FROST & SULLIVAN

50 Years of Growth, Innovation and Leadership

Sustainable Development and Driving Technology Advances in Future Energy

A
Whitepaper
by
Frost & Sullivan

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SUMMARY

The United Nations Organization estimates that the world's population will expand by 35 percent in the next 40 years from the present 6.78 Billion[1]. This will increase the demand for various resources that the world needs for survival – Energy, Water, Environment (for air), and Landmass. With the growth of world's population and resources, as neither landmass nor natural resources like water and air are expandable, there is tremendous pressure on earth's limited resources. Globally, this can have a catastrophic effect on the environment. The effects are already noticeable – climate change, hunger, rising fuel prices, cost of food and its scarcity, social unrest and war.

To support this economic growth, energy consumption is expected to increase by 1.4 percent[2] every year; that is, by 30 percent in the next 20 years. This entails that the coal demand will rise by 53[3] percent in 20 years, which will result in a 39[4] percent increase in CO_2 levels in the atmosphere. Along with energy, water demand would rise rapidly by 50-53[5] percent in the next two decades. However, water resources and its availability would remain fixed at 4,200 Billion meters cubed, creating a deficit of 40 percent over demand. While the economy and population grow between 35-39 percent, the resources that are required to support these two growth areas are limited.

There is a contrast between the economic growth pattern of the previous few centuries, and what the future scenario is likely to be. From the 1700s to the 1900s most growth took place in countries whose combined population was less than the current numbers of India or China. Future world economic growth is likely to come from countries that comprise more than one-third of the world's population. Growth will therefore be at a faster pace than before.

India has ambitious growth plans and is slated to become the third-largest economy in the world by 2020. This would require her to grow at an average rate of 8 percent every year over the next 10-15 years, which in itself is a challenge. To achieve this growth rate, India will need to invest in infrastructure, both social and economic, for which resources like energy, electricity, and water would be required in large measure. All this will put pressure on the available land and environment.

It is, therefore, imperative for both the world and India to work out an Integrated Plan for optimum use of energy, conserving the environment for a sustainable future, using available resources in the most efficient way and with the most advanced technologies. In the Integrated Plan, renewables have to play a major role in order to mitigate the environmental degradation caused by use of conventional sources of fuels, like coal and lignite, which constitute almost 45 percent of the electricity generation fuel share. Ways and means to decrease this share to at least 35-38 percent in the next 20-30 years need to be devised for sustainable development.

This Paper presents the existing scenario and attempts to suggest solutions that need to be looked at seriously by various Energy, Environment, and Policy planners

1 *As of 2010 end, World Bank estimates*

2 *International Energy Association, Paris (IEA) and U.S. Energy Information Administration, Washington (EIA) estimates*

3 *World Coal Association http://www.worldcoal.org*

4 *IEA, Paris*

5 *2030 Water Resource Group – "Charting Our Water Future 2030" 2009*

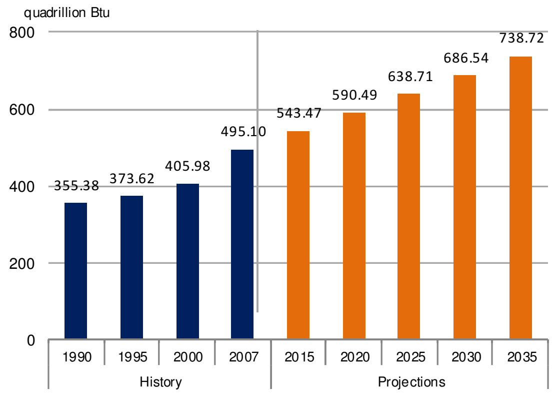
of the world and India for a sustainable future. It is imperative that these solutions are integrated at the earliest into the future energy plans of countries. Support from the policy makers, the Government, financial bodies, and commitment from the people and the industry is required for their early adoption.

PRESENT SCENARIO

Energy

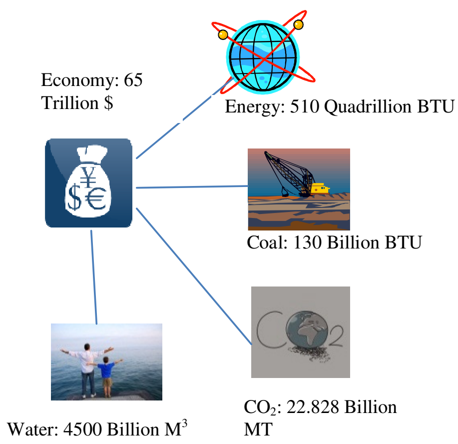
The world's population is nearing the 7 Billion[6] mark, with China and India constituting about 37 percent of this. This has generated GDP of 65 Trillion US Dollars[7] and is expected to grow at about 4.34 percent over the next two decades. In accordance with this economic growth, the world consumed 510 Billion BTU[8] of energy, of which 130 Billion BTU was from coal (spewing out 22.828 Billion Metric Tons of CO2); and 4,500 Billion meters cubed of water[9].

Chart 1. World marketed energy consumption, 1990-2035



Source : IEA World Energy Outlook

Chart 2. Contributing Energy & Environmental factors to Economy



6 *United Nations World Population Report 2300*

7 *International Monetary Fund (IMF) and World Economic Outlook, World Bank*

8 *EIA, Washington*

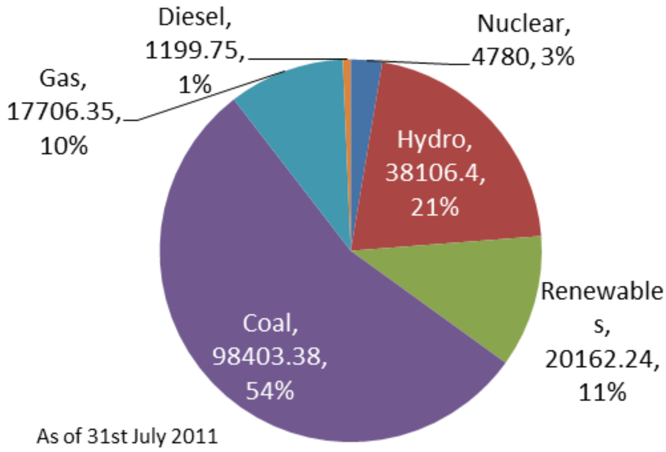
9 *2030 Water Research Group – "Charting Our Water Future 2030" ©2009*

India's GDP with a population of 1.21 Billion stands at 1,587 Billion US Dollars in 2010 and is expected to grow at an average rate of 7.5-8 percent for the next couple of decades. For generating this economic activity, India consumed 21 Billion BTU of Energy of which

• Coal	549 Million Tons
• Lignite	16.30 Million Tons
• Natural Gas	47.51 Billion meters cubed
• Crude Oil	33.691 Million Tons
• Electricity	811 Billion Units
• CO2 Generated	1.607 Billion Metric Tons
• Ash Generated	139 Million MT
• Water Consumed	803 Billion meters cubed
• Discharge of high TDS water	456 Billion meters cubed

Today, about 25 percent of coal and almost 80 percent of crude oil is imported into India to meet its energy requirement. As the Indian economy grows, it is estimated that the country will have to depend on larger amount of imports to meet requirements. With rising demand from China, the world's second-largest user of oil, price hikes and supply shortfall would be the order of the day in the future. Thus, if India has to have a sustainable plan for its energy demand, other sources of energy, like renewables will have to be an integral part of its energy mix.

Chart 3. All India Generation Capacity in MW



As of 31st July 2011
Source : Central Electricty Authority

In the year 2010-11, 54 percent electricity was generated from coal. With the rise in electricity demand and other energy requirements, the demand for coal in India in 2021-22 is projected at 1,353 Million MT against the projected output of 1,084 Million MT; leaving a shortfall of 269 Million MT . Of the estimated reserves of 267

[10] *India Census March 2011 results*

[11] *Source: EIA, Washington, Ministry of Petroleum, Ministry of Power, Ministry of Coal, Ministry of Water Resource, Government of India and Frost & Sullivan Research*

[12] *Minister for Coal, Mr. Shriprakash Jaiswal, Government of India, Reuters, March 2011*

[13] *US Energy Information Administration, Washington 2010 report*

Billion MT of coal, 105 Billion MT is proven. Even on a conservative assumption of 60 percent recoverability for the proven resources, about 64 Billion MT could be recovered. This could sustain a production level of over 1,800 Million MT per year for the next 30 years. However, much of this coal reserve is located in eco-sensitive areas, which cannot be mined. Thus, the actual domestic coal availability will be lower, creating a shortfall in local supply, and hence the need for larger imports.

All the energy demand and its generation will lead to even higher CO2 generation. While India occupies the third position in carbon emissions in the world today at 1,607 Million MT, its carbon emissions have been growing at 8.7 percent every year. At this rate, it would soon overtake the world's second largest emitter, the US, whose carbon emissions have actually been decreasing at 7 percent every year; and it will be closer to China's emission figures. Some say that India may become the largest carbon emitter by 2030, leading to serious environmental and health hazards.

ENVIRONMENT

Water

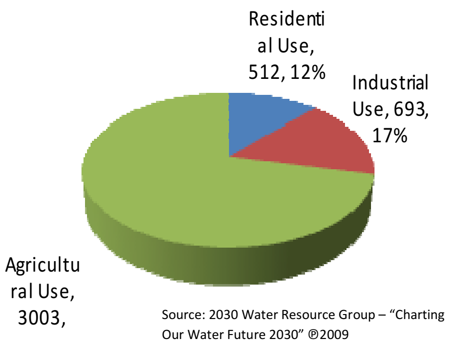
Another vital resource that plays an important role in the growth of an economy is water. Though 75 percent of the globe consists of water and only 25 percent is landmass, the world has limited fresh water resources, which is required for the human population and economic growth. It is estimated that the world's fresh water sources constitute 4,200 Billion meters cubed. However, to keep pace with global economic growth, water demand will grow at an accelerated rate — from 4,500 Billion meters cubed to 6,900 Billion meters cubed by 2030 increasing the water gap[14]. If the consumption and water usage practices remain the same as today, then 40 percent of the global demand will not be met.

Table 1. Consumption of Water by the leading economies

Country	Current Supply*	Demand in 2030*
China	618	818
Brazil	18.7	20.2
India	740	1,500
South Africa	15	17.7

*Billions of meters cubed; Source: 2030 Water Resource Group – "Charting Our Water Future 2030" ®2009

Chart 4. Water Demand 2005 in Billion metres cubed



Source: 2030 Water Resource Group – "Charting Our Water Future 2030" ®2009

[14] *2030 Water Resource Group - "Charting Our Water Future 2030" 2009*

At present, more than one billion people already do not have access to clean water. To make this happen, governments and local bodies must bring in regulations and controls, make investments to use water more efficiently and encourage reuse of wastewater in the mainstream of water resources. Some countries that face water shortage problems and where agriculture is important, like India, will greatly suffer if above measures are not taken.

India will have to invest 6 Billion US Dollars a year for the next 20 years to accommodate a growing demand and help conserve water for the future. With about 70 percent of the water demand coming from the agricultural sector, for countries like India which are large agrarian economies with limited water sources, availability of water assumes prime importance. It is estimated that to keep up with its modest economic growth, India would be woefully short of water resources by 2030.

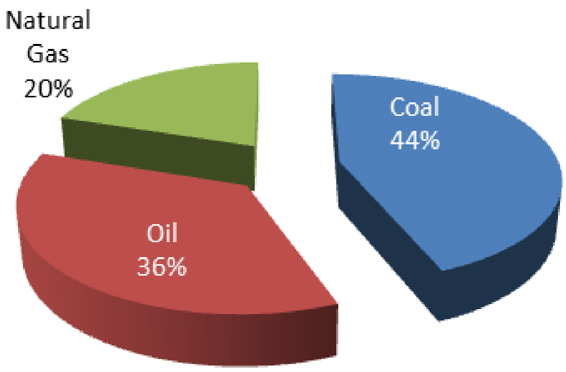
Gaseous Emissions

Another critical environmental concern is Green House Gas (GHG) emissions (measured as CO2 emissions in metric Tons). Climate change arising due to the increasing concentration of greenhouse gases in the atmosphere since the pre-industrial times has emerged as a serious global environmental issue and poses a threat and challenge to mankind. The International Energy Agency (IEA), Paris, estimates that energy-related carbon-dioxide (CO2) emissions reached a record high in 2010, up by 5 percent from the last record in 2008. Emissions in 2010 are estimated to have climbed to a record 30.6 GigaTons (GT), which is an increase of 146 percent over the 1990 figure of 20.956 GT. The last record in 2008 reported CO2 emissions of 29.3 GT, which was followed by a dip in 2009 due to the global recession.

The IEA envisages 2010 data and potential future emissions as 'a serious setback' to a target of limiting temperature increase to 2 degrees Celsius at the UN Climate Change talks in Cancun in 2010. The world has edged incredibly close to the level of emissions that should not be reached until 2020 if the 2 degrees Celsius limitation is to be attained. To achieve the goal of 2 degrees Celsius limitation, global energy-related emissions in 2020 must not be greater than 32 GT. This means that over the next 10 years, emissions must rise less in total than they did between 2009 and 2010.

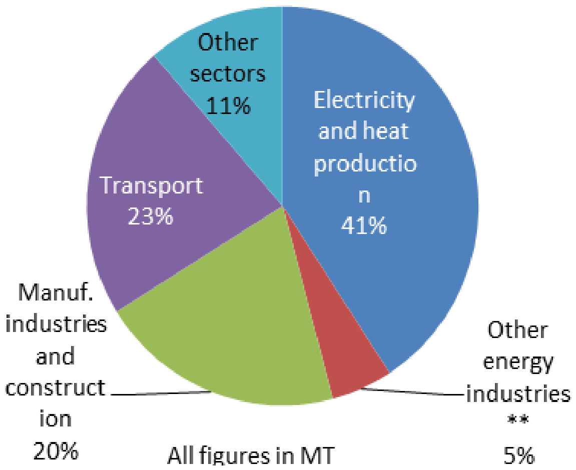
The main contributors to the increased GHG emissions are 44 percent from coal, 36 percent from oil, and 20 percent from natural gas . In terms of economic activity, electricity generation contributes to maximum CO2 emissions (41 percent) 15, followed by the transport sector. It is, therefore, imperative that other solutions for these sectors like the use of non-polluting renewable sources of energy should be looked at.

Chart 5. CO2 Emissions by Fuel Type



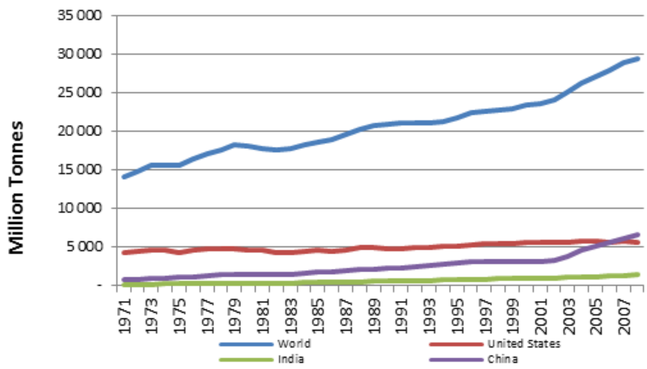
Source: CO_2 Emission from fuel combustion – Highlights, 2010 Edition, IEA, Paris

Chart 6. World CO2 Emissions – contributing activity



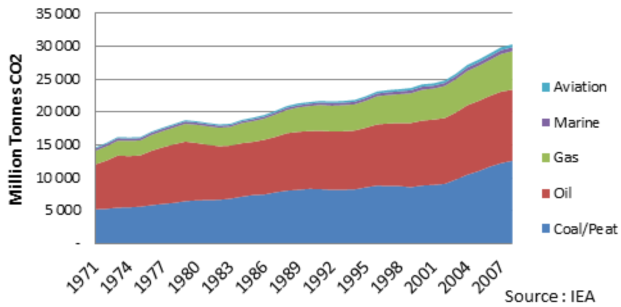
Globally, India ranks third in CO2 emissions with a figure of 1.815 GT. While the per capita CO2 emission at 1.5 Tons is somewhat comforting, the rise in emissions since 1990 to 307 percent, one of the highest in the world, is alarming. Following the world trend, power plants in India are the highest contributor to CO2 emissions. Since India will continue to use fossil fuels, especially coal as its main source of fuel for electricity generation, CO2 emissions are bound to increase in the next two decades. It is predicted that by 2020, India may cross the US in GHG emissions; and by 2030 cross China, which at 7,710 GT today is the highest emitter of GHG. This is alarming because, today, China is already struggling at a per capita emission of 5.1 Tons and India is likely to touch 5.5 Tons by 2030. This rise in emission levels will increase the suspended particulate matter in the atmosphere, which will result in rise in respiratory diseases and thereby lead to an increase in healthcare expenses as a percentage of the National Gross Domestic Product (GDP).

Chart 7. Top 3 CO2 Emitting Countries



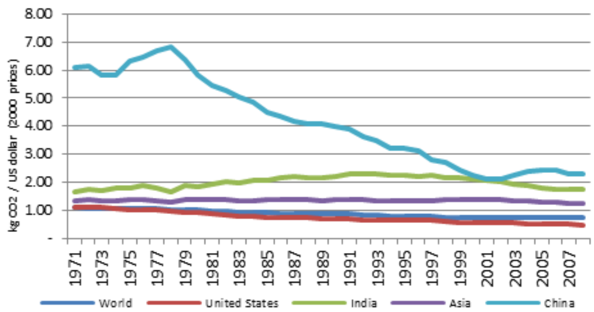
Source: IEA

Chart 8. GHG Emissions by Fuels



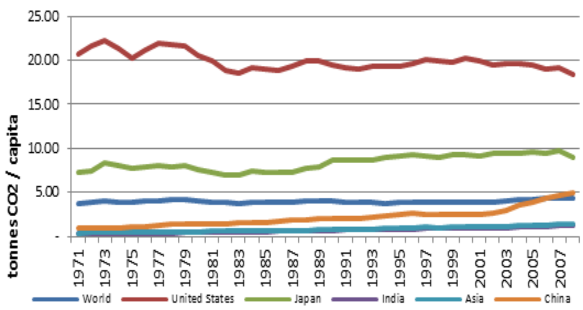
Source : IEA

Chart 9. CO2 emissions / GDP using exchange rates



Source: IEA

Chart 10. CO2 emissions / population



Source: IEA

WHAT IT TAKES TO GENERATE A UNIT OF ELECTRICITY FROM COAL

About 40 percent of the electricity produced today, globally, is based on coal, which is the main fuel in majority of the countries. The share of coal in power generation in China is the highest in the world at 79.5 percent and India is not very far behind at 53 percent. To generate one unit of electricity (kWh) one needs (refer Table 2):

Table 2. Inputs required & output from a coal-based power plant

Coal	0.9 kg/kWH
Carbon	0.36 kg/kWH
CO_2	1.4 kg/kWH
Ash generated	0.315 kg/kWH
Fresh Water Consumed	6 – 6.5 meters cubed[16]

Source: Frost & Sullivan Research & Analysis

- Vast tracts of forest and agricultural land, under which lie the huge resources of coal, or, the large tracts of land required near the sensitive coastal areas for building LNG terminals for import of LNG or for coal imports.
- Displacements and thereafter rehabilitation of villages that are affected due to mining, has a significant impact on social and economic growth of that particular region, although the nation may benefit from the process.
- Consider the investment required for the facilities like mines, ports which are amortised over the long life of a project, and fuel required to transport the fuel over long distances, railway lines to be laid and the rakes to be bought, the cost is actually much larger than it meets the eye or what is accounted for. Thus the real impact of supporting infrastructure is never accounted for in the cost of power generated.
- Same is the case with transmission and distribution of electricity over long distances that require often higher investment than generation itself.

Conventional power generation costs also do not take into consideration the huge environmental impact that it has:

Coal mining

- Land: Disturbance of land, forests, and biodiversity
- Water: Depletion of aquifers and changes in drainage pattern, deterioration in quality of water in receiving water bodies due to mine/washery discharge water
- Air: Fugitive dust emissions, noise, and ground-level vibrations

Coal-based power generation

- Particulate emissions
- Nitrogen Oxides (NOx) emissions
- Sulphur Dioxide (SO2) emissions

[16] Following assumptions have been made:

Plant efficiency 30%, Carbon content in coal 40%, ash in coal 35% & 1 mole of carbon gives 3.667 mole of CO2

With the envisaged increase in coal production from opencast mines of CIL (Coal India Ltd) alone, from 346 MT (million tonnes) in 2005/06 to over 800 MT in 2025, the need for land acquisition and the resultant displacement of people would also increase manifold. Coal Vision 2025 estimates that 170 000 families – or 850 000 displaced persons – would have to be rehabilitated by 2025 when the requirement for land would double from current 147 000 ha (hectares) to 292 500 ha. The requirement of forest land for mining would also increase more than three-fold from the current 22 000 ha (15% of the current total land requirement) to 73 000 ha (25% of the projected total land requirement) since much of the coal resources to be exploited in future are located in forests.

"Environmental challenges of coal production and use in India"

P V Sridharan, TERI, New Delhi
Energy Sector Insights, December 2006

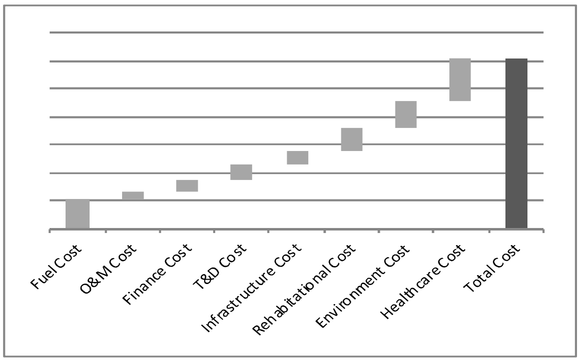
- Mercury contamination
- Acid Rain
- Waste from coal combustion (ash)

If the environmental impact and real infrastructure costs are taken into account in the cost of conventional power generation, then the delivered cost would go up substantially to much higher levels than what is being quoted today. Just the true cost of rehabilitation would make such electricity very expensive and unaffordable. Some of these costs are intangible and, therefore, difficult to put a figure to it. So, are the underprivileged subsidizing electricity for the privileged?

THE REAL COST OF CONVENTIONAL ENERGY

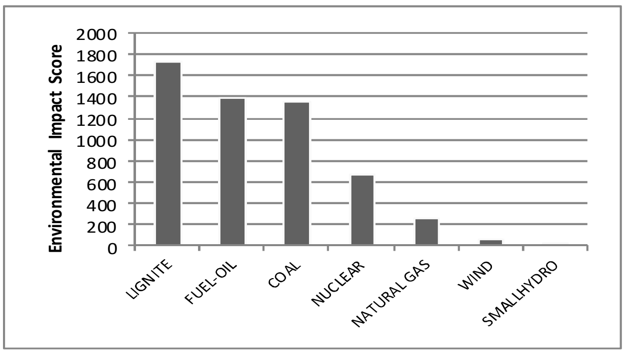
The real cost of conventional energy is much higher than what is used for commercial purposes. If one adds the cost of environment and social rehabilitation alone to the cost of conventional power, it is estimated that as much as 30 percent costs would get added to electricity cost as per present calculations. To get the true cost of conventional electricity, one must add the following costs to the present cost of electricity (refer charts 11 and 12):

Chart 11. Electricity Cost with Social & Environmental Cost



Source: Frost & Sullivan Research

Chart 12. Environmental Impact Study of Various Fuels used in Electricity Generation



Source: IEA Report – CO_2 from fuel combustion 2010

Chart 13. Effect of various types of fuel on environment

Source: IDEA Report July 2000

Legends:

Lig. : *Lignite based*

Cos : *Coal based*

Fuel : *Fuel Oil based*

NG : *Natural Gas based*

Nucl. : *Nuclear based*

Win. :*Wind based*

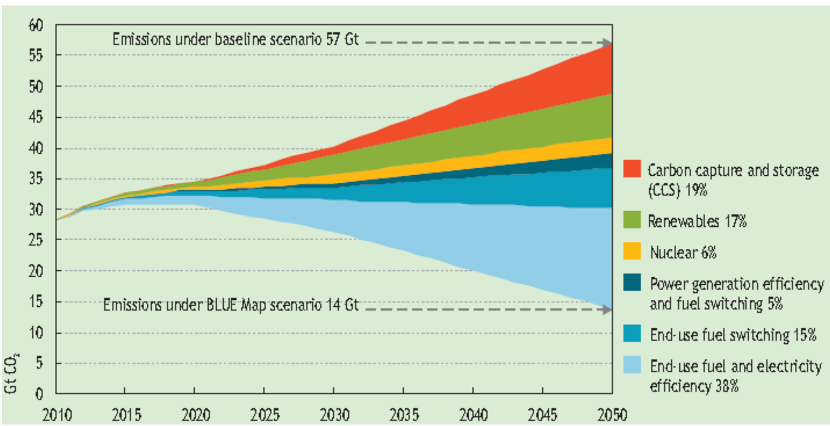
PV : *Photovoltaic*

SMH : *Small Micro Hydro*

ALTERNATIVES AND SOLUTIONS FOR THE FUTURE

There are several existing and emerging technologies that should be increasingly used in every country's energy mix. While some of them have been developed and proven, others are in the process of its development. For sustainability, energy alternatives that do not have high environmental and social impacts should be adopted. Since globally, majority of energy is utilized for heat, electricity generation and transportation, it makes logical sense to look for alternatives – moving away from the conventional sources to non-conventional resources. Electricity generation technologies must utilize resources that have low carbon content, do not cause harm or displace the local populace, and do not burden limited resources like water and the atmosphere.

Chart 14. Key technologies for reducing CO2 emissions



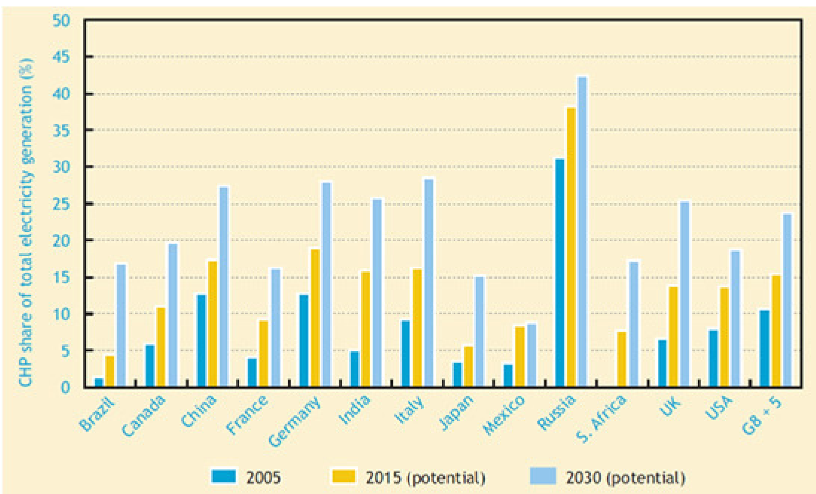
Source: IEA, 2010

In conventional power plants using coal as a fuel, implementation of Integrated Gasification Combined Cycle (IGCC) plants will result in higher generation efficiencies and therefore lower coal consumption and lower emissions. There are several IGCC plants in the world, but their numbers can be increased by retiring the aged coal based power plants with IGCC technology. In India, there are no IGCC plants in operation as yet. Being one of the largest producers of coal based power India there is ample scope to install these plants.

Direct combustion of coal has several implications – high CO2 emission, messy coal handling plants and ash disposal problems. These can be solved using the Coal to Liquid (CTL) and Coal to Gas (CTG) technologies. There are few demonstration plants using these techniques and India too is trying it out. Given the fact that in India, almost 50 percent of the coal reserves are under eco-sensitive forest lands, CTL and CTG technologies will help in utilising the coal in an eco-friendly way. Another technology that has large potential for use is Coal Bed Methanation (CBM) that can be used for multiple purposes – electricity generation, transportation and as a domestic fuel.

Cogeneration (generation of electricity and heat or cooling from the same fuel) plants typically have efficiencies of more than 65 percent as against only electricity generation which have maximum plant efficiency of 40 percent. Some of the cogeneration plants have achieved efficiencies as high as 85 percent, saving precious fossil fuels and cutting down emissions. Unfortunately, cogeneration plants cannot have any standard designs and requires them to be engineered everytime depending upon each location and needs. This is an impediment to its growth. A study conducted by IEA, Paris showed that global potential for cogeneration is 20 percent of total energy generation. As against this, in the year 2005, the world average was only 9 percent. In India, a hot country, the potential to implement cogeneration is low, yet if implemented to its full potential in industries and commercial complexes, the potential could be as high as 25 percent of its total energy needs in 2030.

Chart 15. Major economies' CHP potentials under an accelerated CHP scenario, 2015 and 2030

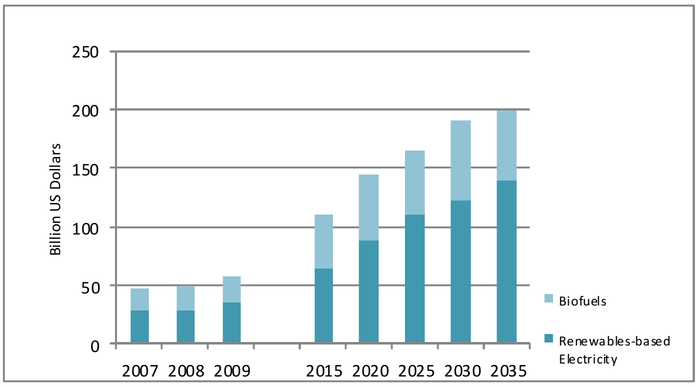


Source : IEA, Paris

Increased use of Renewables is the other alternative that should be used both for electricity generation and transportation. Through proper technology development and financial incentives, share of renewables in global energy mix can be increased substantially.

As depicted in Chart 12. Environmental Impact Study of Various Fuels used in Electricity Generation, resources like water, solar, or wind, also known as Renewables, have the lowest impact on the atmosphere, do not affect social life, use minimum resources, and are sustainable in the long term. With sufficient government support, Renewables can become one of the main resources of energy.

Chart 16 Annual global support for renewables in the New Policies Scenario



Source: IEA World Energy Outlook 2010

The renewable technologies available are:

- Large and Micro Wind Turbine Systems
- Solar PV Systems
- Biomass Systems
- Micro Hydro Systems
- Renewable Hybrid Systems
  - o Wind – Solar Systems
  - o Solar – Thermal Systems
- Geothermal Systems

Emerging technologies that are under development are:

- Tidal Energy Systems
- Biophotosynthesis Systems

Micro Wind Turbine on a roof top

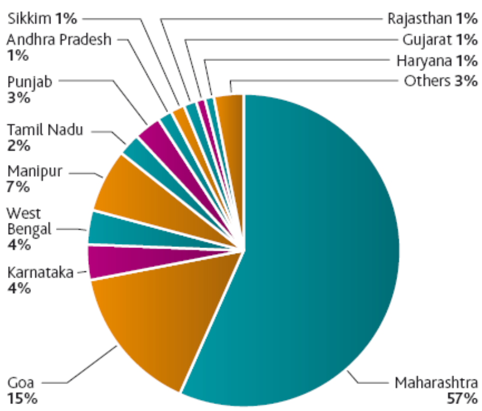
Micro Wind Turbines consists of a small turbine mounted on roof tops of buildings or masts that generate less than 1 kW of power. It is the latest technology in field of renewable energy for generation of energy for private use in rural as well as urban environments. Several such turbines are in operation in US, Europe, Japan and even in India. However, the full potential of Micro Wind Turbines is yet to be realized as shown in Table 3.

Table 3 Potential of Micro Wind Turbines in the World

Facilities	Year					
	2007			2012		
	Number (millions)	Avg. size (kW)	Total MW	Number (millions)	Avg. size (kW)	Total MW
Village Homes	4	10	40,000	5	10	50,000
Single Homes	100	0.3	30,000	150	0.4	60,000
Facilities	7	1	7,000	9	1.5	13,500
Miscellaneous	5	1	5,000	7	1.5	10,500
Total			82,000			1,34,000

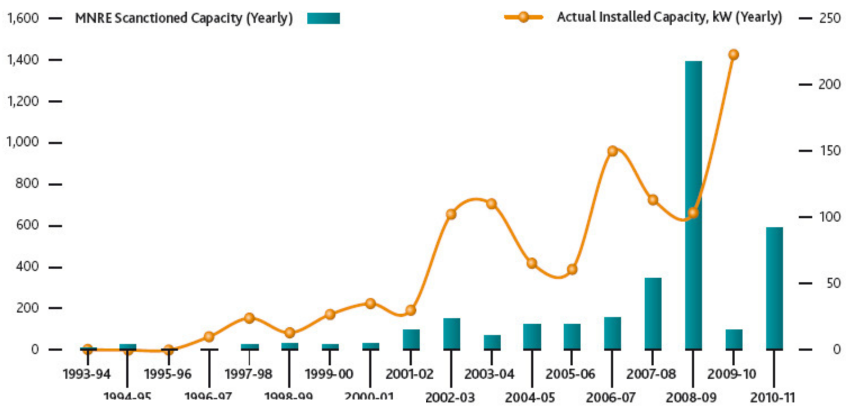
Source: Green Energy Website http://www.greenwindenergy.net/marketpotential.html

Chart 17 State-wise Distribution of Wind - Solar Hybrid Installations in India



Source: MNRE, Government of India

Chart 18 Annual Sanctioned & Actual Installed Capacities of Small Wind Turbines and Wind - Solar Hybrid Systems



Source: MNRE, Government of India

Hybrid Renewable Sources (HRES) consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. HRES are becoming popular in remote area power generation applications due to advances in renewable energy technologies. In developed economies, especially in Europe, HRES is being increasingly used in the domestic sector. In India, after the success of the first-of-its-kind pilot project of setting up a solar hybrid system in one of the villages at Morni hills, Haryana, in 2008, more panchayats have come forward to get a similar system installed in their areas.

Wind – Solar Hybrid Systems consists of a micro wind turbine coupled to a Solar PV system. There are several such systems in operation in the world including India, with a potential to install more systems, integrate it to micro grids of renewable energy systems so that clusters of urban dwellings or villages can be connected to several household just as micro computers are connected through Wide Area Networks (WAN).


A Wind – Solar PV Hybrid

Solar Thermal Hybrid Systems consist of a Solar Panel that generates heat for use in a turbine. While presently, they are more expensive than the PV system and takes more time to install, its advantage over PV system is its generating capacity over PV. The world's largest plant, a 340 MW plant, is in Arizona. Other locations are in Spain, Australia, Middle East and China. In India, Rajasthan has highest potential for solar power followed by Gujarat. Under JNNSM (Jawaharlal Nehru National Solar Mission), Lanco Solar 100 MW in Rajasthan, Reliance Power 100 MW in Rajasthan, Corporate ISPAT 50 MW in Rajasthan and Megha Engineering 50 MW in Andhra Pradesh are in planning solar thermal projects.


Arizona Solar Thermal Project; Source: Wikipedia Commons

A ***Stirling Engine*** is a heat engine that operates by cyclic compression and expansion of air or other gases, the working fluid, at different temperature levels such that there is a net conversion of heat energy to mechanical work which is then converted in to electrical energy. The working fluid is heated using a source of heat which could be either Sun or Waste Heat, making it a low cost generator of electricity. The challenges today are scaling up capacities and making its equipment cost competitive. Today Stirling Engines are mostly in sub kW range. With focused Research and Development, this capacity can be increased to suit most of the distributed generation requirement of 1 – 20 kW ranges when it will be ideal for domestic applications. However, its size limitation can be put to advantageous use too. It can be placed at the focus of a parabolic mirror directly to capture the sun's energy and convert in to electrical energy. Research is going on to see how this application can be commercialized.


Stirling Engine

Stirling Engine mounted on a Solar Dish

Tidal energy is one of the most promising methods of power generation especially for the coastal areas, where the rising tidal waves with large amounts of energy entrapped in them can be used for power generation. Studies the world over, including India, have revealed tremendous potential in this abundant source of energy. The best part is that the energy source is eternal and it is more predictable than either solar or wind energy. The world's first tidal power plant was built in 1966 at Brittany, France. Since then several tidal power plants have been built and the full potential is yet to be realized. In India, Gulf of Khambat, Gulf of Kutch, Sunderbans and East Coast till Tuticorin hold potential to generate at least 10,000 MW of electricity with total generation exceeding 1.6 Tetra Watt Hours (Twh).

Photosynthetic Bioelectricity is one of the most promising methods of electricity generation in future when scientists complete its development for commercial use. Photosynthesis is one of the most efficient ways of producing energy. Found in all plants, it is the most efficient and environment-friendly way of converting the sun's energy into electrical or other types of energy. Scientists are working on further development of this method of energy conversion. And once commercially successful, it can prove to be that innovation, which will meet the world's demand for energy for centuries to come and be a sustainable source of electricity. Scientists in France have transformed the chemical energy generated by photosynthesis into electrical energy by developing a biofuel cell. The advance offers a new strategy to convert solar energy into electrical energy in an environmentally-friendly and renewable manner. Similar work is being carried out in Israel and United States.

The Earth's core has huge source of energy trapped within itself is called Geothermal Energy. As one moves away from the core to the surface, this heat source cools down. But, beneath the Earth's crust (the top land mass) lies a hot surface – hot enough to produce steam and therefore electricity. Though the degree of temperature is not same everywhere, the volcanic activity-prone zones of the world, ironically have many Billion BTUs of energy available that is being tapped. Indonesia has the world's highest potential of Geothermal Energy estimated at more than 28,100 MW. This potential is equivalent to 12 Billion barrels of oil, which nearly doubles the country's 6.4 Billion barrels of oil reserves. Indonesia's National Energy Policy states that by 2025 the country will derive 9,500 MW of power from geothermal sources. As a result, the Energy and Mineral Resources Ministry has set a target of developing 5,000 MW of geothermal electricity by 2014.

Table 4. Potential Geothermal provinces of India

Province	Surface Temperature degrees C	Reservoir Temperature degrees C	Heat Flow milliWatt per square metre	Thermal Gradient degrees C per kilometre
Himalayas	More 90	260	468	100
Cambay	40-90	150-175	80-93	70
West Coast	46-72	102-137	75-129	47-59
SONATA	60-95	105-217	120-290	60-90
Godavari	50-60	175-215	93-104	60

Source: "Geothermal Energy Resources of India" by D. Chandrasekharam, Professor and Head Department of Earth Sciences, Indian Institute of Technology, Bombay, India presented at IBC Conference "Geothermal Power Asia 2000" Manila, Philippines, Feb.2000. SONATA: The area between Cambay in the west to Bakreswar in the east.

In the Transportation Sector, one needs to look at alternatives that consume less crude oil and generate less pollutants, alternatives like renewables. Imposition of norms like Euro 5 and above will help in promotion of these alternatives. Hybrid automobiles, Ethanol blended Diesel for locomotives, and advanced technologies like automotive batteries and storage systems, hold promising potential in the future. Today, they may be expensive. But, governments will have to support these initiatives, so that with the progressive growth of new technologies, they become more affordable and usable. In the process, it would save governments huge investments required to be made in conventional technologies like fossil fuel exploration, infrastructure development, environment protection, and related healthcare costs.

Besides the shift in resources and technologies, one must also look at delivery models that are efficient and do not require large investment in infrastructure. The general rule of 'Big is Attractive' should be done away with and 'Small is Beautiful' must be adopted, thus resulting in a judicious mix of both these models. There is also a need to look for a more Distributed Generation rather than Large Mega Power Plants, which not only are a challenge for infrastructure planners, but also require large investments and have high project gestation times for generating revenues.

With increase in population increases urbanization, and therefore the demand for more energy for electricity, transportation, and daily needs like cooking and food grow. If one follows the 'Business as Usual' model, then the inefficiency of its use will create an artificial increase in demand leading to catastrophic effects. But, with increase in urbanization comes affordability and today people are ready to pay more for better products and services. This is where new technologies and applications come in. Concepts like environment-friendly and hybrid cars at reasonable prices will be preferred over traditional cars that are fuel guzzlers. Standalone electricity generation integrated with water treatment and waste water recycling in commercial and residential complexes will become a reality in the future integrated with Building Energy Management Systems, which will consume much less electricity than a conventional office or a home. Already in developed countries, the local bodies and municipalities have brought in regulations that give tax benefits to the users for complexes that have adopted low energy consumption products and are environment-friendly. In India, some local bodies like the Pune Municipal Corporation, Mumbai Municipal Corporation, and others have started giving tax benefits to eco-friendly office buildings and residential complexes. In Pune alone, it is estimated that through such regulations, in a two-year period, the demand for electricity and water has come down due to the implementation of 'Sewage Recycle Plants', regulated water supply, and Time of Day tariff.

Industries on the other hand should look at Demand Side Management at their locations. While this is easier said than done, regulatory framework and pressure from the utility companies will help in a big way in imposing some discipline on the users' side. It is estimated that Demand Side Management alone can help reduce the demand for electricity by as much as 25-30 percent, in some cases even more that will help curb the huge capacity addition requirements, and hence coal consumption and environmental pollution. Taking into consideration the process heating needs of an industry and the potential savings in energy through Demand Side Management, the reduction in energy demand can be substantial and therefore fossil fuel usage, water demand, and environmental pollution will also reduce.

Besides, Demand Side Management, both the power generation industry and process industries must look at alternative technologies to meet their energy demands. Technologies that need to be pursued passionately are:

- Improvement in generation efficiencies
- Demand Side Management
- Increased use of renewable energy sources

THE SUGGESTED WAY FORWARD

Every country and economy aims to grow. But, to sustain this growth and yet preserve the environment, the following means need to be adopted:

- **Energy Planning:** Energy consumption must be a balanced mix of conventional and renewable sources. To promote higher use of renewables and increase its viability, a fund created out of a cess levied on use of conventional sources of energy will help meet the research and development requirements of renewable technologies.
- **Renovation and retirement:** Old plants using outdated technologies with plant efficiencies less than 27 percent must be either renovated or replaced with modern technologies.
- **Reward instead of penalization:** Reward those who use higher efficiency plants, gadgets or use renewables as their energy source, instead of penalizing them for non-compliance. In this regard, the initiative taken in India by the Bureau of Energy Efficiency (BEE) is commendable.

- **Policies:** Policies facilitating the growth of renewable energy in the existing basket of energy resources must be enforced by the leading energy users of the world. These policies must be supported by suitable financial means, so that they are implemented with the right gusto and effectiveness in those countries where they are needed the most – China, USA, India, Russia, and others
- **Funding:** Adequate funding must be provided by financial institutions: both global and local. Budgetary support from the governments is needed. Funds by the industries must be utilized to adopt advanced technologies, efficiency improvements, and quick adoption of new technologies. Creating a fund from a cess collected from users of conventional energy sources and inefficient plants and products can generate the requisite funding resource.
- **Quick Adoption of New Technologies:** Quick adoption of new renewable technologies will be required if environmental degradation and energy shortage has to stop. The work being done on some of the breakthrough technologies that have far-reaching effects should be adequately funded and encouraged for early commercialization
- **Bring in Distributed Generation into the countries' energy plan:** Going forward, increased distributed generation share in the electricity generation portfolio must be adopted, especially for countries where abundant natural resources are available and are short of conventional sources of energy like coal, oil, and gas. A policy to support integration of distributed generation into the national grid of large plants will go in a long way in this growth
- **Smart Grids:** With about 18-20 percent (in India it is as high as 30- 32 percent, though not all of it is technical loss) of the energy generated being lost in transmission and with the inclusion of more distributed generation in the system, smart grids will play an important role in ensuring availability of energy at the right place, right time and right quality.
- **Demand Side Management through regulations:** Since demand is the main reason for the increase in energy use and therefore searches for more energy resources, demand side management will help keep the need for more energy under check, and control and will be one of the easiest ways to meet the challenges of increased energy demand and preserve the environment.
- **Advanced materials for transport sector:** Use of advanced materials in design of vehicles and automobiles, reducing drag loss resulting in lower fuel consumption, use of Solar PV films and coating for battery storage for hybrid vehicles and higher capacity storage batteries will save on precious fossil fuels.
- **Better roads:** Roads that reduce fuel consumption by reducing travel time, hi-speed railway corridors and efficient locomotives will help reduce fuel oil consumption by at least 20-25 percent over present demand.

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For information regarding permission, write to:

Frost & Sullivan India Pvt Ltd
Tower 6, 4th Floor, Solitaire Corporate Park
Chakala, Andheri (East), Mumbai - 400 093
Maharashtra, India
Phone: + 91 - 22 – 6160 6666
Fax: + 91 - 22 – 28324713
Email: ravinder.kaur@frost.com