid" technologies.

The full agenda is provided in Appendix I.

Major recommendations for further India-US Cooperation at both the bilateral and multilateral level are listed below:

International multilateral

- Strengthen efforts to increase formal participation in IEA by major economies.
- Undertake discussion on potential benefits/challenges of establishing periodic producer/consumer dialogues on both pricing and the long-term availability of supplies and consuming country demand. Consider format and data to be regularly required.
- Jointly support and encourage widespread adoption of national legislation to support the Extractive Industries Transparency Initiative.
- Support international efforts to reduce energy subsidies, in both producing and consuming countries, to enable market forces and international prices to allocate energy supplies and reduce inefficient consumption.
- Request the recently formed International Renewable Energy Agency (IRENA) to identify renewable technologies that would particularly benefit from the multinational development of technologies and standards[2]. Design and implement specific programs to foster the more rapid development of cost competitive renewable technologies.

Simplify Structure of US-India Agreements

Establish an Umbrella Memorandum of Understanding between India' Ministry of Power (MOP) and the U.S. Department of Energy (DOE) to coordinate activities.

Indo-U.S. Clean Research and Deployment Initiative

- Maintain momentum by funding and organizing specific projects and programs in the identified areas of:
    - o Energy efficiency
    - o Smart grids
    - o Second generation bio-fuels
    - o Clean coal technologies
    - o Sustainable transportation
    - o Wind energy, and
    - o Micro-hydro.

Coal Technologies

- Continue and expand training and capacity building with state utilities to improve energy efficiencies in older thermal power plants under the Partners in Excellence Program.
- Develop data on geological potential for CCS.
- Develop data on geological potential for coal bed methane.
- Continue and expand cooperation on designing and operating super critical and ultra super critical plants utilizing Indian coal.
- R&D support is needed for high temperature materials and plant designs.
- Collaborate on advanced R&D on material and processes to further improve efficiencies to 45-50 % using Indian coal.
- Collaborate on the commercialization and dissemination of IGCC technology
- Establish and support of a Clean Coal Laboratory in India to provide technical support for setting up prototypes and pilot plants for high ash Indian coal.
- Joint collaboration on development of Oxy-fuel combustion, and hybrid systems based on fuel cells, gas turbines and gasification to boost efficiencies into 55-60% range.
- Expand level of support and participation in multi-lateral groups such as the Asia Pacific Partnership, the Carbon Sequestration Leadership Forum (CSFL) and the Major Economies Forum (MEF) on Energy and Climate Change.

Natural Gas and LNG

- Undertake joint research on Gas Hydrates
- Undertake more detailed assessment of unconventional gas potential, shale gas and coal bed methane
- Enable private companies (US and Indian) to own and operate Shale Gas fields
- Establish regulatory framework for exploring for and operating shale gas fields
- Consider feasibility of establishing international sharing mechanisms for LNG in event of major disruptions.
- Support with others (like the EU, Russia, China, and key middle east producers) the commissioning of several studies on global gas developments, including analysis of potential pricing. Use independent institutions to supplement IEA and industry supported studies.

Transportation Fuels

- Expand joint research and demonstration projects on developing cellulosic ethanol from indigenous non-food crops and waste.
- Establish joint research on utilizing algae for commercial scale production of Biofuels utilizing private and public/private partnerships
- Collaborative R&D on vehicle fuel cells and potential for hydrogen powered vehicles

Nuclear Power[3]

- Finalize Safeguards Agreement with IAEA
- Organize an international effort based on experience in the US, Europe, Japan and Russia with input from the IAEA and WANO on the regulatory, certification, inspection, and operating processes needed to ensure the long-term viability of expanding nuclear power. Output should provide a road map to steps required to build in-country nuclear capacity.
- Establish educational and training opportunities to support human resource capacity building
- Provide technical collaboration on the best technology for power plant design, equipment manufacture, plant construction, commissioning, operations and management, waste management and decommissioning of light water reactors (LWRs).
- Expand and intensify international collaboration in the design of breeder and reprocessing technologies.
- Undertake joint assessment of best approaches and information needed to address public concerns.
- While not discussed, should consider the potential application of small -scale modular nuclear generation for distributed power.
- Open nuclear support service industries to international vendors
- Jointly commission study on the longer- term availability of uranium supplies given the potential expansion of nuclear power. Study should expand perspectives in 2010 IEA assessment.

Renewables

- Jointly develop better data and information on potential, cost and current status of R&D, and deployment of renewables
- Joint participation in assessment of using mini and large hydro as storage for offsetting the intermittent output of renewables. US currently studying subject.
- Jointly assess fuel cell technologies and potential to be deployed with renewable generation

- While focusing on solar, collaborate on geothermal, ocean and wave power

- Solar Power

o Joint assessment of solar potential using refined technologies

o Establish private and public/private partnerships to do R&D and to participate in newly established demonstration park in US and develop similar facilities in India.

o Enable US and Indian companies to participate in the manufacturing, deployment and servicing of solar installations and generating facilities, both PV and Concentrated Thermal, in both the US and India.

- Wind Power

o Exchange of information on performance under differing wind conditions

o Build data base and knowledge on reliability and maintenance requirements

o Assess potential for offshore wind

Energy Efficiency

- Establish database of Indian and US company expertise (that could be expanded to include others)
- Regular exchange of benchmarking data
- Encourage and enable US private service companies specializing in energy efficiency to partner with energy service companies in India.
- Establish regular interaction between India's Bureau of Energy Efficiency and the US DOE's office of Energy Efficiency and Renewables that focuses on assessing the effectiveness of programs designed to encourage energy efficiency at the state and national level. Specifically, assess conditions affecting the effectiveness of mandatory versus voluntary programs relying on market prices.
- Establish joint research on lowering the cost of LED lighting
- Establish databases on the effectiveness of building material and designs in lowering energy consumption.

Smart Grids

- Establish linkage between Indian and US smart grid industry alliances.
- India should formally establish interface between India's Power Finance Corporation (who is responsible for implementing smart grid programs throughout India) and the architecture and standard setting activities being lead by the US National Institute of Standards and Technology (NIST).
- India should be given access to the one -stop Internet clearinghouse being maintained by Virginia Tech.
- India and the US should establish consistent architecture, standards and processes for establishing Cybersecurity resolving data privacy issues.
- Undertake joint pilot project in India to use mini smart grids in rural areas. (Would also be applicable for US rural)
- Establish US-India working group to review and share knowledge on issues surrounding the creation of a national transmission and distribution grid that has to accommodate renewables.[4]

Water

- Joint research and development of technology and processes to reduce water consumption associated with all forms of energy production and mining operations
- Jointly undertake assessment of impact of differing energy technologies on water consumption

Investment Barriers

- Remove limitations on foreign investment in new technologies and service companies with specialized expertise.
- Strengthen Intellectual Property Protection for Indian and US products and processes
- Consider developing a global convention on liability legislation to systematically address a number of emerging concerns on oil and gas exploration, production and transport, Carbon Capture and Storage, Nuclear Power generation and waste storage.

Financing

- Establish international financial discussions focused on recreating sufficient long -term financing to support major infrastructure projects.
- Expand use of partial risk guarantees from development banks (Currently available from World Bank, but underutilized.)
- Convene international banking community to develop and expand availability of micro- financing for renewable power and rural development

Recommendations were derived from the discussions covered in chapters 3-6. Supporting comments for the recommendations is provided in Chapter 7 Conclusions and Recommendations.

Chapter 2: Introduction

On March 16-18, 2010, the Atlantic Council, the Confederation of Indian Industry and the U.S. India Business Council held a dialogue in New Delhi with government, industry and non-governmental policy experts, to identify challenges and opportunities to expanding collaboration between the U.S. and India. The meeting launched the initial workshop in a series of dialogues focused on achieving a sustainable energy structure in India and the U.S. The discussions examined policy and technology options as well as the legislative, regulatory and economic incentive structures required for the transformation of the nations' energy structures. Both the U.S. and India are concentrating on meeting the needs of their citizens by ensuring adequate, reliable supplies of energy while addressing the related environmental issues and maintaining economic prosperity. These "Track II[5] " workshops are designed to determine the major challenges and opportunities for public/private cooperation between the United States and India. The workshops are intended to compliment the bilateral government dialogues that have continued since 2002.

In 2005, the governments of India and the United States established the US-India Energy Dialogue, composed of five bilateral working groups on coal technologies, power and energy efficiency, oil and gas, civil nuclear, and new technology and renewables, along with a Steering Committee to provide oversight. Following US Secretary of State, Hillary Rodham Clinton's meetings in New Delhi on July 20, 2009, the governments of the United States and India strengthened their relationship in a joint statement announcing the establishment of an "India-U.S. Strategic Dialogue" that would meet annually. The joint statement between Prime Minister Dr. Singh and President Obama on India and the United States: Partnership For a Better World is provided in Appendix II.

Consistent with this joint statement of both governments, discussions during the US – India Dialogue on Sustainable Energy Security workshop focused on expanding cooperation on meeting the challenges of energy security, environmental responsibility and economic prosperity. The workshop focused on identifying opportunities for technical cooperation at the governmental level and for public/private direct investments, as well as in identifying policy and regulatory recommendations. Participants represented a wide range of Indian and American stakeholders from industry, think tanks and government. A complete list of participants and speakers is on pages i-ii.

This report summarizes the information and recommendations presented during the dialogue and discussions. The report is composed of five main sections as follows:

I - Understanding India's strategic Challenges

II - Technologies and Challenges Associated with the Electric Power Sector

III- Improving End-User Energy Efficiency

IV- Increasing Efficiency of Vehicles

V- Conclusions and Recommendations

Chapter 3: Understanding India: Strategic Challenges

Dramatic economic growth over the last several decades has enabled India to become the world's eleventh largest economy by nominal GDP, and the fifth largest by purchasing power parity (PPP)[6] with twenty percent of the world's population. However, roughly a third of the population remains in poverty. India is determined to maintain an 8-10% annual growth in GDP in order to improve standards of living. Enhanced energy security will be crucial to meeting this goal.

Four key issues drive India's current energy strategy[7]:

1. Low income of $1,000/per capita coupled with rising expectations requires very significant investments to be made in the energy sector.

2. Indian energy production and consumption is very low. With 20% of the world's population, India produces only 3% of the world's total energy, and India's per capita energy consumption is only one-third of the world's average.

3. 25-30% of India's population lives below poverty level.

4. 55% of the population (660 million) remained without electricity in 2005 and 2006. India has maintained a goal of electrifying the 100,000 villages which were without power in 2001 by 2012.[8]

In order to address these issues, India's energy policy is based on increasing energy availability by 4 to 5 times over the next 20 years. However, India must have a dramatic expansion of energy availability at reasonable costs to meet these goals. Currently, conventional fuels provide 96% of India's commercial energy. The Integrated Energy Plan envisions raising the share of non-conventional sources from 4% to 10-12% by 2031-32 based on the existing levels of technology. Even with a concerted push for a 20-fold increase in capacity, renewables are likely to account for only around 5-7% of India's energy mix by 2031-32. While this appears small in the overall energy mix, the distributed nature of renewables can provide many social benefits[9]. India recognizes the need to maintain and expand reliable economic supplies of conventional fuels while establishing and lowering costs of renewable technologies by the middle of the 21st Century. The transition from today's almost total reliance on fossil fuels will take many decades to complete. In the meantime, environmental issues associated with today's fuels will also need to be addressed through the application of new technology, energy efficiency measures and changes in the energy mix.

For India, achieving sustainable energy security means eliminating the extensive energy poverty. Today, there remain 400 million Indians with no access to electricity, which rely on kerosene for lighting. Two-thirds of the population relies on traditional biomass for cooking. Figure 1 indicates the extent to which India has fallen behind many counties in providing electricity, which is essential to raising standards of living.

Figure 1: Electricity Scenario of India

- Societal and Country Needs:
    - o India's per capita electricity consumption is among the lowest in the world (631 kWHr/Year; 2007).
    - o According to the 2007 ICLEI Report, PUT REFERENCE IN around 57% of rural households and 12% of urban households did not have electricity in 2000.
    - o The National Electricity Policy envisages increasing the per capita electricity availability to 1000 kWHr/yr by 2012.
    - o Because of India's rapidly growing economy, there is a significant rise in the need for electricity.

Country	Per Capita Electricity Consumption [kWHr/Yr]
Iceland	27,612
Norway	24,633
Finland	16,802
Canada	16,732
Sweden	14,822
United States	12,790
UAE	11,695
Australia	10,897
Japan	7,604
France	7,454
Russia	6,877
Germany	6,596
EU	6,132
UK	5,843
China	2,172
India	631

Source: "The CIA World Fact Book." www.cia.gov. 2005 and "International Council for Local Environmental Initiatives – Local Governments for Sustainability Report, 2007." Iclei.org. 2007.

Attaining a diversified security of supply is also extremely critical to achieving energy sustainability. Relative to energy requirements, India possesses limited domestic energy supplies of conventional fossil fuels, especially of oil and natural gas. Furthermore, although India holds the world's fifth largest reserves of coal, it should not be considered a country rich in energy resources. India's electricity supply depends on coal and will become increasingly dependent on coal imports due to domestic production constraints. Hence, India sees energy security and sustainability as naturally reinforcing goals.

This situation will leave India increasingly dependent on offshore imports for several decades and more exposed to mercurial international markets. Over the next 20 years, imports could be required to meet roughly 60% of India's commercial energy requirements if only existing technologies are used.[10] India's long-term strategy improves energy efficiencies to reduce the energy intensity of GDP, expands the utilization of domestic renewables such as hydro, solar and wind, and significantly expands nuclear power. At the same time, India will create greater supply flexibility through increased utilization of gas, partly from increasing domestic supplies (including shale gas) and partly through increased imports of liquefied natural gas (LNG). It is also clear that development of greater non-conventional energy supplies will be a long-term endeavor. It is thus imperative to secure the fuels required to expand base load power availability while developing economically competitive renewable fuel technologies. India recognizes the need to support the initial introduction of renewable technologies, but wants to avoid support mechanisms that provide permanent subsidies.

Today in India, coal provides 55% of the energy requirements for the power, steel, and cement industries. Despite large domestic reserves, imported coal will be increasingly relied upon. In fact, because of increasing demand, coal imports could grow to 37-55 % of total national coal requirements despite increasing domestic production. Additionally, the price for imported coal is expected to escalate. Coal has become a global commodity and increasingly tight in Asian economies, like China and Japan. China has also become a net importer as it arbitrages the delivered costs of domestic production with the prices of imported coal supplies.[11] Prices have recently escalated with Metcol into Japan recently fetching $200/ton. To meet growing demand, Asian buyers are currently seeking coal properties in the United States.

In order to reduce the growing consumption of coal, India is now building super critical coal power plants that obtain 40% efficiencies, versus 30-34% for existing thermal plants. In the 12th Five Year Plan, which begins in 2012, 70% of all power plants built by the National Thermal Power Corporation (42,900 MW out of 61,120 MW) will be based on super critical technologies.[12] The growing dependency on coal imports for electricity production could be dramatically reduced if there are major breakthroughs in the cost effective production of solar power and/or a rapid expansion of nuclear power. While it is critical to develop and deploy these alternative technologies, their major impact will be over the next 40-50 years. Still, a major initiative is being undertaken to add 20,000 MW of solar power by 2022, and a further expansion to 30,000 MW by 2030. The goal of this initiative is to reduce the cost of solar power enough to compete with conventional thermal power.

By 2030, India plans to utilize all available hydropower (estimated at 150,000 megawatts) and to import hydropower from Bhutan and possibly Nepal. The latter requires the construction of high voltage transmission lines to move power across long distances to population centers. Wind resources (estimated at 48,500 megawatts) will also be utilized, and are in the process of being verified for offshore as well as onshore facilities.

By 2020, nuclear power will expand from today's capacity of 7,500-8,000 MW to 20,000 MW. There is an ambitious plan to increase its share further to 30,000 MW by 2030. Thus far, the nuclear sector is government controlled but private investors are expected to be needed ultimately to meet long term expansion goals. A number of countries, including the United States, Russia, and France, are actively seeking to sell nuclear plants to India. At the same time, India has developed a commercial scale Thorium-based fast breeder reactor and a 500 MW plant is being constructed. India is seeking to develop a very substantial nuclear industry that will compete globally.

India's current installed generating capacity of 156,000 Megawatts (as of March 2010), will need to grow to 800,000 Megawatts by 2030 to address the nation's growing requirements for power to maintain economic growth and reduce poverty. [13] In 2011-12, generation capacity is anticipated to grow by 10,000 KW. In subsequent years, the rate of growth is planned to reach 20,000 KW a year in the 12th Year Plan.[14] Currently the growth in power usage is about 7% per annum, as can be seen in Figure 2.

Figure 2: Indian Power Sector: Driving Significant Investments

Year	Installed Capacity (GW) required at 8% GDP growth
2007	132
2012	220
2017	306
2022	425
2027	575
2032	778
Year	**Energy requirement (Billion, kWh), at 8% GDP growth**
2007	761
2012	1,057
2017	1,524
2022	2,118
2027	2,866
2032	3,380
Capacity Addition Plan	
11th Plan	50,890 MW
12th Plan	61, 170 MW
13th Plan	56, 560 MW

Source: Government of India Planning Commission. Integrated Energy Policy Report of the Expert Committee. New Delhi, India, August, 2006. http://planningcommission.nic.in/reports/genrep/rep_intengy.pdf

India needs to increase generation capacity by 8-9% per annum to support economic growth of over 8%. Meeting these goals will be a major challenge and will require a significant expansion of manufacturing and construction capacity. However, it is also seen as an opportunity to introduce new technologies and reduce emissions.

Despite all the efforts to diversify power supplies, India will remain heavily dependent on thermal coal power for many more decades.[15] Figure 3 notes that thermal power, which is almost solely based on coal, is expected to account for 76% of new capacity in the 11th Five Year Plan.

Figure 3: Coal: Prime Mover of Power Sector

• Thermal power expected to account for 76% of new capacity

• India's energy sources rely on an abundance of coal and few hydrocarbon resources

• Coal remains the most important fuel for the power industry

Energy Type	*Megawatts*
Hydro	15,627 MW (20%)
Nuclear	3,380 MW (4%)
Thermal	59,693 MW (76%)

Source: Central Electricity Authority. Power Scenario at a Glance. December 2009. http://www.cea.nic.in/planning/power%20SCENARIO%20at%20GLANCE/PSG.pdf

Clean coal technologies will be critical to meeting the dual objectives of addressing power shortages and climate concerns over the next two to three decades. It is equally important to note that over the next 40 to 50 years major steps will be needed to migrate away from coal power generation.

Even with all the programs underway to reduce CO_2 emissions, they will likely increase from 1.6 billion tons in 2005 to 5-6.5 billion tons by 2030. India will need ultra super critical boilers and much more nuclear and solar energy than has been proposed (roughly double the 30 GW planned for each).[1.6]

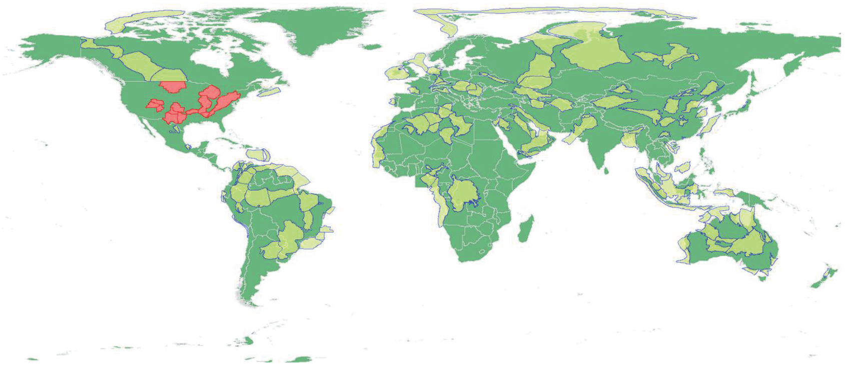
Over the last decade, India succeeded in expanding natural gas consumption. This occurred by selling exploration permits to private companies, thereby increasing domestic production, and by expanding LNG imports when they could be obtained for moderate prices. India's acquisition of overseas gas assets also contributed to Indian owned natural gas supplies equivalent to 9 million tons per year of oil. With this success, natural gas and LNG supplies currently provide about 11% of India's total energy requirements but are unlikely to significantly increase their share of energy supply without major new developments.

Continued emphasis on domestic exploration should add to further supplies, especially with the possibility of private investment in shale gas. A very long-term possibility would be the production of gas hydrates that has been discussed for many years, but remains technologically challenging.

Importing large volumes of gas from the Middle East, Central Asia, Bangladesh, or Myanmar has often been discussed, but appears unlikely in the short term due to both geographical and political considerations. India has an economic interest in the discovery of new gas in Myanmar, but the gas is expected to flow to China. Hence, India will need to rely on increasing domestic production and growing imports of LNG.

There was a brief discussion during the workshop on the possibility of an independent gas market developing with prices decoupled from oil prices. This has occurred in countries with very substantial gas resources and low production costs. The expansion of shale gas production in the United States has already reduced LNG prices into Europe, and could impact Indian gas import prices if shale gas production was expanded significantly in Europe and India. Figure 4 indicates the latest assessment of the geographic location of the world's potential sources of shale gas.

Figure 4: Global Shale Gas Resources Worldwide Shale Potential

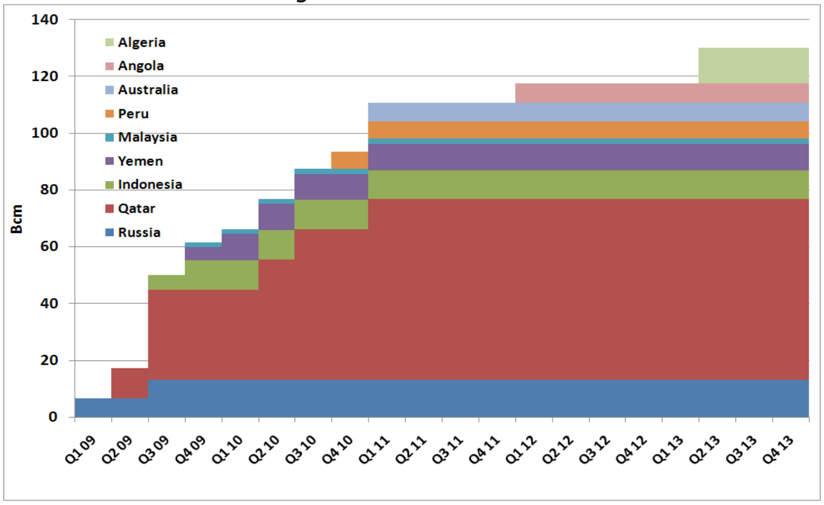


A 2007 study ranked 688 shale formations in 142 petroleum basins.

Source: Hengel, Douglas C. Conference Presentation. US-India Sustainable Energy Security. New Delhi, India, March 17, 2010.

The recent growth in domestic gas production affected multiple industries allowing for greater use of gas as a petrochemical and fertilizer feedstock, as well as enabling gas to penetrate the heating oil market, and enabling a greater use of compressed natural gas (CNG) for road transportation in many municipalities. However, India's demand for natural gas is expected to continue outpacing domestic supplies, and growing imports of LNG will be required. Global LNG liquefaction facilities are continuing to expand as seen in Figure 5, but additional expansion could be delayed as international gas markets adjust to the probable expansion of shale gas production outside of North America.

Figure 5: Global LNG Market



LNG Liquefaction Capacity Additions

- Liquefaction: +50% over 2009-2013
- Potential for project delays due to reduced demand

• Qatar as swing producer – can sell to Atlantic or Pacific basin

Source: Hengel, Douglas C. Conference Presentation. US-India Sustainable Energy Security. New Delhi, India, March 17, 2010.

Although natural gas prices are heavily dependent on national supply and demand conditions, international gas markets remain in transition. An assessment of the potential impact on India could provide useful input in determining the potential for gas in both residential and commercial markets and for power generation.

India relies on oil imports of 120 million tons to meet 80% of its annual demand (150 million tons). India has attempted to increase domestic production (roughly 35 million tons per year) by auctioning off exploration blocks to private companies; but success has been limited. Demand could rise to 400-550 million tons per year over the next 20 years depending on the level of efficiencies obtained, particularly in the transportation sector. India made numerous moves to reduce petroleum subsidies that are distorting markets and leading to over-consumption. For some products like kerosene, over-consumption is compounded by a high reliance on the fuel for lighting among low- income households. During the dialogue, it was suggested that reliance on market pricing and targeted general subsidies would be less distorting and encourage more efficient consumption.

Numerous efforts have been made to obtain oil assets abroad. The state-run OVL has been successful in negotiating arrangements as overseas governments are most comfortable working with state run companies. In any case, only 8 million tons of oil a year is provided by such arrangements, which meets only a small portion of current demand. Even with continuing efforts to encourage such arrangements, overseas oil assets will only be a marginal factor in meeting rapidly growing domestic petroleum demand. Nevertheless, **India could play an important role in helping to stabilize global petroleum supplies by encouraging greater transparency in contracts by joining the Extractive Industries Transparency Initiative.** This initiative is designed to reduce corruption, lower social unrest, and improve governance in producing countries that should lead to fewer supply disruptions and more profitable investments.

The recognition of India's vulnerability to supply disruption lead to the construction of three Strategic Petroleum Reserves located in Vizg, Mangalore and Padhur, 100 kilometers away from Mangalore. These reserves contain a total storage capacity of 5 million tons of crude oil, or 15 days of supply at current demand levels. Such stocks can help offset the impact of a short-term crude oil supply disruption, and are not intended to protect against the economic impact of major price swings. The United States is currently considering the possibility of developing product reserves, and this might also become attractive to India.

To be truly effective in the event of a major disruption of supplies, India needs to cooperate with other countries by sharing global stocks. India recognizes the potential benefits from joining in a global management of reserves. India could benefit from participating in the collective security measures provided by the IEA's mechanisms for sharing stocks, but the bureaucratic processes for including India in these mechanisms need to be formally considered.

India is particularly susceptible to major oil price deviations and remains concerned about protecting the economic interest of both consumers and producers. In 2003-2004, when crude oil was priced at $22-25 a barrel, producers were willing to guarantee prices of $22-28. As countries focus on protecting their revenue streams, any discussion of price guarantees has lagged. The extreme price volatility that raised crude prices to $140 created a tremendous financial burden on developing nations, as much of the cost escalation had to be supported by government subsidies. Passing such price increases on to the public is especially difficult in countries like India, where average incomes are very low and huge public sector deficits can be destructive to national economic programs.

There is a need for a dialogue between consuming and producing countries on both the pricing and long-term availability of supplies. About 75% of India's imported oil supply contracts are currently long–term. The reliability of such arrangements is uncertain. Dialogue could bring added assurance for both exporting and importing nations.

Finding sufficient energy supplies to meet India's energy requirements at economically viable costs will be a tremendous challenge. **Reducing the growth in demand through energy efficiency measures is imperative.** This involves doing the same activities with less energy. (Not discussed, but also under consideration in other countries is the potential to modify life styles to conserve energy. This is already happening in developed countries with a shift in housing, city planning and transportation modes. The opportunity to lower demand through conservation is considerably smaller in a country like India, where per capita incomes are extremely low and over half the population lives without necessities like electricity and clean water supplies.)

India is correctly focusing on undertaking major efforts to increase energy efficiencies. To this end, the prime minister established the Climate Change Council, which created benchmarks for nine energy-intensive industries. The list of industries will be expanded over time. At the consumer level, the Energy Conservation Act promotes a gradual heightening of energy efficiency standards for consumer durables. Lighting is gradually being converted to Compact Florescent Bulbs (CFL). Energy efficiencies standards have been established to promote Green Buildings, especially for new construction. These were voluntary standards that are now being made mandatory for new commercial construction. In addition, under the Energy Conservation Act, the Bureau of Energy Efficiency is in the process of designing a scheme to establish a performance trade mechanism to enable people to earn certificates for exceeding efficiency standards that could be bought and sold.

In the transportation sector, manufacturers are also encouraged to raise fuel economy ratings, as further improvements could significantly reduce oil consumption. For a number of years there have been mandates regarding the quality of fuels, and new mandates have recently shifted the 13 major metros to Euro IV emissions.

In the power sector, there still remain significant opportunities to improve plant performance by establishing operating procedures that increase the role of service companies specializing in improving plant performance. India is also attempting to reduce transmission losses by tightening procedures, and redesigning billing processes and rate structures. While many states have made substantial progress at raising revenue to cover costs, a number of states maintain heavily subsidized utility rates. Targeted subsidies from general government revenues, rather than through utilities, would significantly improve the efficient use of electricity, and enable utilities to provide more reliable service. New policies instituted in Delhi clearly indicated the advantage of altering billing and collection practices, and have resulted in higher customer satisfaction.

India will also address its shortage of energy through the introduction of new technology. Many of these technologies, such as gas hydrates, algae fuels, ocean waves and geothermal, will involve long lead time and technology transfers, but they are all potentially important to creating a new sustainable cleaner energy mix. **Reducing the energy supply shortfall through changing the energy mix and through improving energy efficiencies will eventually enable India to deploy greater resources to tackling climate change.**

Chapter 4: Technologies and Challenges Associated with the Electric Power Sector

In the following sections, the more detailed and comprehensive discussions associated with expanding the electric power sector will be reviewed. The strategic importance and the magnitude of the challenge in diversifying energy sources for electric power were covered in the broad review of India's Integrated Energy Strategy. These sections will focus on clean coal technologies, civil nuclear power, renewable technologies and the impact of growing power usage on system efficiencies and on electricity transmission and distribution.

4.1 The Critical Coal Technologies

As coal will continue to provide over half of India's power through 2030, India will focus on improving efficient coal technologies and adopting clean coal technologies. The National Thermal Power Corporation (NTPC) accounts for one quarter of India's generation capacity and almost 40% of total power output and has been leading the way in the introduction of new coal technologies.

India is facing a number of major challenges in the coal power sector. First, the characteristics of Indian coal make it difficult to directly apply technologies introduced elsewhere. Figure 6 notes that Indian coal has extremely high ash content and low calorific value which reduces the efficiency of plants and has made it difficult to implement Integrated Gasification Combined Cycle (IGCC) technology.

Figure 6: Indian Coal: the Key Challenge

Coal Properties

	Indian Coal	Imported Coal
Benign	Sulfur Content < 0.4%	3% - 4%
High Ash	Ash Content > 40%	6% - 10%
Low GCV	Calorific Value 3500 -4000 Kcal/KWH	7000 - 8000 Kcal/ KWH

The Consequence

High Erosion: Difficulty in maintaining High Plant Availability
Difficulty in Gasification: Impediment for IGCC Technology

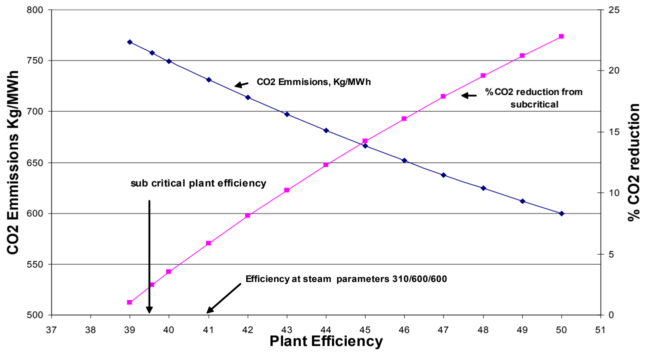
Source: Jain, D.K. "Role of Clean Coal Technologies: India & Industry Perspective." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 16-18 2010.

Second, there is a shortage of skilled manpower and manufacturing capacity, and limited availability of land and water for locating major new facilities. Third, there are climate and environmental issues.

Fortunately, by emphasizing efficiency, power output can be increased, and CO_2 output can be reduced by utilizing clean coal technologies. Figure 7 illustrates this potential for operating with Barth coal (an indigenous 3,300 Kcal/Kg coal) when plant designs are moved from subcritical towards ultrasuper critical parameters at over 600 degrees Centigrade. A substantial shift towards larger, super critical plants is planned over the next two plan periods, so that by 2022, over 90% of NTPC's 56,560 MW coal capacity additions will be using super critical designs. [17]

Figure 7: CO_2 Reduction by Increasing Efficiency

Based on Barh Coal (3300 Kcal/Kg, 31.37 % Carbon)



Source: Jain, D.K. "Role of Clean Coal Technologies: India & Industry Perspective." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 16, 2010.

A study is also underway for adopting ultrasupercritical technologies with efficiencies of over 45% (equivalent to 50% if based on higher calorie non- indigenous coal). See Figure 8.

Figure 8: Plans for Advanced High Efficiency Power Plants

• Large Sized Units: progressive increase in unit size: 200/210 MW –500 MW –660 MW (in construction) –800 MW (under consideration)

• Supercritical Technology:

- o Gradual Adoption of supercritical technology
- o Raising the critical process parameters: HRH temperature from 237 C to 595 C, MS Temp from 537 C to 565 C
- o Enhancement of cycle efficiency from aforesaid efforts: 38.00% –39.96% (2X660 MW Barh-II)
- o Study for adopting ultra-supercritical technology with efficiency levels of 41.1% in progress

	Total Sub Critical (MW)	660 MW Super Critical (Nos)	800 MW Super Critical (Nos)	Total Super Critical (MW)	Total MW (Coal Based)
10th Plan	9,620	0	0	0	9,620
11th Plan	45,470	7	1	5,420	50,890
12th Plan	18,270	25	33	42,900	61,170
13th Plan	4,000	36	36	52,560	56,560

Source: Jain, D.K. "Role of Clean Coal Technologies: India & Industry Perspective." Conference Presentation. US-India Dialogue on Sustainable Energy Security, New Delhi, India, March 16-18 2010.

A complete listing of NTPC's Super Critical units either under construction or in planning is shown in Figure 9.

Figure 9: Super Critical Units-NTPC

• *Plants in Advanced Stage of Construction*

- o 3 X 660 MW Sipat STPP Stage-I
- o 3 X 660 MW Barh STPP Stage-I
- o 2 X 660 MW Barh STPP Stage-II

• *Upcoming Plants*

- o Meja – 2 X 660 MW
- o Solapur – 2 X 660 MW
- o New Nabinagar – 3 X 660 MW
- o Mauda – 2 X 660 MW
- o Kudgi – 3 X 800 MW
- o Darlipalli – 2 X 800 MW
- o Lara – 2 X 800 MW
- o Marakanam – 4 X 800 MW
- o Tanda-II – 2 X 660 MW

Source: Jain, D.K. "Role of Clean Coal Technologies: India & Industry Perspective." Conference Presentation. US-India Dialogue on Sustainable Energy Security, New Delhi, India, March 16-18 2010.

By using more advanced technologies, improvements in operating performance should be substantial. Between 2004-05 and 2007-08, thermal efficiency for coal and lignite based plants thermal efficiency improved only slightly (see Figure 10).

Figure 10: India Power Plant Efficiency

Classification of India Steam Type Electricity Generation Stations Efficiency-Wise (2007-2008)				
Thermal Efficiency	No. of Generating Stations	Installed Capacity (MW)	% of Total Installed Capacity	Energy Generated (GWh)
≤20%	9	1,696	2.23	1,503
>20% & ≤25%	10	4,418	5.81	15,453
>25% & ≤30%	25	14,055	18.49	69,071
>30%	53	55,580	73.47	400,970
Total	97	76,019		486,997

All India Thermal Efficiency (Coal and Lignite Based Plants)	
Year	Efficiency (%)
2004-5	32.16
2005-6	32.73
2006-7	32.44
2007-8	32.69

Source: Central Electricity Authority. General Review. Government of India Ministry of Power, 2009.

Both NTPC and the State Electricity Boards will be working to improve the efficiency of older power stations and replace a number of very inefficient units. Renovation and modernization programs involve:

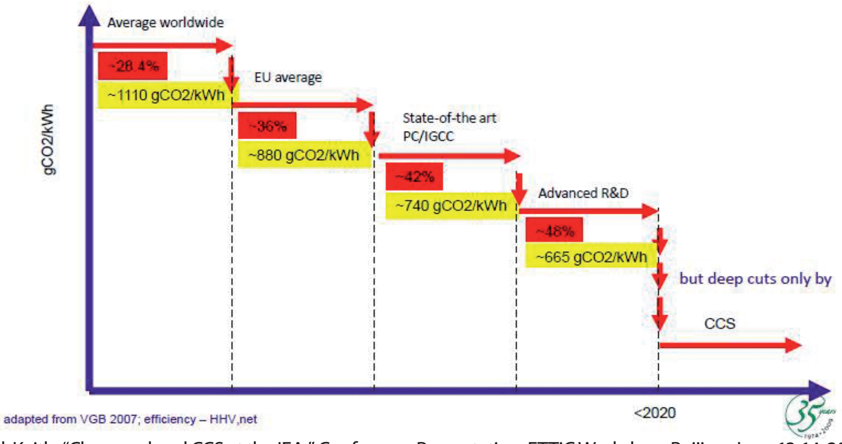
- Improving performance parameter such as power load factors, availability, heat rates and auxiliary power
- Restoring and up-rating de-rated capacity
- Extending of economic life
- Addressing obsolescence and non-availability of spare parts
- Environmental issues and other statutory requirements
- Addressing safety requirements

The government of India established the Partners in Excellence Program aimed at increasing old power plant efficiency, which is actively supported by NTPC. Efforts to maximize operational efficiency are also pursued by the use of modern decision support tools to optimize operating performance. Many of the requisite upgrades can be made for far less than the capital costs of new coal fired power plants.

Ultimately, IGCC and advanced R&D on materials and processes can further improve efficiencies to 45-50% and lower CO2 emissions to approximately 665 g CO2/kWh (roughly half the current world average). However, to make extremely deep cuts in CO2 emission envisioned by the COP, discussions will require Carbon Capture and Storage technologies in conjunction with pre- and post-combustion CO2 Capture. See Figure 11.

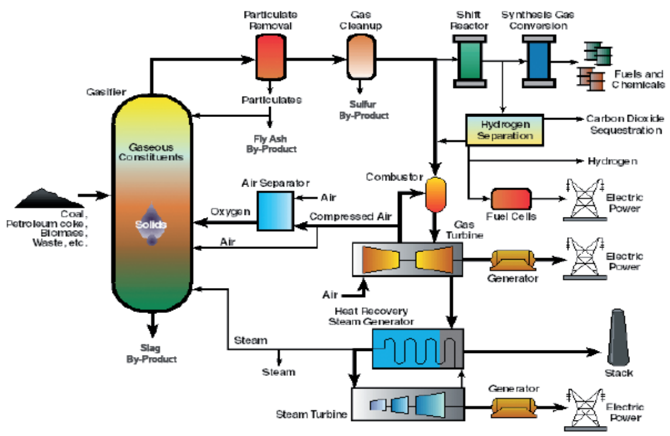
In the United States, NETL is also pursuing oxy-fuel combustion and hybrid systems based on fuel cells, gas turbines, and gasification that have the potential to boost efficiencies into the 55-60 % range. In the U.S., current technologies to achieve plants with near zero carbon emission will have been demonstrated but not deployed. A NETL schematic for such a system is illustrated in Figure 12. [18]

Figure 11: CO2 Emission Reduction by Key Technologies



Source: Burnard, Keith. "Clean coal and CCS at the IEA." Conference Presentation. ETTiC Workshop, Beijing, June 13-14, 2009.

Figure 12: Gasification–based Energy Production Systems



Source: Smouse, Scott M. "Role of Clean Coal Technologies." Conference Presentation. US-India Dialogue on Sustainable Energy Security.New Delhi, India, March 16-18, 2010.

Through a number of multilateral and bilateral mechanisms, U.S. and India collaboration on improving coal-fired power plants has taken place for more than 25 years. This includes activities associated with several Asia Pacific Partnership (APP), Task Forces (Power Generation & Transmission, Cleaner Fossil, and Coal Mining), as well as participation in the Carbon Sequestration Leadership Forum (CSLF), and the Major Economies Forum (MEF) on Energy and Climate. See Figure 13.

Figure 13: U.S.–India Energy Collaboration

Multilateral Cooperative Agreements	Bilateral Cooperative Agreements
Asia Pacific Partnership (APP) on Climate and Clean Development	USAID-India Greenhouse Gas Pollution Prevention (GEP) Project
Carbon Sequestration Leadership Forum (CSLF)	US-India Energy Dialogue
Major Economies Forum (MEF) on Energy and Climate	

Source: Smouse, Scott M. "Role of Clean Coal Technologies." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 16-18, 2010.

The APP involves the collaborative efforts of many governments including the EU, Japan, and China to address subjects as diverse as developing a Young CCS Scientist and Engineer Intern program, coal beneficiation, dry coal cleaning processes and waste coal usage, and, a variety of regulatory, technical and public perception issues related to the deployment of CCS. However, CCS deployment is being pursued through the Major Economies Forum as it is a global issue led by the United States and Japan.

Since 1982, USAID and NETL supported bilateral energy cooperation. This cooperation produced a very effective series of focused activities that resulted in a measured cumulative avoidance of nearly 100 million tons of CO_2 emissions from NTPC and state utility plants between April 1996 and September 2009.[19] A listing showing the range of USAID activities is provided in Figure 14.

Figure 14: U.S. Agency for International Development

Years	Agreements
Phase I: 1982-1987, Phase II 1987-1992	Alternative Energy R&D
1993-1995	Energy Management and Consultancy
1993-1997	Program for Acceleration of Commercial Energy Research
1994-1996	Indo-US Coal Preparation and Beneficiation
1995-2002	Greenhouse Gas Pollution Prevention (GEP)
2002-2005	GEP Climate Change Supplement I
2003-2010	GEP Climate Change Supplement II

• More than 25 years of technical assistance from NETL through series of participating agency service agreements (PASA)

• Currently discussing extension of NETL support for several more years to continue power plant efficiency work and additional technical areas, such as smart grid

Source: Smouse, Scott M. "Role of Clean Coal Technologies." Conference Presentation. US-India Dialogue on Sustainable Energy Security, New Delhi, India, March 16-18, 2010.

Figure 15: USAID/India Greenhouse Gas Pollution Prevention (GEP) Project Summary

NETL Provided Technical Assistance/Training since 1996
Technology Transfer
Communication and Outreach

Source: Smouse, Scott M. "Role of Clean Coal Technologies." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 16-18, 2010.

These activities have involved NETL staff and a number of utilities and technology providers in the U.S. There remains strong support for extending India-US cooperation on developing low emission, efficient generation technologies. The November 24, 2009 Memorandum of Understanding signed by U.S. Secretary of State Clinton and External Affairs Minister Krishna launched an Indo-U.S. Clean Energy Research and Deployment Initiative, supported by U.S. and Indian government funding and private sector contributions. This new initiative will include a Joint Research Center operating in both the United States and India, which will foster efforts to accelerate deployment of clean energy technologies. Priority areas for this initiative include: energy efficiency, smart grids, second-generation bio-fuels, and clean coal technologies including carbon capture and storage, solar energy, energy efficient buildings, advanced battery technologies, as well as sustainable transportation, wind energy, and micro-hydro power. The initiative will allow both countries to leverage expertise from government, private industry, and academia to accelerate the development and deployment of new clean energy technologies. The initiative will facilitate joint research, scientific exchanges, and sharing of proven innovation and deployment policies.

The coal power sector will benefit from this bilateral initiative through:

- Research and deployment components
- Promotion of innovation and collaboration on clean coal energy technologies
- A Clean Coal Technology Assessment Report that creates a roadmap for the future to:
    - o Accelerated introduction of new technologies, instrumentation, equipment, and software
    - o Continued training and capacity building, especially for state utilities
    - o Establishing a "Model" plant for practical demonstration of new technologies
    - o Development of a U.S.-India Service Providers Network

Indian participants showed strong interest in ensuring the completion of the following efforts:

- Ultra Super Critical technologies (USC) capacity building
    - o Cooperative development of high temperature materials and plant design for advanced USC units with 700 Degree C+ temperature
- Commercialization and dissemination of IGCC technology
    - o Joint industry participation in IGCC demonstration with high ash Indian coal
    - o Research collaboration for associated IGCC technology development through slip steam facilities
- Establishing a Clean Coal Laboratory
    - o Undertaking clean coal technology research in India
    - o Using technical support to build prototypes and pilot plants for high ash Indian coal

To facilitate cooperation beyond existing strong business to business connections and historic project by project activities, consideration should be given to establishing a singe government-level Umbrella MOU, between the Ministry of Power (MOP) and the U.S. Department of Energy (DOE) under which individual projects could be taken up without a complex set of interconnecting forums. Additionally, the two nations should consider creating an "applied R&D infrastructure" and capacity building for clean coal technologies in and around the power industry. This framework would supplement the important R&D of academics for education, innovation, and information dissemination.

During the conference, participants noted that a long-term sustainable, secure energy future, which includes coal, can only be achieved by joint actions of the governments and industry in consultation with the general public. This will involve pushing key technologies with fair risk sharing, establishing reliable long-term incentives such as tax credits and loan guarantees, and recognizing the global perspective of equipment suppliers. It also requires legal certainty related to intellectual property, all effluents, geological CO2 storage and open, public dialogue. [20]

The preceding section addressed India's growing power requirements by focusing on reducing emissions and improving the efficiency of coal power plants. The government recognizes that expanding electric power availability can only be met if the industry can diversify the sources of energy used to produce electricity to include non-fossil fuels such as nuclear, hydro and renewables. The strategies to expand India's sources of power generation will be discussed in following sections.

4.2 Expansion of Nuclear Power

Historically, India has had difficulties realizing plans for expanding power plants. Nevertheless, the projected objectives for nuclear power have expanded dramatically over the last few years. **Official projections indicate nuclear power capacity could rise from less than 5 GW today to up to 20 GWe by 2020 and 63 GWe by 2032.**[21] In March 2010, the director of the Bhabha Atomic Research Centre noted that nuclear power could, even reach 35 GW capacity by 2020.[22] To support this aggressive expansion, India opened its civil nuclear industry to international trade.

The U.S. Congress on October 1, 2008, gave final approval to an agreement facilitating nuclear cooperation between the United States and India. The deal is seen as a watershed in U.S.-India relations and introduces a new aspect to international nonproliferation efforts.

Agreements have been signed also with France, Russia, Namibia and are progressing with Canada, Argentina, and others. India is in the process of finalizing liability legislation impacting nuclear operators (currently government owned) and equipment suppliers (foreign and domestic) that will clarify suppliers' financial exposure to participation in India's nuclear industry and address the public's concerns over adequate compensation in the event of an accident. Unfortunately, the late August 2010 legislation will leave both domestic and foreign suppliers' exposure to liability claims undefined and without modification is likely to severely diminish the growth in civil nuclear power. [23]

India currently has 4.6 GW of nuclear power in operation at 19 plants, a number of which are associated with military programs. India is formulating a plan to separate military-run facilities from the civil program and is negotiating an India specific Safeguards Agreement with the IAEA. The above steps are critical to reducing concerns over the proliferation of nuclear weapons which could otherwise be associated with the expansion of civil nuclear programs.

Pursuit of a closed fuel cycle will continue to be a formal part of India's national policy. [24] Concerns over long-term availability of uranium supplies has led India to base its civil nuclear strategy on developing closed fuel cycle plants which involve reprocessing used fuel and multiple recycling in fast breeder reactors.[25] This is also viewed as a necessity if a credible waste management program is to be established. Growth of nuclear power is viewed as a necessity for the environment and to reduce the stress on global fossil fuel resources.

The above policy arises from the realization that using a once-through fuel cycle based on pressurized heavy water reactors or light water reactors exploits only 1% of the reactor fuels (uranium or thorium) energy potential whereas closed fuel cycle and multiple recycling in fast breeders has the potential to exploit 60-70% of the fuel's energy potential.[26] India's Department of Atomic Energy has developed a sequential three-stage program that is described in Figure 16.

Figure 16: Three Stage Nuclear Power Program

Stage - I PHWRS	Stage - II	Stage II
Commercial Domain: PHWRs and LWRs	Globally Advanced Technology: Fast Breeder Reactors	Globally Unique: Thorium Based Reactors

Source: Grover, R.B. "Role of Nuclear Power in meeting the challenges of energy security in India." Conference Presentation. US-India Dialogue on Sustainable Energy Security, New Delhi, India, March 17, 2010.

Stage I involves commercial plant designs and involves existing light water reactor designs and Indian pressurized heavy water reactors, some of which will be scaled up to 700 MWe. Sites already approved in principle totaling 36,100 MW capacity are shown later in Figure 18. India, as well as China, has been able to reduce construction time to about 5 years.

Stage II involves developing and deploying fast breeder reactors. [27] A 40 MW thermal fast breeder has operated since 1985. A 500 MW prototype fast breeder based on sodium cooling, designed with Indian industry is on schedule to begin operations in Kalpakkam, 80 km from Chennai, by September 2011. [28]

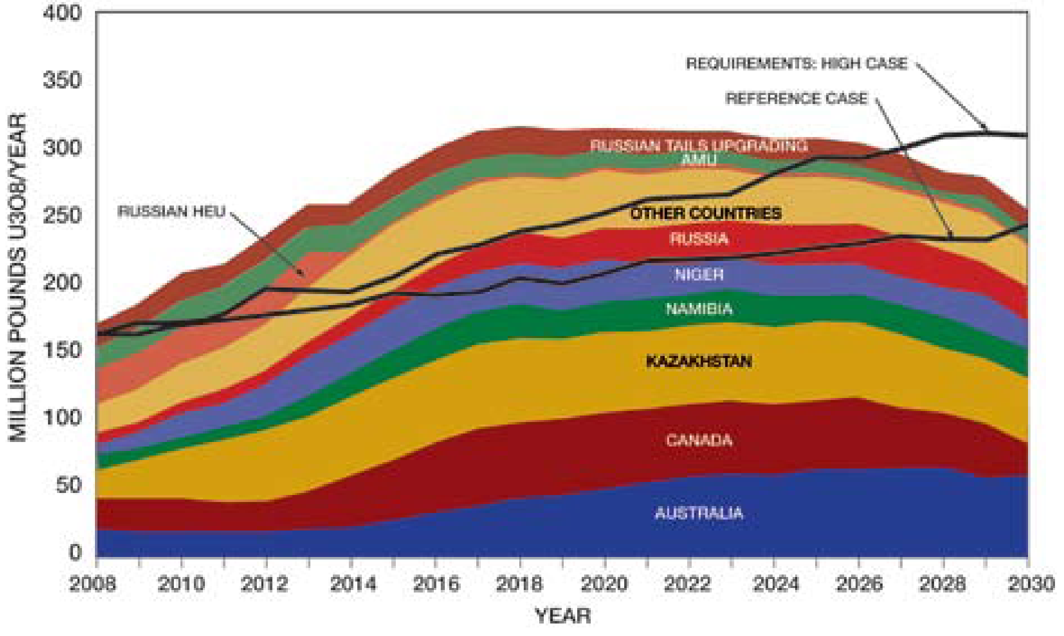
Stage III involves development and deployment of breeder reactors based on Thorium. A 30 KW thermal reactor, called Kamini, has operated for 10 years at Kalpakkam to prove the fuel cycle technology. Another 300 MW advanced heavy water reactor under development will derive two-thirds of its power from thorium.[29]

As noted earlier, India is concerned over the availability of uranium and has been aggressively exploring for domestic uranium supplies, while actively pursing imported uranium supplies. However, India does have known indigenous reserves of thorium. The three-stage program enables the gradual development of the fast breeder technologies to eventually utilize thorium. Eventual deployment of fast breeder technology based on plutonium and/or thorium will require considerable R&D due to the physical complications of recycling fuels.

India faces many challenges in rapidly expanding nuclear power. Until signing the September 2008 Nuclear Suppliers Group (NSG) agreement, procuring even short-term fuel supplies was a critical concern. India's assessment that world uranium supplies are expected to become very tight over the next 20-25 years is supported by other studies indicating that long term supplies of nuclear fuel remains a major challenge. India is addressing this concern partly through increased domestic exploration and long-term supply arrangements with potential fuel suppliers, but mostly through the decision to pursue closed fuel cycle technologies. Figure 17 provides an estimate of uranium supply availability that was prepared in 2009 and discussed in a US-China dialogue on nuclear cooperation.[30] A global reassessment of world uranium supplies would be very helpful in planning the useful lives of non-breeder plant designs. **The Indian government believes that it cannot count on only utilizing light water reactors and does not want to become overly dependent on this technology for plants with 60 year lives.**

Another challenge is to obtain and develop the best technology for power plant design, equipment manufacture, plant construction,

Figure 17: World Uranium Supply and Requirements: 2008 to 2030



Source: Steyn, Julian J. "Cooperation on Fuel Cycle Research: World Status of Fuel Cycle Front-end." Presentation to the Atlantic Council. March 6, 2009.

commissioning, operations and management, handling of waste and the decommissioning of plants. India is confident of addressing these issues for pressurized heavy water reactors (PHWRs), but will need technical collaboration with other counties for light water reactors (LWRs). International collaboration in the design of breeder and reprocessing technologies could also benefit to both India and foreign suppliers. India may eventually become a global supplier of such technologies.

A rapid expansion of nuclear plant construction is highly dependent on establishing a strong manufacturing sector in a broad number of areas related to plant construction and operations. As elsewhere (like in the United States) a critical component is the manufacturing of the special forgings required by the nuclear industry. Today, the world is dependent on a single Japanese supplier for the large vessels required. India's Nuclear Power Corporation (NPCL) and Larson & Toubro (L&T) have established a joint venture to build such capacity in India.

Finding appropriate plant sites will be increasingly difficult as the nuclear program is expanded over time. Currently, plant sites have been identified and designated for the construction of 34 new plants, with all but 6 located on the coast. Water availability for cooling, environmental concerns, and public reaction are all issues impacting long term planning. Figure 18 indicates the sites approved in principle.

Figure 18: Sites Accorded "In Principle" Approval

Site	Capacity	Type of Reactor
Mithi Virdi, Gujarat	6X~1000 MW	PWR
Jaitapur, Maharashtra	6x1650 MW	PWR
Haripur, WB	6X~1000 MW	PWR
Kovvada, AP	6X~1000 MW	PWR
Kudankulam	4x~1000 MW	PWR
Inland site - 1	4x700 MW	PHWR
Inland site - 2	2X700 MWR	PHWR

Source: Grover, R.B. "Role of Nuclear Power in meeting the challenges of energy security in India." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

A number of the sites have been designated for joint facilities with foreign investors. For example, sites for U.S. companies have been identified at Mithi Virdi (Amitiviti) in Gujarat and Kovvada in Andhra Pradesh with space for 12,000 MWe capacity. [31]

Both the U.S. and India have a shortage of skilled laborers to expand and run the nuclear industry. The U.S. has recently addressed this concern with an expansion of university programs and technical training to offset a decline in trained manpower due to a retiring work force and a diminished level of interest in atomic power over the last 30 years. India had limited its education program to a "deemed university" within the department of atomic energy. Fortunately, the U.S.-India Strategic Dialogues have identified education and technical training as an area where further collaboration could be beneficial.

Last, but not least, is the need to expand the scope and ability of the Atomic Energy Regulatory Board (AERB). The AERB was formed in 1983 and is "responsible for the regulation and licensing of all nuclear facilities, and their safety and carries authority conferred by the Atomic Energy Act for radiation safety and by the Factories Act for industrial safety in nuclear plants." [32] The AERB reports to the Atomic Energy Commission but is independent of the Department of Atomic Energy (DAE) which is responsible for research, technology development, and commercial reactor operations.[33] The DAE includes the NPCIL, Uranium Corporation of India (mining and processing), Electronics Corporation of India Ltd (reactor control and instrumentation), and BHAVIN (for establishing fast reactors). [34]

NPCIL, a plant operator, is an active member of the World Association of Nuclear Operators (WANO). Reprocessing of fuel from the civil PHWR plants is done by Bahbha Atomic Research Centre (BARC) at facilities that extract reactor-grade plutonium using the Purex process for use in the fast breeder reactors.

As would be expected from an atomic energy program that has been in existence for over half a century, a complex organizational structure has been established to manage the very extensive industry and to support existing research and development, and deployment. A more comprehensive description on India's nuclear power industry can be found at http://www.world-nuclear.org/info/inf53.html. This website provides an updated report released on May 20, 2010 by the World Nuclear Organization. Staffing throughout the nuclear industry will need to be greatly expanded to efficiently, effectively, and safely manage the programmed rapid expansion in India's nuclear energy industry. The challenge is exacerbated by a multiplicity of reactor designs being introduced and an aggressive move from open fuel cycle technologies to closed fuel cycle technologies. For AERB, the burden to stay ahead of developments is particularly daunting.

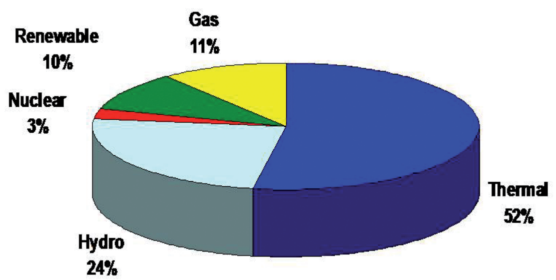
The rapid expansion of India's nuclear power industry is essential to providing the electric power required to support the level of economic growth and to significantly improve standards of living. Although the 1962 Atomic Energy Act prohibits private control of nuclear power generation, there will be many business opportunities for both private manufacturing companies and engineering consulting organizations to participate in the industry's supply chain.

Even if India succeeds in meeting its long-term goal of supplying 25% of total power from nuclear energy by 2050, an equal amount of renewable power supplies will be needed because of expected limits on production from thermal based plants.

4.3 The Necessity of Expanding Renewable Energy

Today, renewables, excluding large hydro plants, provide about 10% of India's electric generating capacity of 155 gigawatts. The responsibility for expanding renewables rest in the Ministry of New and Renewable Technology. Earlier discussions in our dialogue indicated that **India's growing demand for power will require generating capacity to double by 2017 and quintuple by 2032 to over 800 gigawatts in order to support an 8% per annum growth in GDP. Even under the most optimistic scenarios that predict thermal to grow by over 200 gigawatts, nuclear to reach 77 gigawatts , and large hydro to reach 150 gigawatts, demand will not be met. Only with a dramatic increase in the utilization of new, and in some cases unproven, technologies can the significant capacity gap be met.**

Figure 19: Indian Power Sector at a Glance



Wind	10386 MW
Small Hydro	2455MW
Biomass	2300MW
Solar	2MW

Source: Bandopadhyay, Bibek. "Solar energy- way forward." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010.

Even with a very successful expansion of renewable power, over the next several decades, the Planning Commission recognizes that India's power sector will remain highly dependent on fossil fuel, mainly coal, for decades to come. Today, coal provides about 90% of total electric power with only 52% of generating capacity and the growth in coal-fired power will require a significant increase in coal imports. The cost of coal imports is likely to rise with growing demand from China and the need to import from as far away as the United States. Recently, Indonesia (the world's third largest coal producer at 250 million metric tons) announced its output is likely to decline with the decision to close open pit mining to meet environmental concerns.

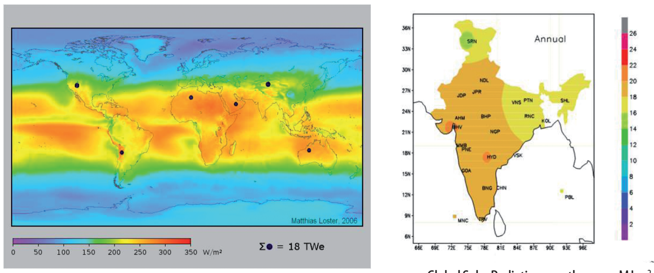
Figure 20: Renewable Power Potential in India

Source	Potential	Resource Assessment
Wind	48,500 MW (Achieved: 23%)	Survey data at 50m hub height. WPD> 200W/sqm. 1% land availability, @12 ha/MW.
Small Hydro	15,000 MW (Achieved: 16%)	Database with information on head and discharge available for ~ 5000 sites
Biomass Gasification, Cogeneration, Combustion, Waste to Energy	25,000 MW (Achieved: 9.2%)	~ 140 million tons of usable agricultural and agro-industrial residues per year.
Solar	-	In solar belt of the world. Handbook available. Further work on DNI in progress.

Source: Bandopadhyay, Bibek. "Solar energy- way forward." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

India's decision to move toward renewables is not an option, it is a necessity. Hence, the government has accepted the long-term challenge to "gradually shift from economic activities based on fossil fuels to one based on non-fossil fuels and from reliance on non-renewable and depleting sources of energy."[35] The magnitude of this challenge is exacerbated by India's relatively limited known potential to expand renewable power through the greater utilization of wind, small hydro, or biomass. Fortunately, India is located in the solar belt of the world and has huge potential to utilize solar power.

Figure 21: Solar Radiation over India



Global Solar Radiation over the year - MJm^{-2}

India is in the solar belt of the world. High incidence of solar radiation, geographic latitude, and demand pattern of energy provide appropriate conditions for utilization of solar energy in the country.

Source: Bandopadhyay, Bibek. "Solar energy- way forward." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

Both India and the United States face a number of significant hurdles in establishing a substantial renewable energy market that is especially relevant to solar power. First, renewable investments typically generate relatively low margins that require costs to be amortized over long time periods increasing investment risks. Second, there are often substantial technology risk premiums associated with early deployment of new technologies such as solar, biomass gasification, cellulosic ethanol and new advanced wind turbines. Third, there are market risk premiums associated with the uncertainty of resource availability and continuing policy support. Finally, variability in power output reduces the ability to sell regularly into the spot market.

In January 2010, Nation Action Plan for Climate Change announced a National Solar Mission with the specific objectives of achieving production levels that will lead to significant cost reductions and the rapid deployment of solar technology throughout the country (See Figure 22).

Figure 22: India's National Solar Mission

Application Segment	Target for Phase I (2010-13)	Cumulative Target for Phase II (2013-17)	Cumulative Target for Phase III (2017-22)
Grid Solar Power Incl. roof top	1,000 MW	4,000 MW	20,000MW
Off-grid solar applications (incl. rural solar lights)	200MW	1,000 MW	2,000MW
Solar Collects	7 million sq meters	15 million sq meters	20 million sq meters

Source: Bandopadhyay, Bibek. "Solar energy- way forward." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

In support of this program, the Central Electricity Regulatory Commission set a tariff of Rs. 18.44 ($0.38 /kwh) on solar photovoltaic power and Rs.13.45 ($0.28 /kwh) on solar thermal purchases by NVVN (NTPC Vidyut Vyapar Nigam Ltd.) which will connect the 1000 megawatts of interactive solar power to the grid. The NTPC will receive financial support, reducing its costs of solar power to Rs.5.50 ($0.11 / kwh) before being blended with coal-fired power. The objective will be to reduce solar cost substantially by Phase II in 2013 and to reach grid parity by 2022.

An immediate impact of program has been an upsurge in foreign companies entering into partnership arrangements for producing and selling solar components in India, including the U.S.-based Sun Power Corporation and Ascent Solar Technologies Inc. Additionally, in January, the Clinton Foundation announced a program in partnership with the government of Rajasthan to create solar parks with the installation and manufacturing of 3,000 to 5,000 MW of solar power. [36] Japan and India have also undertaken the development of solar cities. [37]

Recently, the Central Electricity Regulatory Commission (CERC) made it mandatory for all power utilities to purchase a minimum of 6%of their installed capacity from renewable sources such as solar, wind, mini and micro-hydro projects, and power generated by bagasse and biomass. Companies who fall below the required 6% level will find it necessary to purchase "Renewable Energy Certificates" (REC's) from utilities generating greater than 6% of their power from renewables.

The rate at which power utilities can buy RECs has also been fixed by the CERC. For solar power, it would be Rs 17/unit. Each utility has been assigned a required volume of specific renewable sources. With the costs of purchasing RECs, roughly identical to the current cost of producing power from solar, utilities have a clear incentive to seek lower costs by undertaking their own solar projects. Understandably, utilities that have not invested in renewable power will dislike being required to support investments made by others. However, the policy should accelerate the production of power from renewable sources.

The government has also developed a research and development strategy to support the solar mission by:

- Performing long-term research on materials and devices at academic and research institutions
- Undertaking applied research on existing processes
- Completing field evaluation of materials, components and systems
- Developing Centers of Excellence
- Proving support for incubation and innovation
- Establishing public private partnerships

In addition, programs are being established to train as many as 1,000 young scientists and engineers on different solar technologies in order to develop the manpower needed for future operations, maintenance and management of solar facilities.

If India can achieve competitively priced solar power, the returns will be highly advantageous. For one, large scale facilities can be constructed and commissioned in less than a year. The modularity of facilities will enable flexibility in application both in the size of installation and utilization in conjunction with other sources of power. Modularity can also help in stabilizing parts of the grid, especially if storage options can be developed. (At the same time without careful planning the addition of highly variable sources of power can create grid instability.) With adequate commercial micro-financing, there could be a rapid expansion of solar thermal applications that are currently providing only 200 megawatts of power.

However, the challenges to realizing the potential of solar power are substantial, but not insurmountable. First, government policy has to be clear and supportive of the industry. The recent decisions, discussed above, to introduce a commercially valid tariff applicable for 25 years for the first 1000 megawatts of production facilities should be very helpful, as will the requirement for utilities to use at least 6% renewable sources. The current heavily subsidized tariffs for solar power are 250 -350% greater than current subsidized wind tariffs. [38]

Large-scale financing, with interest rate alternatives to 12% interest over 10 years, will be essential. In order for financing mechanisms to provide 20+ years at 5-6% interest, the banking industry must gain an increased understanding of the availability of solar resources, the mechanics of the technology, and the assurance of either governmental or corporate guarantees from an entity like the NTPC. Hence, there is a need to create greater awareness of how the technology works, including the potential for cost reductions. **The availability of financing has now become a critical next step to further the development of this industry.**

The other necessary is for India to develop globally competitive solar services and manufacturing capability, which includes installation service providers. As was pointed out during the discussion, **a robust and competitive domestic industry will not be developed through protectionism. Failure to open the domestic industry to foreign investment will take away the incentive for the domestic industry to become more efficient.** Cost reduction relies on obtaining access to the expertise and new emerging technologies that can be provided by foreign investors. During the dialogue it was noted that in India every megawatt of solar installed in India could produce 11 manufacturing jobs and 33 jobs in engineering and installation. [39] Moreover, the creation of a globally competitive industry benefits domestic companies who could form partnerships with highly-competitive manufacturers from overseas.

While solar power is seen as having the greatest long term potential for providing the required magnitude of power, other renewable sources like wind, mini-hydro, biomass and geothermal also offer considerable potential and are often commercially viable today.

Figure 23 indicates the estimated potential for wind power is 48.5 gigawatts and that installed capacity today totals over 11 gigawatts. Onshore wind resources have been largely identified while additional measurement is needed for offshore resources. State regulatory frameworks need to be modified for adjoining states so that the optimal location of facilities can cross state boundaries. Expansion of wind power is also slowed by difficulties in acquiring sites and in connecting remotely located wind farms to a grid. India has significant manufacturing and service sector support for wind power although further research and development of materials and components is required to remain competitive on a reliability and cost basis. The U.S. wind industry faces similar issues.

Figure 23: Renewable Power Potential in India

Source	Potential	Resource Assessment
Wind	48,500 MW (Achieved: 23%)	Survey data at 50m hub height.WPD> 200W/sqm. 1% land availability, @12 ha/MW.
Small Hydro	15,000 MW (Achieved: 16%)	Data base with information on head and discharge available for ~ 5000 sites
Biomass: Gasification, Cogeneration, Combustion, waste to energy	25,000 MW (Achieved: 9.2%)	~ 140 million tones of usable agricultural and agro-industrial residues per year.
Solar	-	In solar belt of the world. Handbook available. Further work on DNI in progress.

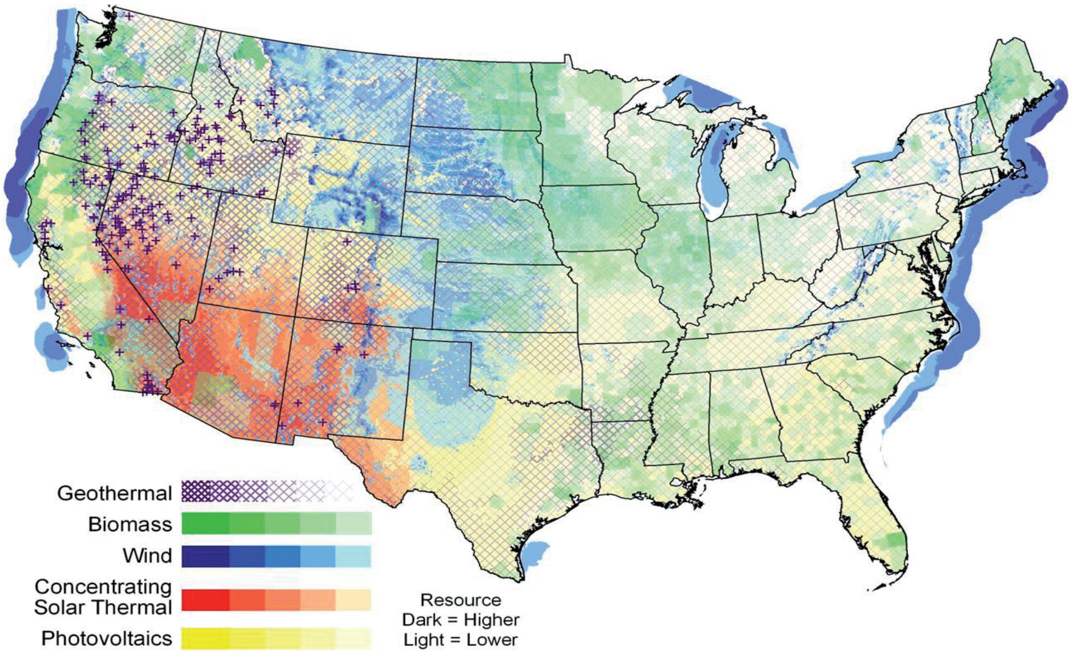
Source: Bandopadhyay, Bibek. "Solar energy- way forward." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

Today, small hydro and biomass provide a capacity of almost 5 gigawatts, and they have the potential to contribute an additional 40 gigawatts. A major effort has been undertaken to identify the potential for mini-hydro, which is particularly attractive for rural and mountainous areas of northern India. However, data is often unreliable and the logistics of moving power from remote sites is difficult. The World Bank designed programs to assist deployment that should be utilized. The unstructured biomass market is hindered by a lack of standardized equipment and spotty availability of adequate feedstock.

Over the last several years, the US Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) maintained an active assistance program with India on renewables. The U.S. is fortunate to possess a very substantial renewable energy resource base. The distribution of these potential resources is shown in Figure 24.

Figure 24: U.S. Renewable Resources

Resource	Solar PV/CSP	Wind	Geothermal	Hydropower	Biopower
Theoretical Potential	206,000 GW (PV)	8,000 GW (onshore)	40 GWe (conventional) 520 GWe (EGS)	>100 GW	78 GW
	11,100 GW (CSP)	2,200 GW (offshore to 50 nm)	7.5 Gwe (co-produced)		



Ginsberg, Mark. "New Technologies and Renewable Energy for Eletric Power." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

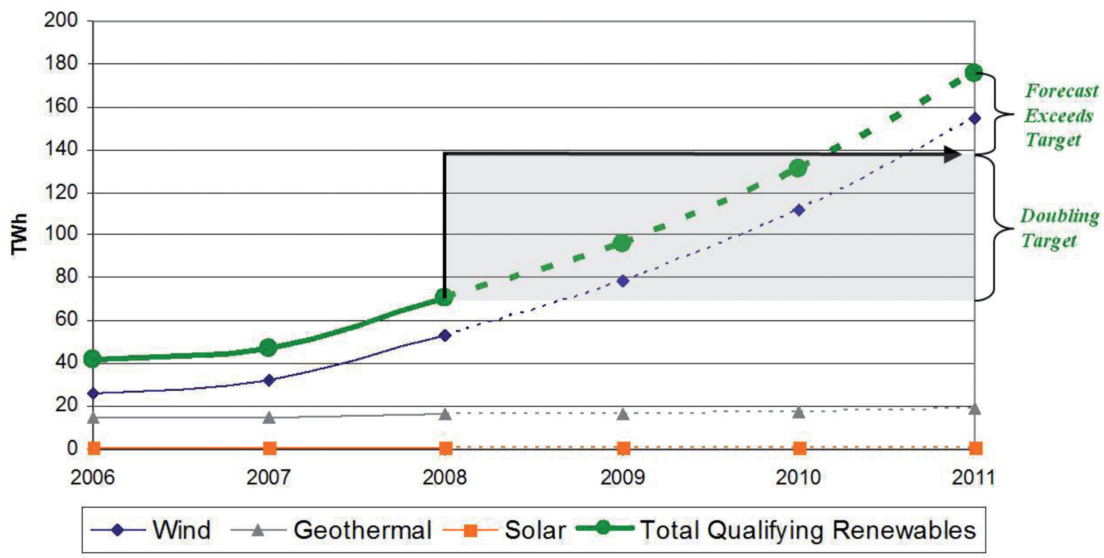
Since 2005, the U.S. experienced a rapid increase in the proportion of power capacity additions attributed to renewables, such that 45 % of all additions in 2008 were from renewables, mostly wind. Currently, the government supports major research and development programs totaling $399 million for the production of power from solar ($225 million), wind ($80 Million), geothermal ($44 million), and water ($50 million). [40]

The distribution of renewable resources is often located far from major consumption centers and tends to provide highly variable service. This can have an adverse impact on the costs of base load power. Breakthroughs in storage and the design of distributed power and smart grid technology will be critical to determining the eventual utilizable levels of renewable power. There is also an active discussion on requirements and investments needed for new transmission lines and the impact of cost allocations for such facilities for suppliers and consumers.

The potential for distributed renewable power sources to meet a high proportion of U.S. power requirements at reasonable costs will only become evident as new technologies and government policies evolve at the federal and state levels. It will also be highly dependent on the amount and terms of financing available for energy investments.

Like India, the U.S. views solar as the greatest potential resource base, but very expensive relative to existing power sources. Hence, the U.S. has made a significant effort to reduce the costs of solar power. On July 8, 2010, the U.S. Department of Energy and the Department of the Interior announced the establishment of a "Solar Demonstration Zone," of a 25 square mile area in Nevada called the "Solar Demonstration Zone" to test cutting edge solar technologies. Without major breakthroughs, the penetration of solar into the energy market will remain insignificant. Figure 25 indicates the progress of renewable power in the U.S. through 2011; expansion of solar has been limited in comparison with the greater penetration of wind power.

Figure 25: Doubling Renewable Energy by the End of 2010



Ginsberg, Mark. "New Technologies and Renewable Energy for Eletric Power." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

However, in the long term factors like dwindling supplies of conventional energy and environmental concerns will ensure that all sources of energy will need to be developed in order to meet growing energy requirements.

Existing collaborative programs with India's solar center include the design of a zero energy building and the solar cities program. Another program is in the process of proposing ways to obtain more precise estimates of solar resources from ground monitoring stations. Opportunities for collaborative basic research and public /private partnerships are also on the table.

There are a number of other areas where greater collaboration on renewable power could be productive:

- Improving the efficiency of wind generation at slow wind speeds and in the mapping of wind resources.
- Improving the reliability of wind equipment and designs to lower the costs of maintenance and increase expected facility life.
- Researching device and components for tidal and hydrokinetic technologies and. Again, may want to consider public private partnerships.
- Developing mapping and technologies to utilize high temperature geothermal potential.
- Utilizing biomass as a supplement in thermal power.

In another section, the potential to increase the utilization of renewables through cooperation on issues related to smart grid technologies and improving the efficiency of transmission and distribution will be discussed.

4.4. Improving Energy Efficiency in the Electric Power Sector

India faces a particularly daunting task of designing policies and programs to decouple GDP growth from energy growth and rising greenhouse gases. As noted earlier, following traditional development models will lead to the substantial gap in energy supply that is unlikely to be met solely with new physical sources of energy from either new technologies or greater imports. **While there is no sole solution, increasing energy efficiency and conservation is a necessary and critical component in bridging the gap.** Again, efforts to reduce energy requirements while meeting developmental needs will involve a large number of policies, investments, and technological innovations.

Utilizing "smart grid" technologies will be essential for the development and deployment of a 21st century transmission and distribution system. India made substantial progress in creating a national power grid operated by Power Grid Corporation of India Limited (PGCIL) that can move 21,000 MW of power inter-regionally throughout the country. There have been no grid failures in the national system over the last 7 years.[41] State grids and distribution grids are operated by the state transmission utilities. Significant improvements in the state power systems have increased reliability although connectivity issues remain and open-access is limited. In order to improve connectivity and access, additional transmission lines will need to be built. As in the U.S., public opposition can lead to problems obtaining right of ways. There are also cost concerns with initial low load levels, which can cause transmission costs to increase by 50-60%. Within the states, strong local area networks need to be established to meet consumer demand and to provide linkages to growing renewable power sources. In some states, the location of renewable power could require a system that functions across state lines and links a strong, local area to the sub-regional systems of neighboring states. This kind of system will require regulatory changes.

Today, some transmission lines are inaccessible or of insufficient capacity to move surplus renewable power, like wind and solar, to distant population centers. Another barrier includes pricing mechanisms that disfavor the transfer of electricity over long distances. The high cost of infrastructure may also require initial connection charges that discourage entry. In the long term, major economies of scale will be necessary to keep costs reasonable.

The implementation of smart grid technology that combines information systems with network operating systems and customer information and billing systems through digital technology is needed to improve the reliability and efficiency of electric power systems while enabling greater customer control over costs. Smart grid technology applications vary between countries and need to be tailored to the conditions of each specific country. Once networks have become relatively robust and access is broadly available, smart grid technology can constantly monitor the generation and distribution of power. Increasing reliance on infirm renewable power will cause grid instability which affects both the distribution and demand for power. The introduction of a number of digital technologies will allow for automatic network optimization that in turn will provide distribution management, advanced metering, and other benefits. Automatic network optimization also provides a fast response to system instabilities and accommodates fluctuating loads. When implemented, customers will be empowered, energy efficiency will be increased, and a greater level of renewables will be efficiently connected to the grid.[42]

India is making significant progress in building a robust electrical infrastructure for its industrial and urban centers thanks to its advanced information technology infrastructure. In July 2008, India's cabinet authorized the Ministry of Power to establish a national framework for implementing smart grid programs to systematically lower transmission and distribution losses. The Power Finance Corporation manages and implements the activities which are then organized at the state-level by the Distribution Reform Committees (DRCs). The Indian Accelerated Power Development and Reforms Program (APDRP), is charged with demonstrating a sustained reduction in losses on the power system. Initial steps entail the establishment of reliable automated systems for the sustained collection of accurate baseline data. The adoption of information technology in the areas of energy accounting is viewed as an essential first step before undertaking specific projects to strengthen the distribution system. State DRCs will be reimbursed 100% for developing the base line data and up to 25% for costs incurred on implementing specific projects. Participating state utilities companies will be required to ensure that a portion of the benefits from loss reductions are passed on to consumers with ring-fenced project areas.

Recently, an APDRA forum was started with many stakeholders from the electricity and information sectors to build a modern electric power sector based on five pillars. The fundamental underpinnings of the evolving system include:

- Demand optimization to improve the efficiency and effectiveness of generation
- Distribution optimization to enable the utilization of renewables
- Asset optimization to manage outage planning and ability to manage peaking
- Transmission optimization to ensure efficient utilization of transmission lines
- Optimizing the operating and engineering workforces to improve labor productivity.

India is finding it timely to change its business model for the electricity sector in order to deal with the absolute increases in technical and non-technical losses. Growing losses are associated with demand growth that continues to outstrip supply availability, the challenge of replacing aging assets, and the need to modernize billing and collections. The potential to use a combination of technologies and altered business practices to radically change performance in the power sector is well documented by the experience of NDPL, a joint venture of TATA Group and the Delhi government. After obtaining responsibility for 5 million customers in Delhi in 2002, they systematically reduced losses from over 53% to under 15% while dramatically improving the quality of assets, customer and employee satisfaction. The remarkable performance between 2003 and 2009 are shown in Figure 26.

Figure 26: NDPL Profile

AT&C Loss Level (FY 2008-09)	15% (reduced from 53% at the time of Take Over)
Turnover (FY 2008-09)	Rs. 2467 Cr (enhanced from Rs 1100 in FY 03)
Peak Load (FY 2009-10)	1259 MW
Annual energy requirement (FY 2008-09)	6325 Million Units
Total registered consumers	1.02 Million (0.743 Mn on Take Over)
Number of employees	3700
Population serviced in Network area (approx)	5.0 Million
Per Capita Consumption (Units)	1240 (National Average of 500,Mumbai – close to 850)
Number of consumers per Sq.Km	2017 (Only Registered)
Load / Energy Growth	05% -07%
Transformer Failures w.r.t Installed Capacity (%)	<2% (11% at time of Take Over)
Percentage Share in Load Shedding (In Delhi)	<2% (40% at time of Take Over)
% Provisional Billing	<1% (22.5% at time of Take Over)
DT – Wise Energy Auditing (%)	100% (Nil at the time of Take Over)

Saini, Sudarshan Kumar. "Delhi Distribution Turn Around: Experience Sharing – NDPL." Conference Presentation. US-India Dialogue on Sustainable Energy Security. New Delhi, India, March 17, 2010.

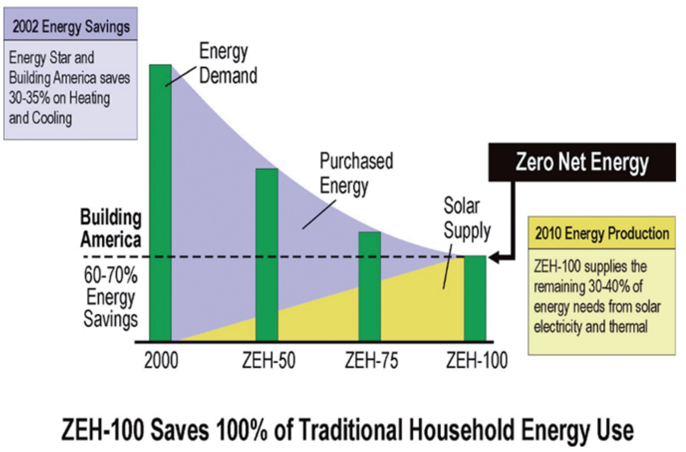
The U.S. is also pursuing an aggressive program to improve energy efficiency through programs of the Department of Energy's Office of Energy Efficiency and Renewable Technology and the Office of Electricity. These programs work with industry to develop codes, standards and the architecture needed to deploy smart grid technologies. The US GridWise Alliance has exchanged information with India to increase knowledge among industry stakeholders. Formal participation in the Alliance would accelerate the sharing of information internationally, and assist India in identifying requirements as well as the costs and benefits of supporting R&D initiatives and the potential for public-private partnerships.[43] For customers and utilities across the globe to embrace smart grid, the technology must operate seamlessly to reduce uncertainty with reliability and availability of service. Global cooperation on the development and deployment of an open architecture with standards and security will enable the faster development and deployment of the many components of this technology. Failure to cooperate is likely to lead to incompatibility and lower international trade in components and equipment.

The U.S. also has a program focused on developing energy solutions for both new and existing buildings to move towards net zero energy buildings. This is recognized to be a long -term program involving:

- Residential and commercial integration
- Components research
- Lighting, HVAC, and water heating
- Windows, walls, roofs
- Simulation tools to improve designs.[44]

Figure 27 provides a conceptual illustration of the long term goals of this program to achieve a 60-80 % reduction in the energy consumption of buildings, which currently account for 40% of the total energy utilized in the United States .[45]

Figure 27: EERE Buildings Program Focus



Source: Ginsberg, Mark. "New Technologies and Renewable Energy for Electric Power." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

4.5 The Electrification of Rural Areas

While substantial improvements in electricity service is underway, the challenge of servicing rural areas, where over 400 million people live off extremely low incomes, remains particularly difficult. Most of the population has no access to grid-connected electric power and remains economically, educationally, and socially disadvantaged.

In August 2006, the Ministry of Power published a Rural Electrification Policy underlining the importance of electricity in accelerating rural development.[46] The policy reflects Central Government's April 2005 scheme, "Rajiv Gandi Grammen Vidhyutikaran Yojana (RGGVYY)" which sets a goal of electrifying all un-electrified villages and hamlets and providing access to electricity to all households by the end of 2009. Where possible and cost effective, grid connectivity was to be established with a Rural Electrification Distribution Backbone (REDB) with at least one 33/11kv (or 66/11kv) substation for each block. Emanating from the REBD there will be supply feeders and at least one distribution transformer at each village settlement. Decentralized generation and supply is also to be provided from conventional energy sources where grid connectivity is either not feasible or not cost effective. The policy also supports capital for other requirements such as irrigation pumps, village industries, health care, education, and information technology that would facilitate overall rural development, employment, and alleviation of poverty. The central government finances this program with a 90% capital subsidy. There is a 100% capital subsidy for the electrification of households below the poverty line and no subsidy for connections to households above the poverty line.

The Ministry of Non-conventional Energy Resources (MNER) implemented a separate program for the electrification of remote villages. The MNER provides capital subsidies for renewable power generated by rooftop solar systems, solar lanterns, solar streetlights, and solar water heating systems. Additional funding for rural electrification is provided by the Rural Electrification Corporation Limited that lends to State Electricity Boards and Rural Electric Cooperatives. This corporation, which is listed on the Bombay Stock Exchange and National Stock Exchange of India, was a government entity that raised funds through the sale of taxable bonds, but in 2008 the government divested 18%.

Through these programs, rural areas are slowly gaining access to electric power. However, a number of challenges still leave many households unconnected. The potential for increasing the use of distributed power through strong local area networks was discussed as a means to address the remoteness of some areas. This solution was believed to work best when connected to a sub regional grid that balanced the load between neighboring regions. Utilizing renewable sources for distributed power is seen as deferring capital investments and lowering operating costs for transmission and distribution by providing electricity closer to the customer and postponing a more robust expansion of state grids until greater customer demand is developed. The disadvantages of distributed power generation in rural areas are numerous; the relatively low utilization of necessary transmission and distribution capacity; diminished ability to support peak loads due to the infirm nature of renewable power; and, less access to skilled labor in remote operating facilities.

The U.S. is also considering the greater use of distributed power and is viewing electricity storage options as potential solutions. These could involve relying on hybrid systems using hydro and/or fuel cells to accommodate fluctuating loads.

Over time, it is critical for India to electrify rural areas so the rural population can achieve a higher standard of living and escape extreme poverty. The programs initiated in the last few years to provide access to power will make a difference; especially if they are accompanied by locally designed supplemental programs to address the particular skills training and education required in each specific rural area to increase agricultural and small industry productivity.

Chapter 5: Improving End-User Energy Efficiency

As just discussed, the critical role of smart grid development can play a critical role in improving energy efficiency and lowering the pace of additional generation in the power sector. **The intelligent integration of electricity infrastructure with communications and information technology is a key component to achieving efficiency.** Through better measurement and real time monitoring of power usage, the full range of consumers - industrial, commercial and residential - will eventually be empowered to make more informed decisions on the type and use of electrical equipment, appliances, lighting and heating/cooling.

In India, the Energy Conservation Act of 2001 established the Bureau of Energy Efficiency (BEE) who has now been promoting energy efficiency for almost 10 years. Initial programs focused on improving industry performance. Energy Service Companies (ESCOs) specializing in energy auditing have been used to establish base lines and implement energy efficiency programs. Some of the programs have attained energy savings of up to 30 percent. However, many of the ESCOs are financially weak which has constrained their growth. Increasing public awareness of potential benefits is required for an expansive utilization of such service companies.

An Energy Conservation Building Code (ECBC) was established in June of 2007 to increase the public's awareness of energy consumption. Originally, the BEE focused on voluntary and informational programs. Then the government mandated deadlines for government buildings to become energy efficient. Recently, the BEE announced that star ratings are to be assigned on all new commercial and residential buildings consuming more than 500 kw. These ratings are expected to become requirements in 2011, and could reduce power consumption for new construction by 25-30 %. [48]

India has already adopted the Energy Star ratings for appliances. This also began as a voluntary program for manufacturers, but has recently been converted into a mandatory program for most manufacturers.

The BEE is continuing to broaden its activities. In July of this year, it announced that it will conduct an energy audit in eight large municipalities in Uttar Pradesh (including Kanpur and Varanasi) covering all government buildings, street lights, and sewage systems. A data bank will be prepared along with specific recommendations for saving energy. [49]

India's energy star program for appliances has been modeled after the U.S. program that is still evolving as new technology continues to improve the potential efficiency of appliances and equipment. Continuing interaction between the two programs on the effectiveness of implementation programs and measuring the impact of power demand should prove beneficial to both countries' efforts to increase the efficiency of consumers' power usage.

Chapter 6: Increasing the Efficiency of Vehicle Fuel Consumption

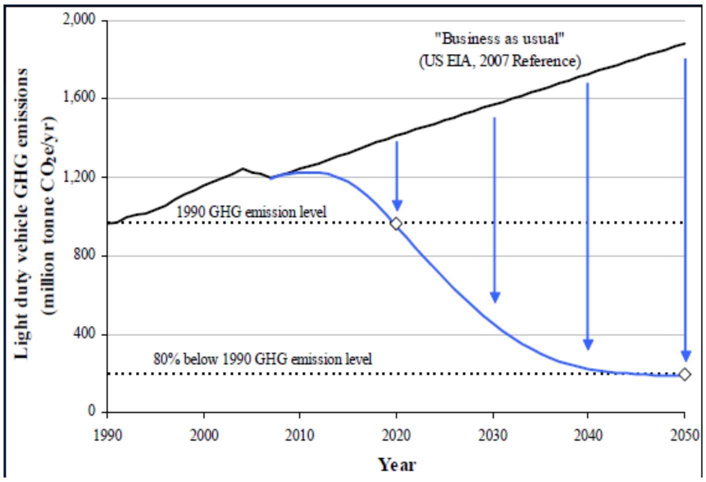
The dialogue also addressed how to transform the transportation sector in such a way that would reduce both countries' dependency on oil and to lower emissions adversely impacting health and climate. The International Council on Clean Transportation recommends three basic principles (known as the Bellagio Principals) that should be followed in developing transportation policies globally:

- Design programs and policies that reduce conventional, toxic, noise and greenhouse emissions in parallel,
- Treat vehicles and fuels as a system,
- Design new vehicle standards for greenhouse emissions and conventional pollutants to be fuel neutral,
- Expect and require the best technologies and fuels worldwide- in both industrialized and developing countries.

The U.S. passed legislation on a systems approach that sets fuel standards to enable clean technologies and provide significant environmental benefits in line with the air quality goals of the states. The Corporate Average Fuel Efficiency (CAFÉ) introduced standards on light-duty tier 2 vehicles in 1999, non-road tier 4 diesel vehicles in 2004, heavy –duty road vehicles in 2007 and 2010, and rail locomotives/marine in 2008. However, as seen in Figure 27,the U.S. objectives for light duty vehicles in 2022 will still leave the nation a long way from the stated goal of achieving an 80 % reduction in 1990 GHG emissions by 2050 pronounced at Copenhagen. The figure also notes that policy makers have three major variables that can be adjusted to achieve GHG emission reductions, namely:

- Gallons of fuel per mile (CAFÉ standards),
- CO2 content of the fuel (type of fuel) and
- Miles traveled per year (transportation habits). [50]

Figure 28: Automobile GHG emissions



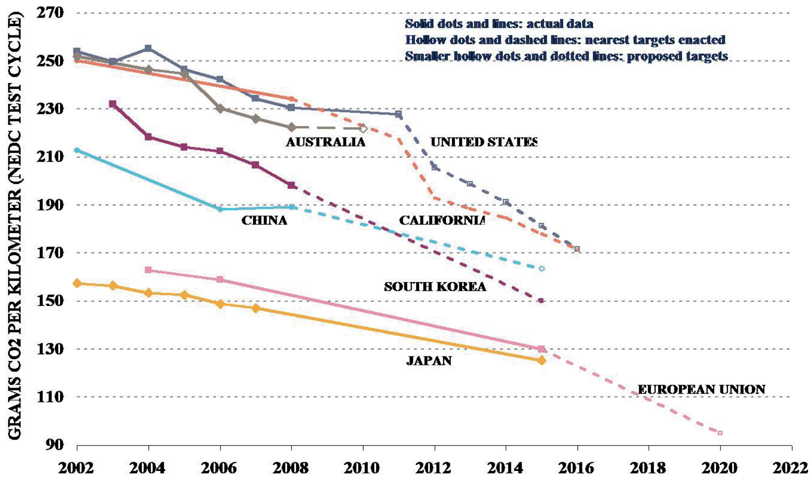
	Vehicle technology	Fuel GHG intensity	Travel behavior

$$\left(\frac{GHG}{emissions}\right) = \left(\frac{gallon\ fuel}{mile}\right) \times \left(\frac{CO_2\ equiv.}{gallon\ fuel}\right) \times \left(\frac{miles\ traveled}{year}\right)$$

Source: Walsh, Michael. "Transforming the Transportation Sector in a Carbon-Constrained World While Reducing Climate and Urban Air Pollution Impacts." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010

Even after passage of the 2008 energy legislation, other major countries have, and are planning, to make much more significant reductions in GHG emissions through tighter fuel specifications and higher mileage standards. See figure 29. **The U.S.'s ability to raise vehicle efficiencies and alter fuel types is made more difficult by the relatively low price of transportation fuels and the role of vehicle transportation in American living patterns.** Furthermore, the sheer size of the U.S. vehicle fleet, 250 million light vehicles and 50 million trucks, means it will take many years to turn over the vehicle fleet.

Figure 29: Actual Fleet Average GHG Emissions Data Through MY2008 and Nearest Targets Enacted or Proposed Thereafter by Region

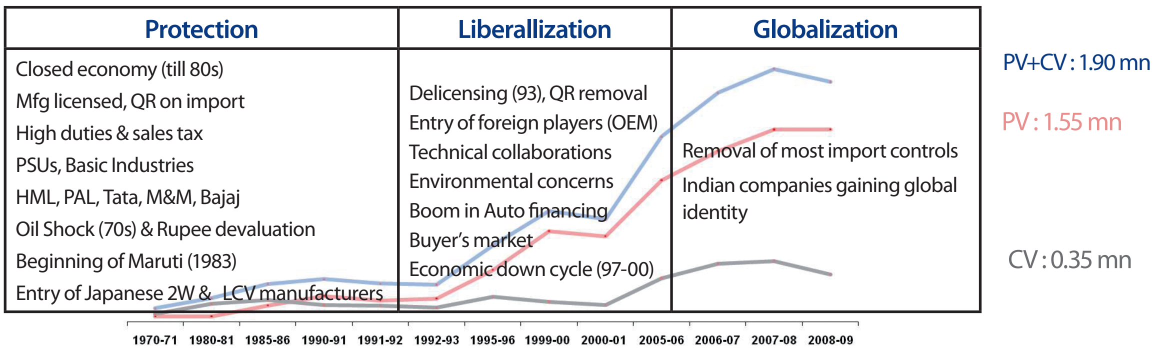


Source: Walsh, Michael. "Transforming the Transportation Sector in a Carbon-Constrained World While Reducing Climate and Urban Air Pollution Impacts." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010

The Department of Energy and the automotive industry have undertaken an aggressive R&D program to develop a more efficient transportation system less dependent on oil. The vehicle program is focused on advanced state of the art energy storage batteries and hybrid drive systems. It is also testing technology needed for plug-in hybrid electric vehicles and developing advanced combustion engines with very high efficiencies and near zero emissions. The vehicle program is also developing lightweight materials to reduce vehicle weight, and enable the use of non-petroleum fuels in all vehicle technologies.[51] The 2010 budget for these activities totals $705 million. [52] In addition, the 2009 stimulus package provided a lump sum of $8 billion for high speed rail, and the Department of Transportation has undertaken a major program to establish high -speed rail lines along a number of key corridors.

India's auto industry evolved slowly through the early 1990's, but is now poised to expand rapidly. Figure 30 indicates that the current market totals about 10 million vehicles, of which private and commercial vehicles total less than 2 million with two wheelers accounting for over 75 percent of the total market and three wheelers another 4 percent. On a revenue basis, private vehicles account for 48% of sales and 23% of commercial vehicles. Indian companies are now gaining global identities and total domestic sales now total over $31 billion with exports of over $2 billion.[53] Before the recent economic slowdown, the Society of Indian Automobile Manufacturers hoped industry sales would expand to US$145 billion by 2016 and contribute to

Figure 30: Evolution of Indian Auto Industry



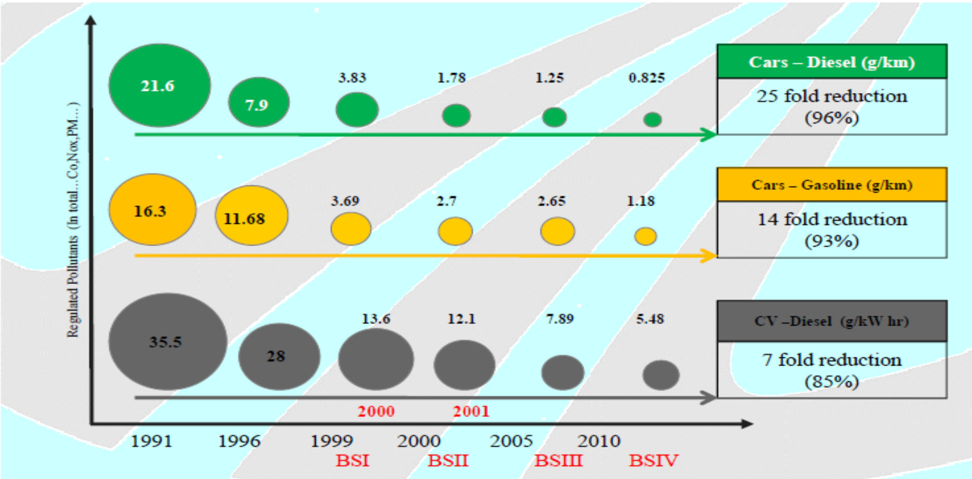
PV	47,000	208,000	690,000	1,143,000	1,552,000
CV	145,000	136,000	137,000	350,000	384,000
3W	13,000	84,000	182,000	360,000	350,000
2W	213,000	178,000	3,634,000	7,056,000	7,438,000
Total	418,000	606,000	4,643,000	**8,909,000**	9,723,000

Source: Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

10% of India's GDP. Such rapid growth from a relatively small base would enable the Indian auto industry to respond relatively quickly to changing standards by introducing new technologies.

It is important to remember that in contrast to the U.S. and the E.U., India primarily relies on two wheelers to provide basic family transportation. Today, India produces one of the most fuel efficient two-wheelers in the world attaining 80-100 kilometers per liter of petrol with emissions of CO2 that run under 50 grams. The huge fleet of around 8 million relatively low cost two-wheelers consumes two-thirds of India's petrol. India cannot afford to use the same sophisticated technology used by Harley Davidson and BMW to produce motorcycles that cost more than a passenger car does in India.

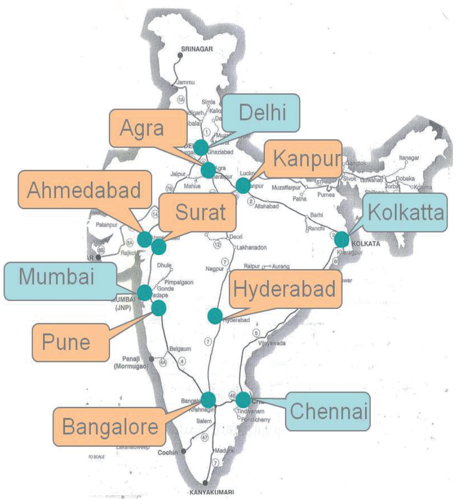
Figure 31: Limiting Pollutants for Making EFV's



Source: Abraham, Mathew, "Indo- US Dialogue on Sustainable Energy Security ", Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010

India had made major strides in reducing pollution over the past two decades. This is seen in the pace at which the industry has limited regulated pollutants since 1991 in order to make environmentally friendly vehicles. See figure 31. These advances reflect India's adoption in April 2010 of Euro III standards throughout the country and Euro IV standards in all major and mega cities. See figure 32. Importantly, by 2011 there will be a mandatory requirement for manufacturers to provide energy efficiency rating on vehicles. **These developments are clearly positive. However, they do not address the issues related to the very high proportion of diesel consumed in India.**

Figure 32: Outcome of Auto Fuel Policy



Fuel Quality	MajorCities	Mega Cities	Rest Of India
Euro II	April 2001.	April 2003.	April 2005.
Euro III	April 2005.		April 2010.
Euro IV	April 2010.		Not decided

Discussions to commence for Regulations Beyond 2010

India Emission Reg = EU Regulation

Required Fuel = Matching Euro fuel.

Challenge to Vehicle Manufacturers:

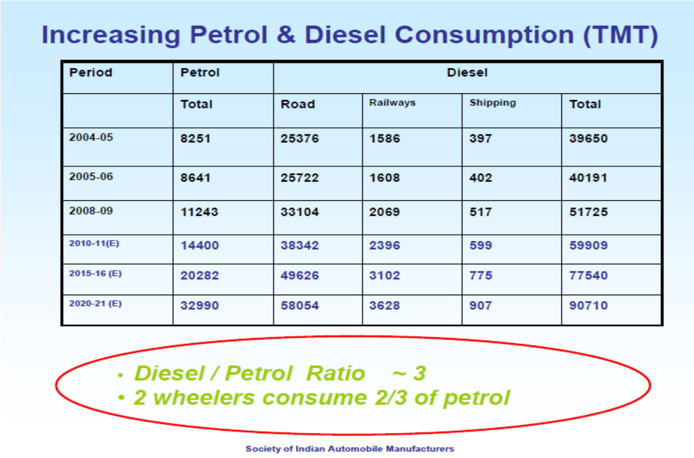
Different Fuel Quality in different parts of the Country

Same vehicle plying in various areas – Would impact after-treatment devices/ OBD/ other engine components?

Source: Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

Figure 33 shows that the current diesel to petrol ratio in road vehicles runs 3 to 1, with two-wheelers consuming about two-thirds of the petrol. Currently, particulate matter in fuels is very high and there is no requirement for particulate filters. This presents a continuing major health concern.

Figure 33: Increasing Petrol and Diesel Consumption (TMT)


Increasing Petrol & Diesel Consumption (TMT)

Period	Petrol	Diesel			
	Total	Road	Railways	Shipping	Total
2004-05	8251	25376	1586	397	39650
2005-06	8641	25722	1608	402	40191
2008-09	11243	33104	2069	517	51725
2010-11(E)	14400	38342	2396	599	59909
2015-16 (E)	20282	49626	3102	775	77540
2020-21 (E)	32990	58054	3628	907	90710

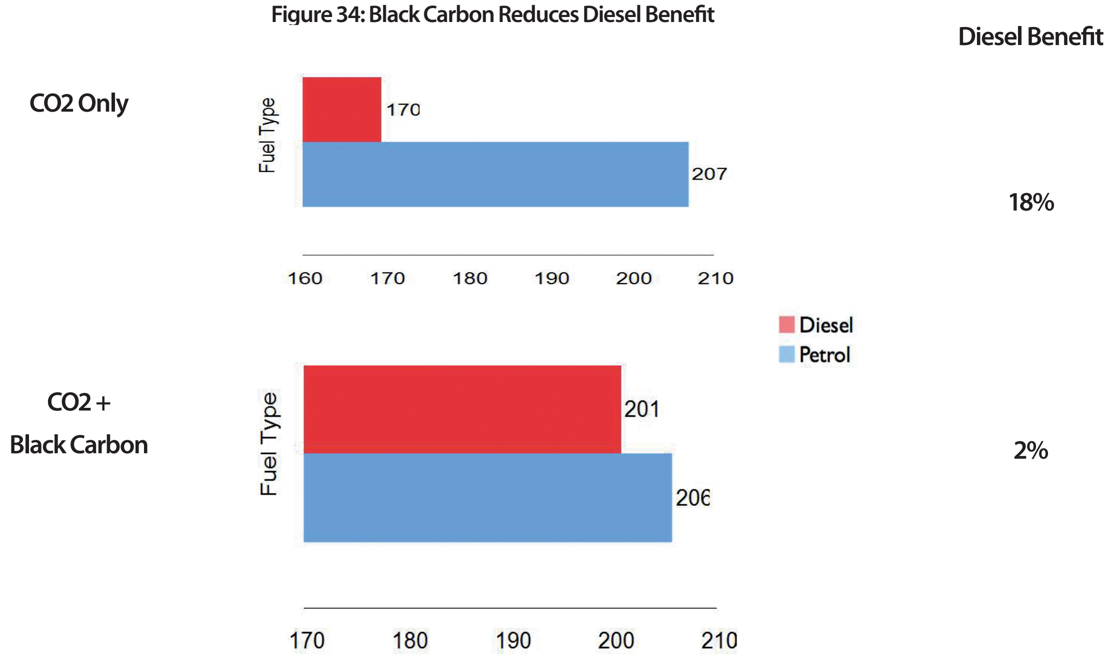
Source: Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

In 2000, the national average of particulate matter in diesel fuels was 2000 parts per million. It was dropped to 500 parts per million in 2005, and the current objective is to reduce this to approximately 300 parts per million by 2010 nationwide, with levels closer to 100 in the metro areas. However, particulate matter should be reduced to 50 parts per million to reduce the risk of premature deaths from lung cancer and other pulmonary diseases.[54]

This will require both after treatment emission controls and refineries to make the investments to produce ultra low sulphur diesel. Taking such steps will also reduce the amount of carbon black associated with the use of dirty diesel fuels. **It is often thought that CO2 levels would be reduced by up to 18% from using diesel versus petrol; but this benefit is probably reduced to 2 % if the impact of carbon black is measured.** See figure 34.

India's ability to require emission control devices on vehicles is currently limited by the dual fuel policy that mandates Euro IV standards (50 ppm sulphur) in metro areas but allows Euro III standards (350 ppm sulphur) in surrounding areas. Until India migrates to a national Euro IV standard with ultra low sulphur diesel, particulate filters will not be logistically possible. Today, the manufacturers rely on catalytic burning of partial traps. The auto industry would like to

Figure 34: Black Carbon Reduces Diesel Benefit



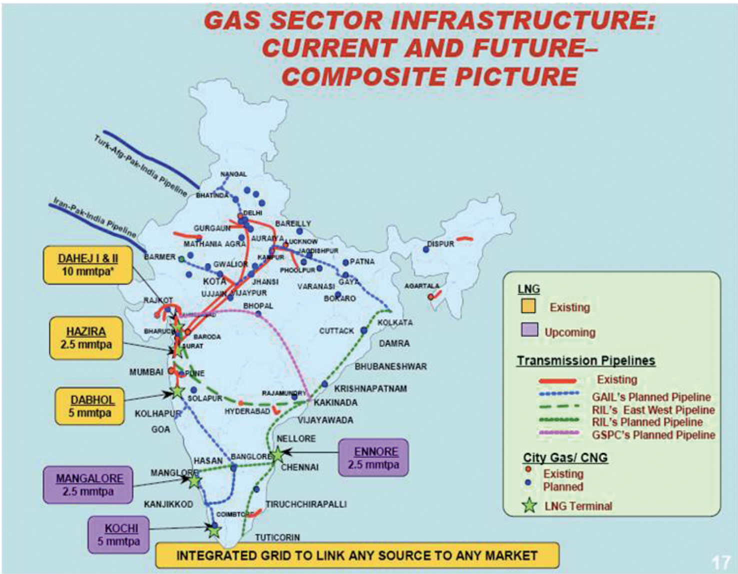
Source: Walsh, Michael. "Transforming the Transportation Sector in a Carbon-Constrained World While Reducing Climate and Urban Air Pollution Impacts." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010.

see the post-2010 regulations resolve this dilemma, by imposing consistent country -wide regulations, but this obviously has pricing implications.

Some major metro areas like Delhi encourage the use of compressed natural gas (CNG). In the U.S., this has been recommended by Boon Pickens, where it is considered a viable alternative fuel for some fleet vehicles. CNG vehicles make sense in India if ultra low sulphur diesel is not available, or diesel engines do not have particulate filters. LPG is also used to a limited extent, but it is not cost competitive and competes with limited supplies needed for cooking. Hence, LPG is not expected to grow as a vehicle fuel. If CNG is used, it should meet Euro V standards, which are tighter than current regulations. In 2009, there were 700,000 CNG vehicles in 30 cities, and this could grow to almost 6 million vehicles by 2020.[55] Figure 35 shows current gas pipelines and indicates possible future connections. The Gas Authority of India is projecting that CNG could be available in 200 cities across the country in the next five years.[56] In 2011, the use of CNG will grow as many cities experiencing high levels of particulate emissions will be banning diesel fuels in favor of CNG.

Figure 35: India Shifting Toward CNG Vehicles in Some Cities and Sectors: Does This Make Sense?

- CNG Vehicles Make Sense For India If:
  - ULSD Not Available For Diesels with PM Filters
  - "Clean" CNG Vehicles Required – At Least Meeting Euro 5/V
  - CNG Designs Focused on Safety



Source: Walsh, Michael. "Transforming the Transportation Sector in a Carbon-Constrained World While Reducing Climate and Urban Air Pollution Impacts." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010.

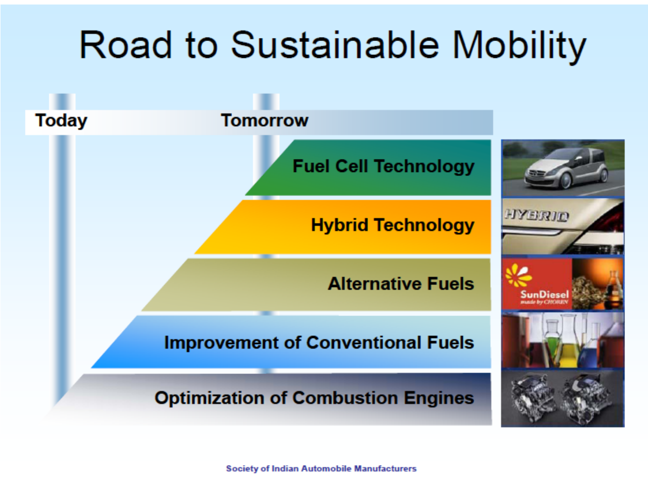
Looking to the future, India is expected to follow a path similar to that of the U.S. Figure 36 provides a schematic representation of the path of development that is identical to that seen in the U.S.

- In the short term, combustion engines will be optimized leading to numerous improvements using conventional fuels that can result in cleaner and more efficient vehicles. This is expected to provide the greatest benefits at the lowest capital cost for vehicles.

- In the midterm, alternative fuels will become more prevalent and there will be increased penetration of clean and efficient hybrid electric-gasoline vehicles and possibly clean and more efficient diesel. The actual environmental benefits from electric vehicles will depend upon the source of electricity. Today, most of such vehicles will be recharged by diesel generators, or with coal-supplied electricity. This will provide few if any life cycle benefits from the use of electric vehicles.

-In the long term electric vehicles and fuel cell vehicles using hydrogen will slowly evolve. Plug-in hybrid vehicles and all electric vehicle deployment will ultimately depend on a robust and widespread deployment of smart grid technologies. Again, the benefits of fuel cells will depend upon the primary energy sources providing the hydrogen. The automotive industry is working with Indian Oil testing zero emission vehicles running on hydrogen and a combination of hydrogen and CNG (HCNG). The production, storage, and transportation of such fuels will be a major challenge, as it is in the U.S. Unless these issues can be resolved through major breakthroughs in a cost-effective manner, automotive fuel cells based on hydrogen will not be commercialized.[57] If a blend of 18% hydrogen and 82% CNG can be commercialized, it will provide better fuel economy and lower NOX emissions.

Figure 36: Road to Sustainable Mobility



Source: Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

India will be focusing on two major approaches to reducing the consumption of energy for transportation. First, there are efforts to reduce the consumption per kilometer traveled by setting new norms, employing new vehicle technologies, retirement policies and inspection and certification programs. Second, programs are being designed to reduce the kilometers traveled through urban planning, shifting to public transportation and designing intelligent transportation systems.

The Ministry of New and Renewable Energy has a vision of achieving a 20 % blending of bio-fuels for diesel and ethanol in gasoline by 2017 that has been approved by the Cabinet. However, Mr. Ramesh, Minister of Environment and Forestry, noted in November 2009 that this is unrealistic due to food and land limitations. [59]

To date, major milestones included the mandatory blending of 5 % ethanol throughout most of the country, subject to commercial viability by November 2006. This was to be followed with the mandatory blending of 10% ethanol from October 2008. Currently, ethanol is produced from sugar cane reflecting the decision to not use food products as a source of bio-fuels. The pace of implementation has been slowed by the need to resolve several issues:

- Currently not all vehicles are compatible with 10 % ethanol
- Compression ratios need to be increased to compensate for lower fuel efficiency.
- There is a need to develop a sustained supply of ethanol;
- It is not possible to achieve even 5 % across the country and it needs to be determined what areas can achieve between 5 and 15 % with the current sugar crop.
- Will clearly need to develop cellulosic sources of ethanol to go beyond 10% blending and probably to reach even a 10 % blending across the country owing to difficulties in obtaining supplies in many states.
- Need to develop clear implementation road map with sufficient time for manufacturers to respond.
- Need clear labeling at fuel pumps

Bio-diesel presents additional challenges. It is agreed that bio-diesel is environmentally friendly when non – food products such as Jatropha are used. It is clean burning, increases engine life, is biodegradable, non-toxic and easy to handle and store. No engine modifications are needed for 3-5% blends. There are issues of supply availability compounded by possible stability issues associated with stored bio diesel that will require quality checks before blending. Utilizing 20 percent bio diesel by 2030 could require up to 38 million hectares of wasteland to be converted to feedstock production, which is not considered feasible.[60] See figure 37. Hence, it is probable that biodiesel will only be deployed country -wide at the 5% blending level, with higher blends limited to areas where feed stocks can be more readily obtained. This will create vehicle specification problems for manufacturers who may be required to design vehicles for separate markets, or to forgo some market areas.

Figure 37: Diesel and Biodiesel Demand

Year	Diesel Dmd	Bio-diesel (5%) MMT	Bio-diesel (10%) MMT	Bio-diesel (20%) MMT
2001-02	39.81	1.99	3.98	7.96
2006-07	52.33	2.62	5.23	10.47
2011-12	66.90	3.35	6.69	13.38
2020-21	111.92	5.60	11.20	22.38
2030-31	202.84	10.14	20.28	40.56

Potential vis-à-vis different yield levels	
Yield level (ton of seeds/ year)	Production (63.85 Mha)
1	13.77
2	27.54
3	41.31
4	55.08
5	68.94

Conclusion: 38 Mha of wasteland required for 20% blending by 2030 with yield of 5 tons/ha

Source: Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

The discussions indicated that the India automotive industry is determined to meet the challenges of air quality, energy diversification, and climate change at affordable costs. It recognises that **it needs to adopt an integrated approach that involves the oil industry, automotive industry, regulator, customers, and public private partnerships.** India will be working on a mixture of transportation options. It needs to keep its options open as research and development allows the deployment of new technologies, and the problems of building a cost effective infrastructure for alternative fuels is created. **Networking with the international community will broaden opportunities as many of the issues are similar around the world.** India does have a unique reliance on two wheelers, but this will slowly change as incomes rise. Others, like the U.S., are facing challenges to develop more efficient vehicles and to utilize a broad spectrum of alternative fuels to reduce dependency on oil. **There is much to learn from greater cooperation and from discussions on the effectiveness of various policy choices.** In some cases, solutions that seem initially attractive will be limited by costs and practical considerations. **International cooperation should enable a faster development of major breakthroughs needed to employ most of the new technologies.**

Chapter 7: Conclusions and Recommendations

India and the United States will have ample opportunities for cooperation to ensure a sustainable energy security. In both countries sustainable security implies developing adequate supplies of environment friendly energy at affordable costs for their citizens. While economic conditions are dramatically different between the two countries, both will find it necessary to consider similar policies and develop many of the same technologies to evolve their energy sectors in a world with tightening resources, growing environmental concerns and a strong desire to economically prosper. **The scale of transitions in both countries will involve substantial shifts in the economy and society that will be as dramatic as those experienced in the industrial revolution.** Although both countries are starting from dramatically different bases, the availability and accessibility of knowledge that can be shared internationally will be a new enabling factor that will allow for adjustments to be undertaken at an accelerated pace. International cooperation and international capital flows will be critical to ensuring global progress in the development and deployment of needed new technologies.

India is facing the staggering challenge of moving a country of 1.2 billion, with 40 percent of the population living below the poverty line, into the 21st century with adequate supplies of electricity and transportation fuels to enable significant economic and social advancement. Limited domestic energy resources and increasing international competition for all resources exacerbate the difficulties in addressing India's challenges.

India's first energy priority is raising per capita energy consumption levels by increasing energy availability by 4-5 times over the next 20 years. At the same time combating climate change is a major concern for India. Therefore, India is committed to reducing GHG emissions. Expanding energy availability at reasonable costs will be a major challenge owing to limited domestic supplies of conventional sources like coal, oil, natural gas and large-scale hydro. Discussion reinforced concerns that conventional fossil fuels (coal, oil and natural gas) will remain the dominant sources of energy for many decades. India is growing increasingly dependent upon imports for all three of these sources, although recent discoveries of natural gas and the possibility of unconventional gas may relieve the growing demand for gas imports.

To meet energy demand by the middle of the 21st Century, India will need to rely heavily on renewables, especially solar power assuming costs can be substantially reduced. Simultaneously, India will face the need to maintain and expand access to reliable supplies of conventional fuels. This will require continuing international investments, but also cooperation and coordination with other consumer countries to ensure that markets remain orderly and transparent. Consuming and producing nations could both benefit from a clearer understanding of government programs and energy supply and demand outlooks.

India's Integrated Energy Plan's most optimistic projections for renewables states, "commercial renewable energy, even when it rises over 20 times it's current capacity will at best meet only about 5-7% of India's commercial energy demand by 2031-32 ". The discussions indicated both the aspirations and challenges of developing economically competitive renewable energy sources on a scale to meet a significant portion of demand for both electricity and transportation.

As in the United States and elsewhere, there is a movement to transform the sourcing, delivery and management of the electric power sector through the integration of information technology with the business and technical systems managing the generation, transmission, distribution and consumption of electric power. The successful implementation of "smart grid" technology will be instrumental in the cost effective and efficient deployment of renewable power.

"Smart grid" will also be one of the major supporting developments supporting the move towards increasing the efficiency of energy production and consumption. Other important developments include benchmarking, building, appliance and equipment standards and supporting policies to ensure new technology and technical knowledge is aggressively employed to lower the demand and costs of energy consumed. Similarly, the pace of energy demand grow is gradually being altered by life style changes affected by urban planning, changing transportation infrastructure and information systems. Again international cooperation can avoid the tendency to reinvent the wheel through the sharing of technologies, knowledge and the effectiveness of policy and implementation programs.

All major economies are striving to dramatically improve energy efficiencies to reduce growth of energy consumption and to lower the level of capital investments required. In many, including the US, energy efficiencies have been improved over the years from continuing efforts to raise profits through cost reductions and from the impact of higher energy prices on consumer behavior. The urgency to seek a step function change in efficiencies is related to a number of factors. These include:

- A concern over an anticipated tightness in long -term energy markets (recent softness related to the current global recession are viewed as short term phenomena),
- Huge capital costs associated with upgrading and expanding energy infrastructure,
- High levels of plant and equipment that need to be retired
- A perceived need to redesign electric power sectors to provide for renewables and to better meet customer requirements.
- Over reliance on unstable sources of energy supplies, particularly for oil and gas,
- Balance of payment concerns related to energy imports and long -term impacts on competitiveness,
- Concerns over the potential impact of climate change associate with rising greenhouse gases.

The potential for substantial energy savings have been well documented but often prove elusive to obtain. There are often debates between the use of market forces (read prices) and the ability to change behavior through regulatory changes. India has many inefficient plants and practices that will benefit from the introduction of new technology, and the rise in energy consumption projected should enable a more rapid adoption of energy efficiency technologies and processes. While the US faces challenges in replacing a large in -place energy structure, it is also seeking to accelerate the introduction of new technologies and processes. Both countries could learn much from each other's experiences and multiple efforts at the state and national level to introduce policies, programs, incentives, regulations and standards to alter energy efficiencies and consumption patterns.

Many initiatives being undertaken that will depend on technology developments and policies that would benefit from international cooperation and an opening of markets to both manufacturers and service companies with specialized knowledge and skills. There was a strong sentiment that protecting India's internal markets would lead to inefficiencies and a slower introduction of new technologies.

Recognizing the critical interdependency between the availability of electric power and economic/social progress, the government has established a goal of raising power generation capacity by 8-9 percent per annum over the next two decades to support an economic growth rate of over 8 percent per year that is viewed as necessary to significantly raise the wellbeing of the 400 million citizens living in poverty without electricity. This will require growing today's 156 gigawatts in capacity to over 800 gigawatts over the next twenty years. This will be extremely difficult to achieve.

Coal plants provide half of the current generating capacity and seventy-five percent of the power generated. In the eleventh five –year plan (2007- 2012), new coal plants will provide seventy-five percent of the additional capacity. The eventual utilization of 150 GWe of potential power from large hydro projects, 50 GWe of potential wind power, 45 GWe of small hydro and biomass, and 63 -73 GWe of nuclear by 2032 would be very aggressive, but would provide about 315 GWe of the over 800GWe goal. This would leave roughly 500 GWe to be provided by coal and solar. It was suggested that a very optimistic projection would envision a total coal capacity of between 250-300 GWe of coal by 2032, which would imply coal providing only between 31- 38 percent of total capacity. Complete success of the National Solar Mission, which is targeted to provide the largest source of renewable electricity, would provide 20 GWe by 2020. Solar would have to grow by over ten fold over the 2020-2032 period to close the gap.

Such growth is not inconceivable, but is highly improbable. Participants clearly noted that Solar will have to become competitive with conventional fuel (hopefully by 2022) and significant breakthroughs will be needed in the near term to reach that goal. Both the US and the EU are hoping to achieve such breakthroughs and may be willing and have the capacity to invest heavily in high initial start up costs on a small portion of their much larger electric power sectors to deploy the technology. India should consider further opening of its domestic solar industry to partnerships with US manufacturers and service companies to more rapidly expand their potential for substantial cost reduction breakthroughs. Given the level of US Federal support going into solar, government–to–government and public–private partnerships might also be considered.

While India pursues renewable technologies, they are planning to expand coal-fired power by a factor of 3-4 using more efficient plant designs. The report notes the considerable ongoing cooperation between the National Energy Technology Laboratory (NETL), usually under AID contracts, and the National Thermal Power Corporation who currently provides roughly 20 percent of India's electricity. Given the growing role of state owned utilities and their very rapid expansion of coal powered thermal plants, the existing programs undertaken by the NETL should be expanded and broaden to support the introduction of new high efficiency clean coal technologies. As noted during the dialogue, coal power will remain the backbone of India's electricity sector for many decades.

The impact of growing demands on energy and the availability of water was also raised during discussions. Large-scale use of water in fossil and non-fossil thermal power plants presents challenges that will require the introduction of new technologies to minimize water requirements. This has emerged as a major concern in the US as well as in other countries and should be the subject of major collaborative efforts, perhaps on an international level.

The above discussion, mainly involves India's internal ability to obtain the necessary resources and technologies to modify its domestic energy sectors. India also faces a number of challenges related to international markets and the availability of capital.

The US and India both have an incentive to improve the level of cooperation between the energy producing and consuming countries. India is increasing its dependence on offshore imports for conventional energy supplies. Even with an active and successful program of introducing renewables and new transportation fuels India will remain highly dependent upon international markets. This issue usually focuses on oil and gas but is increasingly become relevant to other fuels like coal and uranium. The US is unusually fortunate to have a relative abundance of resources (oil being a major exception), but international markets set world prices for all commodities. Hence, the US is also exposed to the need for ensuring relations between energy producers and consuming nations are based on clarity, understanding of intent and transparency of information.

India and the United States should both seek to establish a regular producer/consumer country dialogue and mechanisms for discussing energy outlooks and the expect impact on import and exports of energy supplies. This should be a multinational effort that includes the EU, China and all major importing economies as well as most exporters of energy supplies.

India should also enact legislation similar to the Extractive Industries Transparency Law recently included in the Dodd-Frank July 2010 bill designed to reduce corruption in countries producing and exporting energy and mineral resources.

India should be encouraged to expand strategic stocks of petroleum crude and products, and the United States should work to enable India to become a formal member of the IEA Strategic Stockpile program. It was noted that strategic oil stocks cannot effectively replace market mechanisms, but they can mitigate short-term supply disruptions that remain a cause of unexpected price volatility.

Financing for long-term capital intensive investments may prove problematic. India's Integrated Energy Strategy lays out a holistic program that is likely to require substantial financing from the international community as well from the Government of India and private industry within India. To the extent the government must fund major investments from government budgets, like the expansion of nuclear, Solar Mission deployment and investments in transmission and distribution for rural areas, there will be limited ability to allocate funds within the budget to competing priorities. Fortunately, India has a robust private financial sector from which well defined smaller energy projects can be financed. However, **to the extent mega-projects are not funded by the government, long term financing is likely to be difficult to obtain without major changes in global capital markets. This is worldwide problem that is impacting the pace of energy investment in the United States and Europe. Without international market support for long-term financing of capital-intensive projects it may be impossible to meet the planning goals of India or the rebuilding of the US energy sector on a timely basis.**

Recommendations

The following recommendations involving India–US cooperation to create a sustainable energy future that meets India's aspirations follow from the challenges and concerns that rose during the dialogue:

International multilateral

- Strengthen efforts to increase formal participation in IEA by major economies.
- Undertake discussion on potential benefits/challenges of establishing periodic producer/consumer dialogues on both pricing and the long-term availability of supplies and consuming country demand. Consider format and data to be regularly required.
- Jointly support and encourage widespread adoption of national legislation to support the Extractive Industries Transparency Initiative.
- Support international efforts to reduce energy subsidies, in both producing and consuming countries, to enable market forces and international prices to allocate energy supplies and reduce inefficient consumption.
- Request the recently formed International Renewable Energy Agency (IRENA) to identify renewable technologies that would particularly benefit from the multinational development of technologies and standards.[61] Design and implement specific programs to foster the more rapid development of cost competitive renewable technologies.

Simplify Structure of US-India Agreements

Establish an Umbrella Memorandum of Understanding between India' Ministry of Power (MOP) and the U.S. Department of Energy (DOE) to coordinate activities.

Indo-U.S. Clean Research and Deployment Initiative

- Maintain momentum by funding and organizing specific projects and programs in the identified areas of:
    - o Energy efficiency
    - o Smart grids
    - o Second generation bio-fuels
    - o Clean coal technologies
    - o Sustainable transportation
    - o Wind energy, and
    - o Micro-hydro.

Coal Technologies

- Continue and expand training and capacity building with state utilities to improve energy efficiencies in older thermal power plants under the Partners in Excellence Program.
- Develop data on geological potential for CCS.

- Develop data on geological potential for coal bed methane.
- Continue and expand cooperation on designing and operating super critical and ultra super critical plants utilizing Indian coal.
- R&D support is needed for high temperature materials and plant designs.
- Collaborate on advanced R&D on material and processes to further improve efficiencies to 45-50 % using Indian coal.
- Collaborate on the commercialization and dissemination of IGCC technology.
- Establish and support of a Clean Coal Laboratory in India to provide technical support for setting up prototypes and pilot plants for high ash Indian coal.
- Joint collaboration on development of Oxy-fuel combustion, and hybrid systems based on fuel cells, gas turbines and gasification to boost efficiencies into 55-60% range.
- Expand level of support and participation in multi-lateral groups such as the Asia Pacific Partnership, the Carbon Sequestration Leadership Forum (CSFL) and the Major Economies Forum (MEF) on Energy and Climate Change.

Natural Gas and LNG

- Undertake joint research on Gas Hydrates.
- Undertake more detailed assessment of unconventional gas potential, shale gas and coal bed methane.
- Enable private companies (US and Indian) to own and operate Shale Gas fields.
- Establish regulatory framework for exploring for and operating shale gas fields.
- Consider feasibility of establishing international sharing mechanisms for LNG in event of major disruptions.
- Support with others (like the EU, Russia, China, and key middle east producers) the commissioning of several studies on global gas developments, including analysis of potential pricing. Use independent institutions to supplement IEA and industry supported studies.

Transportation Fuels

- Expand joint research and demonstration projects on developing cellulosic ethanol from indigenous non-food crops and waste.
- Establish joint research on utilizing algae for commercial scale production of Biofuels utilizing private and public/private partnerships.
- Collaborative R&D on vehicle fuel cells and potential for hydrogen powered vehicles.

Nuclear Power [62]

- Finalize Safeguards Agreement with IAEA.
- Organize an international effort based on experience in the US, Europe, Japan and Russia with input from the IAEA and WANO on the regulatory, certification, inspection, and operating processes needed to ensure the long-term viability of expanding nuclear power. Output should provide a road map to steps required to build in country nuclear capacity.
- Establish educational and training opportunities to support human resource capacity building.
- Provide technical collaboration on the best technology for power plant design equipment manufacture, plant construction, commissioning, operations and management, waste management and decommissioning of light water reactors (LWRs).
- Expand and intensify international collaboration in the design of breeder and reprocessing technologies.
- Undertake joint assessment of best approaches and information needed to address public concerns.
- While not discussed, should consider the potential application of small -scale modular nuclear generation for distributed power.
- Open nuclear support service industries to international vendors.
- Jointly commission study on the longer- term availability of uranium supplies given the potential

expansion of nuclear power. Study should expand perspectives in 2010 IEA assessment.

Renewables

- Jointly develop better data and information on potential, cost and current status of R&D, and deployment of renewables.
- Joint participation in assessment of using mini and large hydro as storage for offsetting the intermittent output of renewables. US currently studying subject.
- Jointly assess fuel cell technologies and potential to be deployed with renewable generation.
- While focusing on solar, collaborate on geothermal, ocean and wave power.
- **Solar Power**
  - o Joint assessment of solar potential using refined technologies.
  - o Establish private and public/private partnerships to do R&D and to participate in newly established demonstration park in US and develop similar facilities in India.
  - o Enable US and Indian companies to participate in the manufacturing, deployment and servicing of solar installations and generating facilities, both PV and Concentrated thermal, in both the US and India.
- Wind Power
  - o Exchange of information on performance under differing wind conditions.
  - o Build data base and knowledge on reliability and maintenance requirements.
  - o Assess potential for offshore wind.

Energy Efficiency

- Establish database of Indian and US company expertise (that could be expanded to include others).
- Regular exchange of benchmarking data.
- Encourage and enable US private service companies specializing in energy efficiency to partner with ESCO's in India.
- Establish regular interaction between India's Bureau of Energy Efficiency and the US DOE's office of Energy Efficiency and Renewables that focus on assessing the effectiveness of programs designed to encourage energy efficiency at the state and national level. Specifically, assess conditions affecting the effectiveness of mandatory versus voluntary programs relying on market prices.
- Establish joint research on lowering the cost of LED lighting.
- Establish data base on the effectiveness of building material and designs in lowering energy consumption.

Smart Grids

- Establish linkage between Indian and US smart grid industry alliances.
- India should formally establish interface between India's Power Finance Corporation (who is responsible for implementing smart grid programs throughout India) and the architecture and standard setting activities being lead by the US National Institute of Standards and Technology (NIST).
- India should be given access to the one -stop Internet clearinghouse being maintained by Virginia Tech.
- India and the US should establish consistent architecture, standards and processes for establishing Cybersecurity resolving data privacy issues.
- Undertake joint pilot project in India to use mini smart grids in rural areas (Would also be applicable for US rural).
- Establish US-India working group to review and share knowledge on issues surrounding the creation of a national transmission and distribution grid that has to accommodate renewables. [63]

Water

- Joint research and development of technology and processes to reduce water consumption associated with all forms of energy production and mining operations.
- Jointly undertake assessment of impact of differing energy technologies on water consumption.

Investment Barriers

- Remove limitations on foreign investment in new technologies and service companies with specialized expertise.
- Strengthen Intellectual Property Protection for Indian and US products and processes.
- Consider developing a global convention on liability legislation to systematically address a number of emerging concerns on oil and gas exploration, production and transport, Carbon Capture and Storage, Nuclear Power generation and waste storage.

Financing

- Establish international financial discussions focused on recreating sufficient long -term financing to support major infrastructure projects.
- Expand use of partial risk guarantees from development banks (Currently available from World Bank, but underutilized).
- Convene international banking community to develop and expand availability of micro- financing for renewable power and rural development.

ATLANTIC COUNCIL

US – INDIA DIALOGUE ON SUSTAINABLE ENERGY SECURITY COOPERATION ON MEETING THE CHALLENGES OF ENERGY SECURITY, ENVIRONMENTAL RESPONSIBILITY AND ECONOMIC PROSPERITY

A Joint Project of

The Atlantic Council of the United States, the U.S. – India Business Council and

The Confederation of Indian Industry

March 16- 18, 2010
Hotel Taj Mahal, Mansingh Road, New Delhi, India

Workshop Agenda

WEDNESDAY, MARCH 17, 2010

Welcome Remarks: CII / ACUS

Opening Remarks by the Co-Chairs:

- U.S. Co-Chair: Gen. Richard Lawson, Vice-Chairman Atlantic Council of the United States
- India Co-Chair: Mr Suresh P Prabhu, Chairman, Centre for Energy Environment and Water (CEEW) and Former Union Minister for Environment and Forests

Session I: Strategic issues related to achieving Sustainable Energy Security

Presenters in Session I to address:

- Enhancing oil security thru diversification, sharing of stocks, the Role of Strategic Petroleum Reserve
- Improving producer/consumer county coordination on production and supply of oil. Is there a need for transparency on policies, physical supply availability and consumer country demand?
- Transnational gas pipelines and oil / gas equity abroad
- Energy mix in the wake of climate change imperatives

Indian presentation: B K Chaturvedi, Member-Energy, Planning Commission

US presentation: Douglas C. Hengel, Deputy Assistant Secretary for Energy, Sanctions and Commodities, U.S. Department of State

Moderator: Mikkal E. Herberg, BP Foundation Senior Research Fellow for International Energy

Pacific Council on International Policy

Session II: Plans to achieve Sustainable Energy Security

- Discuss Federal and regional policies and initiatives
- Where there is broad consensus and what is under debate?

• Vision of possible energy mix 2010 to 2050

• Potential impact on GHG emissions

• Emission reduction strategy and key technologies and R&D required

• Pricing policies, fiscal and regulatory actions to support energy efficiency/conservation and

renewables

• What are the major challenges?

U.S. presentation on emerging energy policy and climate change initiatives

Office of Policy and International Affairs, U.S. Department of Energy – to be presented by Mark Ginsberg, Energy Efficiency and Renewable Energy Board of Directors, U.S. Department of Energy

• Discuss plans to implement national policies and state initiatives?

• Vision of possible energy mix 2010 to 2050

• Potential impact on GHG emissions

• Policies to encourage energy efficiency

• Policies to provide affordable electric power to rural communities

• Key technologies and R&D required

• Major challenges to implementing plans, including supply limitations?

India presentation on energy activities in National Action Plan on Climate Change

Nitin Desai, Member, Prime Minister's Council on Climate Change

• What are further opportunities for U.S.-India cooperation? Are existing cooperative efforts moving fast enough to achieve policy goals? What can be done to improve and/or expand cooperation?

• Are there technical, economic or political obstacles to increasing U.S. –India cooperation?

• How can we cooperate to eliminate or reduce national barriers to sharing energy and environmental technologies, including tariff and non-tariff barriers, and intellectual property rights issues?

Moderator: Kirit Parikh, Chairman, Integrated Research and Action for Development (IRADe)

Lunch Keynote Speaker: Mr Hari Shankar Brahma, Secretary, Ministry of Power, Government of India

Session III: Role of Clean Coal Technologies

• Current activities of U.S./India working group on coal technologies

• Opportunities to improve the efficiency of coal consumption through coal washing, improved power plant operations & maintenance and use in industries, such as cement and steel

• Coal Gasification and Coal bed methane

• Utilization of advanced high-efficiency power plants (Super Critical and Ultra Super Critical), and pace of replacing old less efficient power plants.

• How can we expand and accelerate US/India cooperation on capacity building, commercialization and dissemination of Clean Coal Technologies, including liquids from coal, coal/biomass conversion and prospects for Carbon Capture and Storage?

•Challenges and issues associated with:

- Pace and magnitude of expansion in thermal power
- Need to employ more efficient plants with lower emissions

US Presentation – Scott Smouse, Senior International Manager, National Energy Technology Laboratory

Industry Perspective – D K Jain, Executive Director-Engineering, NTPC Ltd

Moderator: Pamela Tomski, Managing Partner, EnTech Strategies, LLC

Session IV: Civil Nuclear Energy: Potential for New Nuclear Technologies.

- Views on U.S.-India civil nuclear agreement
- Final steps: liability legislation and Part 810 licensing assurances
- Prospects for growth in Indian nuclear power sector
- Opportunities for further U.S. – India cooperation
- Opportunities for U.S. firms as suppliers and contractors
- Outlook for nuclear power and can we expand and accelerate cooperation on nuclear power?

US presentation– Blair Hall, Counselor for Economic Affairs and Environment, Science and Technology, Embassy of the United States

- Current activities of US/India working group on Civil Nuclear
- Major challenges associated with expanding nuclear power
- Programs for establishing uniform standards and regulations for permitting and operations
- Potential bottlenecks associated with nuclear manufacturing supply chain
- Programs for training and skilling nuclear contractors, operators and management
- Assessment of storage, safety and waste handling issues

Indian Presentation – R B Grover, Distinguished Scientist and Director, Strategic Planning Group, Department of Atomic Energy

- Challenges posed by rapid expansion of nuclear power
- Identification of areas where greater US-India cooperation could facilitate nuclear program

Industry Perspectives - M V Kotwal, Senior Executive Vice President and Member of the Board, Larsen and Toubro Ltd

Moderator: Brahma Chellaney, Professor of Strategic Studies at Centre for Policy Research

Session V: New Technologies and Renewable Energy for Electric Power

Challenges associated with realizing the plans for:

- National Solar Mission envisaging ambitious plan for both Solar power photovoltaic and concentrated thermal solar
- Small Hydro and Wind power
- Enabling fiscal, regulatory and financial support

India presentation–Bibek Bandopadhyay, Adviser, Ministry of New and Renewable Energy

- Current activities of U.S./India working groups on New Technology & Renewables
- Need for fiscal, regulatory and enforcement support to realize potential
- U.S. outlook on economics and potential for renewable technologies
- Specifically provide update on new technologies such as ocean waves, tidal and geothermal
- Major challenges to expansion of renewable power in the U.S.
- Need for base load power
- Opportunities for cooperation on the development and commercialization of renewable technologies
- Are there technical, economic and /or political obstacles?

US Presentation - Mark Ginsberg, Energy Efficiency and Renewable Energy Board of Directors, U.S. Department of Energy

Industry Presentation: Aparna Doshi, COO, Astonfield Renewable Resources

Industry Presentation: Kishore Jayaraman, President & CEO, GE Energy

- Impact of renewables and distributed power on transmission and distribution grid
- Potential for smart grid to increase efficiencies, reduce costs and improve service
- Basic requirements for smart grid technology

Moderator: V Subramanian, Secretary General, Indian Wind Energy Association and Former Secretary- MNRE

Dinner:

Chief Guest: Dr Montek Singh Ahluwalia, Deputy Chairman, Planning Commission

Special Guest: Mr Deepak Gupta, Secretary, Ministry of New and Renewable Energy

THURSDAY, MARCH 18, 2010

Session VI: Increasing Oil Security by Transforming the Transportation Sector in a Carbon-ConstrainedWorld with Tightening Supplies

- Alternative transportation fuels:
    - o Role for CNG and LPG
    - o Biofuels – ethanol from food, cellulosic ethanol, bio diesel -algae, seed crops
- Creating sustainable transportation systems
    - o Vehicle technologies: Diesel vs. Gasoline, Hybrids, Plug in Hybrids and Electric vehicles
    - o Potential for moving transportation onto the Electric Grid
    - o Changing urban transportation modes

US presentation – Michael P. Walsh, International Consultant and Chairman, Board of Directors, International Council on Clean Transportation - presentation delivered by John R Lyman, Director, Energy and Environment Program, Atlantic Council of the United States

- Alternative transportation fuels:
    - o Role for CNG and LPG
    - o Biofuels – ethanol from food, cellulosic ethanol, bio diesel -algae, seed crops
- Creating sustainable transportation systems
- Vehicle technologies
    - o Diesel vs. Gasoline
    - o Hybrids
    - o Plug in Hybrids
    - o Electric vehicles
- Potential for moving transportation onto the Electric Grid
- Changing urban transportation modes

Indian Presentation –K K Gandhi, Executive Director, Society of Indian Automobile Manufacturers (SIAM)

- Opportunities and Challenges
- Are there technical, economic and /or political obstacles?
- Potential for US-Indian Cooperation

Industry Presentation- Mathew Abraham, Co Chairman, SIAM Emission & Conservation Group and General Manager, Mahindra and Mahindra

Moderator – Kathryn Clay, Director of Research, Alliance of Automobile Manufacturers

Session VII: Energy Efficiency and Distribution Reform

- Impact of renewables and distributed power on transmission and distribution grid
- Energy efficiency and effectiveness
- Policies to provide affordable electric power to rural communities

India Presentation: R P Singh, Vice Chairman and Managing Director, Jindal Power

- Challenges to improving grid performance
- Distribution reform
- Challenges to providing affordable reliable power to rural communities
- Potential to employ smart grid technologies
- Programs to improve availability and reliability

Industry Presentation–Sudarshan Kumar Saini, Vice President-Commercial, North Delhi Power Ltd

Moderator: V Raghuraman, Chief Adviser, Jaguar Overseas

Session VIII: Opportunities for expanding and enhancing US-India Cooperation

Moderator: Leena Srivastava, Executive Director, TERI

Closing Comments

US Co-Chair: Gen. Richard Lawson, Atlantic Council of the United States

India Co-Chair: Suresh P Prabhu

APPENDIX I

INDIA AND THE UNITED STATES: PARTNERSHIP FOR A BETTER WORLD

Joint Statement between Prime Minister Dr. Singh and President Obama

Prime Minister Dr. Manmohan Singh and President Barack Obama today reaffirmed the global strategic partnership between India and the United States, and launched a new phase in this partnership. Commending the deepening bilateral cooperation between the world's two largest democracies across a broad spectrum of human endeavors, the two leaders recognized that the common ideals and complementary strengths of India and the United States today provide a foundation for addressing the global challenges of the 21st century.

The two leaders noted that the shared values cherished by their peoples and espoused by their founders – democracy, pluralism, tolerance, openness, and respect for fundamental freedoms and human rights – are acquiring an increasingly greater prominence in building a more peaceful, prosperous, inclusive, secure and sustainable world. These values are exemplified by the vibrant linkages between their peoples, which are a unique asset for both countries, and are reflected in the role played by the Indian-American community.

The two leaders resolved to harness these shared strengths and to expand the U.S.-India global partnership for the benefit of their countries, for peace, stability and prosperity in Asia, and for the betterment of the world. To this end, they committed to build upon the India-U.S. Strategic Dialogue announced in July 2009. President Obama stated that the United States looks forward to a stable and prosperous India playing an increasingly important role in world affairs.

ADVANCING GLOBAL SECURITY AND COUNTERING TERRORISM

Prime Minister Singh and President Obama recognized that the India-U.S. partnership is indispensable for global peace and security. In this context, the interests of both countries are best advanced through the values mirrored in their societies.

They acknowledged the common threat that international terrorism poses to regional and global security. They condemned terrorism in all its forms and manifestations and declared that there could be no justification for terrorism anywhere.

On the eve of its first anniversary, President Obama reiterated the United States's condemnation of the terrorist attack in Mumbai in November 2008. The two leaders underscored the absolute imperative to bring to justice the perpetrators of this terrorist attack.

They expressed their grave concern about the threat posed by terrorism and violent extremists emanating from India's neighborhood, whose impact is felt beyond the region. The two leaders agreed that resolute and credible steps must be taken to eliminate safe havens and sanctuaries that provide shelter to terrorists and their activities. These undermine security and stability in the region and around the world.

They vowed to redouble their efforts to deal effectively with terrorism, while protecting their countries' common ideals and shared values and committed themselves to strengthening global consensus and legal regimes against terrorism. They decided on a Counterterrorism Cooperation Initiative to expand collaboration on counterterrorism, information sharing, and capacity building.

The two leaders reiterated their shared interest in the stability, development and independence of Afghanistan and in the defeat of terrorist safe havens in Pakistan and Afghanistan. President Obama appreciated India's role in reconstruction and rebuilding efforts in Afghanistan. The two leaders agreed to enhance their respective efforts in this direction.

The two leaders committed to continue pursuing mutually beneficial defense cooperation through the existing security dialogue, service-level exchanges, defense exercises and trade and technology transfer and collaboration. They recognized the scope for cooperation in the areas of non-traditional threats to security, peacekeeping, humanitarian and disaster relief, and maritime security and protecting sea lanes of communication. They agreed to expedite necessary arrangements to facilitate these activities.

The two leaders agreed that strengthening high technology trade between their countries is in the spirit of their strategic dialogue and partnership. They reiterated their shared commitment to technology security and that it is in their mutual interest to invigorate this area of their partnership.

Prime Minister Singh and President Obama reaffirmed their shared vision of a world free of nuclear weapons and pledged to work together, as leaders of responsible states with advanced nuclear technology, for global non-proliferation, and universal, non-discriminatory and complete nuclear disarmament. Part of that vision is working together to ensure that all nations live up to their international obligations. India reaffirmed its unilateral and voluntary moratorium on nuclear explosive testing. The United States reaffirmed its testing moratorium and its commitment to ratify the Comprehensive Test Ban Treaty and bring it into force at an early date. Both leaders agreed to consult each other regularly and seek the early start of negotiations on a multilateral, non-discriminatory and internationally verifiable Fissile Material Cutoff Treaty at the Conference on Disarmament. They noted that nuclear terrorism, and clandestine networks are a matter of grave concern. Prime Minister Singh and President Obama look forward to the April 2010 Nuclear Security Summit and working together with all participating states for the success of the Summit.

ENSURING SUSTAINABLE GLOBAL DEVELOPMENT AND A CLEAN ENERGY FUTURE

Recognizing that energy security, food security, climate change are interlinked, and that eliminating poverty and ensuring sustainable development and a clean energy future are among the foremost global objectives, the two leaders agreed to enter into a Green Partnership to address these global challenges.

They two Leaders reaffirmed their intention to promote the full, effective and sustained implementation of the United Nations Framework Convention on Climate Change (UNFCCC) in accordance with the Bali Action Plan. Recognizing their special role in promoting a successful and substantive outcome at the UNFCCC 15th Conference of Parties at Copenhagen in December, 2009, they reaffirmed their intention to work together bilaterally and with all other countries for an agreed outcome at that meeting.

The two leaders also affirmed that the Copenhagen outcome must be comprehensive and cover mitigation, adaptation, finance and technology, and in accordance with the principle of common but differentiated responsibilities and respective capabilities, it should reflect emission reduction targets of developed countries and nationally appropriate mitigation actions of developing countries. There should be full transparency through appropriate processes as to the implementation of aforesaid mitigation actions. The outcome should further reflect the need for substantially scaled-up financial resources to support mitigation and adaptation in developing countries, in particular, for the poorest and most vulnerable. It should also include measures for promoting technology development, dissemination and transfer and capacity building, including consideration of a center or a network of centers to support and stimulate climate innovation. India and the United States, consistent with their national circumstances, resolved to take significant national mitigation actions that will strengthen the world's ability to combat climate change. They resolved to stand by these commitments.

Recognizing the need to create the clean energy economy of the 21st century, Prime Minister Singh and President Obama agreed to launch a Clean Energy and Climate Change Initiative. The goal of the Initiative would be to improve the lives of the people of both countries by developing and improving access to technologies that make our energy cleaner, affordable and more efficient. The Initiative will include cooperation in wind and solar energy, second generation bio-fuels, unconventional gas, energy efficiency, and clean coal technologies including carbon capture and storage. The success of this Initiative is expected to enhance the ability of India and the United States to provide new economic opportunities for their people and create new clean energy jobs.

The two leaders intend to take practical steps to promote global food security, including by advancing the L'Aquila Food Security Initiative. They looked forward to increasing India-U.S. agricultural cooperation with the purpose of promoting agricultural research, human resources capacity building, natural resource management, agri-business and food processing, and collaborative research for increasing food productivity. This cooperation would contribute to joint development of technology that would improve weather forecasting, including predicting monsoons, and technology that would contribute to food productivity and food security efforts in India.

They agreed to collaborate in the application of their space technology and related scientific capabilities in outer space and for development purposes, including in the field of agriculture.

The two leaders reiterated their intention to realize the full potential of the India-U.S. Agreement for Cooperation concerning the Peaceful Uses of Nuclear Energy through the implementation of its provisions. They agreed to expedite U.S. firms' participation in the implementation of this agreement.

STIMULATING GLOBAL ECONOMIC REVIVAL

Prime Minister Singh and President Obama noted the new opportunities offered by their economies and their respective strengths, and their potential for future growth to catalyze global economic growth, and pledged to create conditions that would facilitate their continued expansion.

The leaders also noted that the United States is currently the largest trading partner of India in goods and services. The leaders reiterated their pledge to bolster and deepen cooperation on economic, trade and agricultural issues, including working bilaterally and with multilateral trade organizations to foster increased trade. Both leaders welcomed the potential for further expanding trade and investment between their countries, including in sectors such as infrastructure, information and communication technologies, healthcare services, education services, energy and environmentally friendly technologies.

As members of the G 20, they agreed to advance the G 20 understandings including with regard to energy security and resisting protectionism in all its forms. The two leaders agreed to facilitate greater movement of professionals, investors and business travelers, students, and exchange visitors between our two countries to enhance their economic and technological partnership.

They committed to strengthen and reform the global economic and financial architecture in the G-20, World Bank and the IMF. They resolved to seek an ambitious and balanced outcome of the Doha Round, consistent with its mandate and reaffirmed their commitment to an open, fair, equitable, transparent and rule-based multilateral trading system.

The two leaders announced their intention to develop a Framework for Cooperation on Trade and Investment. This Framework is expected to foster an environment conducive to technological innovation and collaboration, promote inclusive growth and job creation, and support opportunities for increased trade and investment - including for small and medium-sized enterprises. They agreed to launch the U.S.-India Financial and Economic Partnership to strengthen engagement on economic, financial, and investment-related issues.

The two leaders welcomed the progress achieved in the discussions on a Bilateral Investment Treaty and pledged to take further initiatives that would contribute to creating a more conducive environment for investment flows.

They recognized the contribution of the business and industrial sectors of both countries in this regard and called upon the India-U.S. CEOs Forum to identify new directions in the India-U.S. economic relationship.

EDUCATING AND EMPOWERING FUTURE GENERATIONS

Recognizing the cultural emphasis on education in both countries, Prime Minister Singh and President Obama emphasized that education holds the key to the advancement of their societies, and to a more prosperous and stable world.

They agreed that access to and development of technology was a cross-cutting requirement to meet the challenges that their two countries face. They acknowledged the fruitful collaboration between the two countries in the fields of education, research and science and technology, which has contributed to their emergence as knowledge societies.

Taking advantage of that strength, President Obama and Prime Minister Singh launched the Obama-Singh 21st Century Knowledge Initiative with funding from both sides to increase university linkages and junior faculty development exchanges between U.S. and Indian universities, including greater emphasis on community colleges.

They agreed to substantially expand the Fulbright-Nehru program to provide more student and scholar exchange grants in priority fields such as science, technology and agriculture. The two leaders reaffirmed the importance of expanding cooperation in higher education and research, and according priority to cooperation in the area of skill development.

They also expressed their support for the India-U.S. Binational Science and Technology Commission and the Endowment, which is expected to give a fresh impetus to collaboration in the cutting edge areas of scientific research, technology and development. The leaders affirmed the importance of women's empowerment to advancing global prosperity and stability, and welcomed the establishment of a Women's Empowerment Dialogue to promote women's participation and equality in all spheres. They emphasized that women's empowerment is a cross-cutting goal that should be pursued across the full scope of U.S.-India Strategic Dialogue initiatives.

PROTECTING THE HEALTH OF OUR PEOPLE

Prime Minister Singh and President Obama welcomed the strong collaboration between India and the United States in the area of public health. They agreed to build on existing strong ties across academia and scientific communities by advancing public health and biomedical research collaborations between the United States and India. The two countries plan to establish a Regional Global Disease Detection Center in India and to build a partnership with the U.S. Centers for Disease Control and Prevention . The leaders also pledged to enhance collaboration in controlling diseases such as polio, and discovering new and affordable technologies and treatments for the benefit of their peoples and for those of other countries who seek their assistance.

TOWARDS MORE EFFECTIVE GLOBAL COOPERATION

Prime Minister Singh and President Obama recognized that the India-U.S. relationship is important for managing the challenges the world will face in the 21st century.

The two leaders underscored the compelling need to put in place global institutions which are both inclusive and effective to meet present and future challenges. They welcomed the emergence of the G-20 as a premier forum to deal with international economic issues. The two leaders recognized the scope for their countries to increase cooperation in peacekeeping, development and the promotion of essential human freedoms. They committed themselves to achieving genuine reform of the United Nations including in its Security Council in a manner that reflects the contemporary realities of the 21st century and thereby enhances its ability to carry out its mandate as a representative, credible and effective forum for meeting the challenges of the new century.

Prime Minister Singh thanked President Obama and the people of the United States of America for their generous hospitality and warm welcome. President Obama looks forward to visiting India with his family in the near future.

List of Abbreviations

APP	Asian Pacific partnership
CCS	Carbon Capture and Sequestration
CFL	Compact Florescent Bulbs
CII	Confederation of Indian Industry
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
CSC	Convention on Supplementary Compensation
CSLF	Carbon Sequestration Leadership Forum
DOE	Department of Energy
GDP	Gross Domestic Product
GWe	Giga-Watt of Electricity
IAEA	International Atomic Energy Agency
ICLEI	International Council for Local Environmental Initiatives
IGCC	Integrated Gasification Combined Cycle
ISEA	International Safety Equipment Association
Kcal	Kilocalorie
KG	Kilogram
kW	Kilowatt
kWh	Kilo-Watt hour
L&T	Larson and Tubro
LNG	Liquefied Natural Gas
LWR	Light Water Reactor
MEF	Major Economies Forum
MoP	Ministry of Power
MOU	Memorandum of Understanding
MW	Mega-Watts
MWe	Mega-Watts of Electricity
NETL	National Energy Technology Laboratory
NPCL	Nuclear Power Corporation
NSG	Nuclear Suppliers Group
NTPC	National Thermal Power Corporation
PHWR	Pressurized Heavy Water Reactors
USAID	United States Agency for International Development
USC	Ultra Super Critical
R&D	Research and Development

Endnotes

1. Examples of current multilateral cooperative efforts include ITER for Fusion Power, the Generation IV initiative for advanced fission power, the Carbon Sequestration Council and the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE).

2. As noted by Wikipedia, IRENA currently provides practical advice and support for industrialized and developing countries by helping them to improve their regulatory framework and build capacity. The agency facilitates access to all relevant information including reliable data on the potential of renewable energy, best practices, effective financial mechanisms and state-of-the art technical expertise.

3. A Civil Liability for Nuclear Damage Bill pending in the Indian Parliament at the end of August includes provisions that could expose both domestic and foreign equipment and fuel suppliers to undefined liability for 60 plus years. Without modifications before final approval by the President and the Upper House of Parliament, the growth of India's civil nuclear program is likely to be severely curtailed.

4. Note: The location of renewables and base load coal and nuclear power can lead to very different transmission configurations.

5. Track-II, or unofficial, diplomacy can be a valuable adjunct to the formal government –to- government negotiations.

6. The Central Intelligence Agency. "The World Factbook: India." CIA website, https://www.cia.gov/library/publications/the-world-factbook/geos/in.html.

7. Chaturvedi, Shri B.K. "Strategic Issues on Sustainable Energy Security: Indian Perspective." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

8. The Economic Times, May 21, 2010.

9. Integrated Energy Policy, India. Page no.ix.

10. Chaturvedi, Shri B.K. "Strategic Issues on Sustainable Energy Security: Indian Perspective." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

11. Morse , Richard K. and He, Gang. "The World's Greatest Coal Arbitrage: China's Coal Import Behavior and Implications for Global Coal Market." Freeman Spogli Institute for International Studies at Stanford University, August 2010.

12. Jain, D.K. "Role of Clean Coal Technologies." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

13. Brahma, Hari Shankar. Keynote Address. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

14. Ibid.

15. Ibid.

16. Desai, Nitin. "India Presentation on Energy Activities in National Action Plan on Climate Change." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18.

17. Currently, India has no super critical plants in operation. As of 2009, Japan (at 70%) had installed the greatest percentage of supercritical plants, followed by the United States (30%), China (12%), and the EU (10 %), according to Platts, UDI, March 2009, and IEA, 2009.

18. For this development, roadmaps are also available on the NETL websites.

19. Current data understates achievement as state utilities have not reported avoidance since 2002. Smouse, Scott. "Role of Clean Coal Technologies." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

20. Smouse, Scott. "Role of Clean Coal Technologies." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

21. World Nuclear Association. "Nuclear Power in India." Updated June 2010. http://www.world-nuclear.org/info/inf53.html.

22. The target since about 2004 has been for nuclear power to provide 20 GWe by 2020, but in 2007 the Prime Minister referred to this as "modest" and capable of being "doubled with the opening up of international cooperation." However, it is evident that even the 20 GWe target will require substantial uranium imports. Late in 2008 NPCIL projected 22 GWe on line by 2015, and the government was talking about having 50 GWe of nuclear power operating by 2050. Then in June 2009 NPCIL said it aimed for 63 GWe nuclear by 2032, including 40 GWe of PWR capacity and 7 GWe of new PHWR capacity, all fuelled by imported uranium. The Atomic Energy Commission however envisages some 500 GWe nuclear on line by 2060, and has since speculated that the amount might be higher still: 600-700 GWe by 2050, providing half of all electricity.

23. Pierson, Natalie. "India risk nuclear isolation with break from Chernobyl Accord." Bloomberg. August 25,2010.

24. Grover, R.B. "Role of Nuclear Power in meeting the challenges of energy security in India." Conference Presentation US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

25. A US-China dialogue on Nuclear Cooperation in March 2009 also identified a long term concern over the availability of uranium supplies that would accompany a dramatic expansion of global nuclear power. Lyons, Blythe J. "United States-China Cooperation on Nuclear Power: An Opportunity for Fostering Sustainable Energy Security," Figure 5 and pages 17-18, Atlantic Council, http://www.acus.org/files/publication_pdfs/65/AtlanticCouncil-USChinaNuclearPower.pdf.

26. Grover, R.B. "Role of Nuclear Power in meeting the challenges of energy security in India." Conference Presentation US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

27. Grover, R.B. "Role of Nuclear Power in meeting the challenges of energy security in India." Conference Presentation US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

28. Jagannathan, Venkatachari. "India's new Fast-breeder on track, nuclear power from September next." Indo-Asian News Service, http://www.hindustantimes.com/India-s-new-fast-breeder-on-track-nuclear-power-from-September-next/Article1-542155.aspx.

29. Grover, R.B. "Role of Nuclear Power in meeting the challenges of energy security in India." Conference Presentation US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

30. Lyons, Blythe, Lyman, John and Carstei, Mihaela. "US-China Cooperation on Nuclear Power: An Opportunity for Fostering Sustainable Energy Security." The Atlantic Council of the United States, July 2009.

31. Grover, R.B. Discussion at Conference. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

32. World Nuclear Association. "Nuclear Power in India." Updated June 2010. http://www.world-nuclear.org/info/inf53.html.

33. World Nuclear Association. "Nuclear Power in India." Updated June 2010. http://www.world-nuclear.org/info/inf53.html.

34. Bhartiya Navhikiya Vidyat Nigam Ltd. A Government of India Enterprise. http://www.bhavini.nic.in/main.asp.

35. Prime Minister Manmohan Singh quote cited in Bandyopadhyay, Bibek. "Solar Energy – Way Forward." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

36. The Economic Times, January 19, 2010.

37. The Hindu Business Line. "India, Japan to jointly develop solar city." January 7, 2010. http://www.thehindubusinessline.com/2010/01/07/stories/2010010752111800.htm.

38. Singh, R.P. "Harnessing Renewable Energy in Indian Power Sector." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010.

39. Doshi, Aparna. "Unleashing the Potential of Solar Energy in India – A Private Developer's Perspective." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

40. Ginsberg, Mark. "New Technologies and Renewable Energy for Electric Power." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

41. Singh, R.P. "Harnessing Renewable Energy in Indian Power Sector." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010.

42. A fuller description of the benefits and challenges of implementing smart grid technology is provide by US-EU Cooperation on Smart grids available at http://www.acus.org/publication/us-eu-smart-grid-deployment.

43. Lyman, John, Zachos, Lee and Carstei, Mihaela. "US-EU Cooperation Towards Smart Grid Deployment." The Atlantic Council of the United States, May 2010.

44. Ginsberg, Mark. "New Technologies and Renewable Energy for Electric Power." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

45. Ibid.

46. The Gazette of India. "Rural Electrification Policy." Resolution No.44/26/05-RE (Vol-II), August, 23, 2006.

47. In January The Energy and Resource Institute (TERI) suggested incentivizing energy efficiency in industry through the provision of up front capital. Reported by Business Daily from the HINDU group on January 22,2010.

48. The Economic Times. "Power-saving drive may earn stars for realty." February 3,2010. http://economictimes.indiatimes.com/markets/real-estate/news-/Power-saving-drive-may-earn-stars-for-realty/articleshow/5529408.cms.

49. Business Standard. "UP municipalities face the energy tests." July 15, 2010.

50. Walsh, Michael. "Transforming the Transportation Sector in a Carbon-Constrained World While Reducing Climate and Urban Air Pollution Impacts." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 18, 2010.

51. Ginsberg, Mark. "New Technologies and Renewable Energy for Electric Power." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

52. Ibid.

53. Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

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56. Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

57. Ibid

58. The Financial Express. "Biofuel role limited in India:Ramesh." November 23, 2009. http://www.financialexpress.com/news/biofuel-role-limited-in-india-ramesh/545130/.

59. Ghandi, K.K. "Cooperation on Meeting the Challenges of Energy Security, Environmental Responsibility and Economic." Conference Presentation. US-India Energy Dialogues. New Delhi, India, March 16-18, 2010.

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