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2490-10

Joint ICTP-IAEA Advancing Modelling of Climate, Land-use, Energy and Water (CLEW) Interactions

7 - 11 October 2013

Assessing Interdependencies among Energy, Water, Land-Use and Climate Change in India

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IAEA:Coordinated Research Project : Assessing Interdependencies among Energy, Water, Land-Use and Climate Change(CLEW)

Assessing Interdependencies among Energy, Water, Land-Use and Climate Change in India

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- Climate change has origins in anthropogenic activities and is engaging the attention worldwide.

- Climate has a significant role in the economic development of India. Many sectors of the economy are climate sensitive.

- Climate, energy, water and land are interconnected and understanding of these linkages is needed in order to maintain the security of energy, water, and food supply

India comprises of

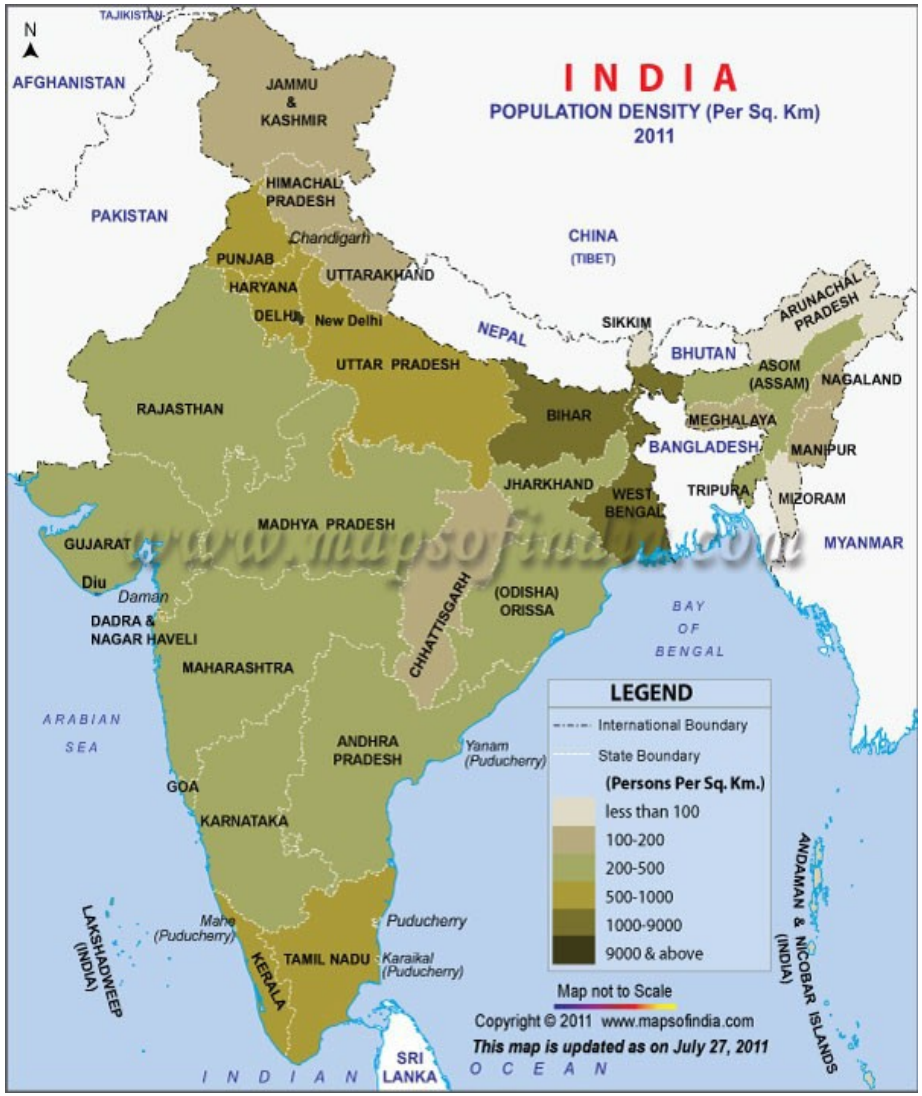
- **Himalayan region**: 5,33,000 Sq.km.
- **The Western Ghats:** 1,60, 000 Sq.km.
- **North-Eastern region:** 2,62,179 sq. km.
- **Coastal region:** 75,500 km

Agriculture

- major sector of Indian economy
- occupies 43 % of the total land area
- employs 2/3 of total work-force
- account 18% of the GDP

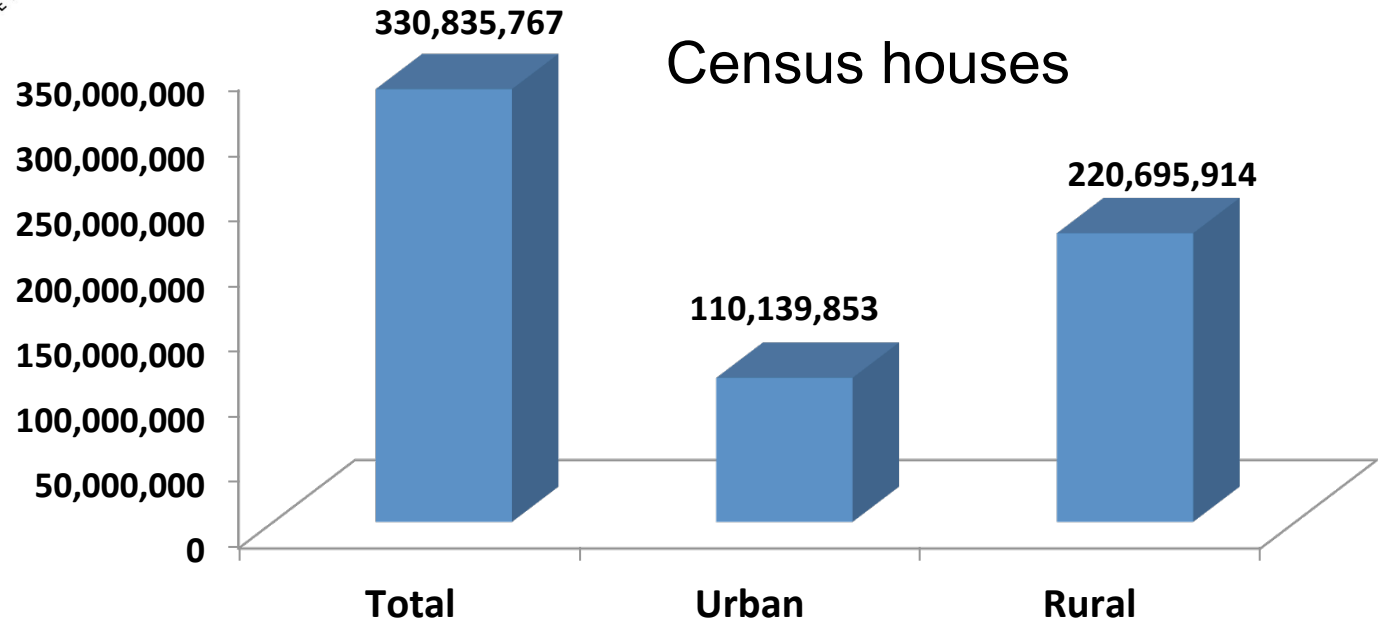
.

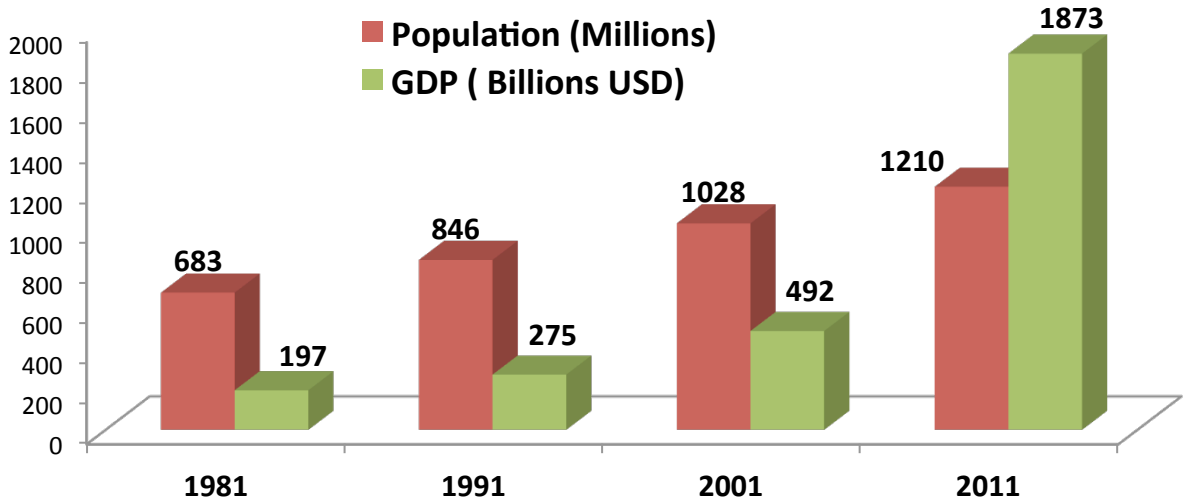
Indian population density, 2011



India's population density is very high; the density of 264 persons/km^2 in 1991 increased to 325 persons/km2 in 2001 and 382 persons/km^2 in 2011.

India Census Data





Climate

Seasons and Temperature Pattern of India

Four seasons can be identified in a year.

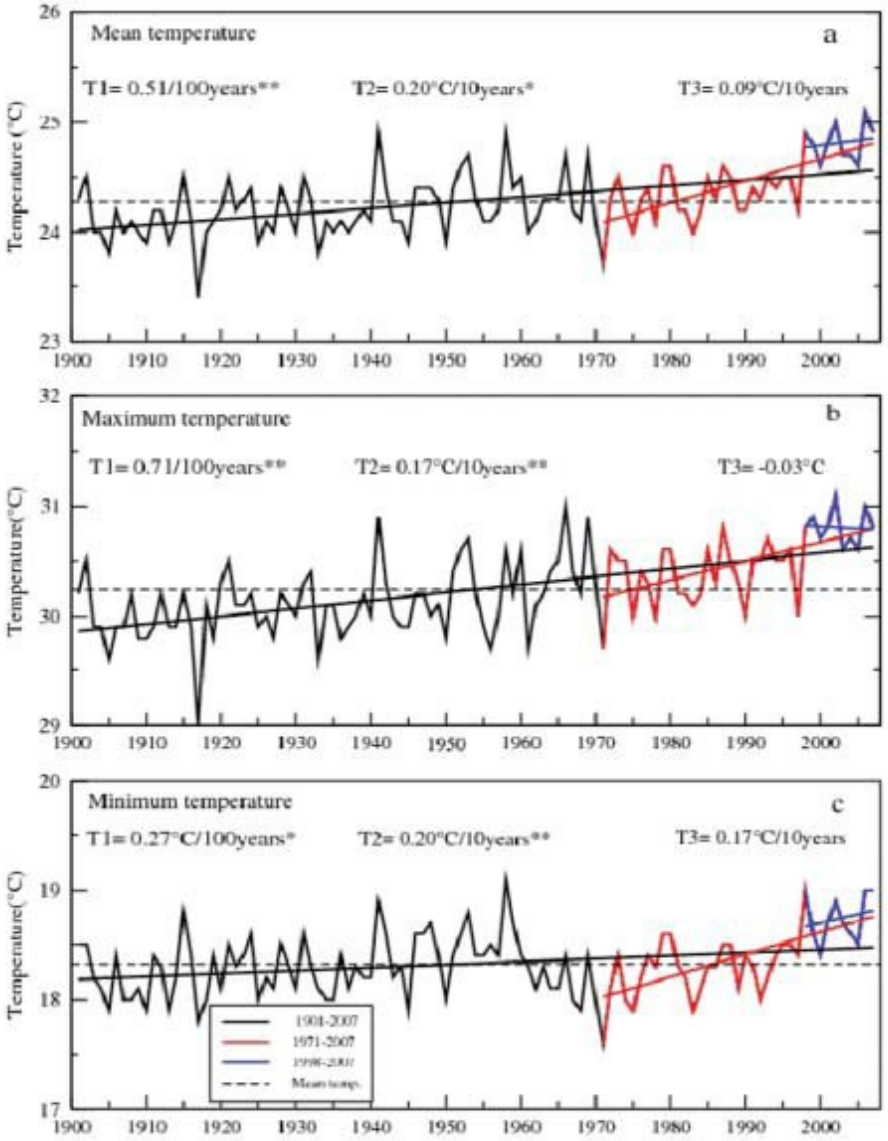
Winter season: January and February

Summer season: March, April and May

South-west monsoon season: June, July, August, and September

Post-monsoon or north-east monsoon season: October, November and December

All-India annual mean, maximum and minimum temperature variations during 1901-2007



Indian annual mean temperature showed significant warming trend

0.51˚C per 100 year, during the period 1901-2007

Accelerated warming observed after 1971, particularly from 1998-2007 and was around 0.82 ˚C

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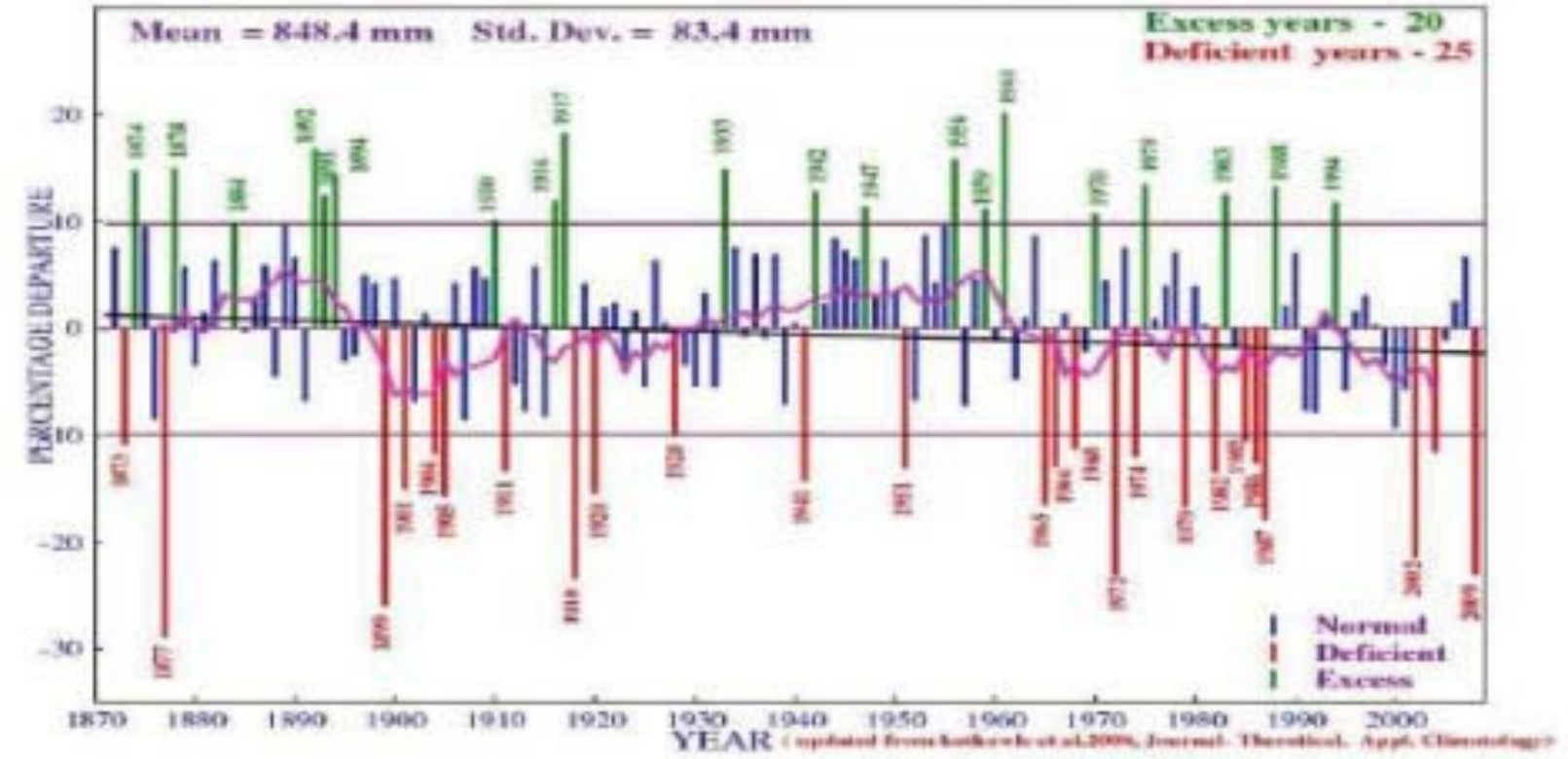
Inter-annual variability of Indian monsoon rainfall 1871-2009



All India monsoon rainfall series based on 1871-2009 indicates mean rain fall is **848±83 mm**

Water Resources

Water Resources in India

- 1/25th of world's water resources & 1/50th of world's land
  Rainfall: 4000 bcm/yr, translates into water resources
- (~48%),
  groundwater recharge (~11%).
- **Water consumers** - Agriculture (85%); Domestic (4%)
- **Availability of water per capita** (cu.m/ca/year)
  – World: 6700
  – North America : > 15,000
  – India : ~ 1200
- **Storage of water per capita** (cu.m/ca/year)
  – World : 900
  – North America : 3600
  – India : 170

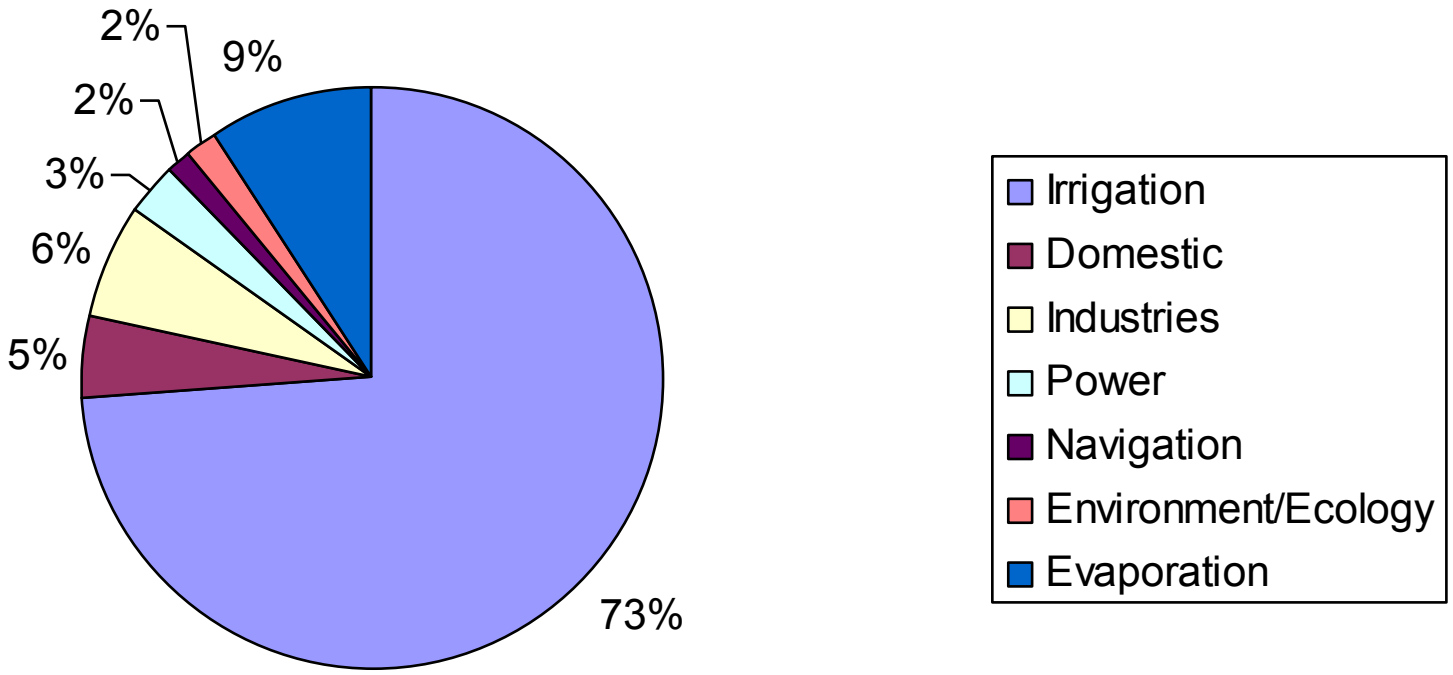
Water resources of India

Estimated annual precipitation (including snowfall)	4000
Run-off received from upper riparian countries (Say)	500
Average annual natural flow in rivers and aquifers.	1869
Estimated utilisable water	1123
(i) Surface	690
(ii) Ground	433
Water demand _ utilization (for year 2000)	634
(i) Domestic	42
(ii) Irrigation	541
(iii) Industry, energy & others	51

Units in cubic Km

Source: National Water Mission under National Action Plan on Climate Change, MoWR, GOI, 2010

India - Water Requirements for Different Uses (Year 2010)

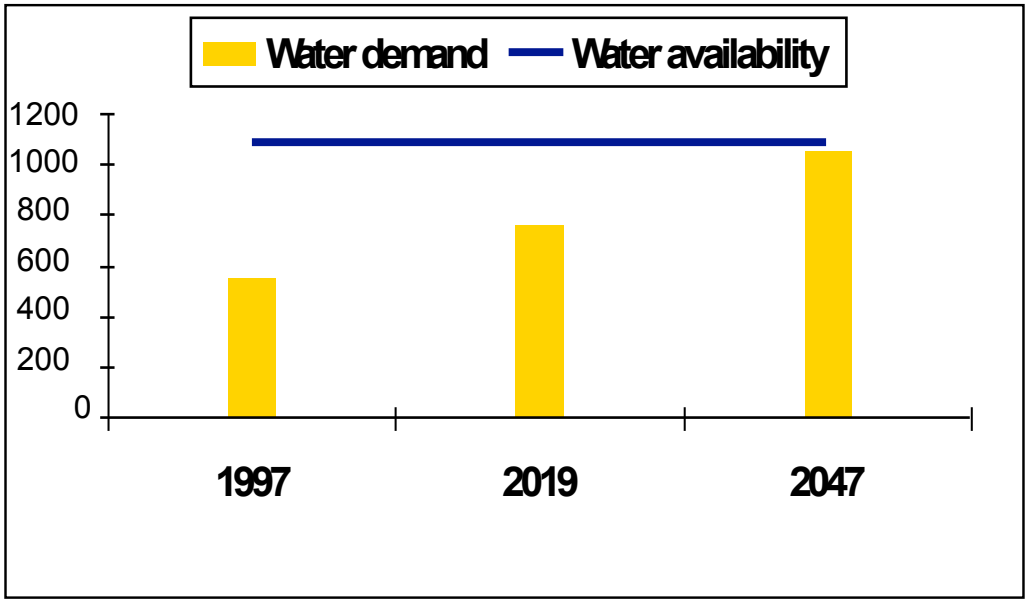


Source : Ministry of Water Resources, 1999

Water Needs (1997-2047)

Water availability constant at 1086 billion cum/yr

Water requirement to double: population to grow by 0.5 billion; livestock by 0.4 billion; industrial expansion, urbanisation



Recent retreat pattern of selected glaciers in the three North-Western Himalayan States of India

demonstrated that

- ***rainfall contributions are greater in the eastern region***

- ***snow and glacier melt contributions are more impo*rtant in the western and central Himalayan regio**n.

Mean-sea-level-rise trends along the Indian coast.

Tide gauge station	No. of years of available data	Trends (mm/Yr)	Glacial Isostatic Adjumstment corrections (mm/ Yr)	Net sea level rise (mm/Yr) trends
Mumbai	113	0.77	-0.43	1.20
Kochi	54	1.31	-0.44	1.75
Vishakapatnam	53	0.7	-0.39	1.09
Diamond harbour (Kolkata)	55	5.22	-0.52	**5.74**

Global average sea level rise at an average rate of 1.8 mm per year over 1961 to 2003.

The rate was faster over 1993 to 2003, at about 3.1 mm per year.

Land Use

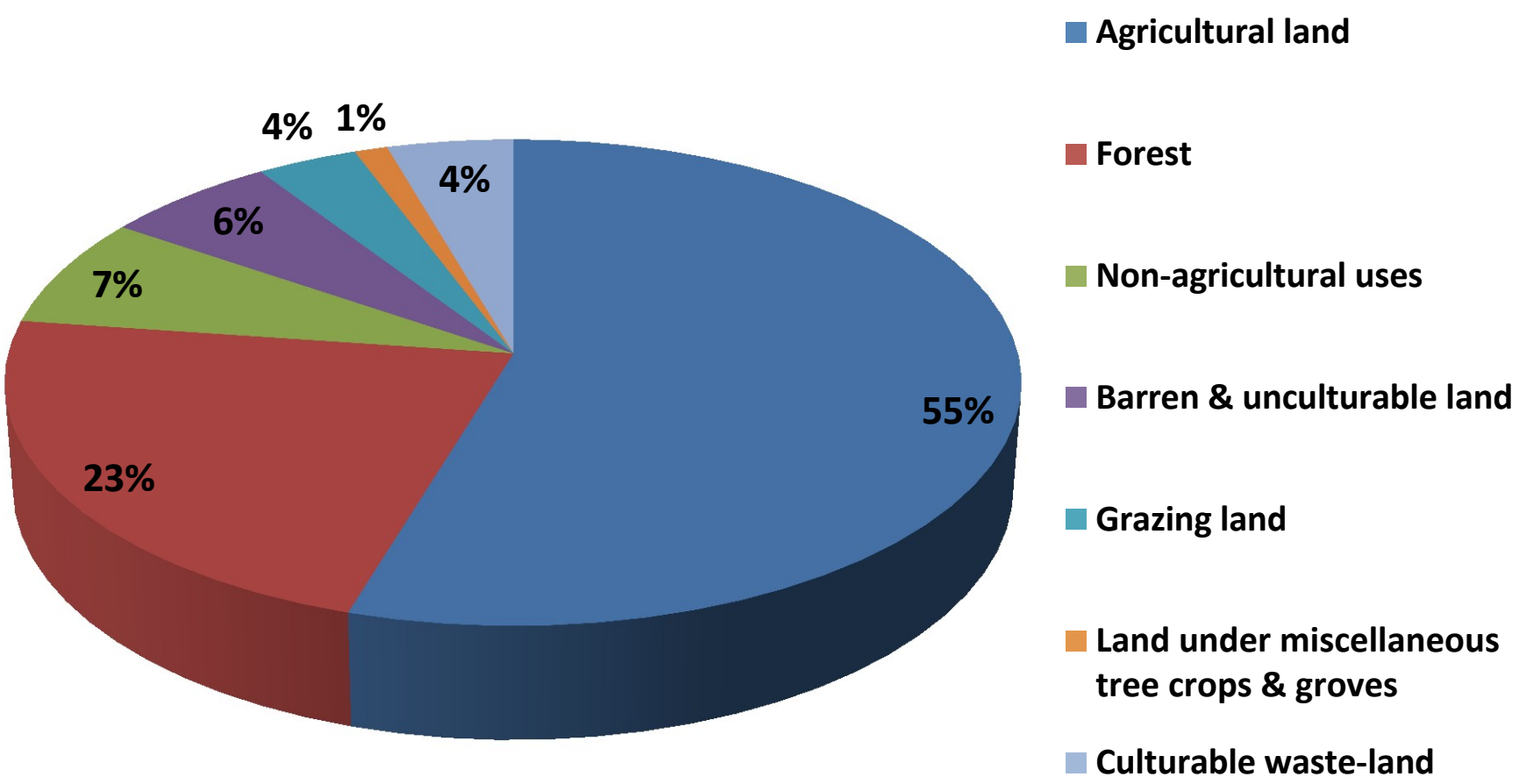
Land use in India

According to the "Agricutural Statistics at a Glance 2010",

- 46.1% is under agriculture, and
- 23.9% under forest and tree cover
- Remaining nearly 1/3 of the land area is distributed between fallow land, other uncultivated land excluding fallow land and not available for cultivation.
- The land use pattern in India has been affected
  - population pressure
  - expanding urbanization
  - industrial growth

	Availability of forest land
1950/51	0.113 ha /capita
2007/08	0.061 ha/capita

Land Use Pattern in India



Energy

In 2011-12, India was the fourth largest consumer in the world of Crude Oil and Natural Gas, after the United States, China, and Russia.

Petroleum demand in the transport sector is expected to grow rapidly in the coming years with rapid expansion of vehicle ownership.

Combustible renewable and waste constitute about one fourth of Indian energy use. This share includes traditional biomass sources such as firewood and dung, which are used by more than 800 million Indian households for cooking.

The power sector in India had an installed capacity of 236.38 Gigawatt (GW) as of March 2012 recording an increase of 14% over that of March 2011. Captive power plants generate an additional 36.5 GW.

At the end of March 2012, thermal power plants accounted for 66% of the total installed capacity in the country, with an installed capacity of 1,56,107 MW. The share of Nuclear energy was 2.02% (4.78 MW).

Hydro power plants come next with an installed capacity of 38,990 MW, accounting for 16.49% of the total installed Capacity.

Renewable energy accounted for 15.45% (36510 MW) of the total installed generation capacity.

Nuclear Power

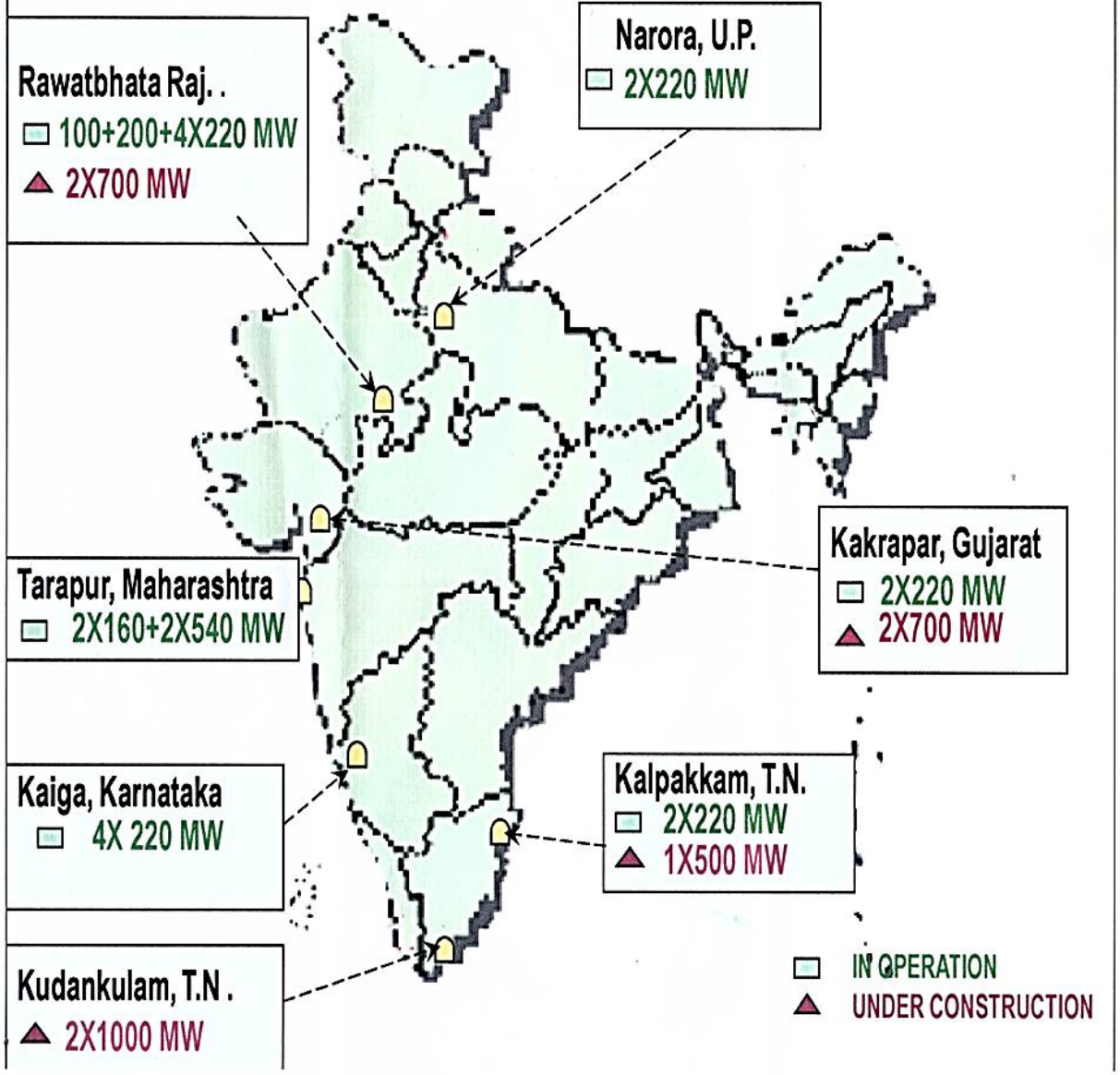
- In India to utilize the resources appropriately a three stage nuclear power programme has been chalked out by the Department of Atomic Energy.

- **First stage**, indigenously built Pressurized Heavy Water Reactor (PHWR) which used domestic uranium resource is developed and presently under operation at different locations.

- **Second stage** of the nuclear power programme involves building a chain of fast breeder reactors multiplying fissile material inventory along with the power production.

- **Third stage** consists of exploiting country's vast resources of thorium through the route of fast or thermal critical reactors or the accelerator driven sub-critical reactors (ADS).

Nuclear Power Reactors in operation and under construction



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National Policy

National Policy on Biofuels

- Biofuels are derived from renewable bio-mass resources and, therefore, provide a strategic advantage to promote sustainable development
- The focus for development of biofuels in India will be to utilize waste and degraded forest and non-forest lands only for cultivation of shrubs and trees bearing non-edible oil seeds for production of bio-diesel. In India, bio-ethanol is produced mainly from molasses, a by-product of the sugar industry.
- The Goal of the Policy is to ensure that a minimum level of biofuels become readily available in the market to meet the demand at any given time. An indicative target of 20% blending of biofuels, both for bio-diesel and bio-ethanol, by 2017 is proposed.

Clean Transport – to improve energy efficiency

- Several measures are taken
  - upgrade automobile technology,
  - improve fuel quality,
  - enhance pollution under control checking systems, and
  - expand urban public transport systems.

- Gross emission standards for vehicles have been made more stringent

- Roadmap developed to improve fuel quality.

- Need of clean fuel options: CNG, LPG, and biofuels.

Modeling Energy Sector using MESSAGE

Model

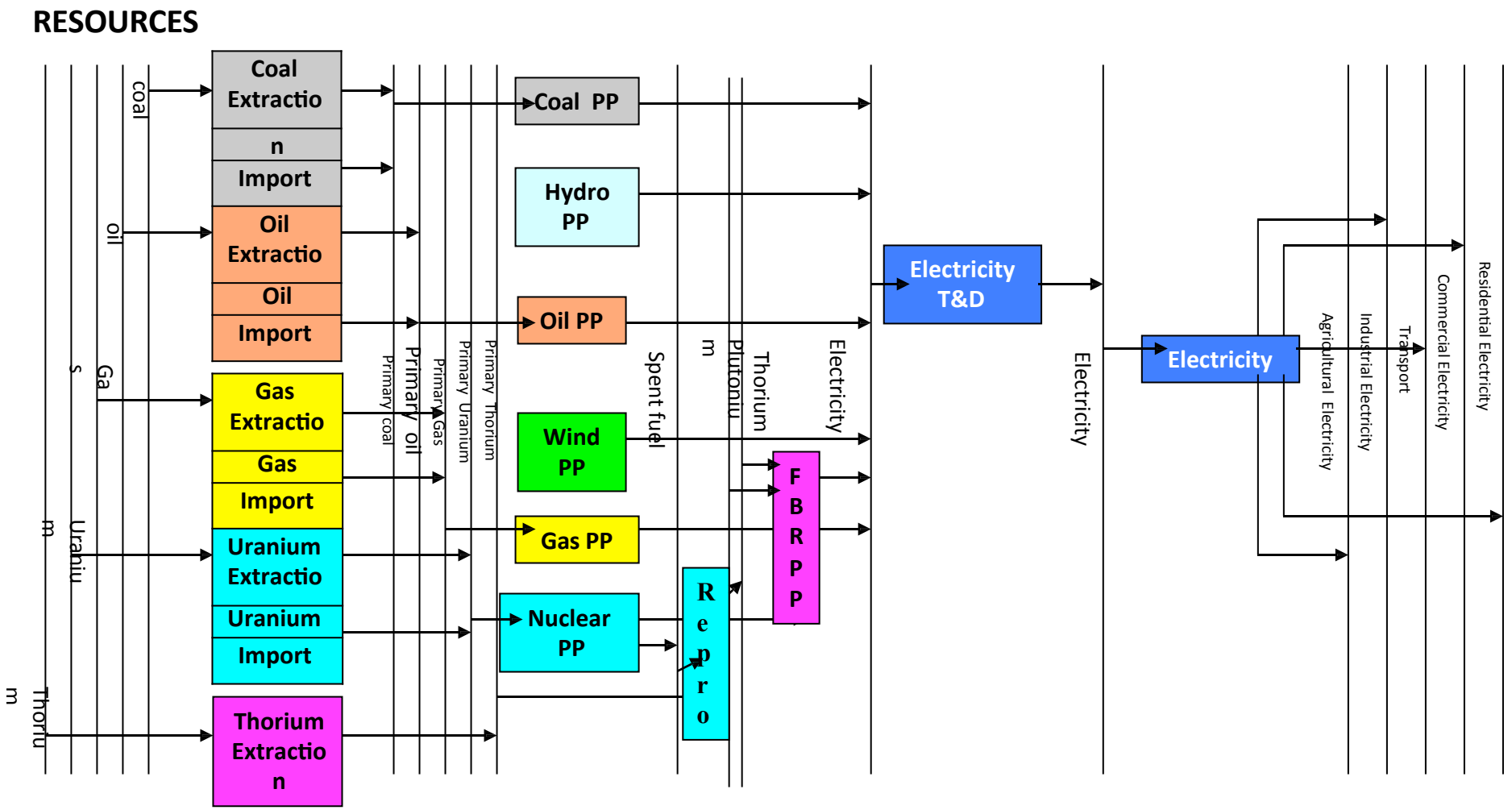
MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental impacts)- Optimized energy systems model based on Linear Programming

Scenarios Developed

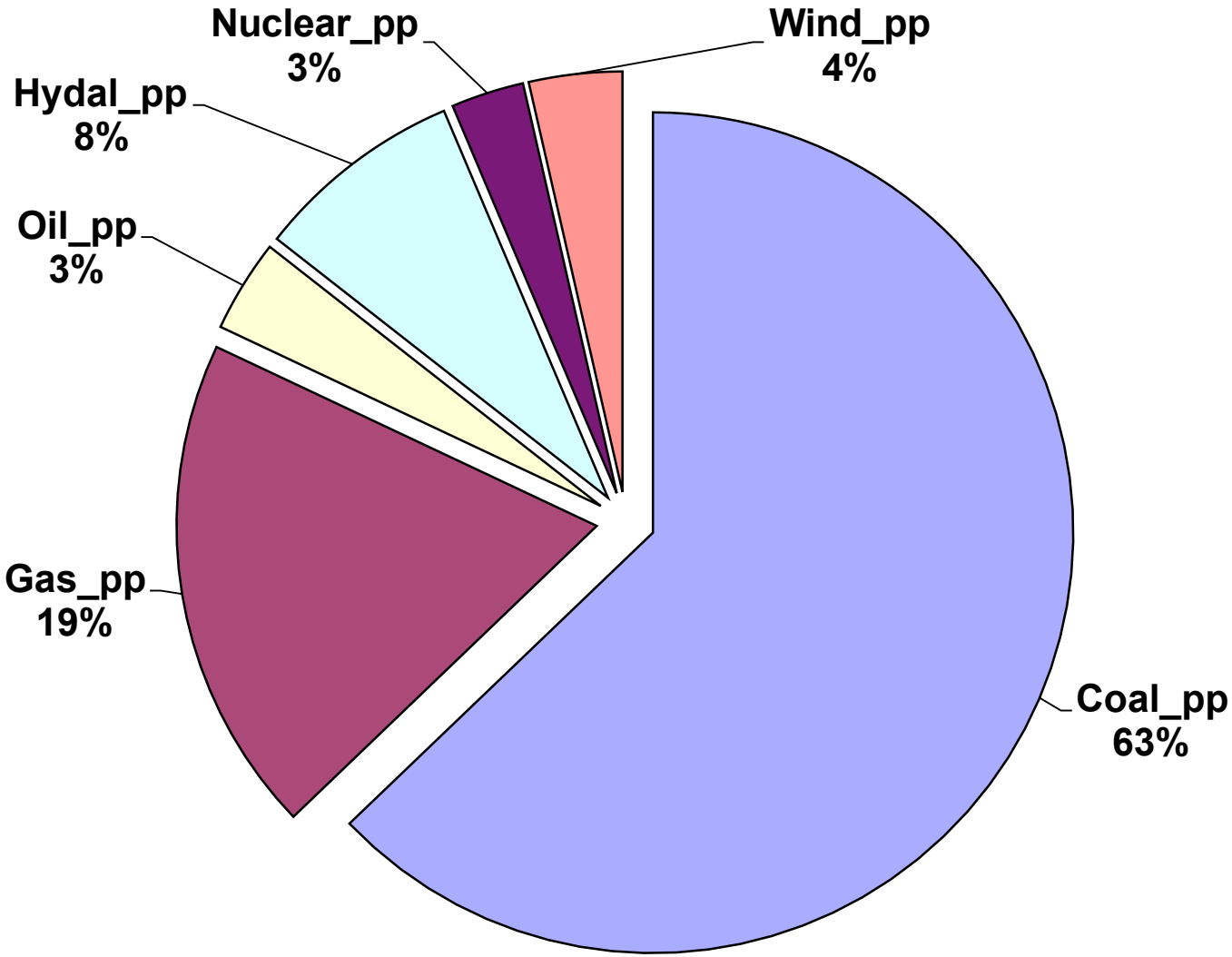
Different scenario of India's projected electricity requirements

- business-as-usual scenario
- scenarios with high nuclear intervention
- scenarios with aggressive renewable energy sources
- scenarios with hybrid

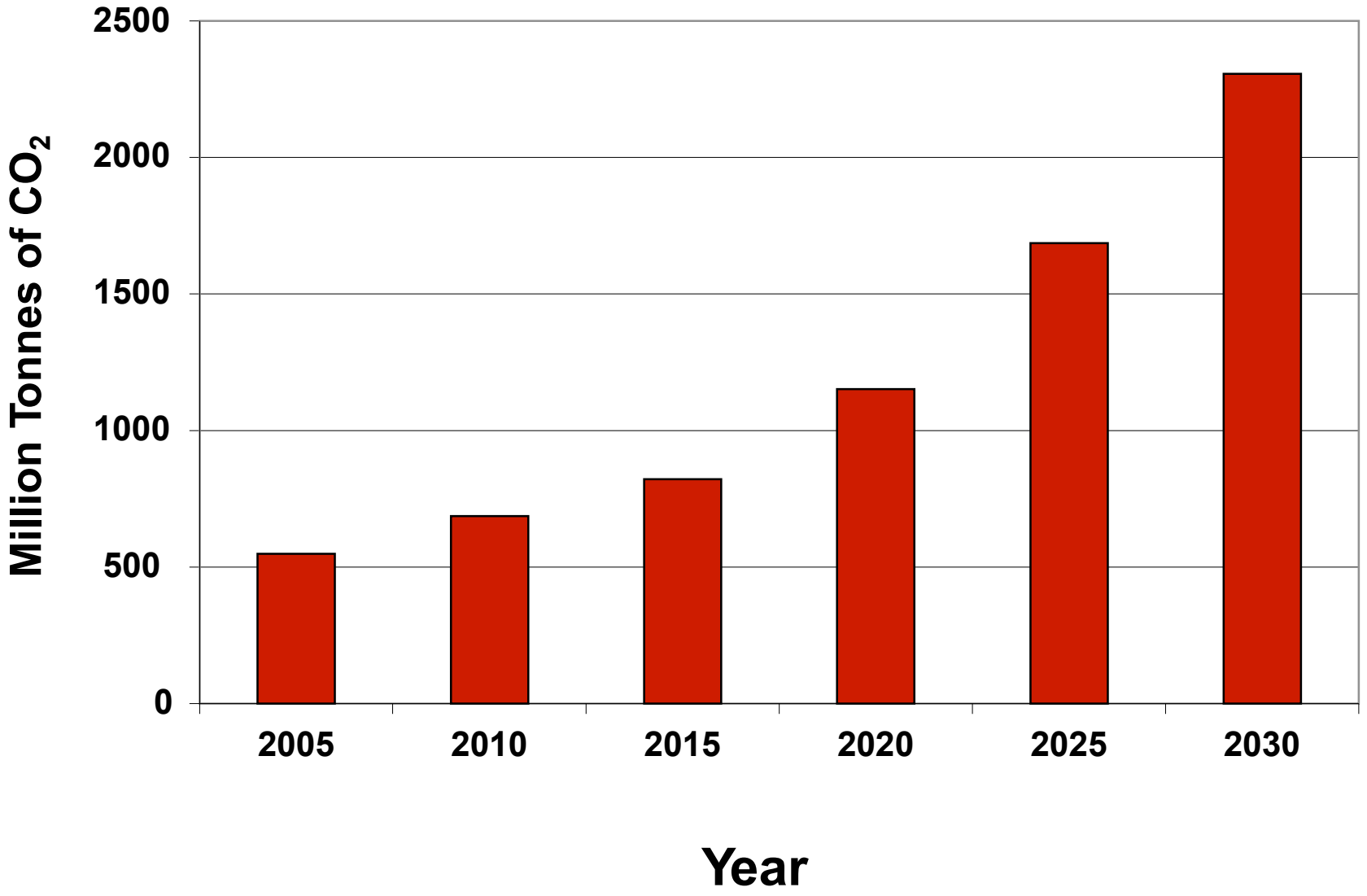
Electricity Flow Network - India



Percent contribution of different technologies in Business-as-Usual scenario



CO2 Emissions in Business-as-usual scenario

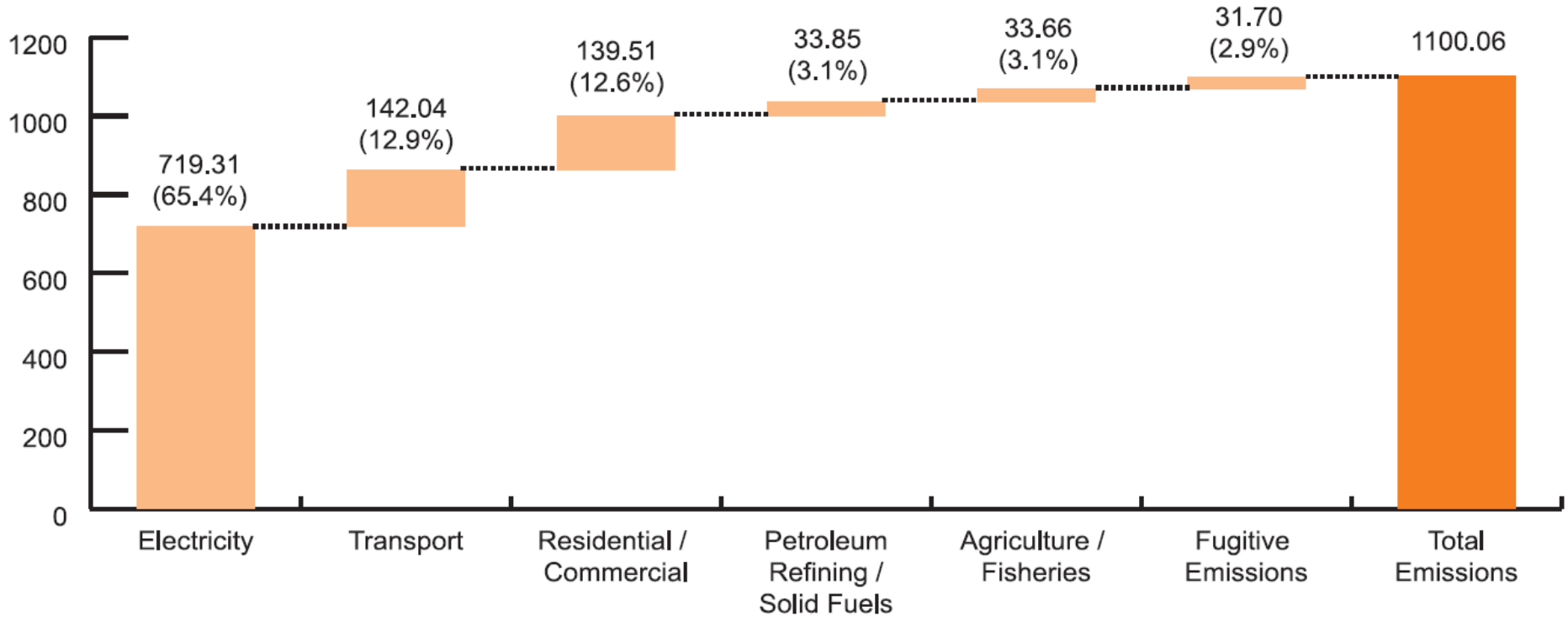


Lowest Possible Limit on Carbondioxide emissions for different scenarios (Year 2030)

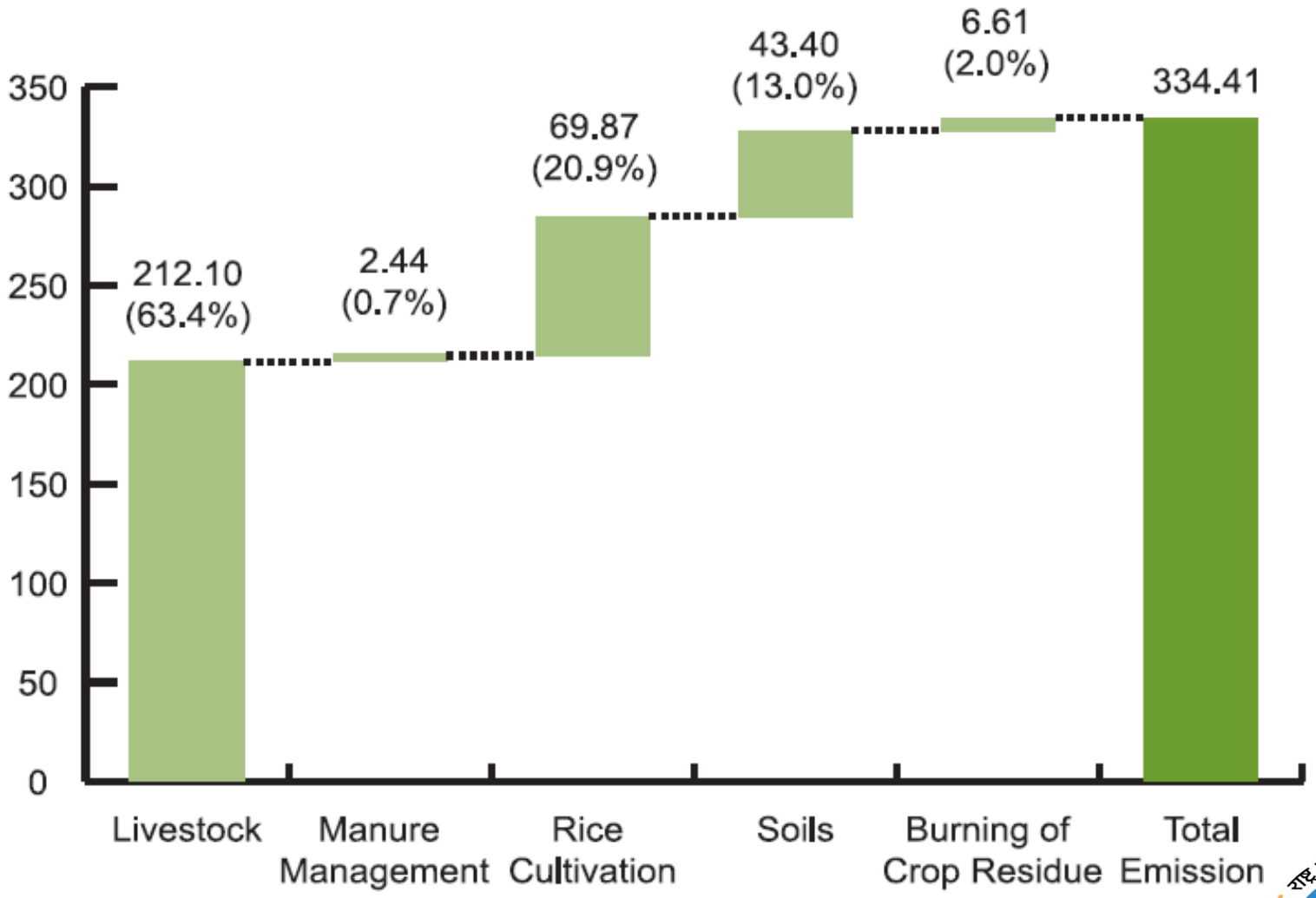
S.No.	Scenario	CO2 emissions (million tonnes)
1	Business-as-usual	2300
2	High Nuclear	1900
3	High Renewables	2000
4	Hybrid	1800

GHGs Emission Inventories for India

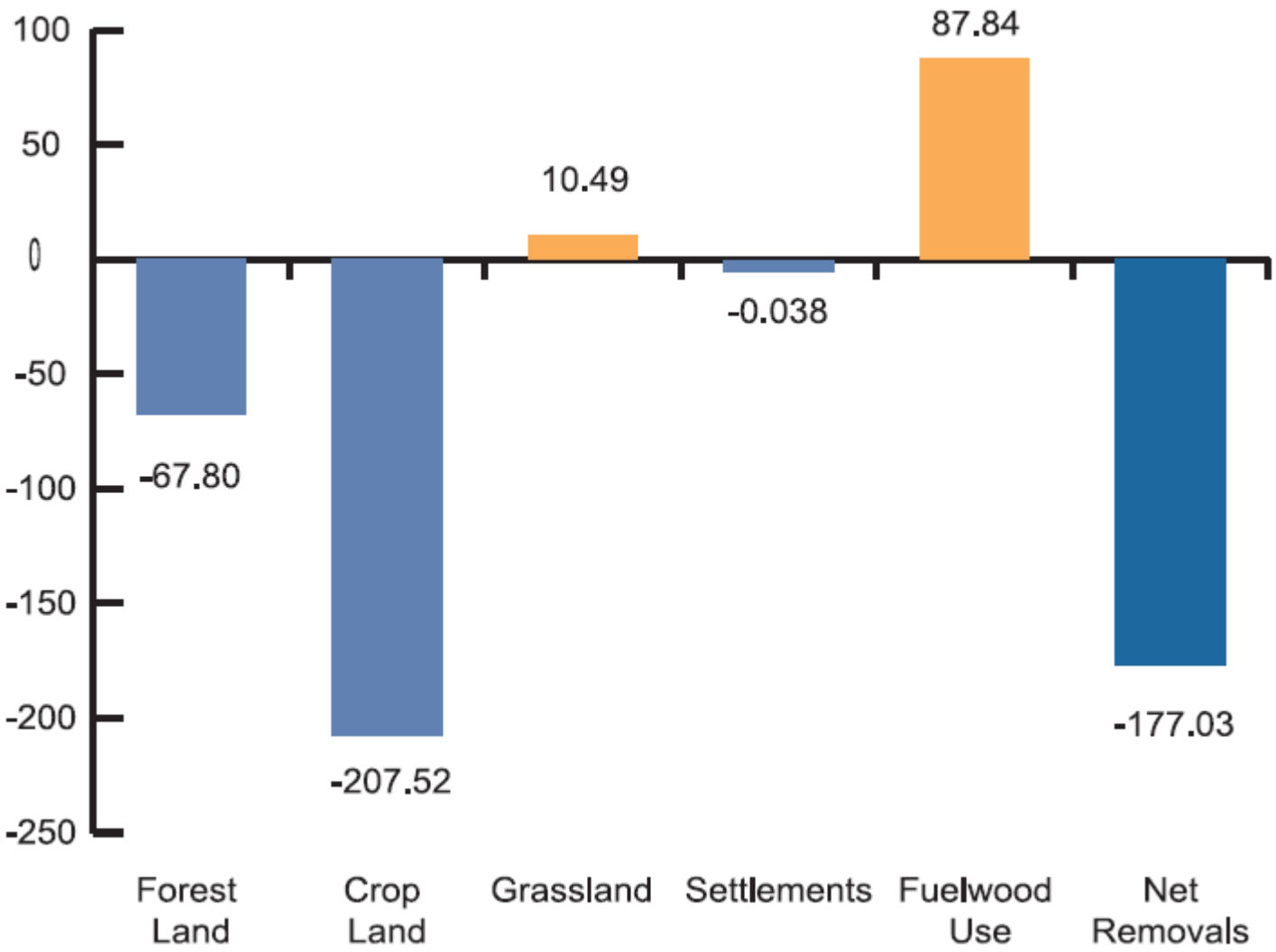
GHG emissions from Energy Sector (million tons of CO2 eq)



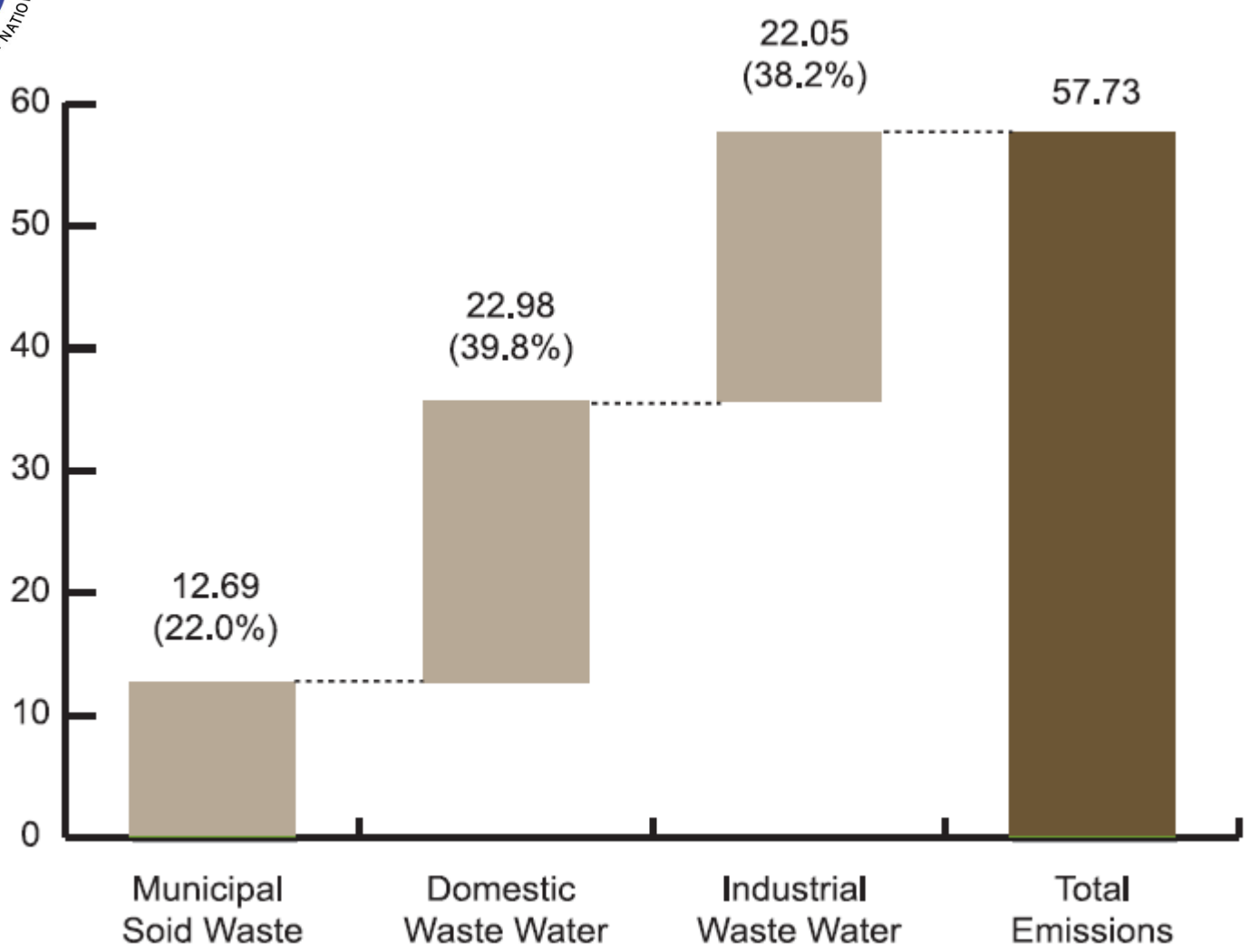
GHG emissions from Agriculture Sector (million tons of CO2 eq)



GHG emissions and removals from LULUCF sector (million tons of CO2 eq)



GHG emissions from waste (million tons of CO2 eq)

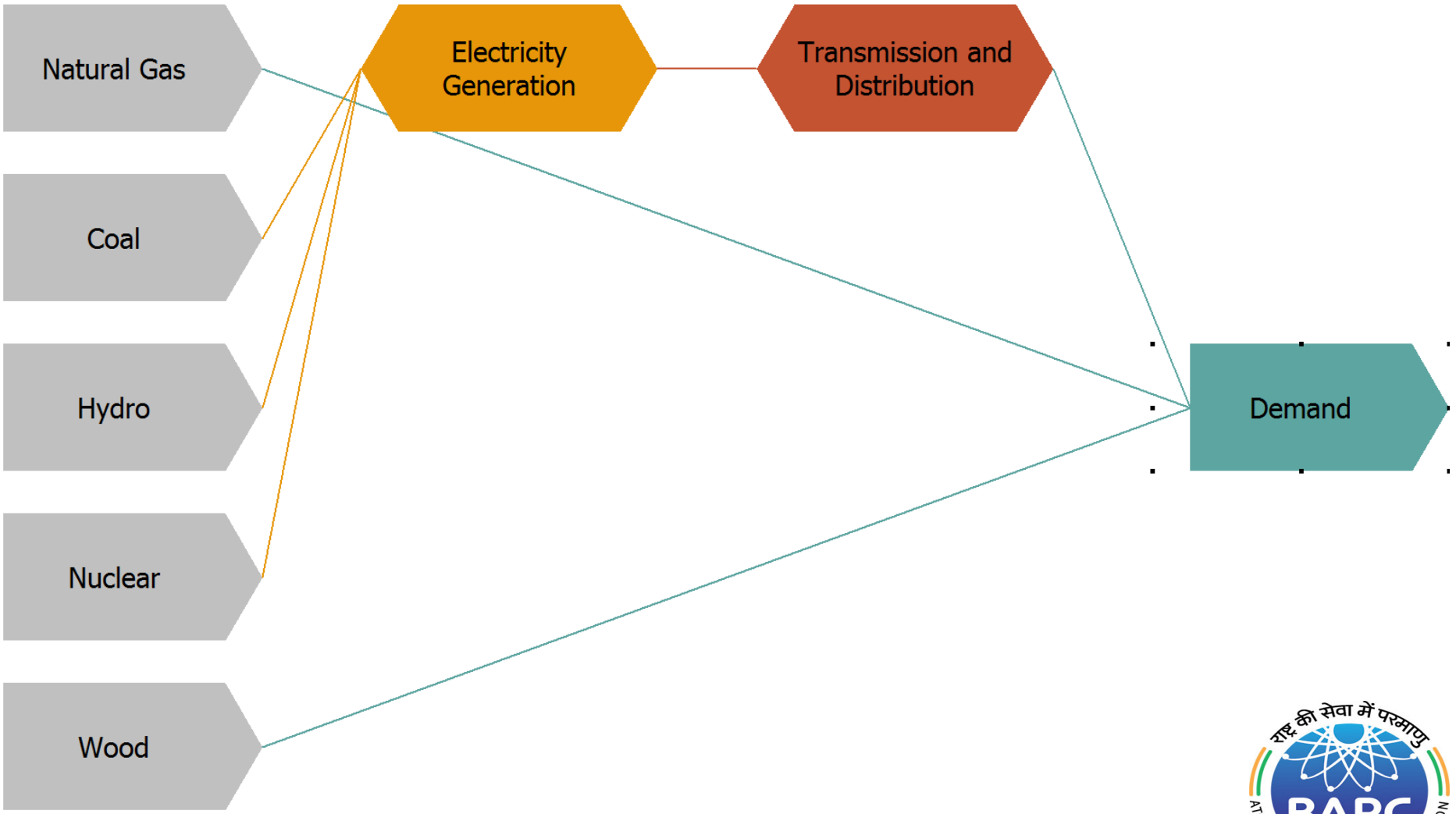


Greenhouse gas emissions by sources and removal by sinks from India (thousand tons)

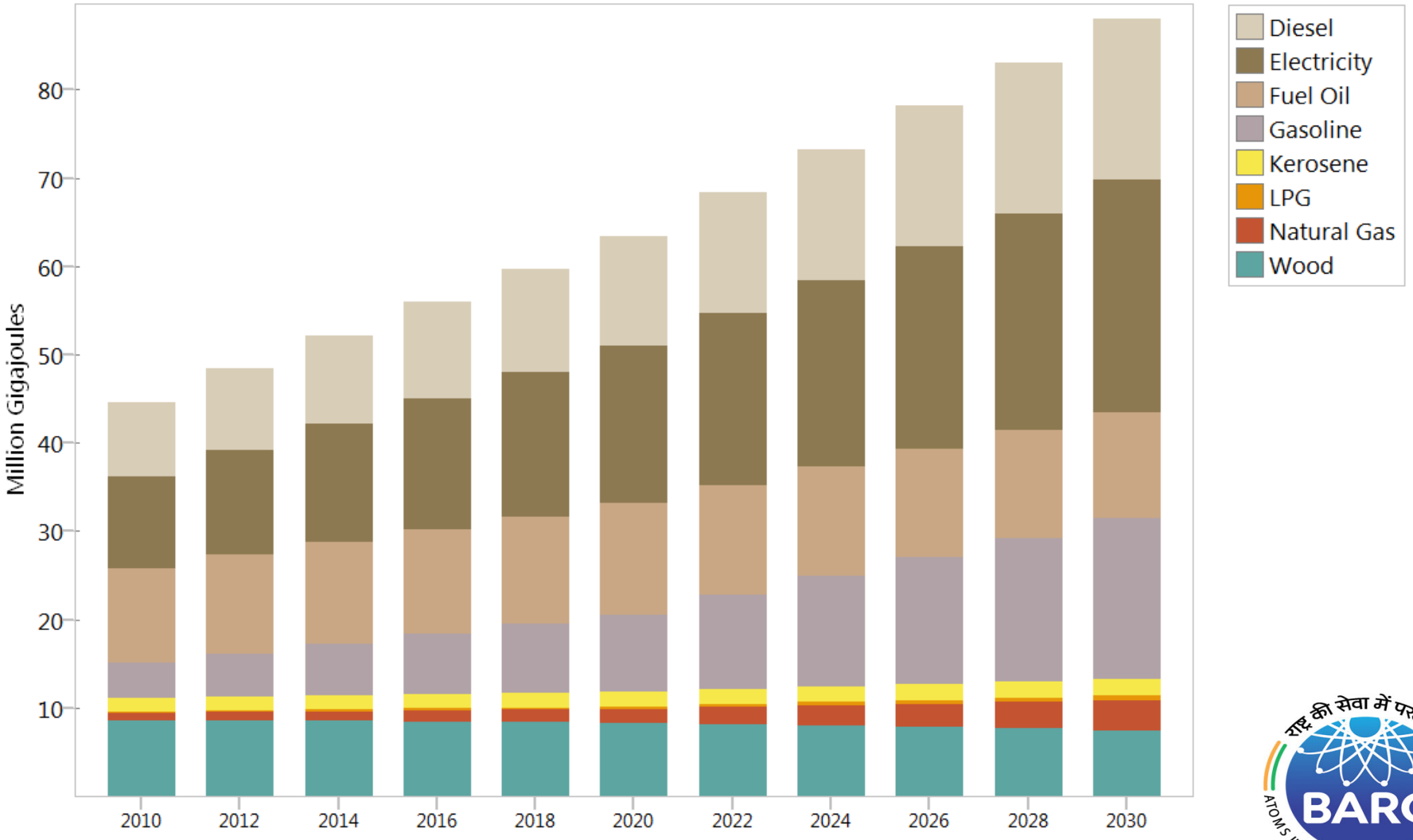
	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	CO_2 eq
Energy	992836.3	-	4266.0	56.88	1100056.9
Industry	405862.9	-	14.8	20.6	412546.5
Agriculture	-	-	13767.8	146.1	334405.5
LULUCF	98330	275358	-	-	-177028.0
Waste	-	-	2515.6	15.8	57725.2
Grand Total	1497029.2	275358.0	20564.2	239.3	1727706.1

Application of LEAP for Green House Gas Mitigation Exercise for India

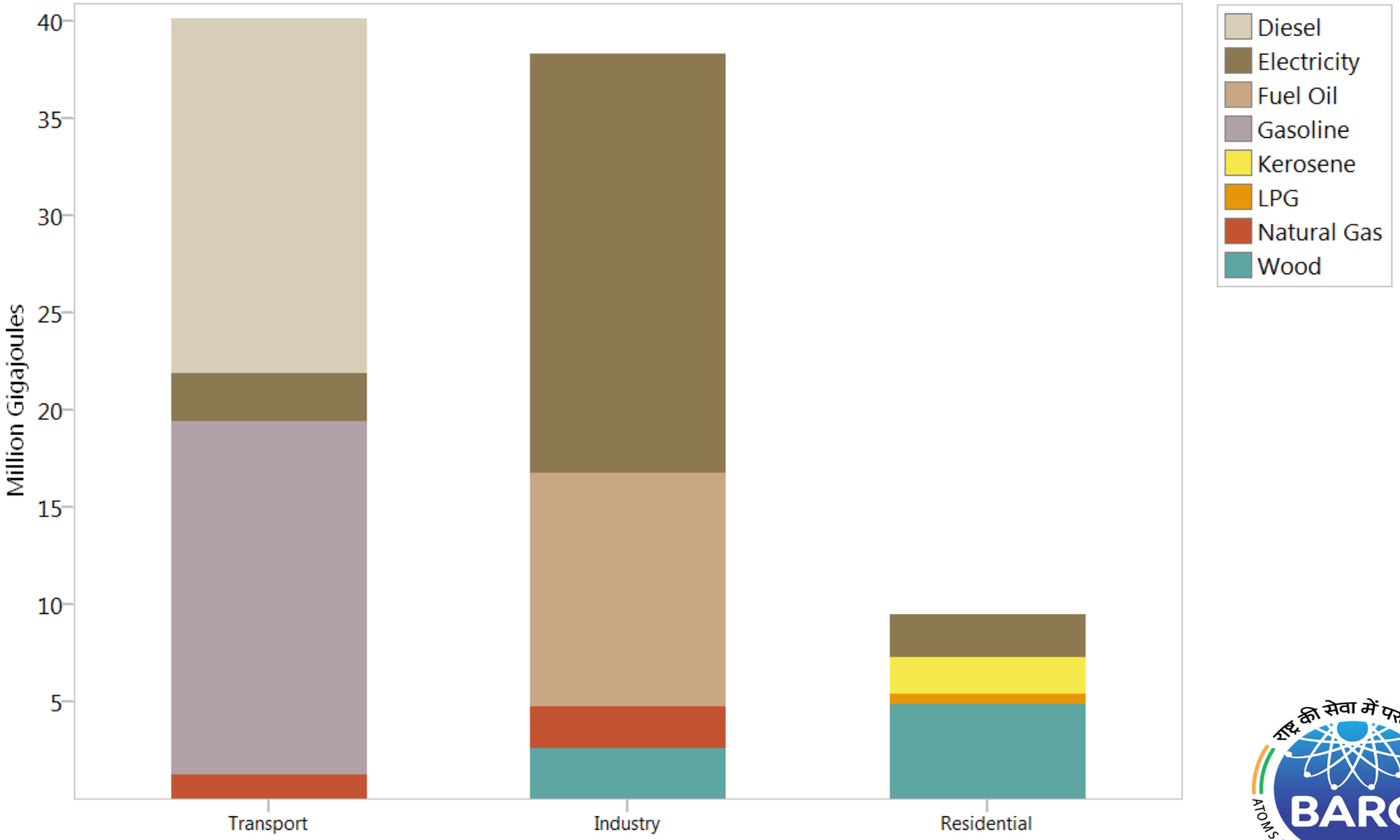
Reference Energy System



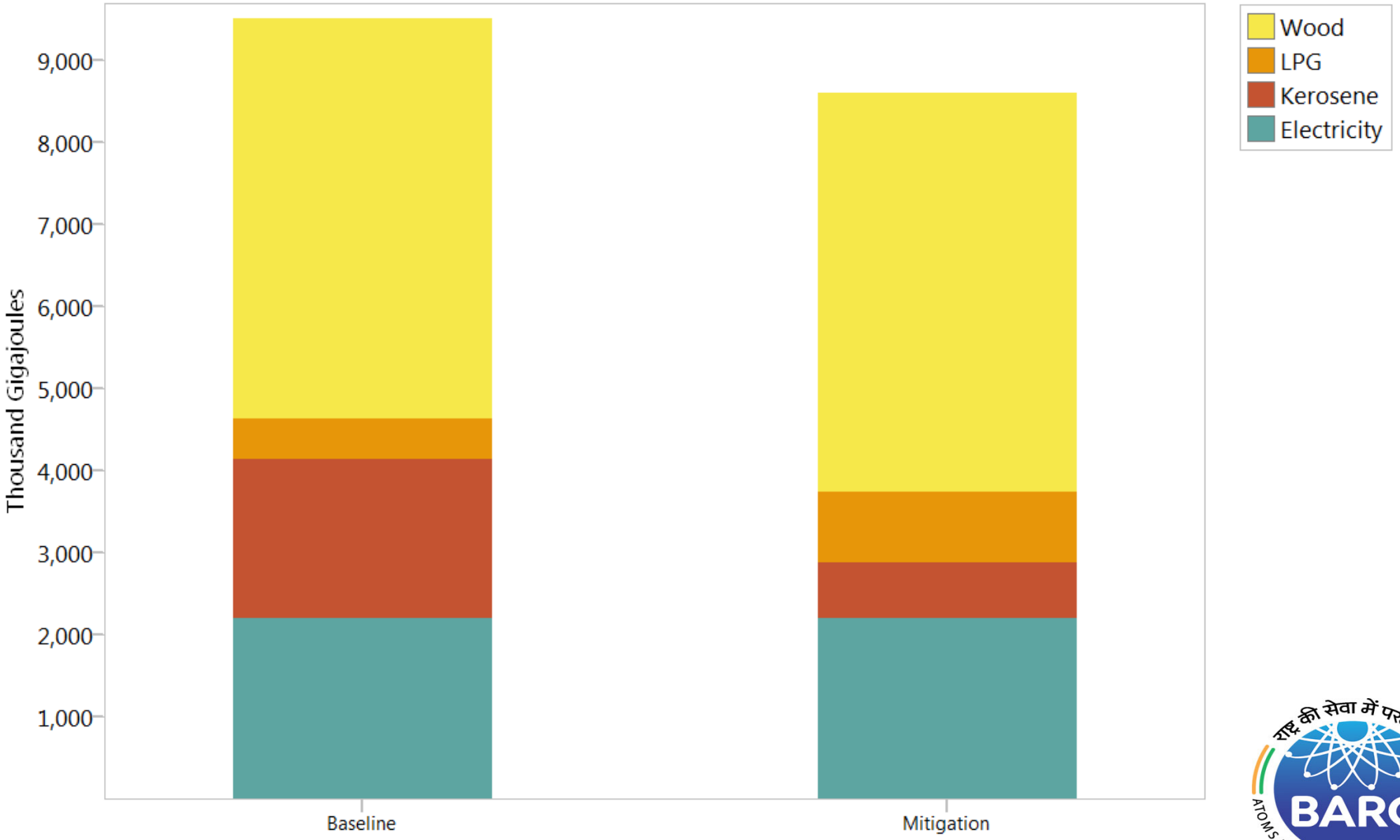
Total Energy Demand for Baseline Scenario



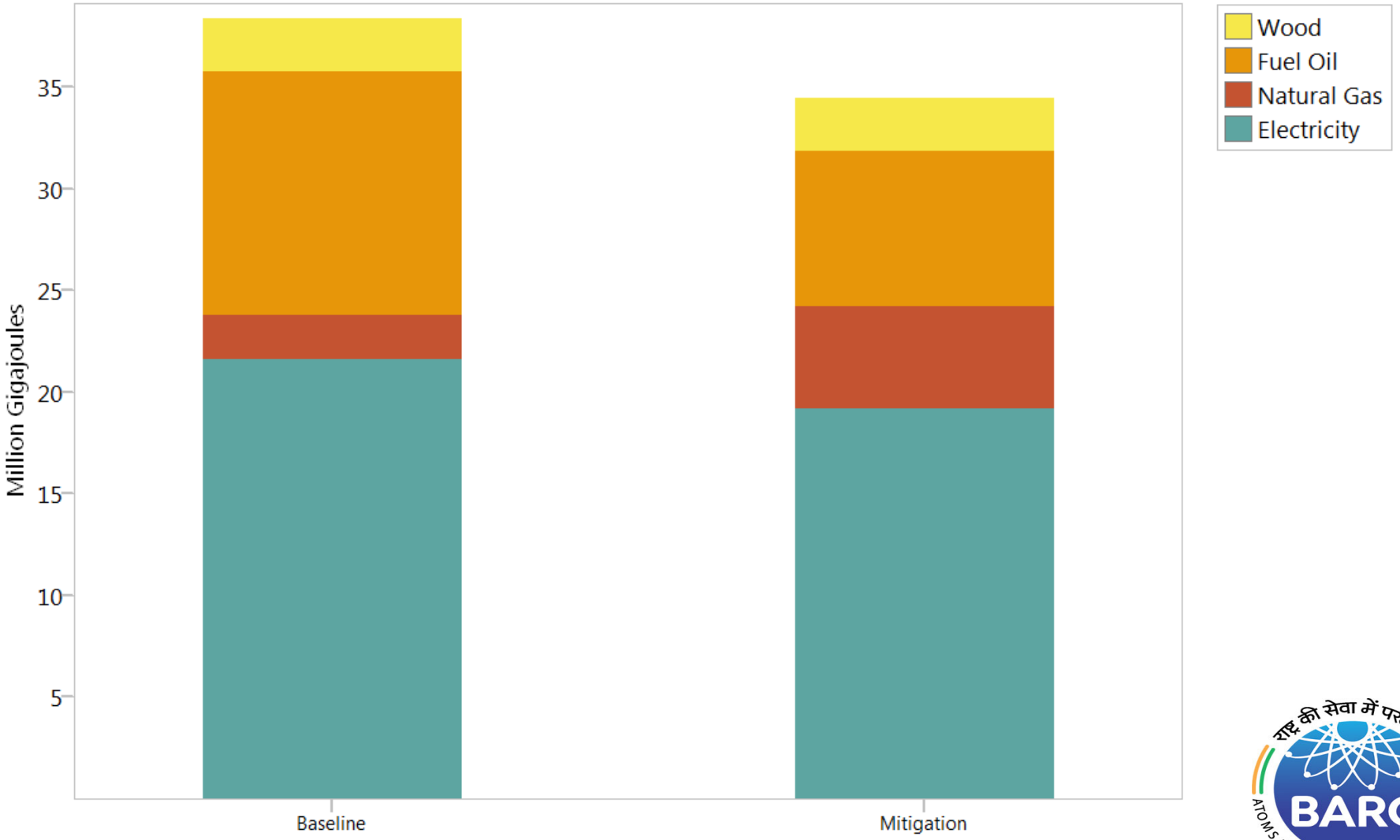
Energy Demand Baseline Scenario, Year: 2030



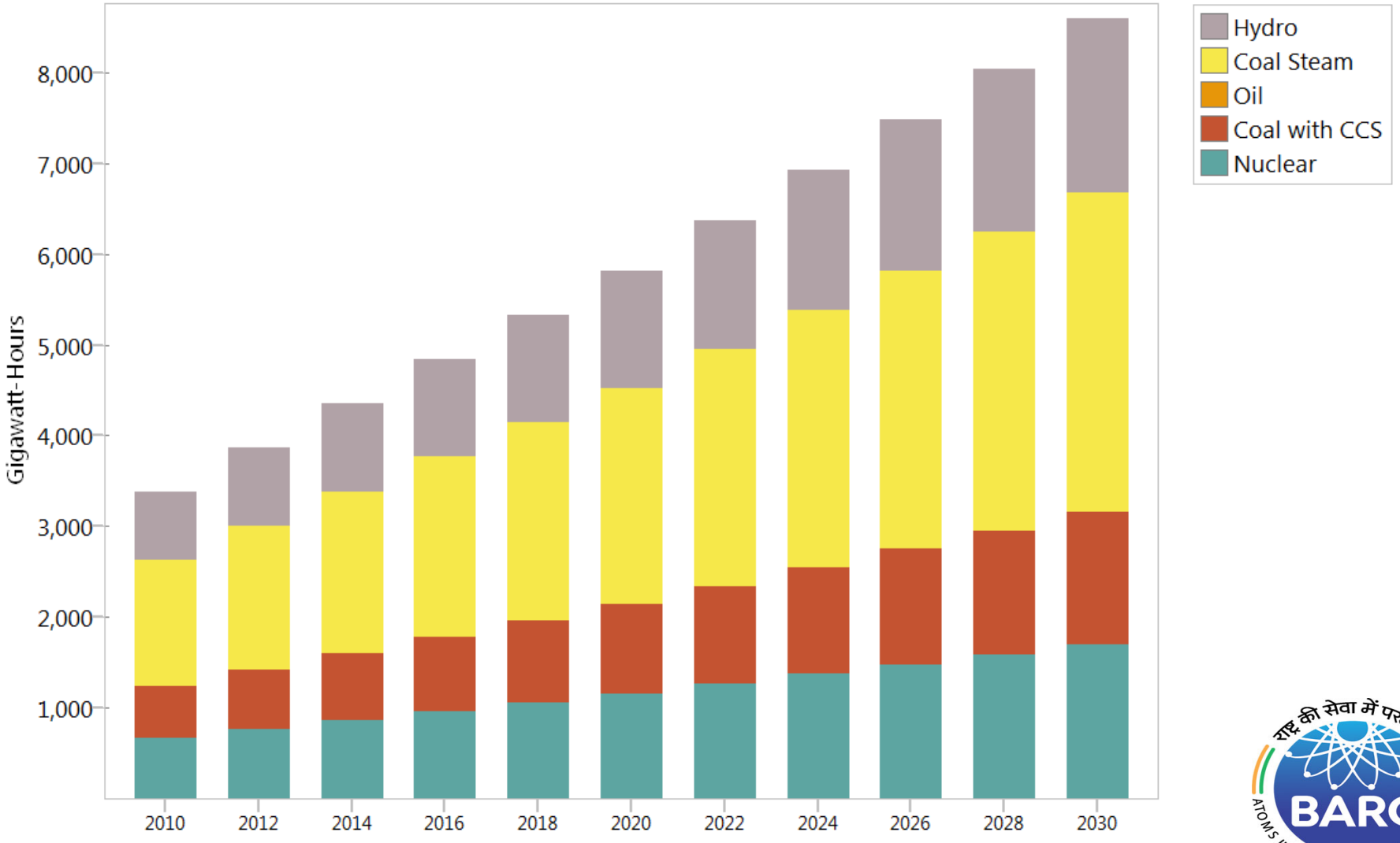
Energy Demand For Residential: 2030



Energy Demand For Industry: 2030

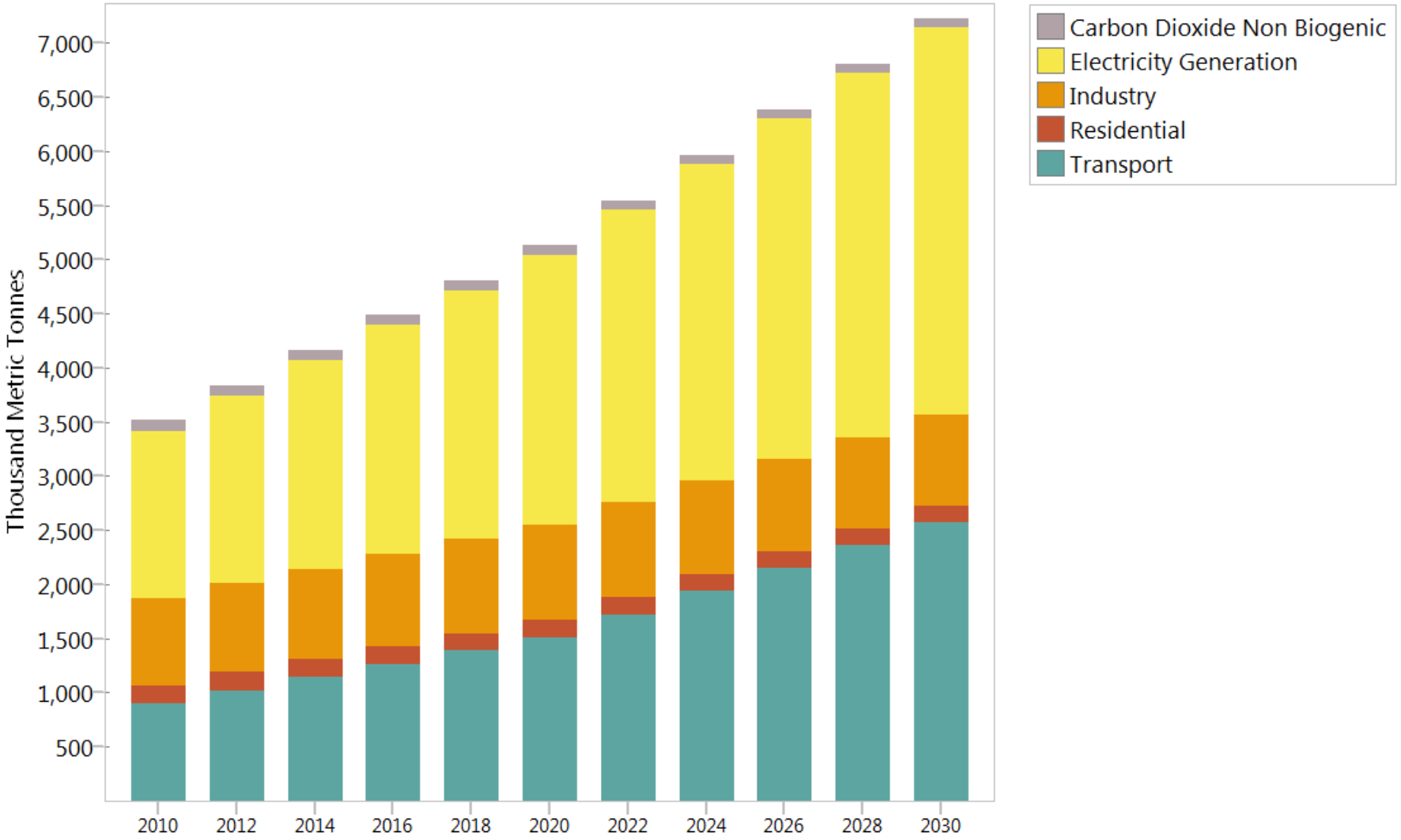


Electricity Generation for Baseline Scenario

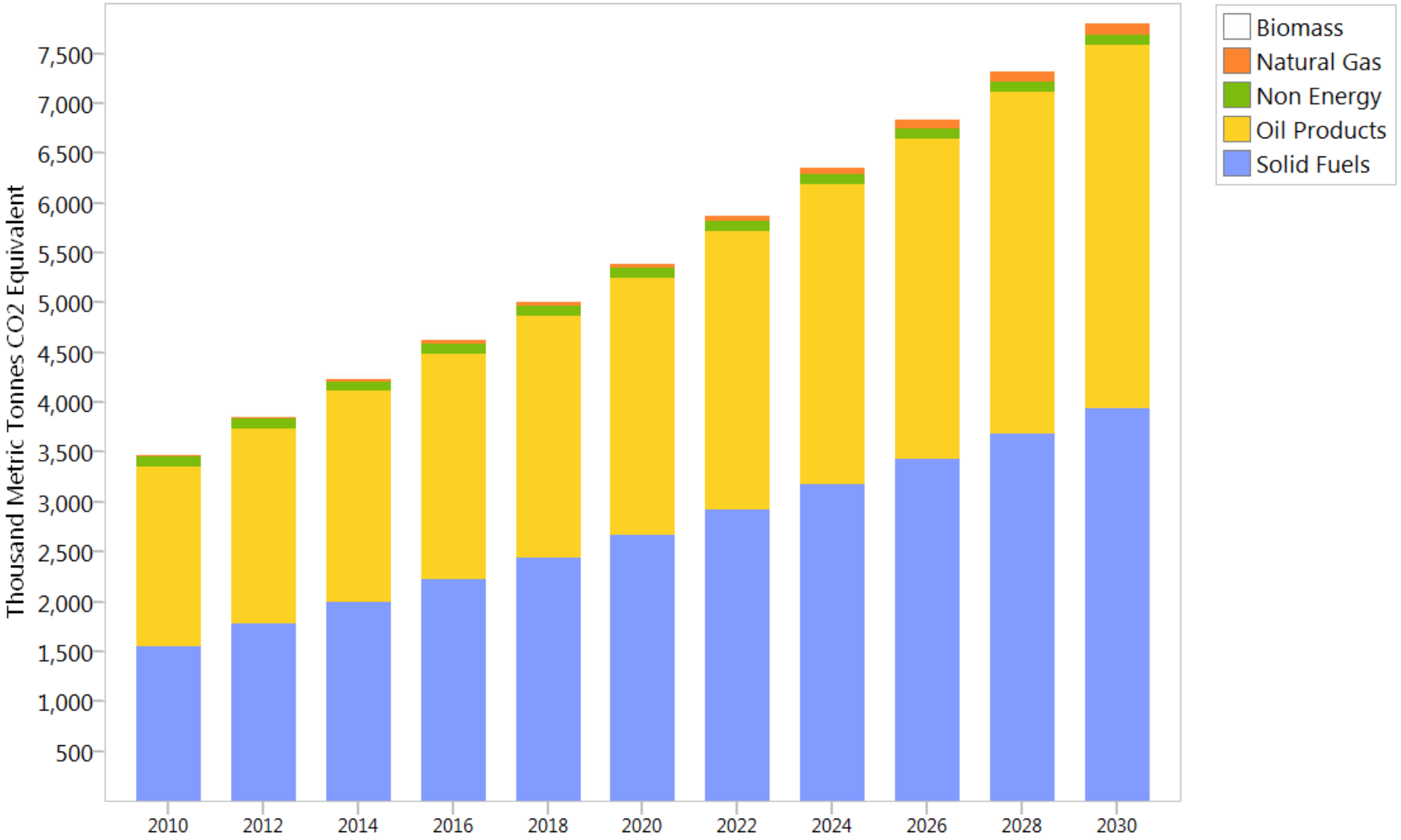


Global Warming Potential by Sector

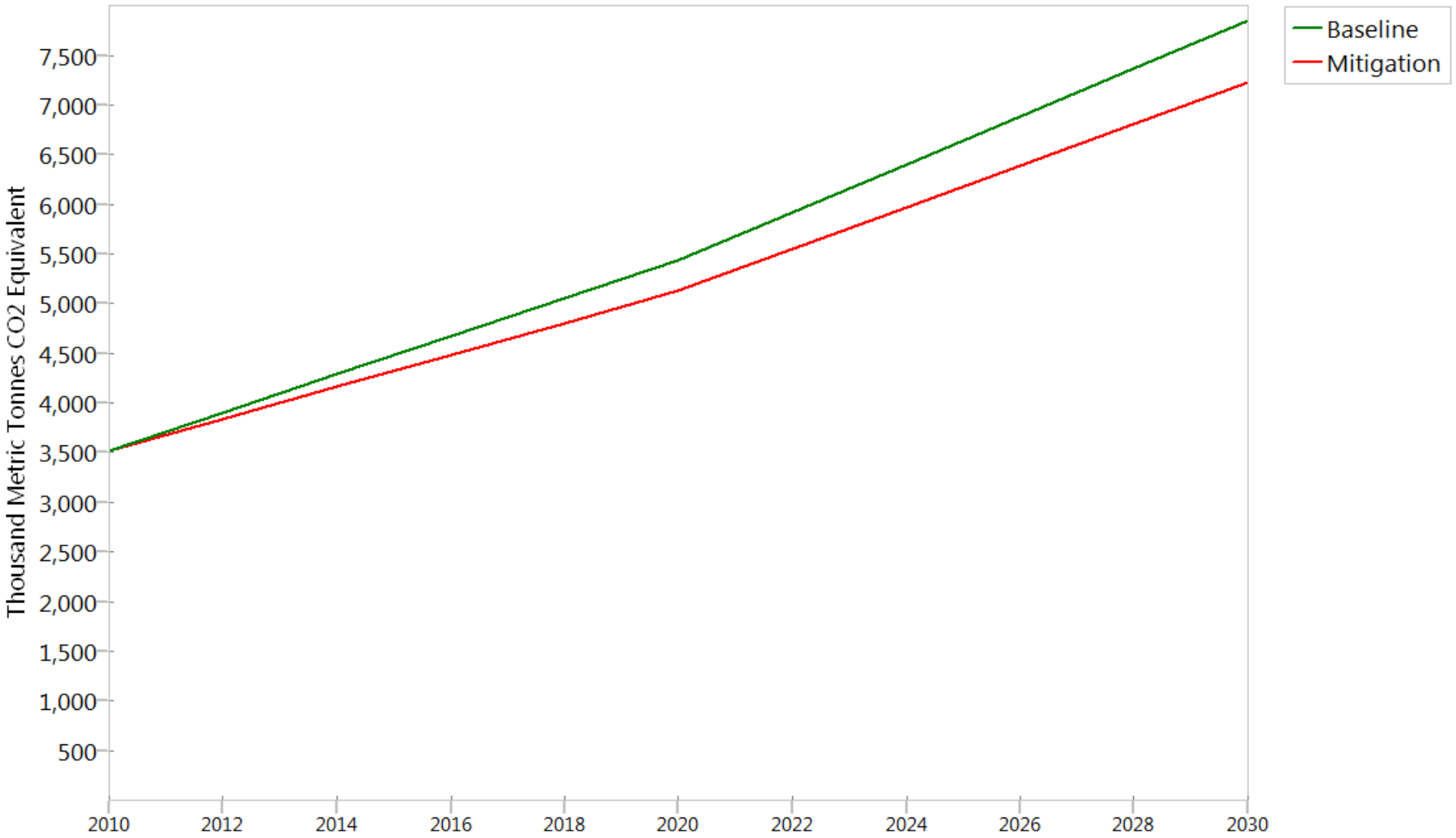
Scenario: Mitigation



Global Warming Potential by Fuel
Scenario: Baseline



Global Warming Potential

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