# Governance & Development: Views from G20 Countries

**Session 3** **Presentation**

## Third Industrial Revolution and India's Approach to Sustainable Energy Development

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# Third Industrial Revolution and India's Approach to Sustainable Energy Development

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- Industrial Revolution in its various phases has been induced by the discoveries of different energy resources and technologies for their transformation and innovative uses.

- There has been a convergence of a new communication technology with that of energy in each phase having revolutionary impact on social and economic organization, human capital formation and knowledge capital development.

# First Industrial Revolution: revolved around coal and steam energy.

- Fall Out:

1. Development of railways
2. Factory system of production
3. Steam powered printing technologies with rotary press, linotype etc.

- Explosion of printed communication- books, newspapers, journals etc.

- Spread of mass literacy contributing to the development of a skilled work force which could organize and manage industrial production.

# Second Industrial Revolution: Revolved around hydrocarbons and electricity

- Fall Out:

1. Automobile revolution and highway development
   - Locational reorganization of habitats and production.
   - Social reorganization accompanied further by the development of electrical communication - telecommunication, telegraph, radio, TV etc.

2. Use of electricity (cleanest fuel) vastly raised the efficiency of use of material and energy resources and also cleanliness of the workplace.

Fast communication having an important impact on human mobility and opportunities of betterment of life and flow of knowledge and information.

# Gas emissions

- However fossil fuels which drove the two revolutions have had serous adverse consequences due to Green House Gas emissions and other solid and liquid effluent waste arising.

- Global Warming and Climate change and environmental degradation. Upward pressure on carbon footprint and ecological footprint.

- Hence the search for new carbon free renewable energy resources to bring about a new third revolution.

# Third Industrial Revolution

1. Would revolve around the development of renewable, hydrogen and fuel cell technology and that of energy internet for energy sharing.
2. It is based on five pillars:

- Every house, building, factory to become a power plant.
- Power to be produced mainly out of renewable resources – biotic and abiotic – other than storage hydro resources.

# Contd..

3. Energy resource development to converge with the development of the communication technology of internet leading to the emergence of smart grid of power.
   - This would enable two way flow of information and energy for energy sharing and improving overall energy system efficiency.
4. Automobiles are to be driven by electricity replacing internal combustion engine.
5. Hydrogen to be developed as energy resource and fuel cell as a device of storage and supply of electricity as per requirement.

# Contd..

- All these would be accompanied by fast digitization of manufacture. Infrastructural operations and development of new synthetic materials and technologies (like 3D printing) which will enable the achievement of higher energy efficiency, reduce micro level scale of production and make production of complex commodities cost effective.

- Emergence of distributed capitalism, inclusive growth along with higher energy system efficiency.

- Growth of deployment of clean technologies shows growth rate in the range of 27% to 56% in the first decade of the present century.
- However, we are still grappling with the problems of the Second industrial revolution
- There is still a huge dependency on fossil fuels.
  - fossil fuel has supplied 50% of the new energy demand
  - oil has supplied 94% of the total fuel requirement of the transport sector
  - non-hydro power from renewable supplied only 3% of the final energy produced in 2009

- This has led to steady rise in the $CO_2$ emission by G-20 countries, the world emission level in 2010 reached a record high of 30.6 giga tonne
- The G-20 countries today account for 80% of the energy related $CO_2$ emission
- Per capita $CO_2$ emission widely varies across countries in the range from 1.4 to 17.7 tonnes as was found in 2009.

## Ecological Footprint and Bio-Capacity (global hectares per capita), 2007

| | Population (million) | Total Ecological Footprint | Carbon Footprint | Share of Carbon Footprint in Total Ecological Footprint | Total Biocapacity | Ecological (Deficit) of Reserve |
|---|---|---|---|---|---|---|
| **World** | 6.476 | 2.7 | 1.41 | 52.2 | 2.1 | -0.6 |
| **China** | 1323.3 | 2.1 | 1.13 | 53.8 | 0.9 | -1.2 |
| **India** | 1103.4 | 0.9 | 0.33 | 36.7 | 0.4 | -0.5 |
| **Japan** | 126.1 | 4.9 | 3.58 | 73.1 | 0.6 | -4.3 |
| **North America** | 330.5 | 9.2 | 6.21 | 67.5 | 6.5 | -2.7 |
| **Canada** | 32.3 | 7.1 | 3.44 | 48.5 | 20 | 13 |
| **USA** | 298.2 | 9.4 | 6.51 | 69.3 | 5 | -4.4 |
| **Europe(EU)** | 487.3 | 4.7 | 2.58 | 54.9 | 2.3 | -2.4 |

*Source: Global Footprint Network 2008, www.footprintnetwork.org*

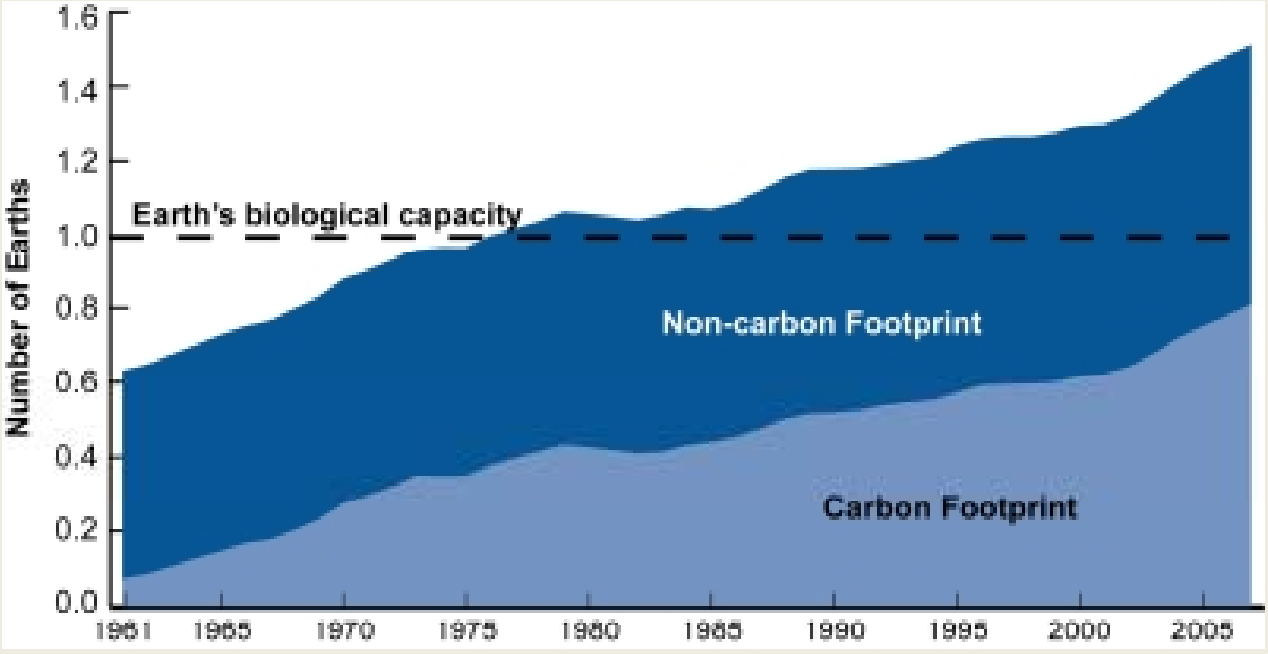


**Fig. 9.2: INDIA'S ECOLOGICAL FOOTPRINT, BIOCAPACITY AND DP, 1961-2003**

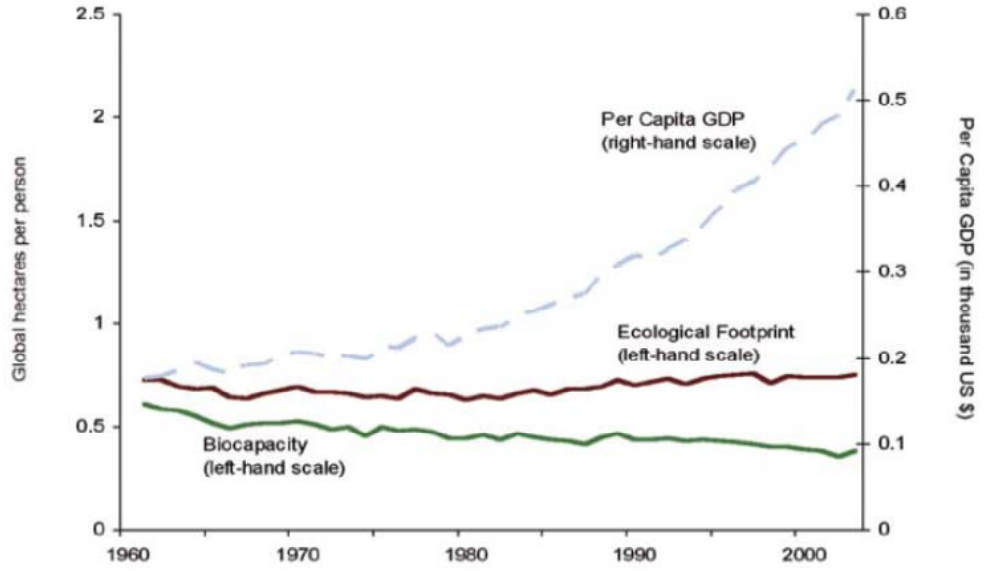
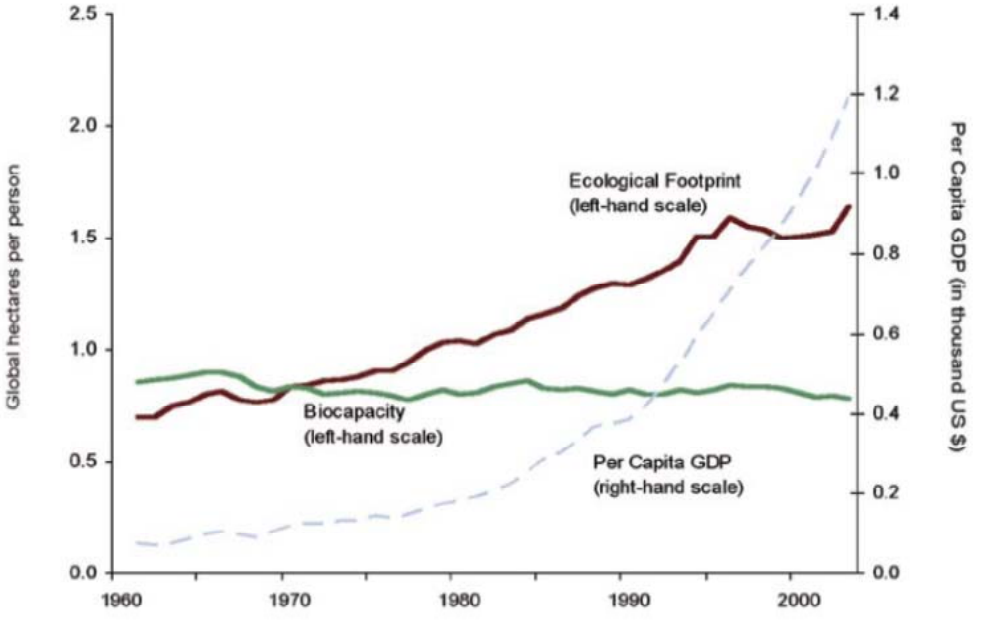



**Fig. 9.1: CHINA'S ECOLOGICAL FOOTPRINT, BIOCAPACITY AND GDP, 1961-2003**



- In India about 35% rural households have no access to reliable supply of electricity and about more than 80% of the rural households are primarily dependent on unclean unconverted polluting biomass for meeting their cooking fuel.
- This poses a big problem of health hazard.
- In order to alleviate energy poverty, there has to be rise in the supply of modern clean energy of electricity and natural gas implying an upward pressure on $CO_2$ emission.

- To ensure the control of GHG emission the G-20 countries need to co-operate and give special thrust to the following issues:
  - Energy conservation by raising efficiency of end use of energy
  - Raising the efficiency of energy resource conversion into electricity and its distribution
  - Raising the share of carbon free or carbon neutral resources in electricity generation
  - Carbon capture and storage as and when the technology stabilizes and attains maturity

- Ushering of a third industrial revolution as induced by deliberate policy initiative and co-ordination at international level would contribute substantively to the mentioned objectives of sustainable energy development.

- This would be achieved mainly through the accelerated introduction of non-hydro renewables, development of energy internet for energy sharing through a smart grid and through the digitization of manufacture and infrastructure.

## Table Showing Energy Efficiency Performance Indicators for Selected Regions

Source: World Development Indicators, UN (2011)

| Country | Purchasing Power Parity Gross National Income (Per Capita $) | Energy per capita koe | Energy Intensity of GDP (Koe/PPP 2005$) | Share of Biomass in total Primary Energy (%) | Electricity Consumption per capita (in KwH) for 2008 |
|---|---|---|---|---|---|
| Brazil | 11000 | 1243 | 0.087 | 31.6 | 2408.36 |
| China | 7640 | 1695 | 0.270 | 9.0 | 2775.74 |
| India | 3400 | 560 | 0.196 | 24.5 | 778.49 |
| Japan | 34610 | 3700 | 0.126 | 1.4 | 8158.30 |
| Russia | 19240 | 4561 | 0.333 | 1.0 | 6976.74 |
| South Africa | 10360 | 2921 | 0.312 | 9.8 | 5006.08 |
| USA | 47310 | 7051 | 0.169 | 3.9 | 13568.07 |
| European Union | 11399 | 3536 | 0.120 | 6.7 | 6863.30 |

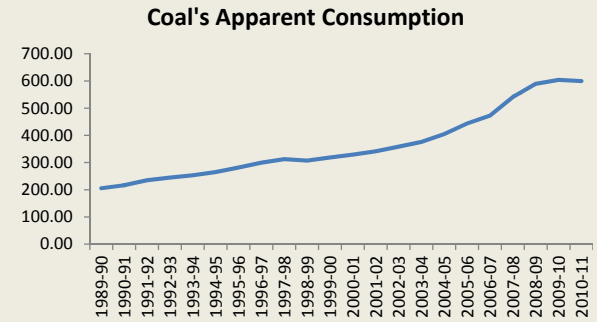
**India's Energy Scenario:**

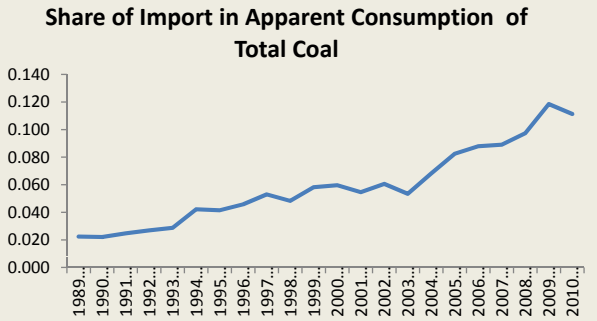
**Composition of Primary Commercial Energy**

| Coal | Oil | N.Gas | Total Fossil | Hydro | Nuclear | New Renewables | Carbon.Fr. Renewables | Total |
|---|---|---|---|---|---|---|---|---|
| 55.2 | 31.1 | 10.1 | 96.4 | 1.9 | 1.3 | 0.38 | 3.58 | 100 |

# Apparent Consumption of Coal

- The sum total of production and net imports for coal give us the Apparent Consumption of coal (Coking + Non-coking Coal) not taking account of stock adjustment.
- The share of net imports in Coal's Apparent consumption is rising; we are increasingly turning to imports to meet our demand.

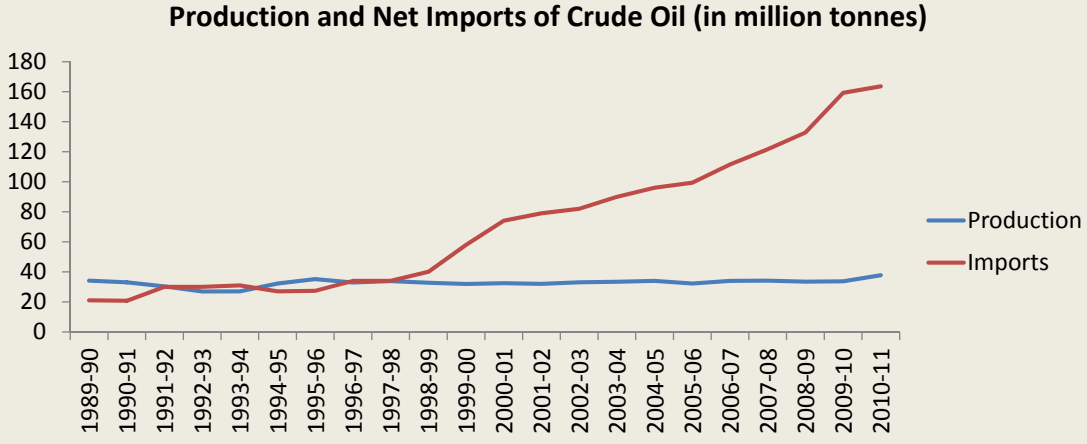



| Year | Apparent Consumption in million tonnes | Share of Imports in % |
|---|---|---|
| 1989-90 | 205.48 | 2.2 |
| 1994-95 | 264.91 | 4.2 |
| 1999-00 | 318.51 | 5.8 |
| 2004-05 | 404.85 | 6.8 |
| 2010-11 | 599.75 | 11.1 |
| Growth: | 5.16% | 7.94% |

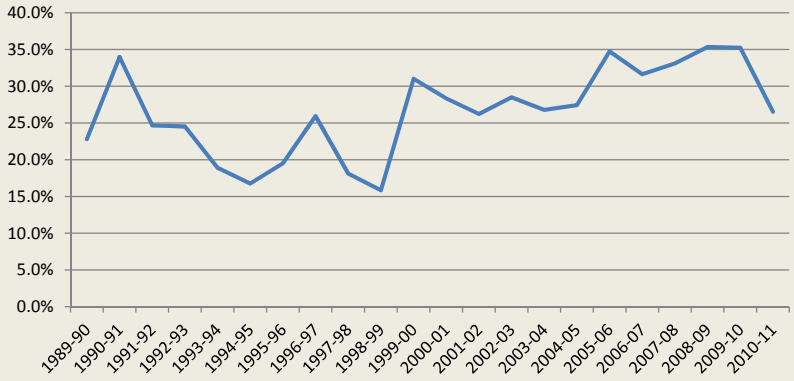
# Oil

- India imports most of its crude oil and its export of oil is virtually zero.
- India has developed sufficient processing capacity over the years to produce different petroleum products and become a net exporter of petroleum products. Net import of oil after adjustment of export of products has been always positive and growing fast.
- China and India have registered the highest growth in oil consumption in the world, and security of oil import seems to be the number one concern for both the countries




Source: Author's own calculations

## Share of Value of Oil Imports in Total Export Earnings

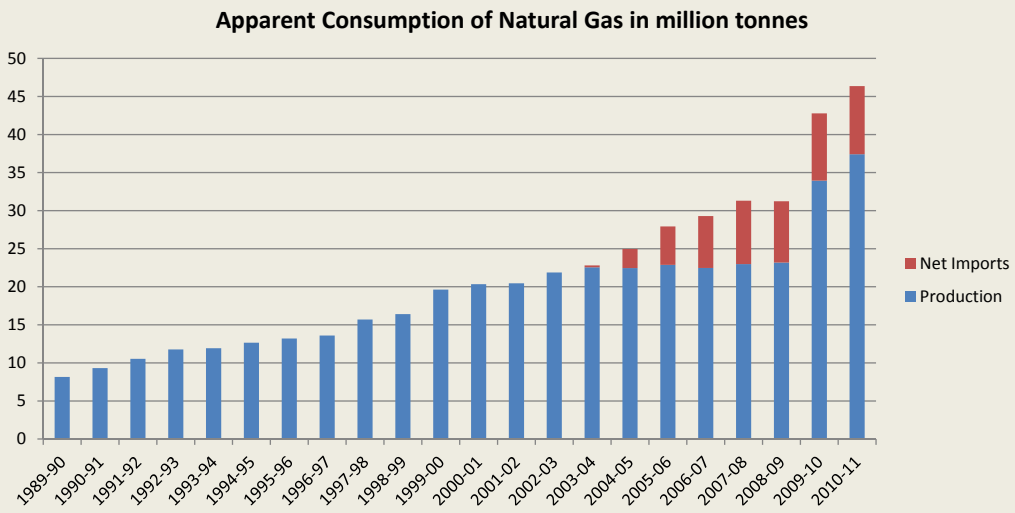



Source: Author's own calculations

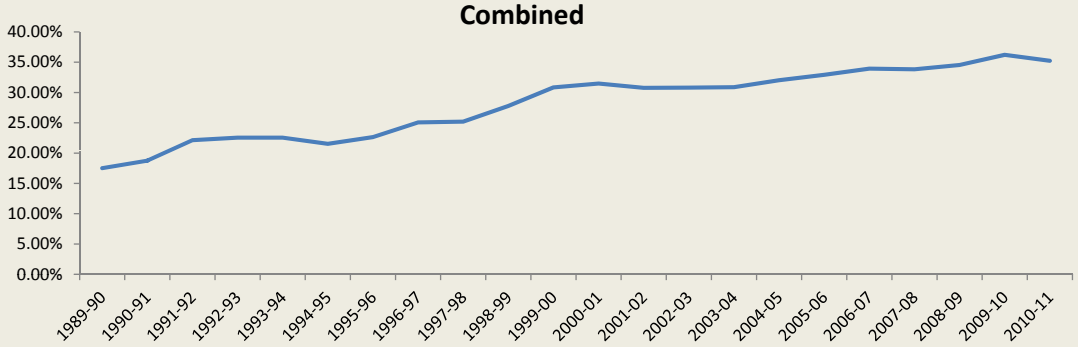
| Year | Share in Total Export Earnings |
|---|---|
| 1989-90 | 22.8% |
| 1994-95 | 16.85% |
| 1999-00 | 31% |
| 2004-05 | 27.4% |
| 2010-11 | 26.5% |

## Apparent Consumption of Natural Gas

- The sum total of production and net imports give us the Apparent Consumption of natural gas not taking account of stock adjustment.
- For the initial few years of our analysis, the quantity of net imports has been quite low and therefore its share in total apparent consumption is almost zero till 2004-05



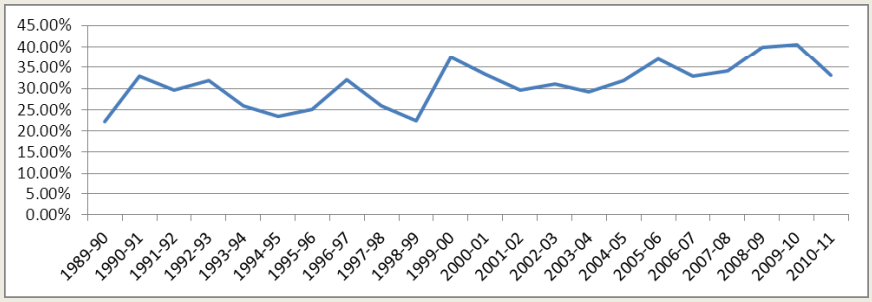
## Share of Net Imports in Apparent Consumption of Fossil Fuels Combined



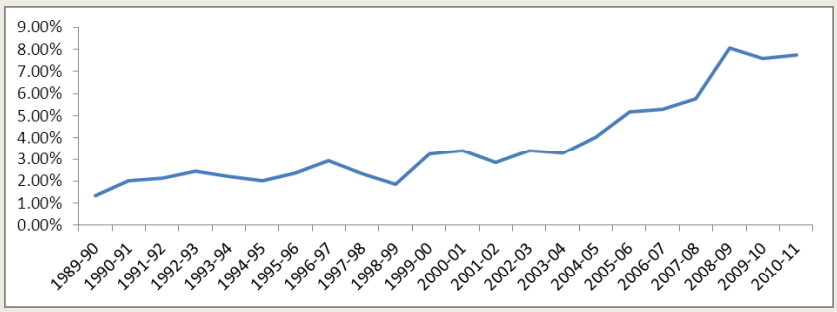

| Year | 1989-90 | 1994-95 | 1999-00 | 2004-05 | 2010-11 | Growth (in %) |
|---|---|---|---|---|---|---|
| Apparent Consumption | 153.32 | 193.45 | 258.95 | 318.15 | 466.61 | 5.36% |
| Net Imports | 26.85 | 41.63 | 79.8 | 101.86 | 164.35 | 8.79% |
| Share of Net Imports | 17.5% | 21.5% | 30.85% | 32.02% | 35.2% | 32.5% |

Source: Author's own calculations

## Share of Value of Fossil fuel Imports in Total Export Earnings




## Share of Value of Fossil fuel Imports in India's GDP




| Year | Share in Total Export Earnings |
|---|---|
| 1989-90 | 25.01% |
| 1994-95 | 18.74% |
| 1999-00 | 33.93% |
| 2004-05 | 31.79% |
| 2010-11 | 38.05% |

Source: Author's Own Calculations

• The growing imbalance between demand and supply of fossil fuel resources from domestic sources results in a growing share of imports in apparent consumption as well in export earnings if the supply from domestic sources grows at a much slower rate than demand because of ***inadequate accretion of reserves caused by slow discovery of deposits and inadequate technical progress in the recoverability of reserves and high cost of new sources of non-renewable resources.***

• This imbalance can result in the growing share of nominal energy import bill in the nominal total export earnings as we have noted above.

• How far such imbalance or deficit would create pressure on exchange rate and macroeconomic financial condition would depend on how far the growth of service exports, net remittances received from abroad and the inflow of foreign capital in the form of foreign direct investment or portfolio investment in equity or other financial stocks or instruments can offset the effects of growing current account balance of trade deficit .

## Energy Efficiency Issues:
## Elasticities of Energy Use in India.

Source: Author's own estimation using IEA Data on Energy balances of Non-OECD countries, different volumes.

| Variable / Period | 1971-1990 | 1991-2000 | 2000-2009 | 1991-2009 |
|---|---|---|---|---|
| GDP at Factor Cost | - | - | - | - |
| Total Primary Energy | 0.9400 | 0.5617 | 0.3612 | 0.4562 |
| Total Primary Commercial Energy | 1.3275 | 0.8424 | 0.7379 | 0.7840 |
| Final Energy | 1.0841 | 0.6186 | 0.7336 | 0.6308 |
| Gross Generation of Electricity | 1.7995 | 1.1079 | 0.7026 | 0.8845 |
| Final Use of Electricity | 1.7254 | 0.8921 | 0.9405 | 0.8318 |

• These growth rates or elasticity estimated are regression based over time and show that there has been a substantive drop of the decadal or period GDP elasticity of energy at all levels of final commercial energy, primary energy, primary commercial energy and particularly of electrical energy over time.

• The final commercial energy intensity of GDP (excluding the share of residential sector) has declined at an annual average rate of 3.52% during the post reform period while the primary commercial energy intensity and CO2 intensity of GDP declined at the rate of 4.09% and 2.37% respectively per annum during the same period.

• It may further be noted that while the fuel composition of primary energy resources of the economy has shown gradual substitution of non-commercial biomass energy by modern commercial cleaner and efficient energy, the fuel composition of primary commercial energy and electricity generation have remained rigid for over time in India as reflected in such results.

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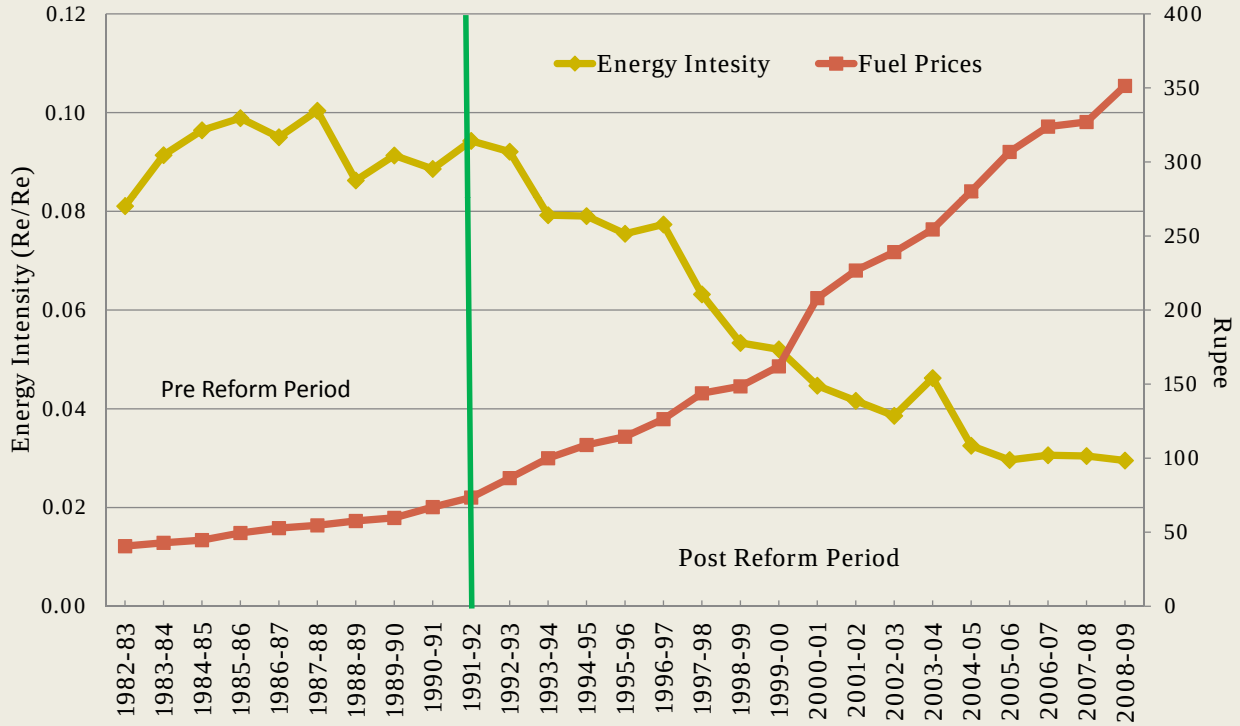
•At micro industry level, there exists substantive scope of energy conservation

**Potential of Energy Saving in % of the Actual Consumption in 7 Selected Industries in 2007-08**

| S. No | Name of Industry | Range of Saving (in %) |
|---|---|---|
| 1 | Textile Industry | 46-88 |
| 2 | Paper and Pulp Industry | 43-94 |
| 3 | Iron and Steel Industry | 51-92 |
| 4 | Fertilizer Industry | 26-94 |
| 5 | Chor-Alkali Industry | 37-95 |
| 6 | Cement Industry | 30-84 |
| 7 | Aluminium Industry | 9-58 |

Source: Author's Own Calculations

**Energy Intensity of Indian Manufacturing Sector and Real Energy Price [1982-83 to 2008-09]**




Source: Author's Own Calculations

## Energy Saving Potential in Infrastructure

| Intervention | Sector | Potential Energy Savings (in %) |
|---|---|---|
| Various motors, drives capacitors, etc. for energy intensive industries like steel, cement, aluminum, glass, etc. building | Cross-cutting | 10 to 20 |
| Lighting | Commercial/industrial/institutional | 50 to 60 |
| Efficient Pumpset | Agriculture | 30 |

Source: Suki Lenora (2010) which obtained from Bureau of Energy Efficiency (BEE) and India Renewable Energy Development Authority (IREDA).

## Future Energy Scenarios

| Scenario | Description |
|---|---|
| Scenario 1(Baseline) | 8% GDP growth rate, 0% annual rise in real energy price, baseline use of new renewables |
| Scenario 2 | 8% GDP growth rate, 3% rise in real energy price per annum, baseline use of new renewables |
| Scenario 3 | 8% GDP growth rate, 0% rise in real energy price per annum, Accelerated use of new renewables |
| Scenario 4 | 8% GDP growth rate, 3% rise in real energy price per annum, Accelerated use of new renewables |
| Scenario 5 | 6% GDP growth rate, 0% rise in real energy price per annum, baseline use of new renewables |

## Estimated Medium Term (2023) Potential and Cumulative Achievement

| Source | Units | Estimated Potential | Cumulative Achievements as on 31.03.2007 | Capacity Factor | Potential Generation (Bkwh) |
|---|---|---|---|---|---|
| **Power from Renewables** | | | | | |
| **Grid Interactive Renewable Power** | | | | | |
| **Bio power from agro residues etc.** | MW | 16881 | 524.8 | 60% | 88.72654 |
| **Wind Power** | MW | 45195 | 7092 | 25% | 98.97705 |
| **Small hydro (<25 MW)** | MW | 15000 | 1975.60 | 20% | 26.28 |
| **Cogeneration (Bagasse)** | MW | 5000 | 615.83 | 60% | 26.28 |
| **Waste to Energy** | MW | 7000 | 43.45 | 60% | 36.792 |
| **Solar** | MW | 50000 | 2.92 | 20% | 87.6 |

Source: Eleventh Plan Document (Planning Commission), Expert Group on Low Carbon Strategies for Inclusive Growth of the Planning Commission (2011) and Interview with World Institute of Sustainable Energy (WISE) in 2012.

## Gross Generation of Electricity (in Bkwh) for 6% GDP growth

| | With 0% Energy Price Rise | | | With 3% Energy Price Rise | | |
|---|---|---|---|---|---|---|
| Year | Gross Generation (in Bkwh) | Per Capita Gross Generation (kwh/capita) | Installed Capacity Requirement (MW) | Gross Generation (in Bkwh) | Per Capita Gross Generation | Installed Capacity Requirement (MW) |
| 2009 | 979.87 | 811.33 | 186429 | 979.87 | 811.33 | 186429 |
| 2021 | 1400.99 | 999.36 | 266551 | 1200.50 | 856.34 | 228406 |
| 2031 | 2039.59 | 1328.35 | 388050 | 1633.02 | 1063.56 | 310696 |

Source: Author's Own Calculations

## Gross Generation of Electricity (in Bkwh) for 8% GDP growth

| | With 0% Energy Price Rise | | | With 3% Energy Price Rise | | |
|---|---|---|---|---|---|---|
| Year | Gross Generation (in Bkwh) | Per Capita Gross Generation | Installed Capacity Requirement (MW) | Gross Generation (in Bkwh) | Per Capita Gross Generation | Installed Capacity Requirement (MW) |
| 2009 | 979.87 | 811.33 | 186429 | 979.87 | 811.33 | 186429 |
| 2021 | 1537.28 | 1096.58 | 292481 | 1356.25 | 967.45 | 258038 |
| 2031 | 2577.99 | 1679 | 490485 | 2057.70 | 1340.15 | 391495 |

Source: Author's Own Calculations

## Share of Fuels in Electricity Generation- Baseline Growth in Electricity from Renewables Scenario

| Year | Coal | Gas | Fuel Oil | Hydro Electricity | Nuclear | Renewables |
|---|---|---|---|---|---|---|
| 2009 | 70% | 11.5% | 1.7% | 13% | 2.3% | 1.5% |
| 2021 | 65% | 14% | 1.7% | 13% | 2.3% | 4.0% |
| 2031 | 60% | 16% | 1.0% | 13% | 2.3% | 7.7% |

Source: Author's Own Calculations

## Share of Fuels in Electricity Generation- Accelerated Generation using Renewables

| Year | Coal | Gas | Fuel Oil | Hydro Electricity | Nuclear | Renewables |
|---|---|---|---|---|---|---|
| 2009 | 70% | 11.5% | 1.7% | 13% | 2.3% | 1.5% |
| 2021 | 60% | 14% | 1.3% | 13% | 2.3% | 9.4% |
| 2031 | 50% | 16% | 1.0% | 13% | 2.3% | 17.7% |

Source: Author's Own Calculations

**Primary Commercial Energy Intensity of GDP (goe/ rupee)**

| Year | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| 2009 | 9.89 | 9.89 | 9.89 | 9.89 | 9.89 |
| 2021 | 6.65 | 5.60 | 6.67 | 5.61 | 7.37 |
| 2031 | 5.23 | 3.74 | 5.27 | 3.78 | 5.92 |

Source: Author's Own Calculations

**Per Capita Primary Commercial Energy (toe/ capita)**

| Year | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| 2009 | 0.303 | 0.303 | 0.303 | 0.303 | 0.303 |
| 2021 | 0.441 | 0.372 | 0.442 | 0.373 | 0.391 |
| 2031 | 0.684 | 0.490 | 0.690 | 0.494 | 0.513 |

Source: Author's Own Calculations

**$CO_2$ Emissions Intensity of GDP (g/rupee)**

| Year | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| 2009 | 63 | 63 | 63 | 63 | 63 |
| 2021 | 38.3 | 33.1 | 36.6 | 31.7 | 43.1 |
| 2031 | 27 | 20.5 | 24.6 | 18.6 | 31.6 |

Source: Author's Own Calculations

**Per capita CO2 Emissions**

| Year | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| 2009-21 | 1.93 | 1.93 | 1.93 | 1.93 | 1.93 |
| 2021-31 | 2.54 | 2.2 | 2.43 | 2.10 | 2.29 |
| 2009-31 | 3.53 | 2.69 | 3.22 | 2.44 | 2.74 |

Source: Author's Own Calculations

**GDP Elasticity of Emissions**

| Year | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| 2009-21 | 0.451 | 0.2954 | 0.4038 | 0.248 | 0.451 |
| 2021-31 | 0.5368 | 0.3704 | 0.4746 | 0.304 | 0.459 |
| 2009-31 | 0.49 | 0.329 | 0.436 | 0.273 | 0.455 |

Source: Author's Own Calculations

**Percentage Drop in $CO_2$ Intensity of GDP**

| Year | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 |
|---|---|---|---|---|---|
| 2009-2021 | 33 | 43 | 33 | 43 | 25 |
| 2021-2031 | 21 | 33 | 21 | 33 | 20 |
| 2009-2031 | 47 | 62 | 47 | 62 | 40 |

Source: Author's Own Calculations

## Conclusion

- As per the projections of the current study, the total CO2 emission which is supposed to be responsible for the carbon footprint, would rise from 2.3 billion tonnes in 2009 to somewhere in the range of 3.7 billion to 5.4 billion tonnes in 2031-32 for 8% GDP growth
- The Integrated Energy Policy Committee Report of the Planning Commission projected such total primary commercial energy requirements and the supporting supply to meet them for 8% growth rate under alternative assumptions of technology, fuel choice and energy conservation that had implied the total CO2 emission to vary in the range of 3.9 billion tonnes to 5.5 billion tonnes in 2031-32.
- It is thus a robust conclusion that **India would be able to substantively weaken the CO2 emission – growth linkage by reducing the CO2 intensity of GDP in the coming decades as evident from the implicit decline in GDP elasticity of CO2 emissions in both the studies.**

- How cost effective the transition to the new industrial order would be. The new technologies of the third revolution would in fact be highly knowledge intensive.

- As the patented knowledge market is highly imperfect and monopolistic, the capital cost of such transformation process may become quite high, standing in the way of cost effectiveness and the redistribution of capitalism in the new order.

- So far as the inclusiveness of the development process is concerned, wide sharing of knowledge, transfer of technology and control of price of the knowledge capital by governmental intervention become important for both the sharing of the benefit of the new industrial revolution between the rich and the poor and between the developed and the developing countries

- Co-operation among G-20 countries in joint research in science and technology and in sharing and transferring technologies across borders would only enable the developing countries to leapfrog to a higher stage of development characterized by the Third revolution.

- The intellectual property right regime would be of critical importance in such knowledge sharing and delivering the R&D output to the users at affordable prices .

- All the renewable energy resources are ultimately solar powered. The divergence between the time distribution of the demand for electric power and that of solar powered resource supply like wind and sunlight which often *widely* fluctuates and creates the problem of full utilization of such opportunities as well as that of meeting the demand. This may require *strong* and *wide costly* grid connectivity.

- It is difficult to conceive how the supplies from a large number of small to medium scale power generation units or stations can be synchronized with the demand of large point sources like steel, aluminum, paper, railway traction etc;
- Unless the industrial landscape of the economy drastically changes to be one of cottage and small to medium scale units.
- Can digitization and automated control of production processes and new materials based technologies effect such a transformation of the industrial economy?

- Energy saving potential in the existing industrial system in both non energy end use and energy conversion and supply sectors is an important resource with potential to meet the growing final energy demand at lower resource cost.
- The Government of India should continue to give due priority to the policies for energy conservation and faster delinking of carbon emission with growth. This would contribute substantively in the transition to the Third Revolution.

- On the front of fuel substitution , as part of the National Action Plan on climate change the Government of India has mandated certain share of new renewable energy in the total annual electrical energy supply to the meet requirements over the time horizon 2009-10 to 2016-17 starting with 5% in 2009-10 and ending up with 12% share in the terminal year of 2016-17.

- However, the actual capacity addition of new renewables is falling short of the requirement to implement such mandates as their exist great uncertainties regarding their implementability in view of the unwillingness of distributors to buy such high cost power in a regulated regime of fixed tariffs.

- Economic reforms in India particularly in the power sector need to be innovative to induce greater and faster development of entrepreneurship.

- A transition to the third industrial revolution and India's becoming a partner in guiding and participating in the transition process would demand long range vision and political will of the leaders and policy makers and substantive development of our institutional capability through better reform directed towards the transition.

***Thank you***