National Energy Map for India: Technology Vision 2030 and Low Carbon Paths

Seminar on Climate Change, CDM and Renewable Energy
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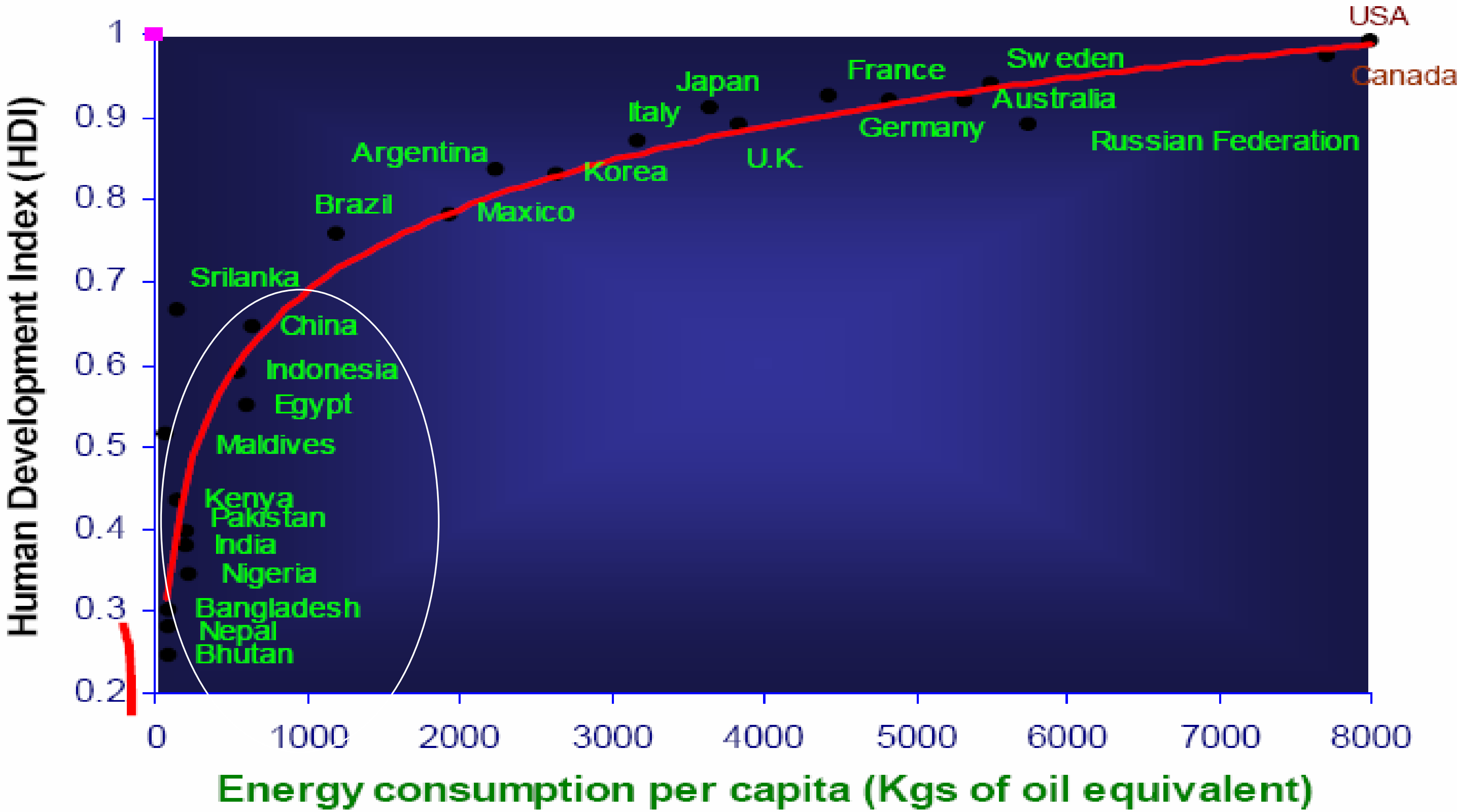
India's Energy Situation

- Development objectives require the Indian economy to grow at 8%
- Low (One fifth the world average) per capita commercial energy consumption
- High dependence on traditional energy sources in rural (75%) areas; urban (22%) – environmental and health implications
- Low vehicle ownership and rising incomes, aspirations

Human Development Index VS Energy Consumption per capita



Ali Sayigh, 2005

http://europa.eu.int/comm/research/energy/pdf/18_sayigh_en.pdf

Energy Policy concerns

- Energy Access
- Energy Security
- Economic efficiency
- Environmental protection

Objectives of the TERI study

- Develop a framework for optimal exploitation of energy resources through appropriate technology deployment
- Determine the energy technology policies and strategies that would lead to optimal use of energy resources
- Suggest technology deployment strategy at the national level given India's energy resources
- Identify energy demand, supply and energy technology related data gaps

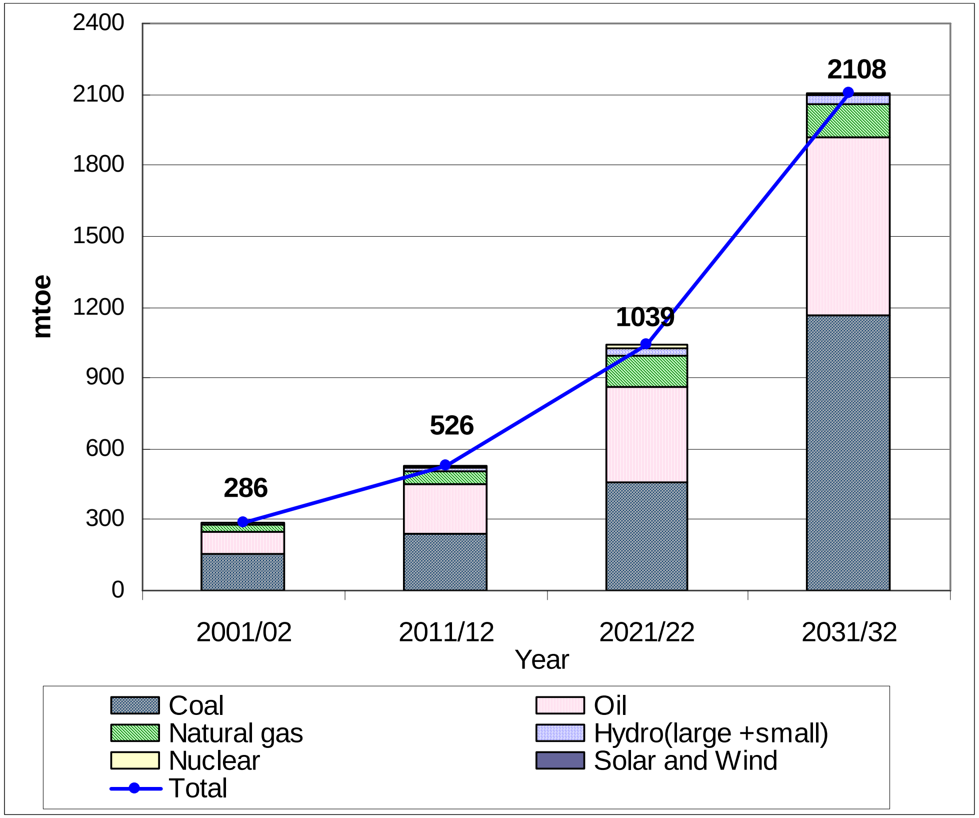
Main Assumptions

- Time-Frame: 2001-2036 (5- yearly results till 2031)
- Population: ~1.4 billion by 2030 *(Population Foundation of India, GoI)*
- Gross Domestic Product and its sectoral distribution: overall CAGR 8% *(Planning Commission)*
    - Alternative GDP growth rates: 6.7% and 10% are also considered
- End use sectors: Agriculture, Industry, Transport, Residential & Commercial
- Fuel availability as per Government of India's polices and plans
- 2005 energy prices

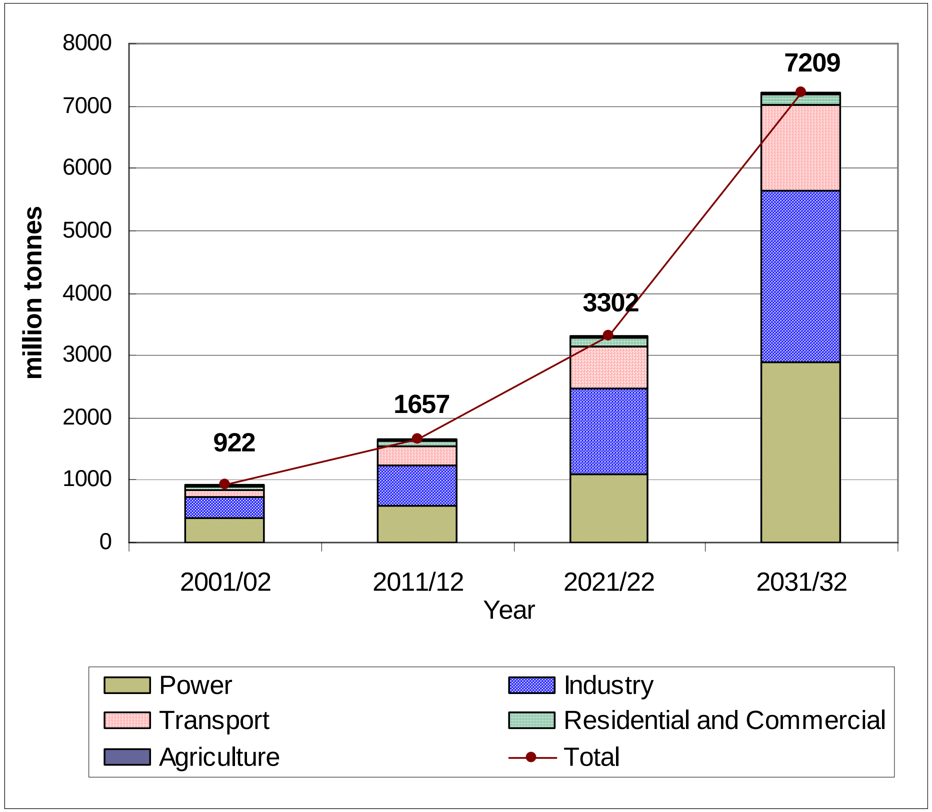
Results

Energy Demand and Associated CO_2 Emissions in India (BAU scenario)

Commercial Energy Requirements



CO_2 Emissions from Energy Use



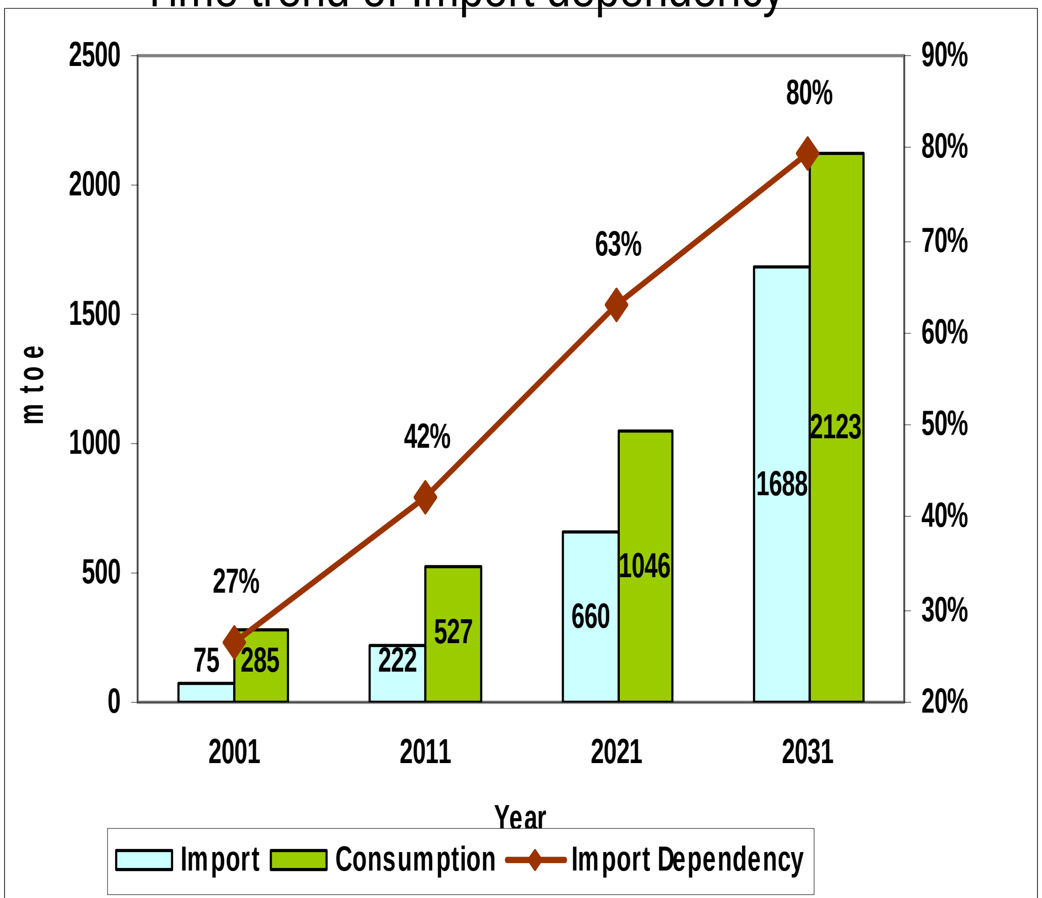
Source: TERI estimates, (2006)

Most developing countries are on the pathway of developing their economies

→ Increased energy consumption & GHG emissions

Energy Security: High Import Dependency - BAU

Time trend of Import dependency



Fuel Import in 2031

- ❖Coal import: 1438 MT
  - ➢~4 times of consumption in 2001
  - ➢Import dependency: 78%
- ❖Oil import: 680 MT
  - ➢Import dependency: 93%
- ❖Gas import: 93 BCM
  - ➢Import dependency: 67%

❖Maximum indigenous production levels for all fuels is achieved by the year 2016

Implications

- Issues
  - Energy security and economic strain due to increasing imports
  - Additional burden on already stressed infrastructure
  - Impact on environment
- No path breaking solutions in sight over next couple of decades
  - India does not have the luxury of choices
  - Dominant role of coal & oil: environmental implications
- Minimize energy needs whilst achieving economic growth to reduce stress on infrastructure, economy and environment – Sustainable development pathways

Economy-Wide Scenarios

Socio-Economic

- **BAU scenario -** 8% GDP growth rate (BAU)
- **Low-growth scenario-** 6.7% GDP growth rate (LG)
- **High-growth scenario-**10% GDP growth rate (HG)

Technology-Deployment

- **BAU scenario (BAU)**
- **High-nuclear capacity (NUC)**
- **Aggressive renewable energy (REN)**
- **High-Efficiency scenario (EFF)**
- **Hybrid scenario (8% GDP) (HYB)**
- **High hybrid scenario (10% GDP) (HHYB)**

Key assumptions of Scenarios

- **<u>High-nuclear capacity</u>**
  - Nuclear-based generation capacity considered to increase to 40 GW by 2021 and 70 GW by 2031/32

- **<u>Aggressive renewable energy</u>**
  - 12 GW of wind capacity to be installed by the year 2036. Availability factor of wind power plant assumed to increase from 17.5% in 2001 to 26% in the year 2011 and 35% in 2016 onwards.
  - Installed capacity of SPV based power plant assumed to increase up to 20 GW in 2036.
  - Lower-bound on the installed capacity of biomass based power generation to the extent of 8 GW in 2031
  - Bio-diesel penetration to the extent of 32 mtoe by 2031

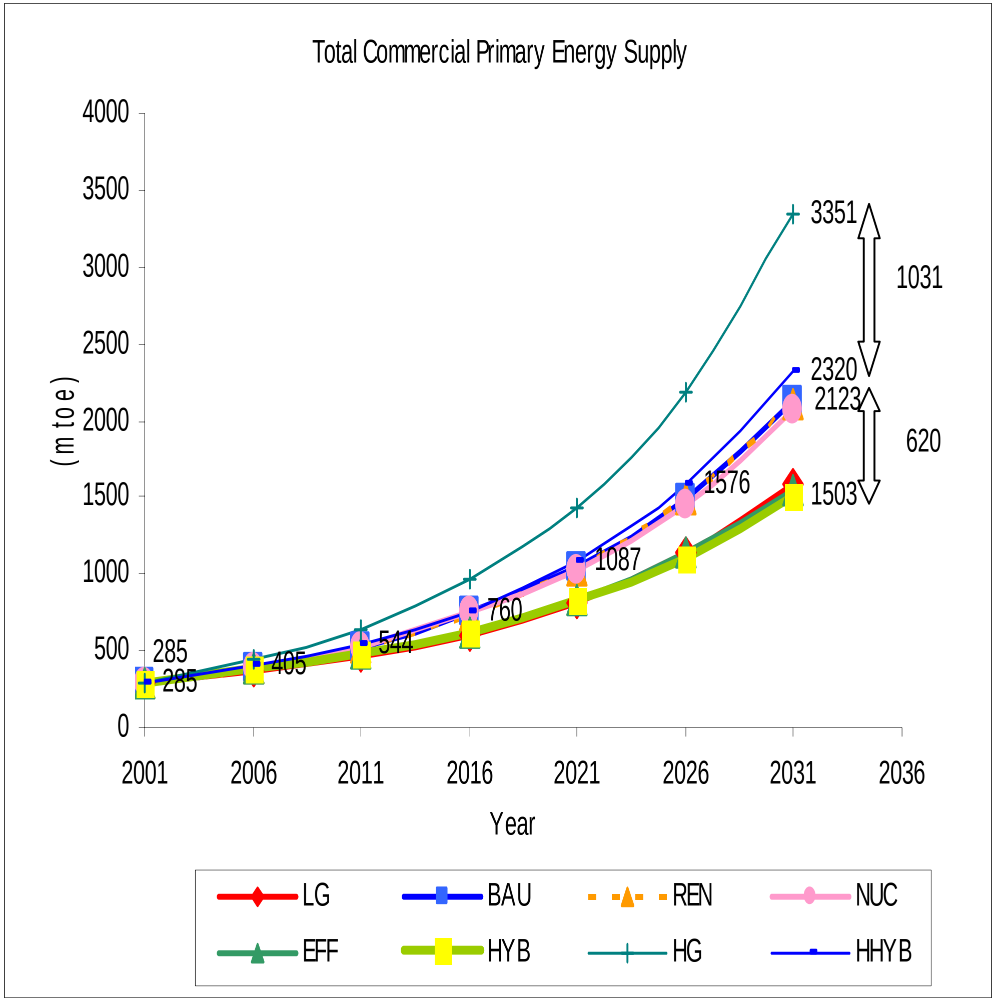
- **<u>High-efficiency</u>**

  Supply-side
  - Advanced gas-based power generation (e.g. H-frame combined-cycle gas turbine) with 60% efficiency to be commercially available by the year 2016/17.
  - All clean coal technologies allowed to penetrate in an unconstrained manner to their maximum capacity

  Demand-side
  - *Residential and Commercial Sectors* :Increased share of efficient electrical appliances for space-conditioning, lighting and refrigeration
  - *Transport sector*: Increased share of rail vis-a-vis-road in passenger and freight movement, promoting public transport etc.
  - *Energy-efficiency measures in Industry*: For instance, in Iron and steel industry penetration of efficient BF-BOF allowed up-to 80% by the year 2036,

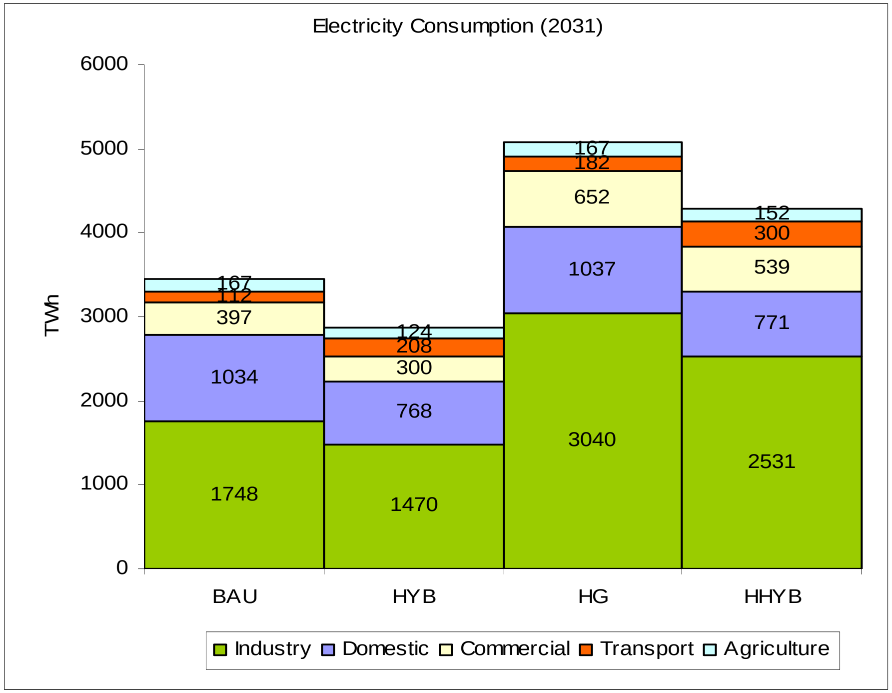
- **<u>Hybrid</u>**
  - Combination of the BAU, High-efficiency, aggressive renewable energy and high nuclear-capacity scenario.

Total Primary Commercial Energy Requirement



- ❖ Increase in primary energy by 2031
  - ➢ 7.5 times (BAU)
  - ➢ 5.3 times (Hybrid)
  - ➢ 11.8 times (High growth)
  - ➢ 8.2 times (High growth hybrid)
- ❖ Energy consumption in hybrid scenario (8% GDP) is even less than that in low growth scenario (6.7% GDP)
- ❖ Difference in commercial energy consumption
  - ➢ Between BAU and Hybrid in 2031 is double the total commercial energy consumption in 2001
  - ➢ Between High-growth and High-growth hybrid in 2031 is 3.6 times the total commercial energy consumption in 2001

Sectoral Electricity Consumption



❖ Decline in total electricity consumption to the extent of 588 TWh by 2031 in hybrid scenario vis-à-vis BAU (17% reduction by 2031), reduction in high growth hybrid vis-à-vis high growth is 785 TWh (15% reduction)

❖Sectoral reduction in electricity consumption hybrid vis-à-vis BAU in 2031

- ➢Agriculture & residential sectors: 26%
- ➢Commercial Sector: 25%
- ➢Industry sector: 17%

❖Reduction in electricity consumption in hybrid scenario attributed to efficiencies on end-use side

❖Increase in electricity consumption in transport sector by 96 TWh in hybrid scenario vis-à-vis BAU by 2031 due to increase in the share of rail based movement vis-à-vis road and higher electrification of rail in hybrid scenario

Suggested Technology Deployment Pathway:

Power Generation

Technology	2006	2011	2016	2021	2026	2031	Impact on energy system	Recommendation
Hydro power	Technology is mature and available indigenously						low	Immediate implementation may carried out
Super critical boilers	Technology is mature and available internationally						medium	Immediate implementation instead of sub-critical boilers
Ultra super boilers	Technology is mature and available internationally						medium - high	Strongly recommended to implement immediately
Advanced aero derivates gas turbines - H Frame	Technology is mature and available internationally						medium - high	Strongly recommended to implement immediately
IGCC based on refinery residue	Technology is mature and available internationally						medium	Strongly recommended to implement immediately
IGCC based on imported coal	Technology sourcing Demonstration Project		Technology learning & cost reduction		Commercialization of technology		Very High	Plan for commercial scale demonstration project
IGCC based on indigenous coal	R&D and Demonstration Project		Technology learning & cost reduction		Commercialization of technology		Very High	Plan for commercial scale demonstration project
Nuclear fast breeder reactor	R&D and Demonstration Project based on indigenous technology		Technology learning & cost reduction		Commercialization of technology		Very High	Strongly recommended to progress as per the plans of GOI
Nuclear thorium based rectors	R&D and Pilot Plant Studies indigenous technology development		Technology scale up from pilot plant to demonstration plant		R&D and Demonstration Project based on indigenous technology		Very High	Strongly recommended to progress as per the plans of GOI

Technology Deployment: Power Generation

- In absence of clean coal technologies for power generation combined cycle gas based are preferred option over subcritical coal plant
- IGCC and H-Frame CCGT equally preferred options for power generation in the hybrid scenario.
- IGCC based on imported coal has better economics and hence is a preferred option as against the IGCC based on indigenous coal
- Hydropower is important
- On pure economics, renewables is less preferred; changes with high oil prices

Suggested Technology Deployment Pathway:

End Use Sectors

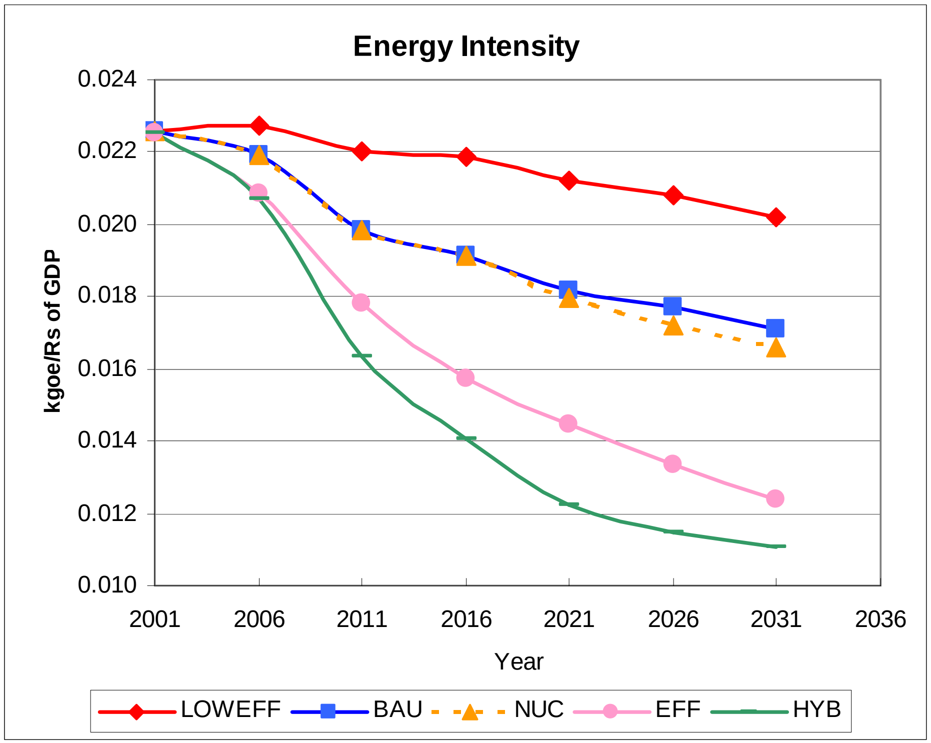
	2006	2011	2016	2021	2026	2031	Impact on energy system	Recommendation
Industry								
Industrial cogeneration	Technology is mature and available indigenously						low	Strongly recommended to implement immediately
Waste recovery	Technology is mature and available indigenously						low	Strongly recommended to implement immediately
Residential								
CFL	Technology is mature and available indigenously						medium - high	Strongly recommended to implement immediately
LED	Technology is mature and available indigenously						medium - high	Strongly recommended to implement immediately
Refrigerators	Technology is mature and available indigenously						medium - high	Strongly recommended to implement immediately
Air conditioning	Technology is mature and available indigenously						medium - high	Strongly recommended to implement immediately
Transport								
Integrated transport system	Technology is mature and available indigenously, needs to be integrated in urban planning						medium - high	Strongly recommended to implement immediately
Efficiency improvements in automobiles	Technology is mature and available internationally						medium - high	Strongly recommended to implement immediately

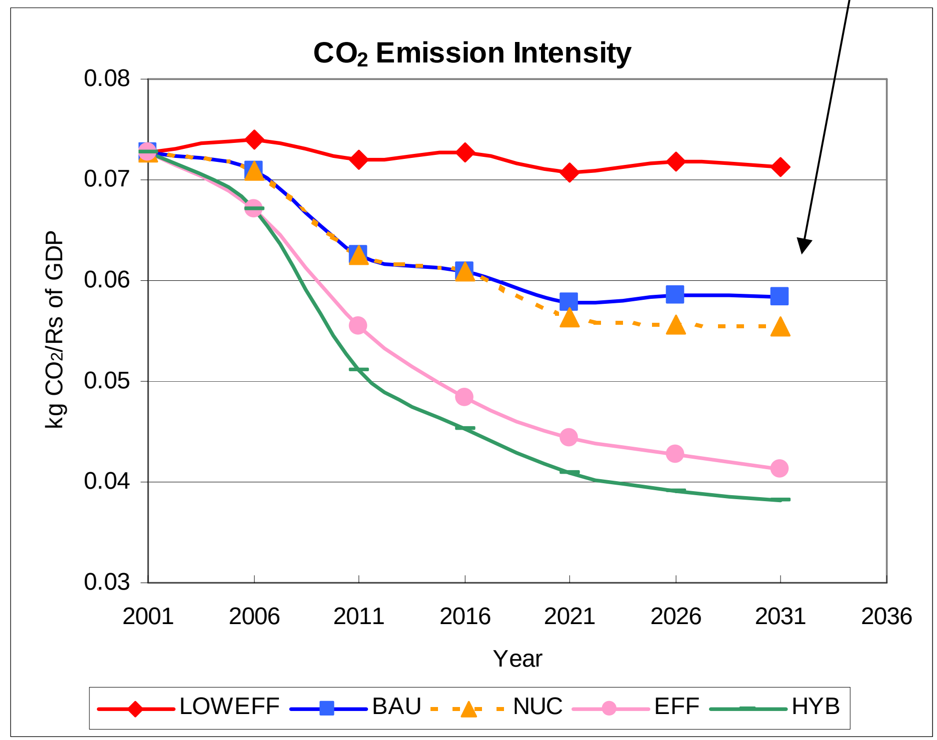
Key Observations

- In the BAU scenario, the total commercial energy consumption increases by 7.5 times between 2001-2031
- Coal remains the predominant fuel accounting for 50% of the total fuel mix followed by oil contributing to around 35-40% of commercial energy supply over the entire modelling period in the BAU.
- BAU exhibits a decline in energy-intensity to the extent of 23% from 0.022 kgoe/Rs. of GDP in 2001 to 0.017 kgoe/Rs. of GDP in 2031
- In high growth hybrid scenario at 10% GDP growth, the energy intensity is exactly halved to 0.011 kgoe/Rs. of GDP in 2031
- IGCC plants are the preferred choice over ultra supercritical, CCGT, and compete with high efficiency H Frame CCGT plants
- Import dependency of all fossil fuels is likely to increase significantly by the year 2031
- Renewable energy for power generation are not preferred option for power generation. However, their role in providing electricity for remote villages is very important.
- If the modelling time frame is extended to 2050 and beyond the positive impacts of nuclear energy can be captured
- Futuristic technologies such as hydrogen, fuel cell etc. are not expected to play major role till 2031

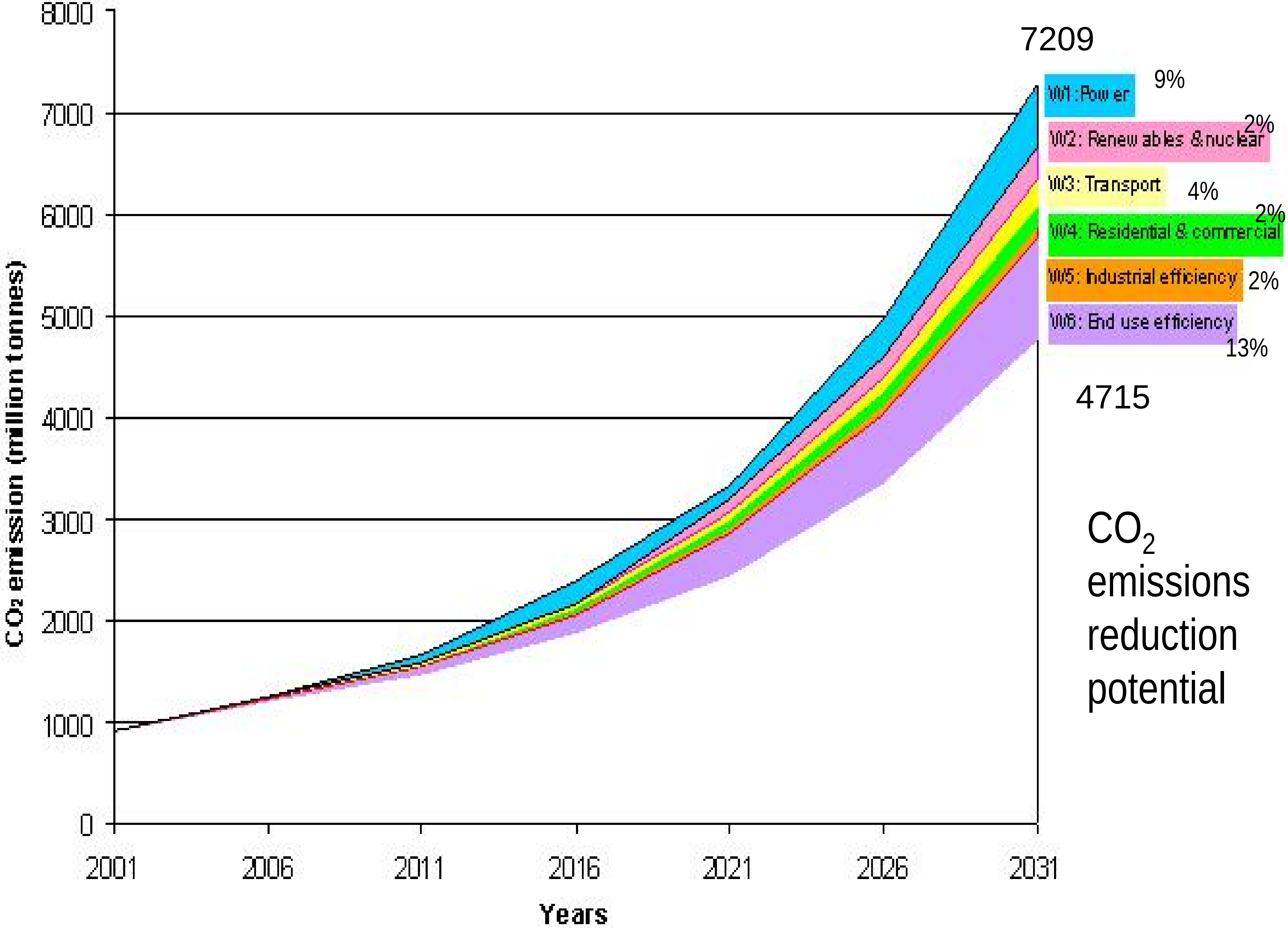
Reducing trend of Energy and CO_2 Emissions Intensity

Govt. policies, energy sector reforms, etc.





- **Low carbon futures for the economy can be targeted through the introduction of ESTs**
  - enhanced energy efficiency; shift towards renewables and cleaner power generation options etc.



CO_2 emissions reduction potential

Challenges / Constraints

- R&D needs for cleaner technologies
- Technology transfer/IPR issues for available technologies
- Institutional mechanisms necessary to stimulate demand for and uptake of low carbon technologies
- Financial resources required for infrastructural development

Key research needs/business opportunities

- Power: developing clean coal technologies; Promoting hydro and renewable energy; enhancing nuclear capacity
- Industry – improving energy efficiency in SMEs
- Across all sectors: end use efficiency and addressing barriers to uptake of efficient options
- Transport: Bio diesel (2nd generation) given high oil prices

Thank you

Technology Characterization in Model

- Technology characteristics specified in the model include:
  - Costs (Capital investment, O&M cost)
  - Efficiency
  - Availability factor
  - Time frame and limits to rate of penetration
  - Phasing out of residual capacity
  - Economic life of technology
  - CO_2 emissions
- Technological choices are also mapped on to
  - Sector-Specific characteristics (e.g. share of blended cement)
  - Income classes (e.g. energy ladder in cooking)

Sustainable Consumption: Some Comparisons

- **Steel: Per capita annual consumption**
  - India (30 kg), World average (135 kg), USA (426 kg), Korea (814 kg), China (111 kg)
  - In 2031 India (272 kg)

- **Cement: Per capita annual cement consumption**
  - India (110 kg), World average (273 kg) Korea (1090 kg), Japan (540 kg), Thailand (300 kg),
  - In 2031 India (847 kg)

- **Paper: Per capita annual consumption**
  - India 5.5 kg (2003), 1/9th of world average (50 kg), In 2031 India (37 kg)

- **Electricity: Per capita annual consumption**
  - In 2001 India (361 kWh), USA (13053 kWh), China (1069 kWh), Japan (8092 kWh)
  - In 2031 (2994 kWh including captive)

- **Motorized Transport: Per capita annual passenger transportation**
  - In 1950: Industrialized region (4,471 km), World average (1,334 km), USA (11,205 km)
  - In 1997: Industrialized region (16,645 km), World average (4,781 km), USA (24,373 km)
  - India in 2001 (2,117 km), in 2031 (9,590 km)

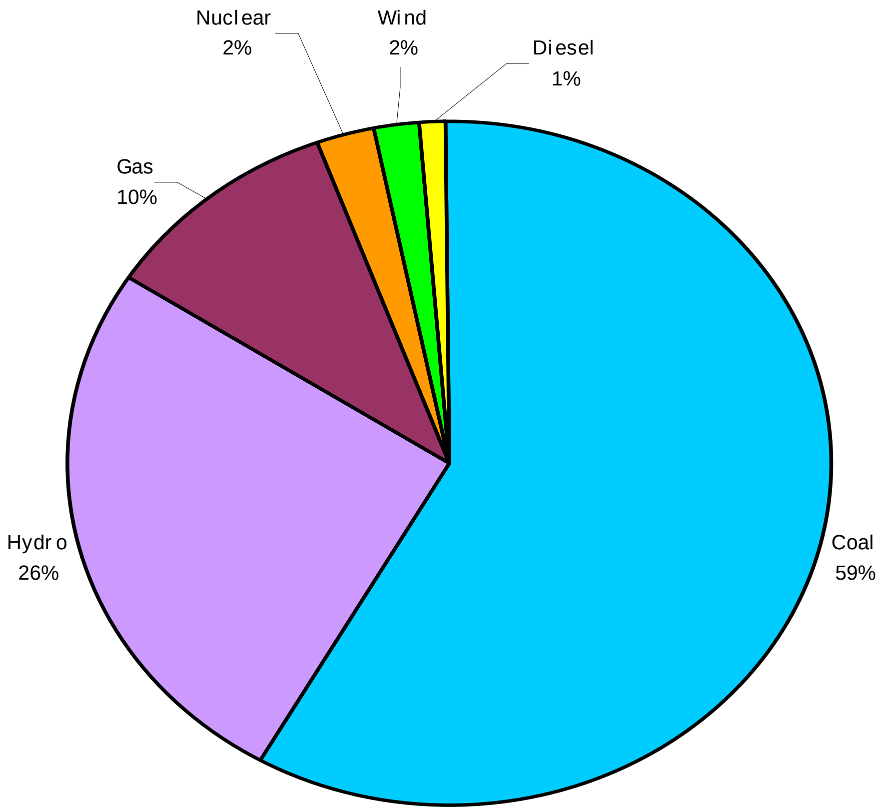
India’s Energy Resource Base

	Amount	Electricity Potential[¤] GWe-yr
Coal	53.3 -BT	10,660
Hydrocarbon	12 –BT[#]	5,833
Uranium-Metal	61,000 -T	
- In PHWR		320
- In Fast Breeders		42,000
Thorium-Metal (In Breeders)	2,25,000 –T	155,000
Hydro	150 -GWe	69 GWe-yr / yr
Non-conv. Ren.	100 -GWe	33 GWe-yr / yr

¤ Assuming entire resource is used for generating electricity.

Currently known resources (including coal bed methane) are 3 BT. However, MP&NG has set a target of locating at least 12 BT as per Vision Hydrocarbon-2025. Source; Grover, DSDS, 2007

Fuel wise installed capacity in India



Indian PHWR Programme

REACTOR TYPE AND CAPACITIES	CAPACITY (MWe)	CUMULATIVE CAPACITY (MWe)
> 14 reactors at 6 sites under operation Tarapur, Rawatbhata, Kalpakkam, Narora, Kakrapar and Kaiga	3,580	3,580
4 PHWRs under construction at Kaiga (2x220 MWe), RAPS-5&6(2x220 MWe)	880	4,460
Pre-project approvals for 4 reactors (4x700 MWe)	2,800	7,260
PHWRs to be taken up to complete 10000 MWe (4x700 MWe)	2800	10,060
> TOTAL PHWR Programme		10,060 MWe

Source: R Grover, DSDS, 2007

Three Stage Nuclear Power Programme

Stage – I PHWRs

- 14 - Operating
- 4 - Under construction
- Several others planned
- Scaling to 700 MWe
- Gestation period has been reduced
- **POWER POTENTIAL ≅ 10,000 MWe**

LWRs

- 2 BWRs Operating
- 2 VVERs under construction

Stage - II

Fast Breeder Reactors

- 40 MWth FBTR - Operating since 1985 Technology Objectives realised
- 500 MWe PFBR- Under Construction
- **POWER POTENTIAL ≅ 530,000 MWe**

Stage - III

Thorium Based Reactors

- 30 kWth KAMINI- Operating
- 300 MWe AHWR- Under Development

POWER POTENTIAL IS VERY LARGE

Availability of ADS can enable early introduction of Thorium on a large scale

Source: R Grover, DSDS, 2007