New Energy Technologies and Integrative Capability: A Case Study of India

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Abstract

The growing Indian population and increased energy demand has is leading to growing environmental pressure. Hence, there is a need to invent and secure energy technology options that can increase energy efficiency by checking environmental pollution. The question is no longer whether we can check environmental pollution, but whether we can do so fast enough without harming its rapid economic growth. What are the available energy technologies options before India? and how they can be assimilated to secure a healthy and energy efficient economic future. This is a herculean challenge that India faces today. It has to adjust its energy economy with the economic well being?

India shares with other nations the desire for affordable energy to fuel its economic growth without harming the environment. Achieving this, will require technological ingenuity, pathways that minimize economic costs and political determination. The development and assimilation of new energy patterns of production and use will be crucial. The paper provides a brief discussion of the available energy technologies and the strategies needed for their assimilation. Improved energy technology has a crucial role to play in addressing India's energy challenges. The paper tires to assess the potential of various energy technologies and how they can be assimilated for a faster economic growth. Development , and deployment of these energy technologies is likely to advance sustainability in production, transformation, transportation and use of energy.

Technological progress has created enormous benefits for world's energy consumers. It has enabled the global commercially viable resource base to grow, despite the so called Peak oil Production. According to certain estimates, it now takes 50% less energy to create a dollar of GDP than it did 30 years ago. Improved seismic mapping methods, deeper onshore and offshore drilling and production techniques, reservoir simulators and other advances have increased the accessibility of oil and natural gas. Not only that, technology has diversified supply sources by allowing more energy to be accessed in more locations around the world. The current Saudi Arabia's move to store oil in china can be one example. Ice resistant and ice breaking innovations, new state of the art platforms and sub sea drilling technologies have the capacity to open rich reserves. Technology can also contribute towards reduction in environmental impact. Especially it can reduce carbon monoxide, sulphur, and particulates emissions. Security of energy supplies needs assimilation and understanding of emerging technologies and continued innovation.

Secure, reliable, and affordable energy resources are fundamental to India's sustained economic development. The threat of disruptive climate change, the erosion of energy security and India's growing energy demand pose major challenges and, are transforming its energy system. Understanding and better use of new energy technologies will be crucial along with significant scientific innovation to spur growth. Urgent action is needed to rapidly advance energy efficiency and low carbon technologies and practices. There is a need to adopt emerging technologies, in hydrogen and fuel cells, advance renewables, search prospects for next generation biofuels, and enhance energy storage capacity.

Today there are a number of existing scientific breakthroughs that could provide solutions to India's energy challenges. These opportunities stem from innovations in technologies and instrumentation, computing, communications, biotechnology, nano- sciences, information technologies, and infrastructure. These opportunities can help in exploration, production, and use of energy at a lower cost and in a sustainable manner. Although the direction and pace of change are unpredictable, but the technological process is certain to continue.

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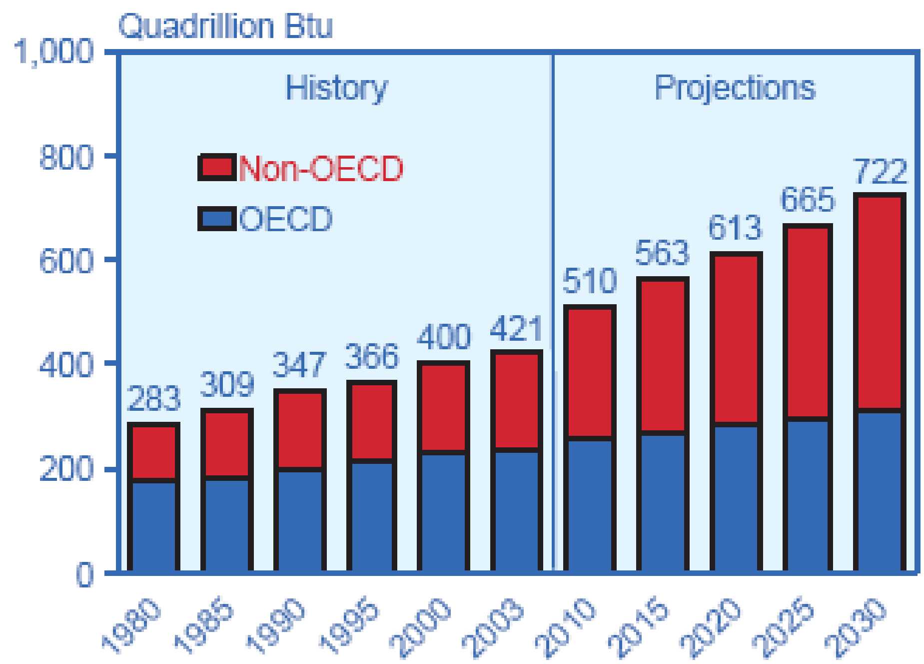
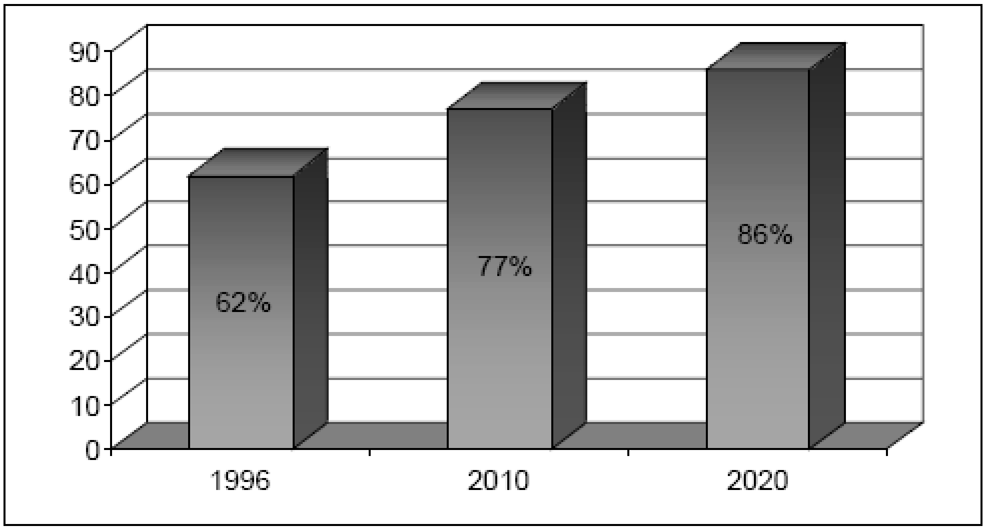
The deep waters of the Arabian Sea, hot and dusty deserts of Rajasthan, and undeveloped regions of North East are merely geographical challenges that Indian oil and gas industry is facing today. There are other challenges which are as serious. Certain new developments have created a highly volatile, rapidly fluctuating crude oil and gas market. Competition for depleting resources continues to drive the need to lower operating costs and increase finding and recovery rates. In this context, advanced technology such as 3D and 4D seismic downhole sensors, and bandwidth can provide vast amounts of near and real-time information that can help in meeting the domestic energy needs. Yet, still, there is a need to understand the emerging technologies.
According to the *International Energy Outlook 2006* (*IEO2006*), world marketed energy consumption will increase on average by 2.0 percent per year from 2003 to 2030. Although world oil prices in the reference case will remain between \$47 and \$59 per barrel (in real 2004 dollars). Total world energy use will continue to increase as a result of robust economic growth. Worldwide, total energy shall grow from 421 quadrillion British thermal units (Btu) in 2003 to 563 quadrillion Btu by 2015 and 722 quadrillion Btu by 2030, the most rapid growth in energy demand from 2003 to 2030 is projected for nations outside the Organization for Economic Cooperation and Development (non-OECD nations). Energy demand growth averages 3.7 percent per year for non-OECD Asia, which includes China and India[1].



World Marketed Energy Consumption By Region, 1980-2030
Source: History, Energy Information Administration, *International Energy Outlook 2006*

India, for instance, has emerged as a net energy importer, and with a growing population and continued economic growth, its energy consumption is growing accordingly. Self sufficiency in oil and gas will not be reached. Consequently, energy imports have become a vital interest for New Delhi. Its oil consumption in 2001 amounted to 2.07 mbbl/d, and is expected to reach 3 mbbl/d by 2010[2]. The transport sector is responsible for 70 percent of the rise in oil demand[3]. According to certain estimates its Energy Intensity stood at (2001E):25,307 Btu/\$1995 (vs. U.S. value of 10,736 Btu/\$1995. The Gas consumption for 2001 stood at 2.5 bcf/d. India imports around 70 percent of its oil and gas. The International Energy Agency, predicts that, its dependence on oil and gas will further grow to 91.6 percent by the year 2010 by 2010, India is expected to be the world's fourth largest consumer of oil, absorbing 3.2 million barrels per day. This means that there will be increased competition no only for existing oil resources but also to discover and lock in new discoveries. Hence, search for new energy technologies have become an imperative.



India – External oil dependency outlook[4]

Source: IEA, March 2000 *India- A Growing International Oil and Gas Player*, p7

Enormous changes have occurred in the international energy market. It is partly driven by new energy technologies and partly by IT revolution. India's increased energy demand coupled with rapid growth has created enormous challenge. It is obligated to expand access to the existing oil and gas reserves, search new reserves, go for alternative energy mix, and find even newer ways to increase production levels. Emerging new energy technologies along with Information Communication has emerged as an enabler that can help in resolving the issue. Indian society needs a robust, secure, and flexible Energy technology capability in order to meet its growing energy needs. The key for securing its energy future will be the strategic application of Emerging Energy technologies for its domestic energy needs.

Society is facing an increasingly globalized and competitive world in the new millennium. It is widely believed that, the coming decades will be characterized by even newer technologies in energy sector like Gas to Liquids (GTL) technology, E-drilling, Offshore energy technology, CTL, LNG technology, microelectronic based production systems, software/computer innovations, new management systems. Information highway will play an important role in meeting the energy demand and needs of Indian society. These new innovations in the energy sector, together with globalization process have brought both opportunities as well as challenges.

Opportunities incur in the sense that, Indian society would substantially benefit from the wide dispersal of knowledge. With appropriate strategies, policies and programs, it can acquire, assimilate, and successfully apply new energy technologies to become more energy efficient society. Globalisation process and the emerging patterns of competition present a rare opportunity to bridge the energy divide prevailing between developing and the developed world.

Failure to seize this opportunity will result in long term undesirable consequences. For instance, it would continue to fall far behind the international energy frontier with no access to alternate fuels and lack of cutting edge technologies to discover new oil and gas reserves, its aspiration to emerge as a superpower by 2020 shall be frustrated.

Herein lies the challenge, how might Indian society could acquire and assimilate new energy technologies for sustainable development? What are the emerging new technologies in energy sector? Whether India is equipped enough to utilize them? And what implications these emerging technologies can have in meeting India's energy demand?

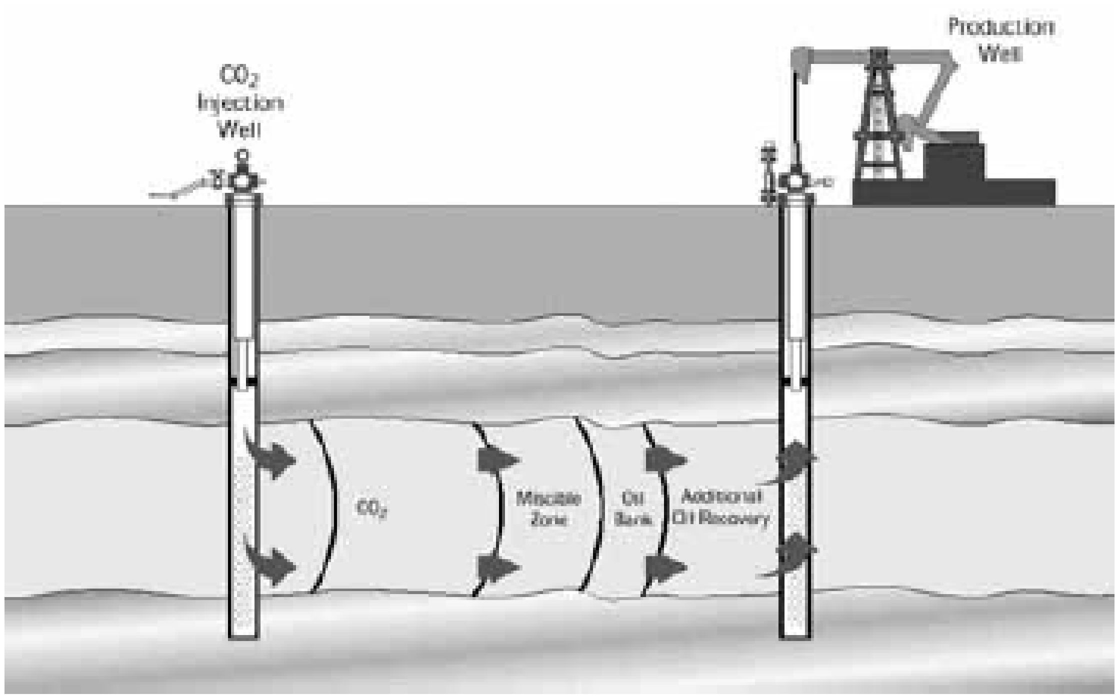
A major attempt of this paper is to identify and discuss various new energy technological opportunities that are potentially available to Indian society in the new millennium. This paper also analyses the perquisites and conditions for exploiting these opportunities and evaluates the implications emanating from their absorption. The overall objective is to ascertain the role of new energy technologies in meeting India's energy security concerns and their implications for a sustainable development. Finally the paper suggests certain strategies, policies, and programs that India could adopt in order to successfully exploit the technological opportunities available today.

New Energy Technologies

New Energy technologies will play a critical role in achieving the objective of improving productivity and maximizing oil recovery in depleted, high pressure, high temperature reservoirs, and wells. These technologies have the capacity to power the growing Indian economy and satisfy increasing energy needs, while stabilising atmospheric CO2 concentrations in the long run. Although intellectuals may not agree, as to what is the best technology, or what future shape they may take, what follows is an honest appraisal of emerging energy technologies in the energy market today and it may be taken to represent the dominant opinion in the field. Of all the new technologies that have made forays into the energy industry, following features prominently:

(1) Gas Injection Technique

Gas injection technique increases the recovery of oil originally in place and therefore extends the economic life of the reservoir. As can be seen below, gas injection increases the mobility of oil. After gas/oil separation, the associated gas is reinjected into the reservoir at high pressure. As the reservoir pressure increases, the production flow rate increases[5].



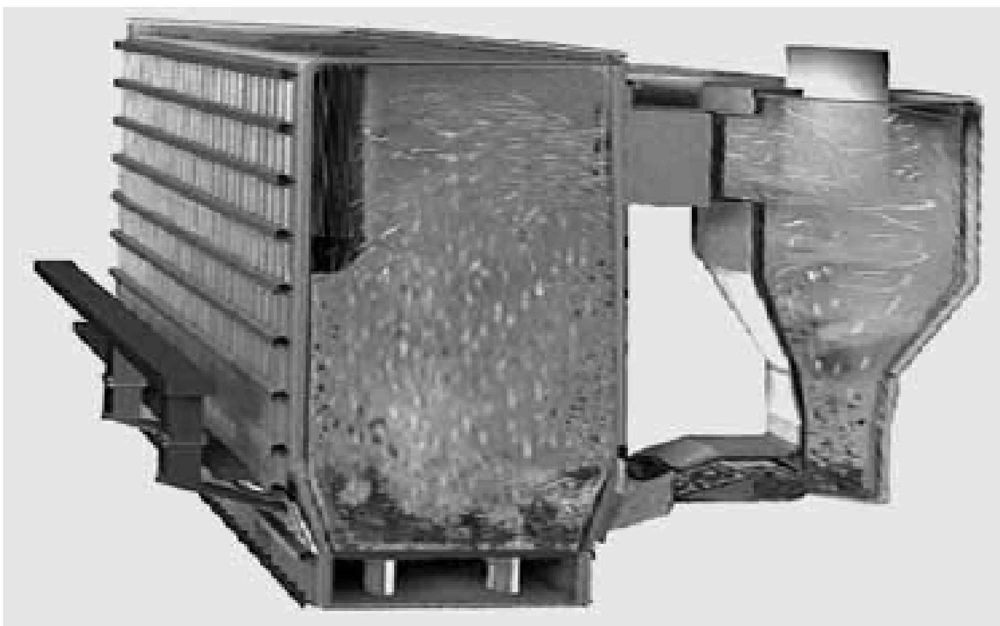
CO2 injected into the oil reserve moves additional oil to the production well

Source: IEA, (2005), *Energy Technologies at the Cutting Edge*

(2) Fluidized Bed Combustion (FBC)

Fluidized bed combustion (FBC) is used for converting the energy in fuels into electric power, process steam and building heat. A fluidized bed combustor is a vessel containing fine granular material that is held in suspension by air blown into the bottom of the vessel through uniformly distributed nozzles. The uniform upward flow of air keeps "bed" particles suspended in constant motion. Fuel fed into the vessel mixes uniformly throughout the "bed" (usually sand or limestone) of hot particles. This allows combustion of the fuel at lower nitrogen oxide emissions. At FBC conditions limestone reacts directly with sulphur dioxide gas, therefore using limestone as the granular bed material allows in bed removal of sulphur dioxide generated during combustion resulting in clean flue gas[6].

Burning in a fluidized bed offers the ability to turn a wide range of low grade and difficult fuels such as waste and biomass. Fluidized bed conversion technology offers an advantage over conventional technology in the sense that it principally lowers NOx emissions. Units operating with supercritical steam conditions offer the potential for power generation efficiencies as high as 45 percent[7].



Interior of a circulating fluidized bed combustor

Source: IEA, IEA, (2005), *Energy Technologies at the Cutting Edge*

(3) Multiphase Flow Technology

Multiphase flow is the flow of a mixture of two or more of solids, liquids, or gasses (generally solid-liquid, solid-gas and liquid gas). It can help in achieving more efficient and cost effective energy production, and fuel transport and use technologies. Multiphase flow has many applications within the fossil fuel energy sector. It can help in discharging of a solid fuel such as coal from storage, its classification, and its combustion in a fuel flame. It is mostly useful in production, transport, and refining of oil and gas, particle separation from flue gasses, transport of solids –fuel or waste products in slurry pipelines etc.

(4) GTL Technology

GTL technology has made great strides recently. GTL products, particularly GTL diesel has started playing major part in the emerging energy mix today. It is a production technology. The conversion of natural gas or any similar gaseous hydrocarbon into liquid transportation fuels and related petrochemicals is called GTL Technology. It involves an integrated three step process[8]:

- The conversion of natural gas, or another methane rich feed stock, through reforming into synthesis gas (syngas), a predetermined mixture of hydrogen and carbon monoxide.
- The synthesis of syngas through some form of proprietary Fischer- Tropsch (FT)[9] reactor with unique cobalt- based iron based or similar catalyst to produce a range of liquid hydrocarbons in the form of a synthetic version of crude oil (syncrude).
- The upgrading and refining of the subsequent syngas derived liquid hydrocarbons into specific slate of liquid fuels and or petrochemical products of intermediaries, according to a predetermined suite of refining plants and the preferred process of selectivity[10].

It is clear that GTL technology is a high potential emerging technology. However, it is visited by a major technological challenge, that is the need to lower the capital and operating costs of a GTL plant with a view to bringing daily per barrel capital cost below $20,000. Still, depending on geographic location, plant scale, cost of feedstock, site preparation costs and the extent of support utilities and infrastructure per barrel of installed capital cost could be reduced significantly. Costs will be further lowered as process know how improves, and as smarter, new engineering and construction techniques develop. Companies like ExxoMobil, Sasol, and Shell etc are continuously exploring newer and more advanced options.

The environmental benefits of products generated from gas to Liquids (GTL) technology are widely recognised, low sulphur, low aromatic content diesel. However, there are more than environmental factors driving the development of GT, particularly the monetization of natural gas reserves[11]. India's rapid growth in gas consumption over the past decade is set to continue. The broadly recognized environmental benefits of gas, compared with other energy sources, and advances in technology have elevated its role in meeting the energy needs. The adoption of GTL technology has made it easier to exploit natural gas in an environmental sustainable manner. The rationale for the adoption of GTL technology emerges from:

(a). the expected long term change from a predominantly oil based energy sector towards increasing dependence on natural gas.
(b). the continued dependence at least in the medium term on liquid fuels especially in the transport sector.
(c). The increasing requirement for clean and clean burning fuels without sulphur, with minimum content of aromatics.
(d). The distant location of many important gas fields from major energy consumption areas.

(5) Oil Refining

There has been some major changes in the refining industry recently, prompted in part by a significant decline in the quality of imported crude oil and by increasing environmental restrictions. The average sulfur content of crude oil imports have increased to 1.4 percent in 2005. Crude oil has also become more corrosive and heavier than they were in the past. The industry standard measure for oil density is API gravity, a lower gravity indicates higher density and a higher gravity indicates lower density. Over the past years the API gravity of crude oil has steadily declined. The standard measure for corrosiveness is the Total Acid number (TAN) indicating the number of milligrams of potassium hydroxide needed to neutralize the acid in 1 gram of oil[12].

New environmental rules require the refineries to reduce the amount of sulfur in most gasoline to 30 ppm by 2006, from over 400 ppm in the early 1990s and the sulfur content of highway diesel fuel to 15 ppm by October 2006. By 2014 virtually all diesel fuel must be below 15 ppm[13]. To meet this, refiners must produce low sulfur products. The principal method for reducing sulfur content in fuels is hydrotreating a chemical process in which hydrogen reacts with the sulfur in crude oil to create hydrogen sulfide gas that can easily be removed from the oil. Hydrotreaters are specialized for the refinery streams they process[14]. The lower sulfur specifications for petroleum fuels will require India to increase its hydrotreating capacity.

India can "convert" heavy oil at the refinery directly into light products, through "Thermal cocking process", in which heavy oil from a vacuum distillation unit is fed to a heating unit (cocker) that splits off lighter hydrocarbon chains and routs them to the traditional refinery units. The almost pure carbon remaining is coal like substance known as petroleum coke. The accumulated coke can be removed from the coking vessels during an off cycle and either sold, primarily as a fuel for electricity generation, or used in gasification units to provide power, steam, and or hydrogen for the refinery[15].

(6) Intelligent oil field

The latest Information Technology innovation has made the "Intelligent Oil field" possible. Massive amounts of sensor data can now be stored and searched using advanced visualization technology allowing data to remain at the source and avoiding transmissions of massive data stores. Complex data patterns can be detected automatically, such as for sanding or carbonate, so the right person can be alerted and a response can be initiated before a production problem occurs. Visualization, modeling, and analytics have made it easier for the decision makers to understand the wealth of complex information leading to improved reservoir management. The technology groundwork has been already laid down for the intelligent oil field to become a reality[16].

Early warnings and alerts, along with suggested treatments can be sent to the designated command and control centers through the detection of complex data patterns from sensors. Oil and gas companies can access the wealth of data generated from the pertaining to assets, such as real-time sensors and trend histories, which can help them make more informed, predictive decisions. Wells and fields can be managed remotely, helping to save time and money, extend the leverage of skilled resources and increase recoverables[17]. Information and Technology can improve production and recovery rates with fewer people onsite and on platform.

Information Technology has emerged as a driving force in energy operations, strategies, structures, ownership, and performance. IT innovations and applications have not only brought significant change into the nature of energy economics, but also, it has altered the energy space, conduct and performance. Real time sharing and distribution of knowledge and work without regard for geography distance and language has become a possibility.

New technologies have paved the way for oil and gas companies to collect an increasing amount of information about their sub-surface assets. However, data must be catalogued, stored, backed-up and should be easily accessible, which means many companies engaged in India will have to re-evaluate their core infrastructure, including hard drive space, processor capacity, security applications and even disaster recovery plans. Energy plants need reliable communications for onshore and offshore locations, and even the smallest delay can potentially cost a millions of dollars loss. Wireless platform phones, and machine-to-machine communications using RFID are a few of the devices transforming wireless communication. Now there are w ireless broadband networks that can immediately transfer critical data and establish secure communications with remote teams. The integration of desktop, mobile, network system, applications, help desk and asset management with related configuration management tools has become easier.

A greater contributor to plant efficiency has been the development of information technology systems, the so-called Distributed Control Systems (DCS), and the electronic automation. DCS were introduced in the late 1980s, enabling centralized process monitoring and control. DCS systems replaced integrated circuit board controllers. Inputs from field instruments and outputs to valves and pumps were converted to electronic signals. They were generally run short distances to cabinets in the process area which contained a manageable number of control loops. Each DCS cabinet was connected to a main control computer. Process instruments, output to pumps and valves, and controller settings driven from a computer console (dashboard) located in a central control room. This design also enabled monitoring and control from multiple (and redundant) locations, such as local control rooms, engineering offices, or even remote locations[18]. Since then, the system has grown in capability.

(7) Floating LNG Technology

Since 1970s a number of floating Production, storage, and off-take (FPSO) vessels have been used for oil production. Now a number of oil companies are using this technology to the LNG industry. In the case of LNG, existing production technology is combined with that of FPSO vessels. Under this concept, a weather vaning barge complete with gas processing, liquefaction and storage is moored in the immediate vicinity of gas field. The LNG produced is then offloaded on to standard vessels for transport to markets. Promoters of this concept are targeting offshore gas fields that are either too small or too remote to be developed economically on their own[19]. This technology will bring large project cost savings. And hence, allow the producers to tap the potential that would have gone undeveloped. The largest saving can be realised by reduce investments in related infrastructure.

The use of floating production units eliminate the need to construct pipelines to shore as well as port facilities. And using subsea well completions removes the requirement for offshore production platform. On the processing side, CO2 can be removed earlier in the production chain than is the case with onshore facilities[20]. The floating LNG unit can be towed to a different location in case a field's life ends. Thereby it can eliminate the need to build anew all support structures to monetize new offshore field. Under the normal conditions, floating LNG units can remain on site for at least 20 years. And most importantly floating LNG export vessels along with offshore import and regassification terminals are less vulnerable to sabotage than onshore facilities[21]. It has assumed an important significance in a security conscious world.

Implications for India: Technology Solutions

India's rapid progress and increasing energy consumption has brought to the fore, the question of sustainable development. 'Sustainable development' as defined by Brundtland Commission is the 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs'[22]. Adequate and affordable energy supply is proving to be a key, to economic development and the transition from subsistence agricultural economy to modern industrial and service-oriented society. Energy is central to improved social and economic well-being, and is indispensable to industrial and commercial wealth generation. It is essential for relieving poverty, improving human welfare and raising living standards. But however essential it may be for development, it fulfills its goal only through the availability, utilization of and assimilation of emerging energy technologies. The goal of good health, high living standards, a sustainable economy, and a clean environment be achieved, only by a proper and defined structure, which directs these emerging technologies towards the stated ends. No form of energy coal, solar, nuclear, wind or any other is good or bad in itself; it is the level of technology which makes the difference.

Assimilation/Integration

In India, much of the current energy supply and use, based, as it is, on limited resources of fossil fuels, is deemed to be environmentally unsustainable. There is no adequate energy production or conversion technology. Somewhere along the energy chain from resource extraction to the provision of energy services pollutants are produced, emitted, and disposed of, often with severe health and environmental impacts. Integration of emerging energy efficient technologies can significantly reduce these hazards.

Combustion of fossil fuels is chiefly responsible for urban air pollution, regional acidification and the risk of induced climate change. The growing acceptance of nuclear power has created a number of concerns, such as the storage or disposal of high-level radioactive waste. The noncommercial use of biomass is contributing to desertification and loss of biodiversity. Hence it has become quiet an imperative for India to search the available technological options.

Rural India still largely relies on the use of animal power and non commercial fuels. Majority of them have no access to electricity. This lack of access to modern energy services severely limits the level of socioeconomic development. Nonetheless, because of improved technology and an increased understanding of the effects and impacts of energy and energy systems, a country like India can make early transition from an agricultural to a market economy, with much lower costs and with less environmental damage.

The maintenance of above 9 percent growth rate will require, not only the judicious use of resources, but also- appropriate energy technologies with strategic policy planning. It will also require their assimilation.

It is essential at this stage to know the country's current status on the energy efficiency scale, the level of existing energy technologies and the emerging or new energy technologies in the international market. Then an attempt should be made towards integration of new technologies. Second it is important for policymakers to understand the implications of selected technologies and their impact on the shaping of development and on the feasibility of making this development sustainable. There is an imminent need for informed and balanced technology choices and their assimilation.

Infrastructure

There is an increasing need for energy technology infrastructure development. The planning and consenting system for R&D is complex. There is a need to ensure fair, transparent, and quality decision making. Delays (official/unofficial) in initiating new projects are a major problem. The timely official response plays an important role in generating support for emerging technologies. System for securing the necessary consents, including planning permission for potential developers should be made more flexible. New laboratories, maintaining adequate level of taskforce of scientists and researchers are a crucial element of energy technology infrastructure. Hence efforts should be directed to attain these objectives.

The major challenge is to repair and expand energy technology infrastructure. The current outdated network of electric generators, transmission lines, pipelines and refineries that convert raw materials into usable presents a dismal picture. There is a need to build pipeline and refining technology capacity. Exploration and transportation of energy is hindered by lack of these adequate technologies.

Investment

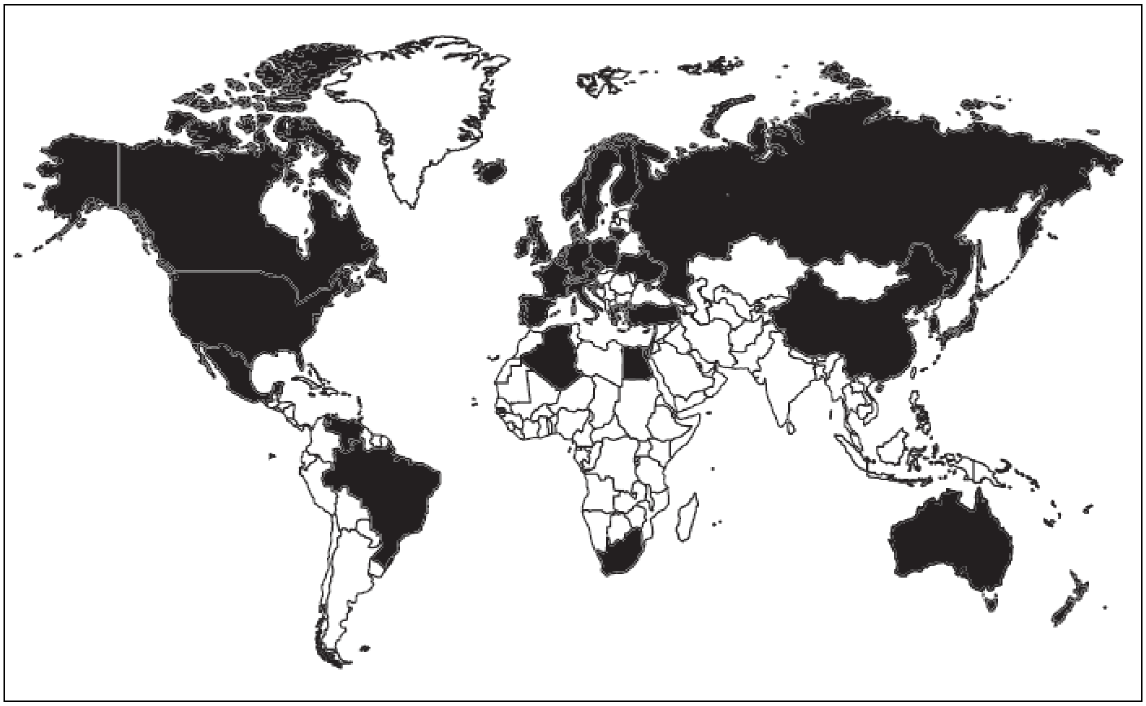
Assimilation of emerging energy technologies, to a greater extent will depend on the adequacy of investments. Securing reliable investment will be quiet crucial for it. The availability of investments in research and development of energy technology infrastructure is a daunting task. A current rate of investment in this sector is not enough to meet the gap, which is expected to open up due to increased energy demand. Without sizable increases in capital investment in emerging energy technologies, oil and gas production will remain stagnant and prices will remain high. The current shortfall in investments, if continued will alter India's energy balance. The government has to increasingly orient its policy towards attracting more FDI in this sector.

In the last 10 years India's energy situation has confronted many challenges, oil supply disruptions have led to oil price fluctuations and shaken its economy. In addition to sufficient Research and Development budget, it has to combine technology efforts and sharing costs on an international level. India can leverage and strengthen its national energy research and deployment efforts by:[23]

- Bring the abundance of existing Technologies closer to commercial deployment through technology learning.
- Identify the challenges in bringing viable medium term technologies forward (i.e enhanced oil recovery, carbon capture and storage, hydrogen and fuel cells) and

- Offer a successful, cost sharing structure for expensive exploratory research (i.e. fusion, gas hydrates).

Reaching out to private sector would be crucial for energy solutions. Indian industry will ultimately test the economic efficiency of the existing energy technologies assimilating those which are market efficient. It will also define the next steps needed for cost efficient deployment of energy technologies. In addition to ensuring an ideal connection between the government and industry, it is immensely important that, India should reach out to rest of the world in energy research collaboration. The following figure shows that India do not figure anywhere in energy collaboration programme. It should join collaboration programmes such as offered by IEA (energy technology collaboration programme).



Participating countries in the IEA Energy Technology Collaboration programme.
Source: IEA, (2005), Energy Technologies at the Cutting Edge

India should participate in the international energy technology collaborations. It should devise adequate mechanism for joint ventures in R&D, exchange of experts and researchers should be promoted. Multilateral and bilateral institutions should be involved. Recognizing, says Naimi Minister of Petroleum and Mineral Resources of Saudi Arabia, "that greater cooperation and coordination are indispensable elements of our energy future is the first step in making that vision of shared progress and prosperity a reality"[24].

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