Challenge of the *new* balance

Chandra Bhushan

The study

- ‘Bottom-up’ study to understand the potential to reduce GHG emissions in five most emissions-intensive industrial sectors and the power sector
  - Benchmarking energy and GHG emissions with Best Available Techniques (BAT)
  - Researching technology options; round table with industries to understand their future technology deployment pathway, limitations, dis/advantages

The study

- **Two pathways projected till 2030-31**
  - **Business As Usual (BAU):** Changes that industry is making or will make on its own to reduce energy consumption -- **high cost of energy is the main driver of change**. Promises made by the government in NAPCC included in this scenario; changes due to environmental regulations also included
  - **Low Carbon (LC):** Policy push required to mainstream emerging, not yet commercialized technologies. In many sectors, it is also a ***'leap into the unknown'***. **Combating climate change is the main driver of change**.

The study

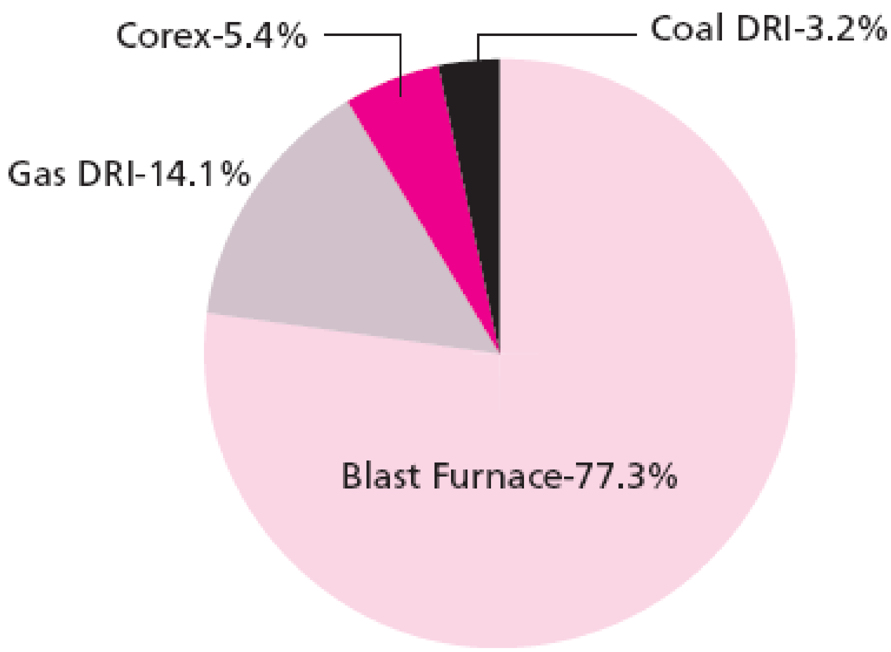
- **Resource requirement**
  - Study of 164 greenfield projects cleared in last 3 years by MoEF
  - Land and water requirements in the BAU and LC scenarios
  - Raw material and fuel requirements based on production projection and energy profile

Iron and steel

Iron and Steel

- **Sample:** All 11 Integrated steel plants and one stand-alone DRI plant (Tata Sponge) -- **63% of total steel production in the country**

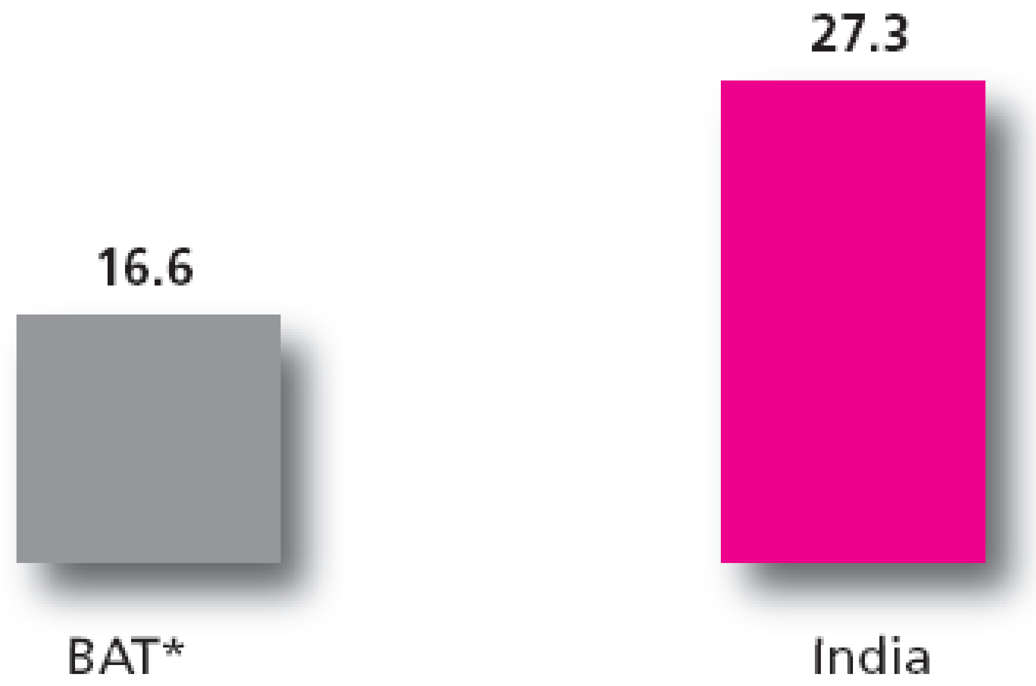
Process routes in the surveyed plants



Primary energy consumption

Iron and Steel

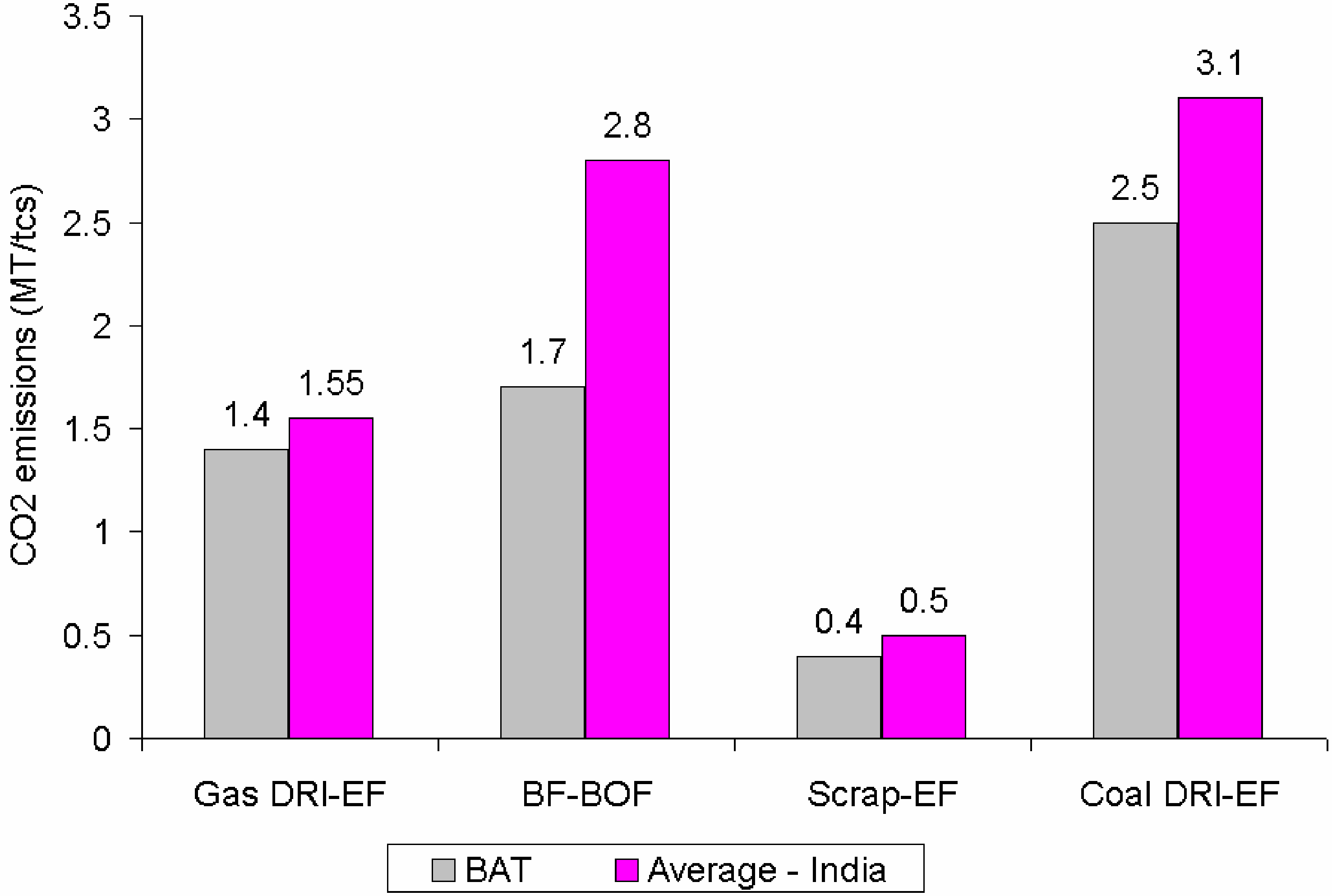
GJ/tcs



Average 65% higher than BAT; even the best plant 30% above BAT

GHG emissions

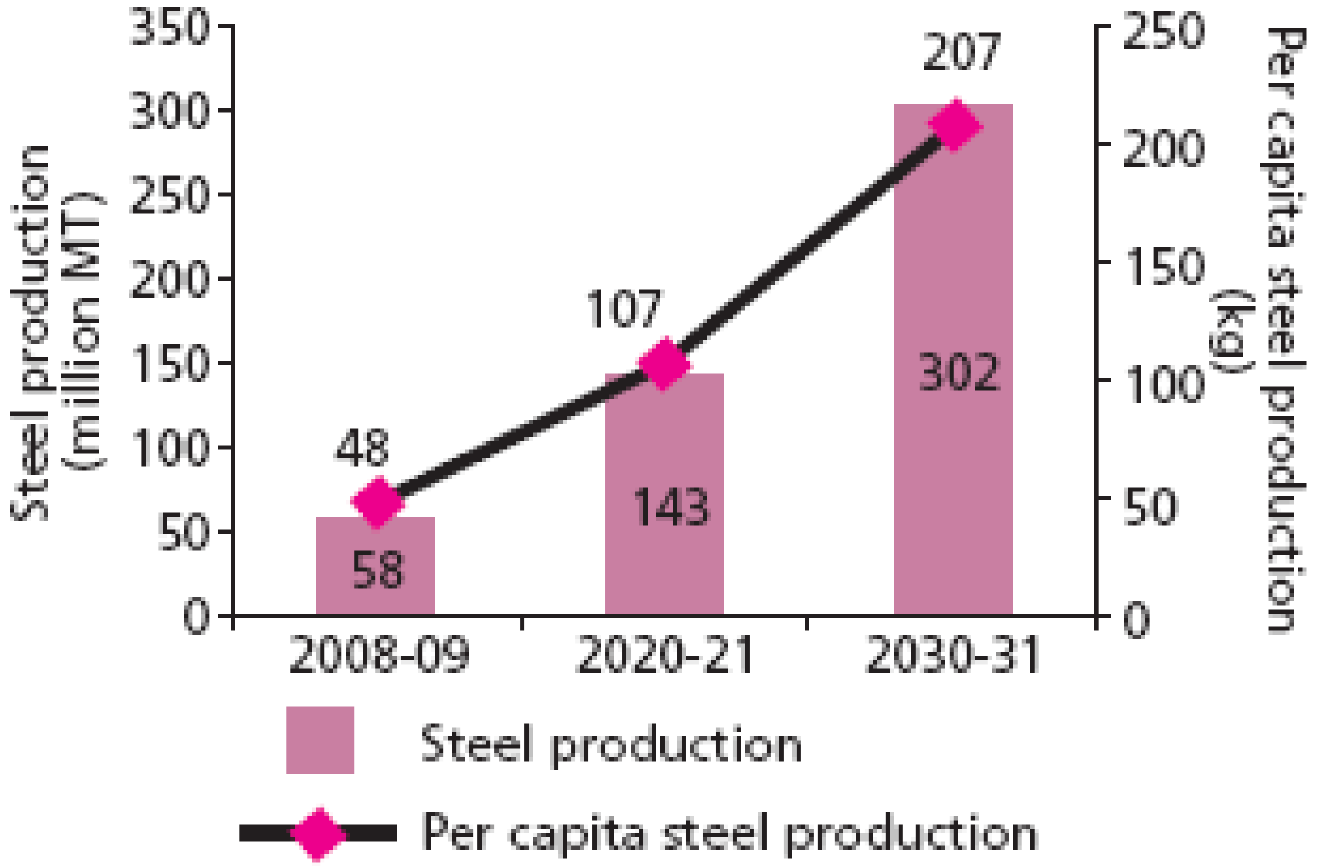
Iron and Steel



Highest potential in BF-BOF; about 25% in coal DRI-EF

Production projection

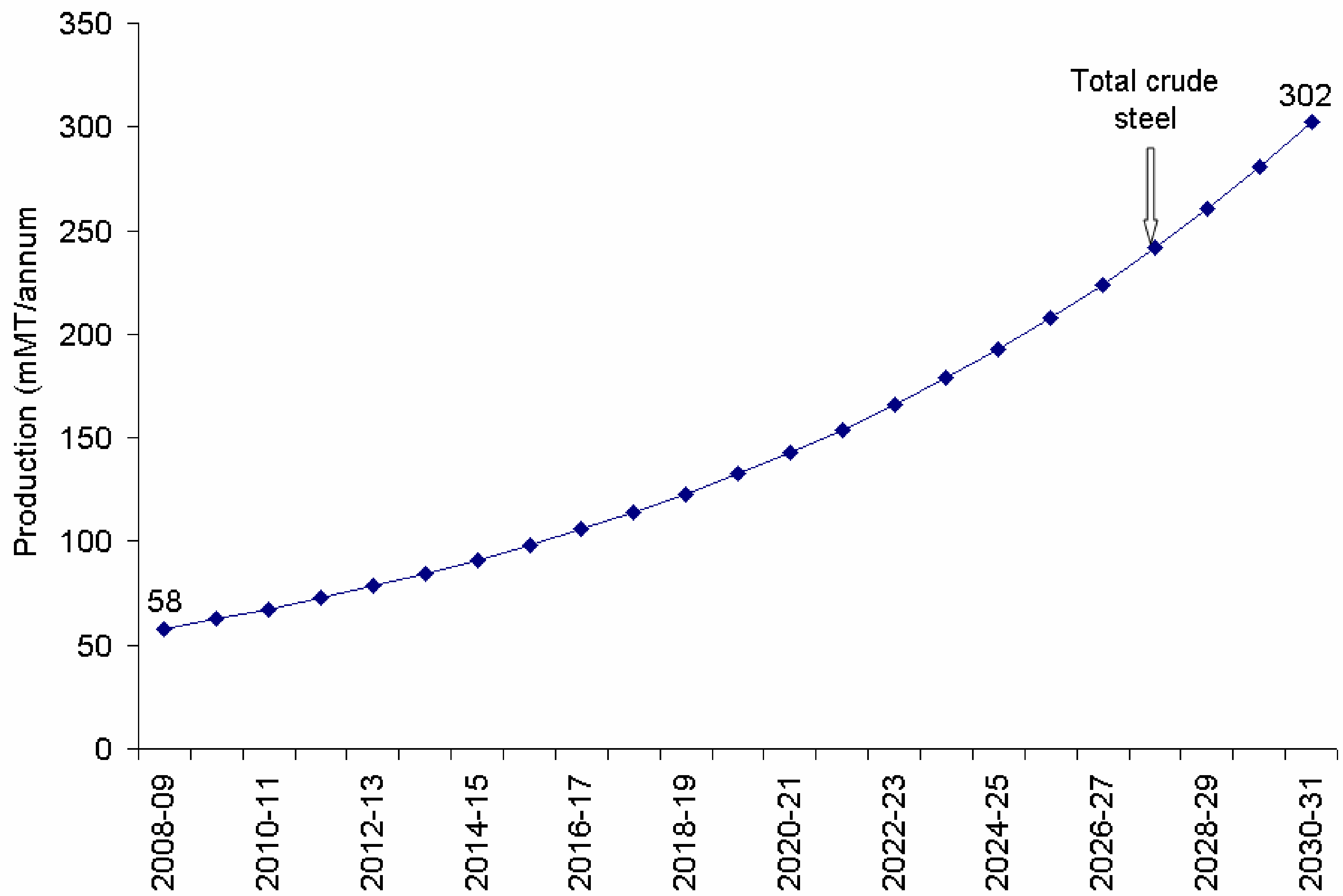
Iron and Steel



Per capita steel production in 2030-31 will be about 210 kg; equal to the <u>current</u> global per capita steel consumption

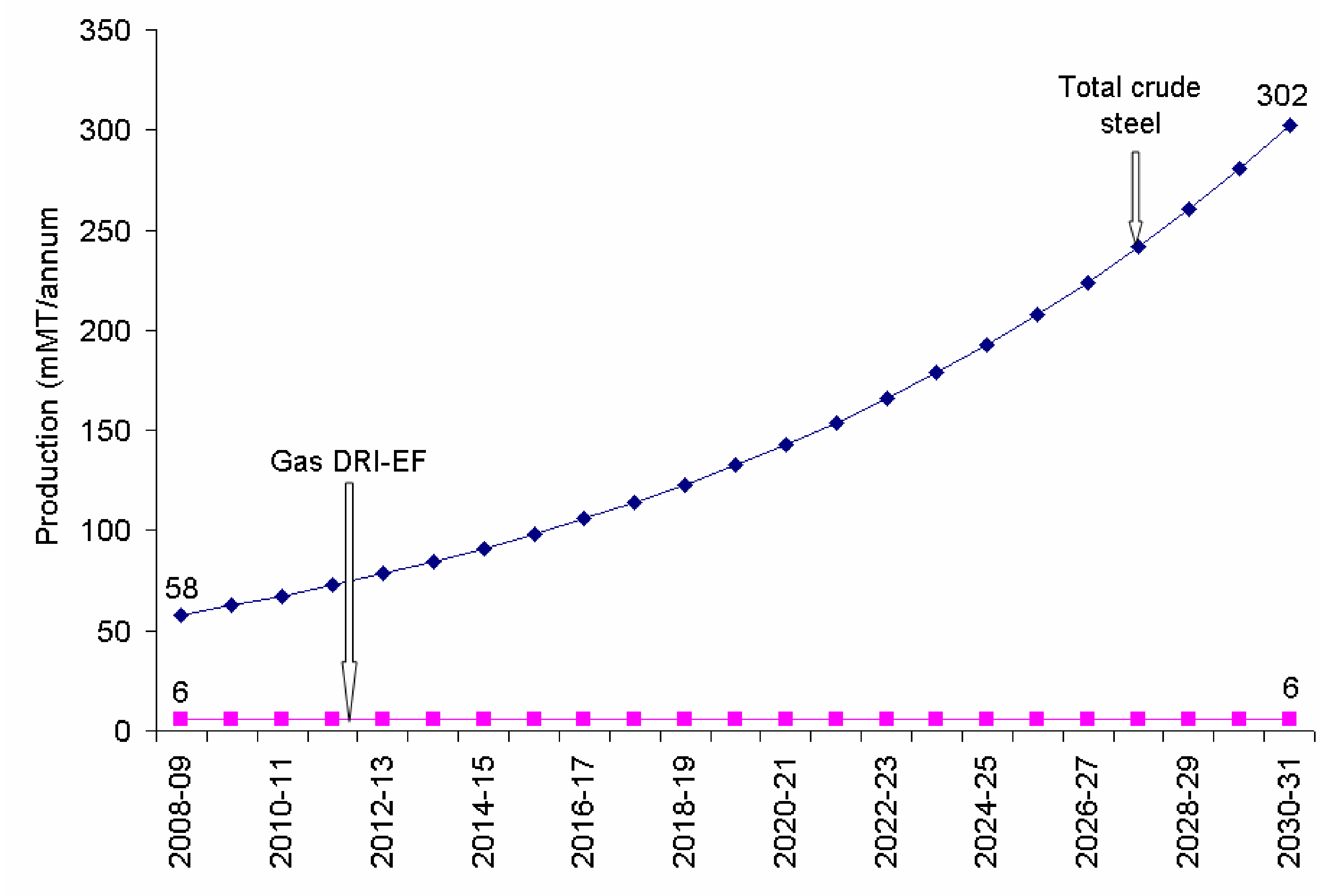
Production projection

Iron and Steel



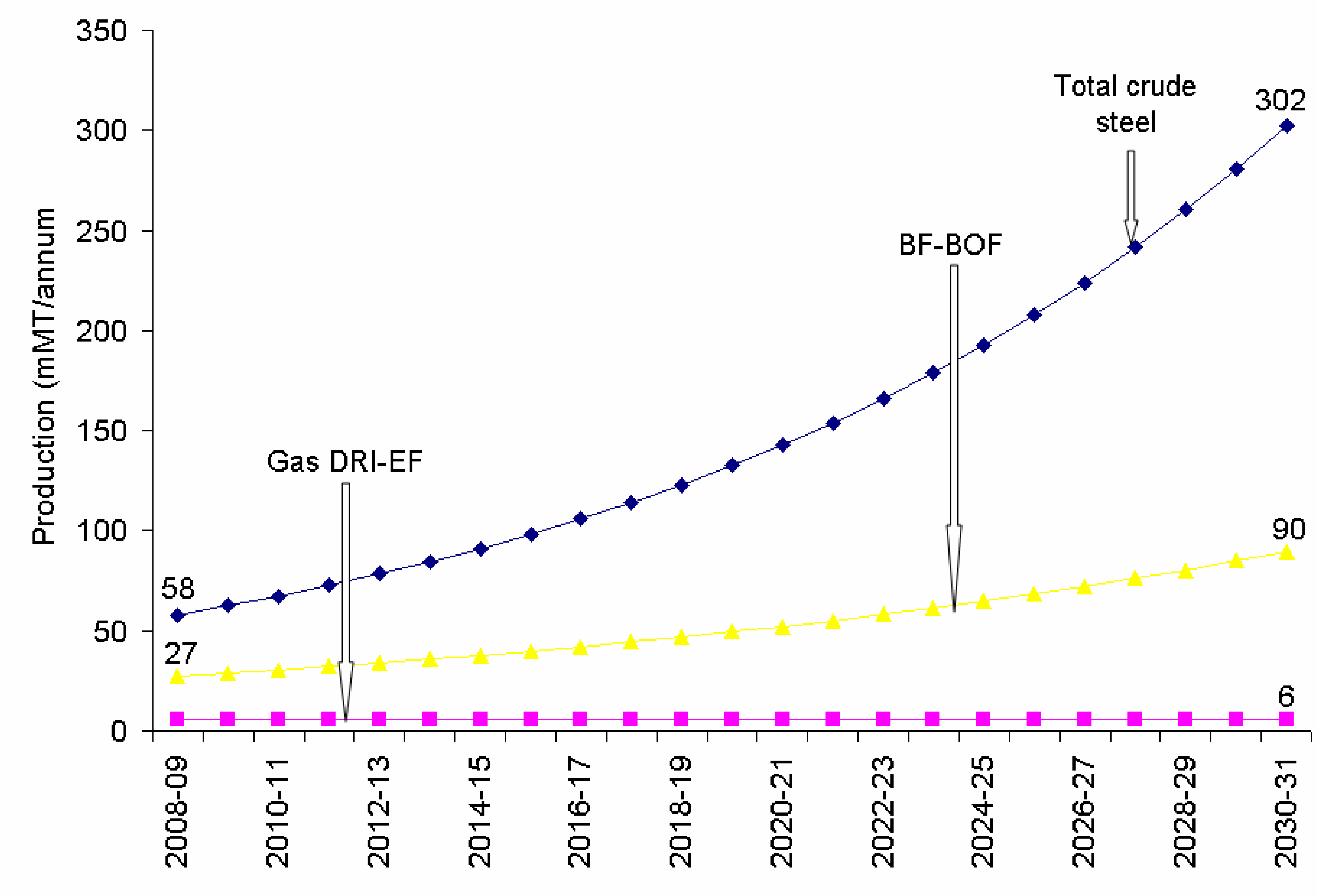
Production projection

Iron and Steel



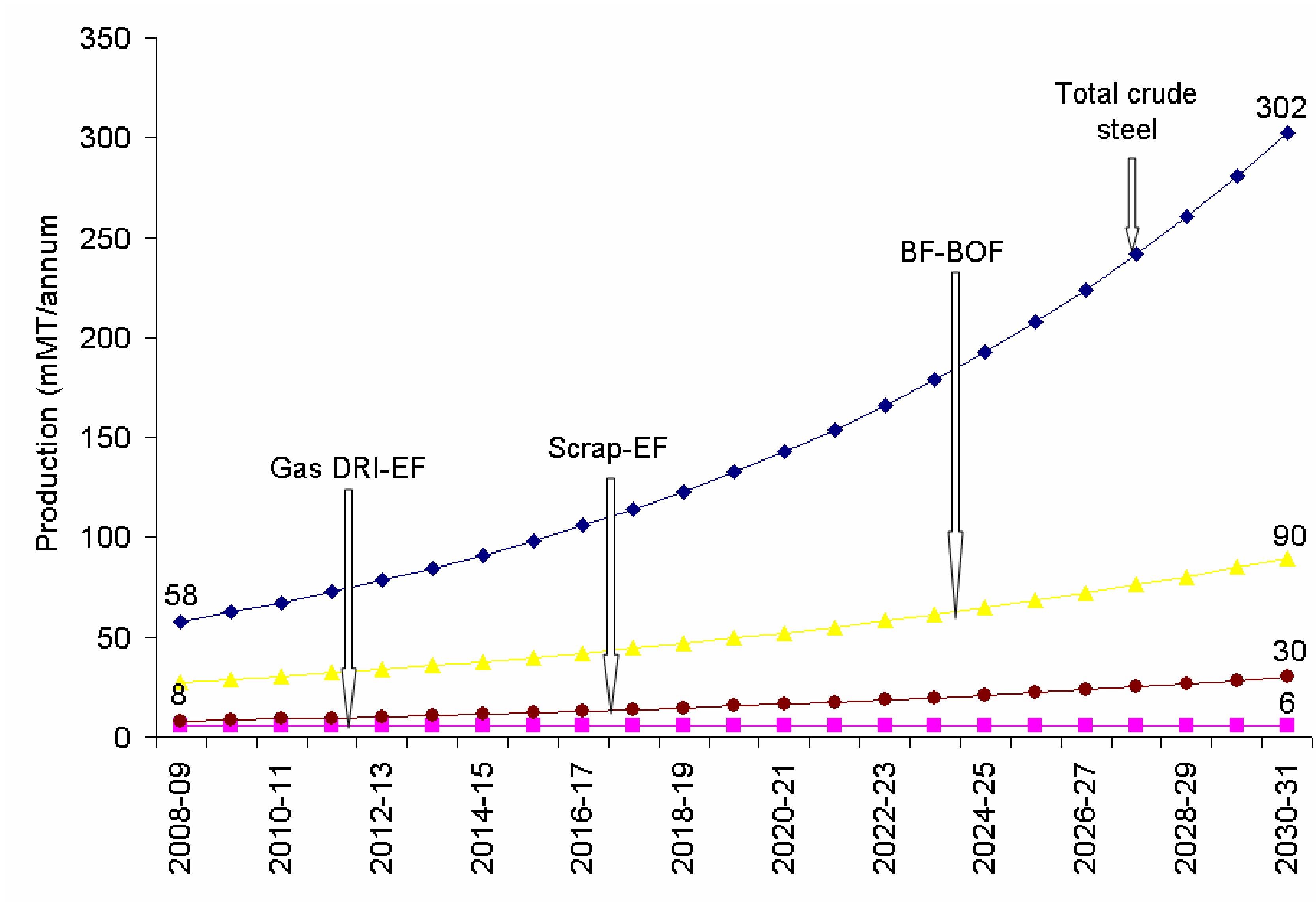
Production projection

Iron and Steel



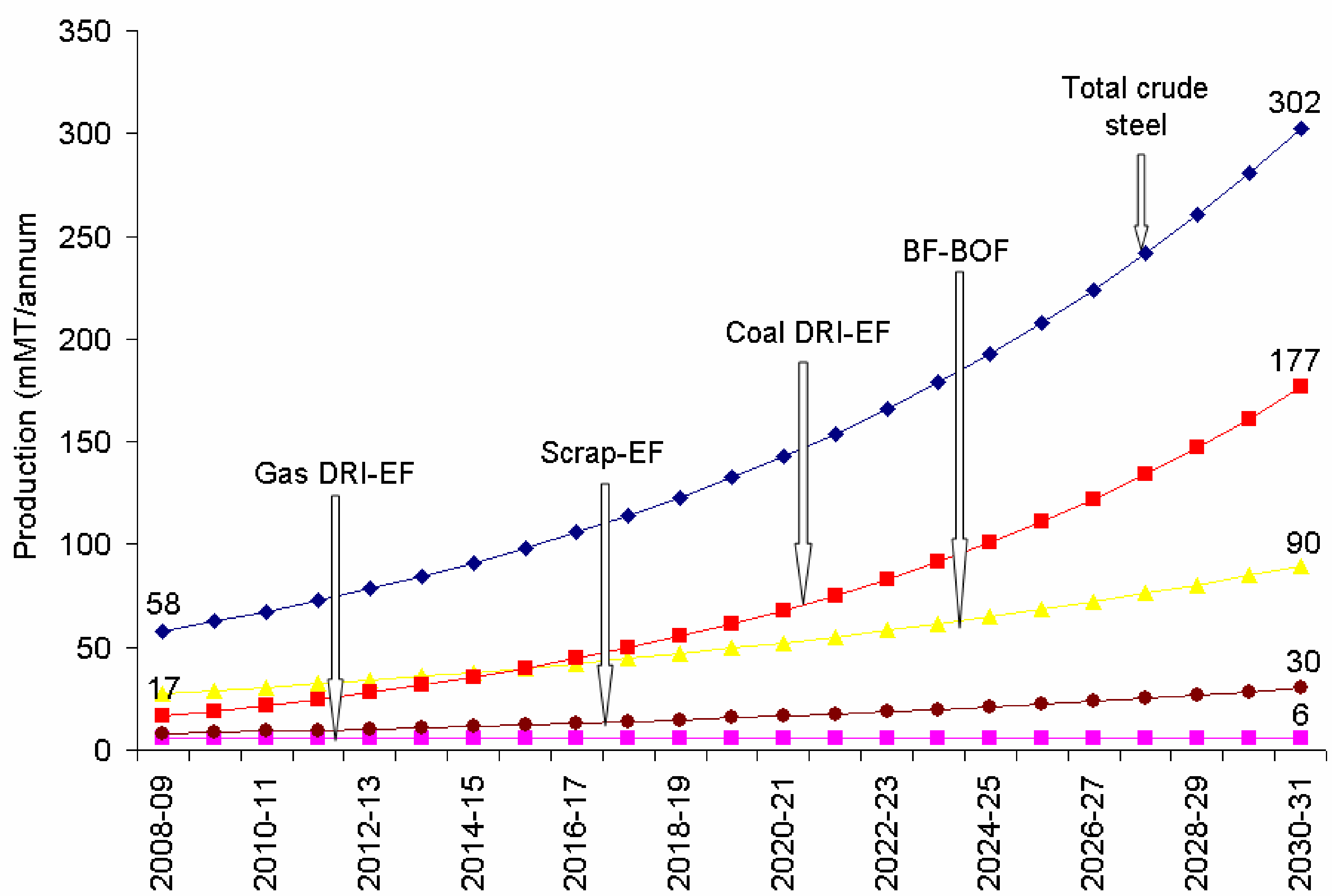
Production projection

Iron and Steel



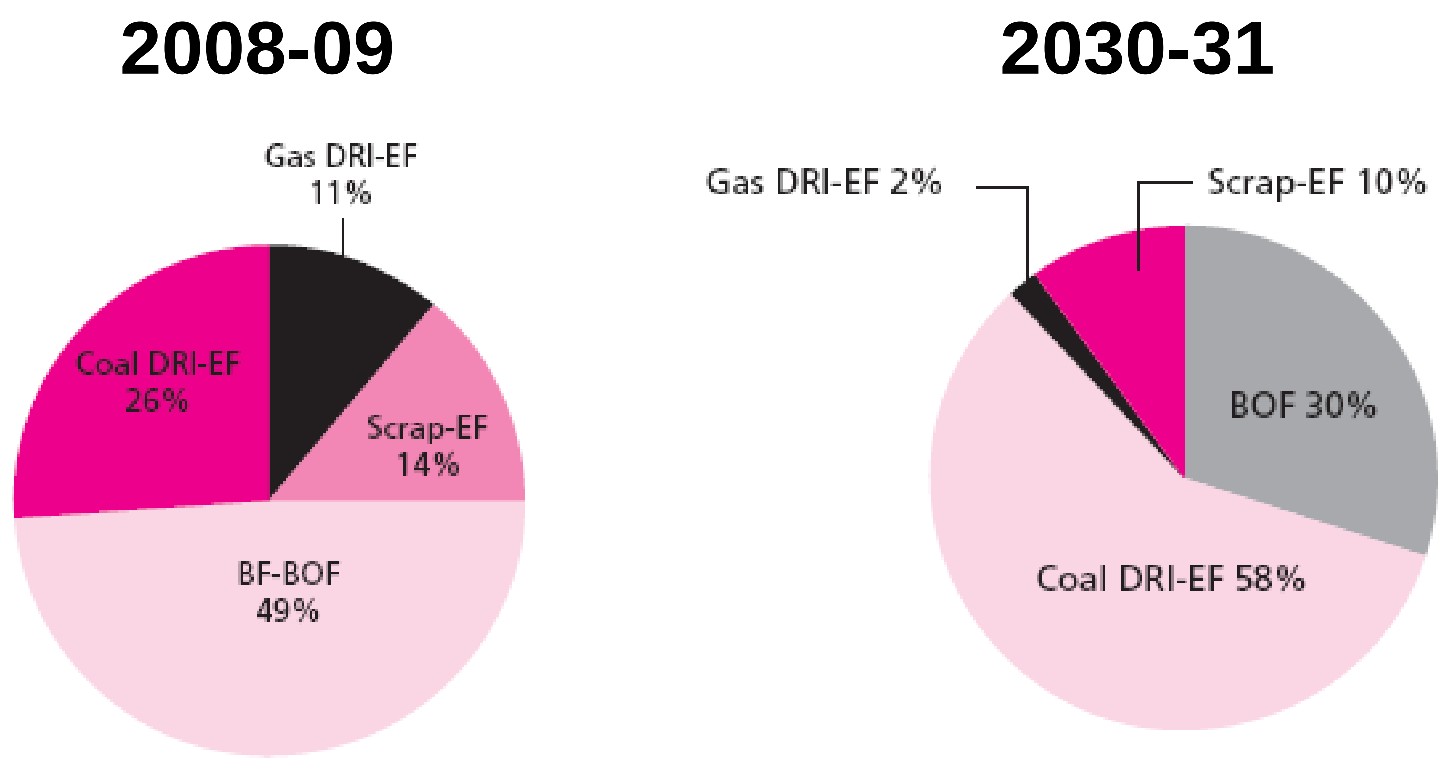
Production projection

Iron and Steel



Process route: steel production

Iron and Steel



Technology roadmap: BAU

Iron and Steel

- **BF-BOF**: Energy consumption to reduce by about 5 GJ/tcs by adopting three mature technologies – CDQ, TPT & PCI – and by improving process controls
- **Coal DRI-EF:** Power generation 500-600 kWh/tonne-DRI from waste heat recovery and char boilers; power consumption in EF reduced by 200 kWh/tcs.
- Marginal improvements in gas DRI-EF

Technology roadmap: LC

Iron and Steel

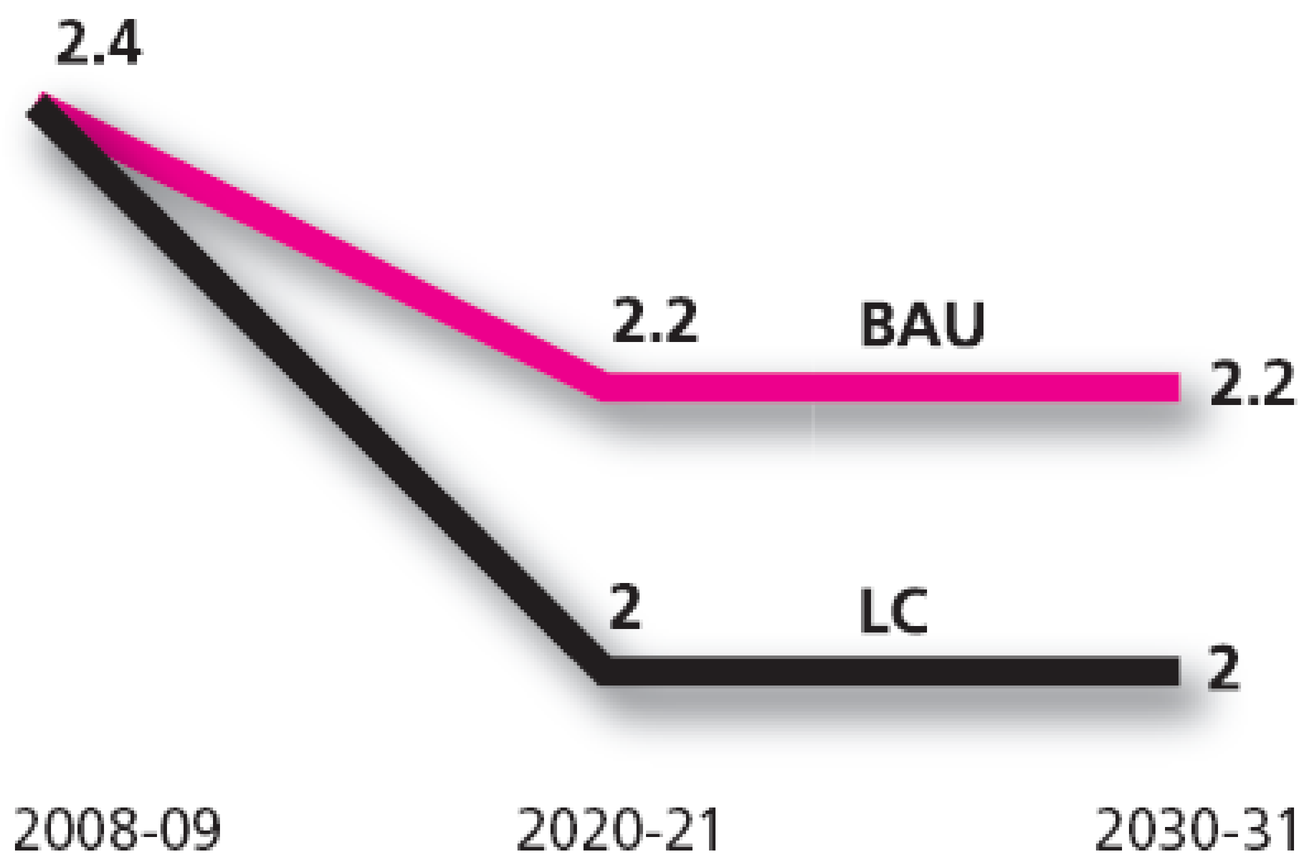
- **BF-BOF:** Energy consumption can be reduced further by about 3 GJ/tcs by installing cogeneration systems and recovering all low grade waste heat (all experimental technology)

- **DRI-EF:** No change in DRI production. EF power consumption can be reduced by another 300 kWh/tcs by adopting advanced technologies like scrap/DRI preheating by post combustion of flue gases, oxy-fuel burners etc.

Emissions intensity

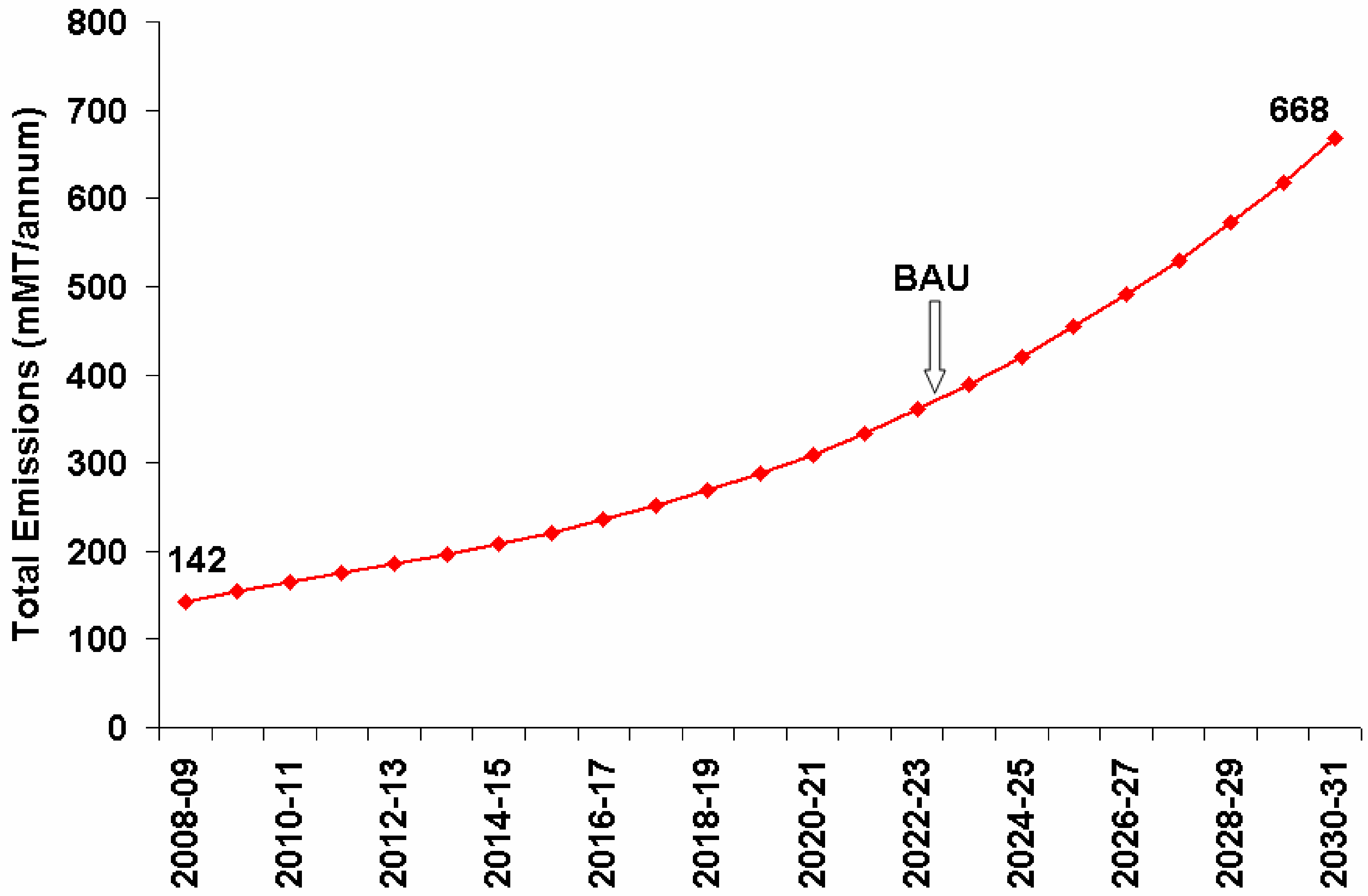
Iron and Steel

MT CO_2/tcs



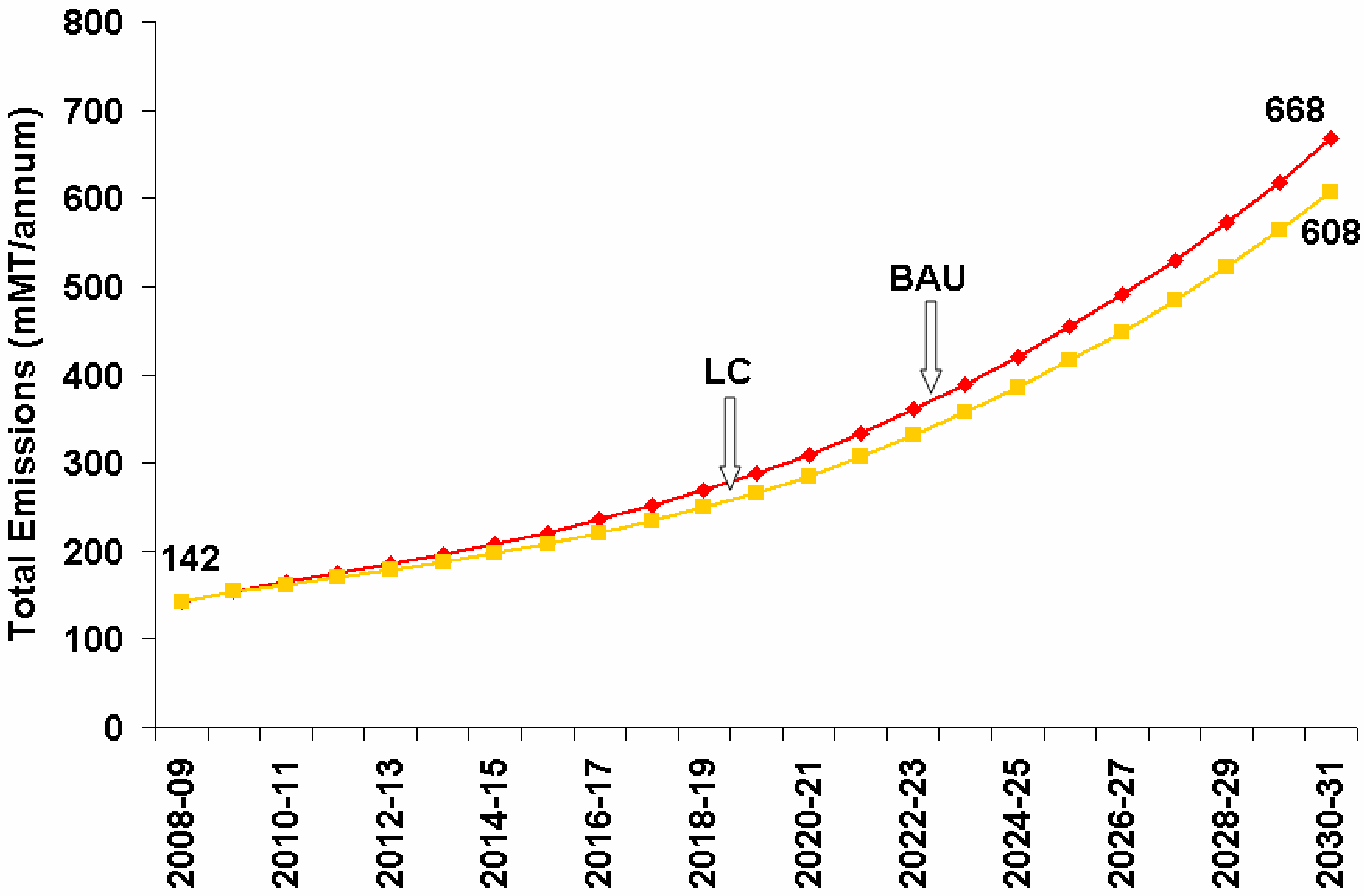
Emissions trajectory

Iron and Steel



Emissions trajectory

Iron and Steel



Limitations

Iron and Steel

- High ash coking and non-coking coal
- High silica and alumina content in iron ore
- **BF-BOF energy consumption difficult to reduce below 20 GJ/tcs**
- **DRI-EF energy consumption difficult to reduce below 25 GJ/tcs**

Aluminium

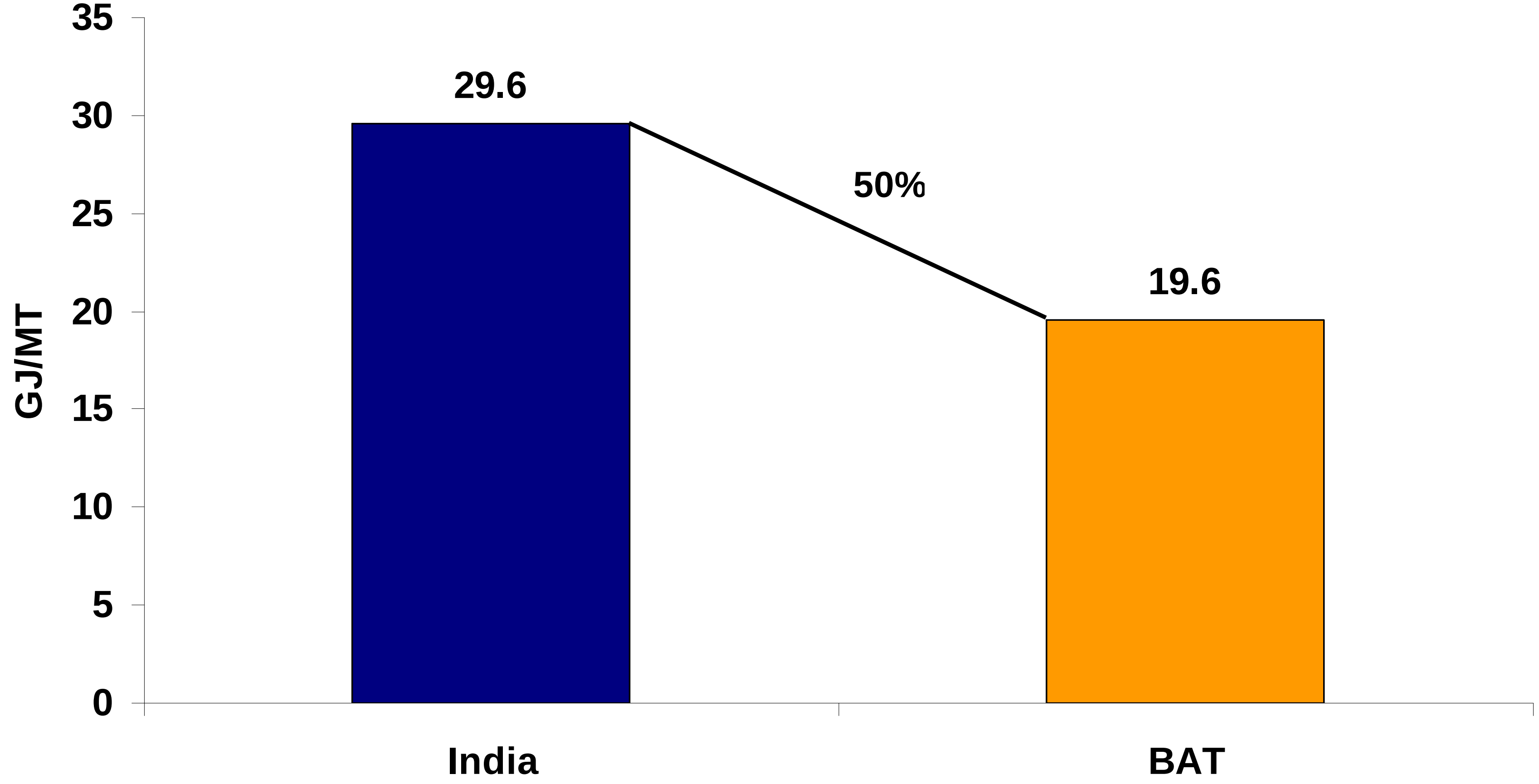
Aluminium

- **Sample**: 3 out of 5 operating smelters; **62 per cent of total aluminium production**

- All smelters in the sample based on state-of-the-art pre-baked anode technology – all upcoming plants also based on the same technology

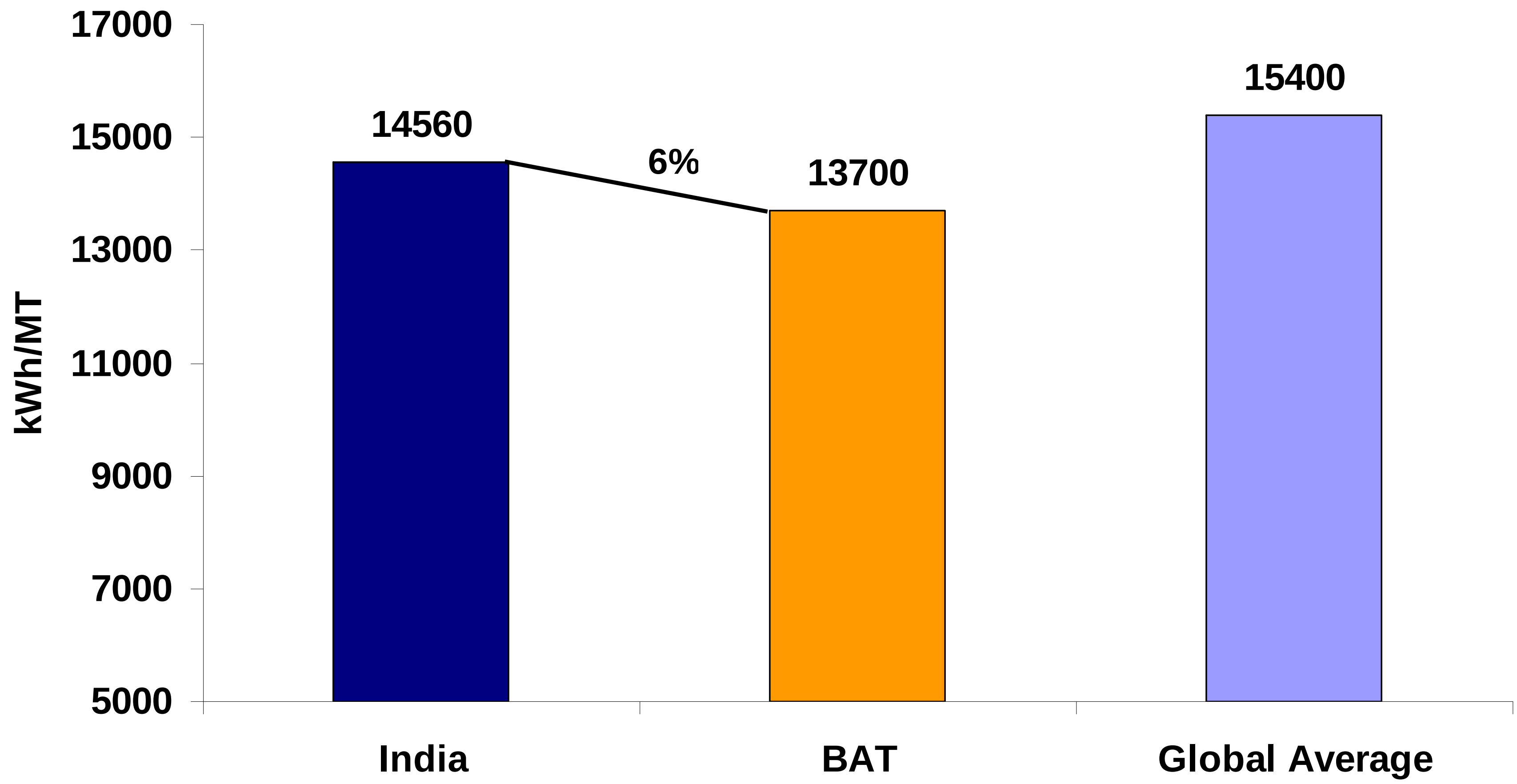
Fuel consumption: refinery

Aluminium



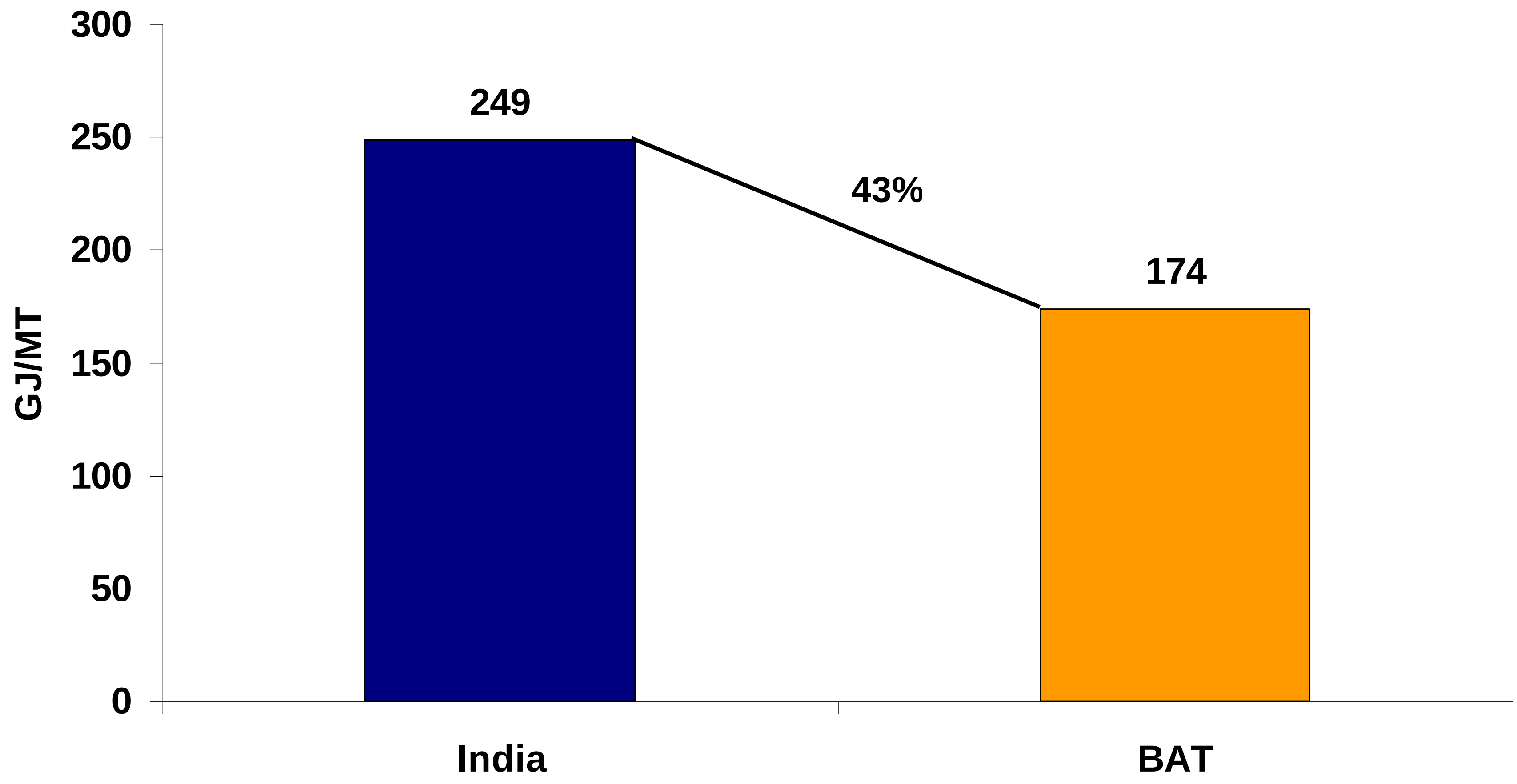
Power consumption: smelter

Aluminium



Primary energy consumption

Aluminium

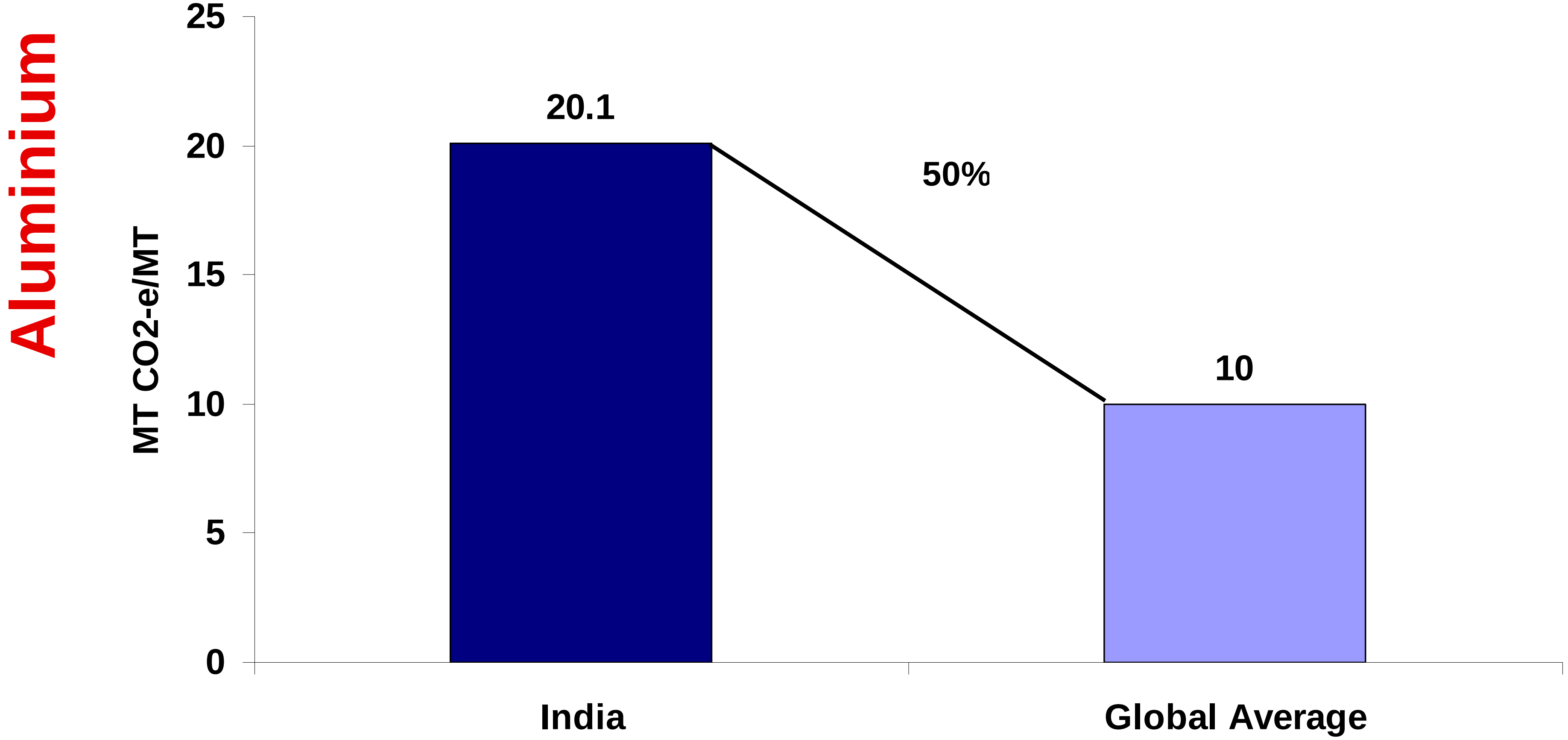


Aluminium

Aluminium

- Scope to reduce energy consumption in refinery
- Aluminium smelters in India are among the best in the world in power consumption
- Power, while efficiently used, is produced in inefficient coal-fired power plants (Hindalco 23%; Nalco 29%).

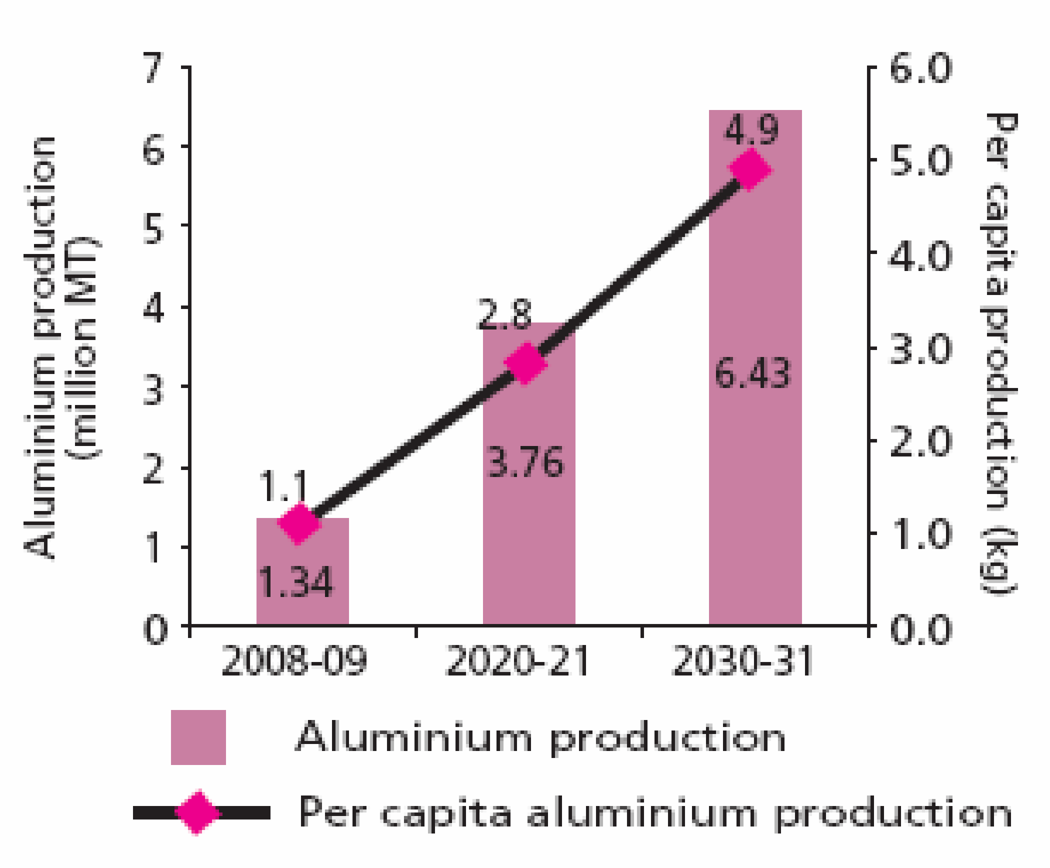
Aluminium



Low global average GHG emissions primarily due to sourcing of 50% electricity from hydro power

Production projection

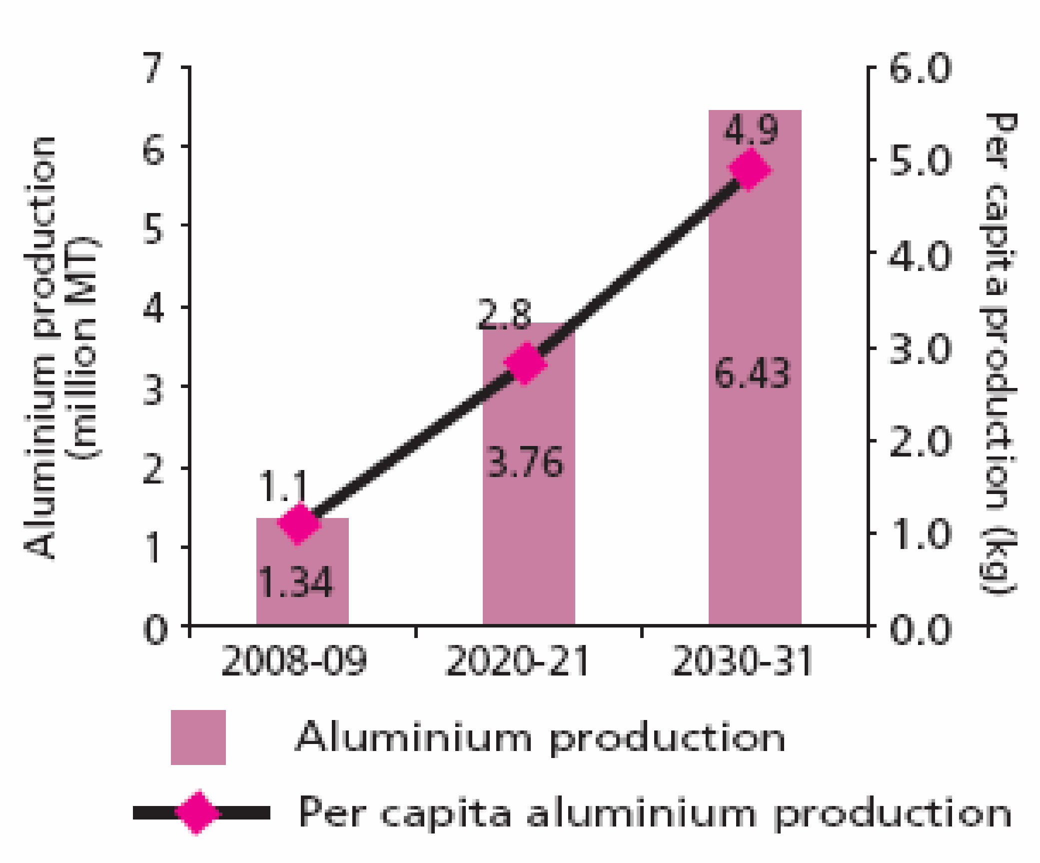
Aluminium



Per capita aluminium production in 2030-31 will be about 5 kg -- one-third of the current per capita consumption in Japan

Production projection

Aluminium



Per capita aluminium production in 2030-31 will be about 5 kg; one-third of the current per capita consumption in Japan

Technology roadmap

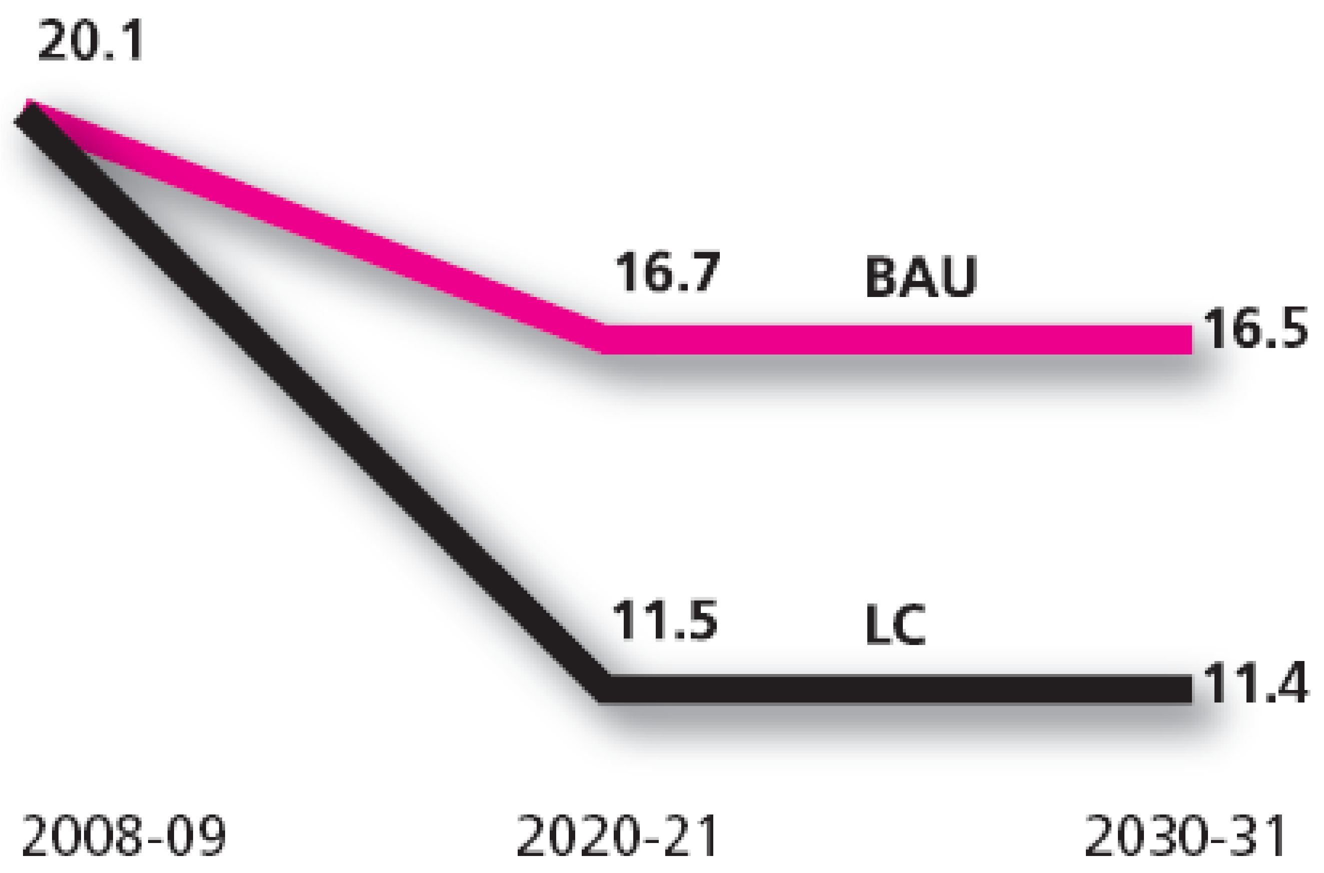
Aluminium

- **BAU**
  - – Improve efficiency of captive power generation and reduce emissions intensity to 0.9 kg/kWh
  - – Convert remaining soderberg smelters to PFPB
  - – Reduce fuel consumption in alumina refinery by 15 per cent
- **LC**
  - – BAT for alumina production
  - – Captive power emissions factor 0.85 kg/kWh
  - – 30 per cent electricity from renewables

Emissions intensity

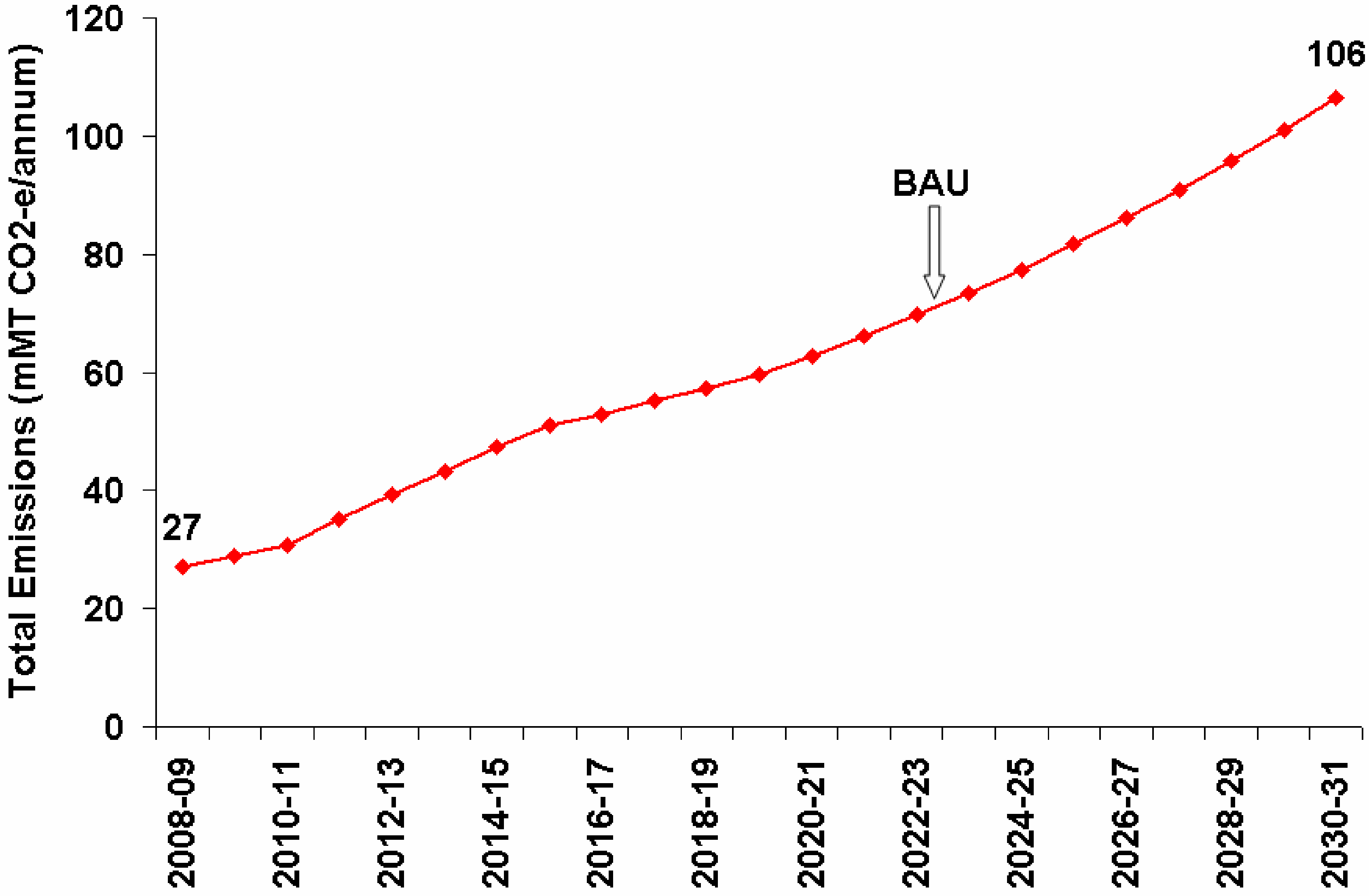
Aluminium

MT CO_2-e/MT aluminium

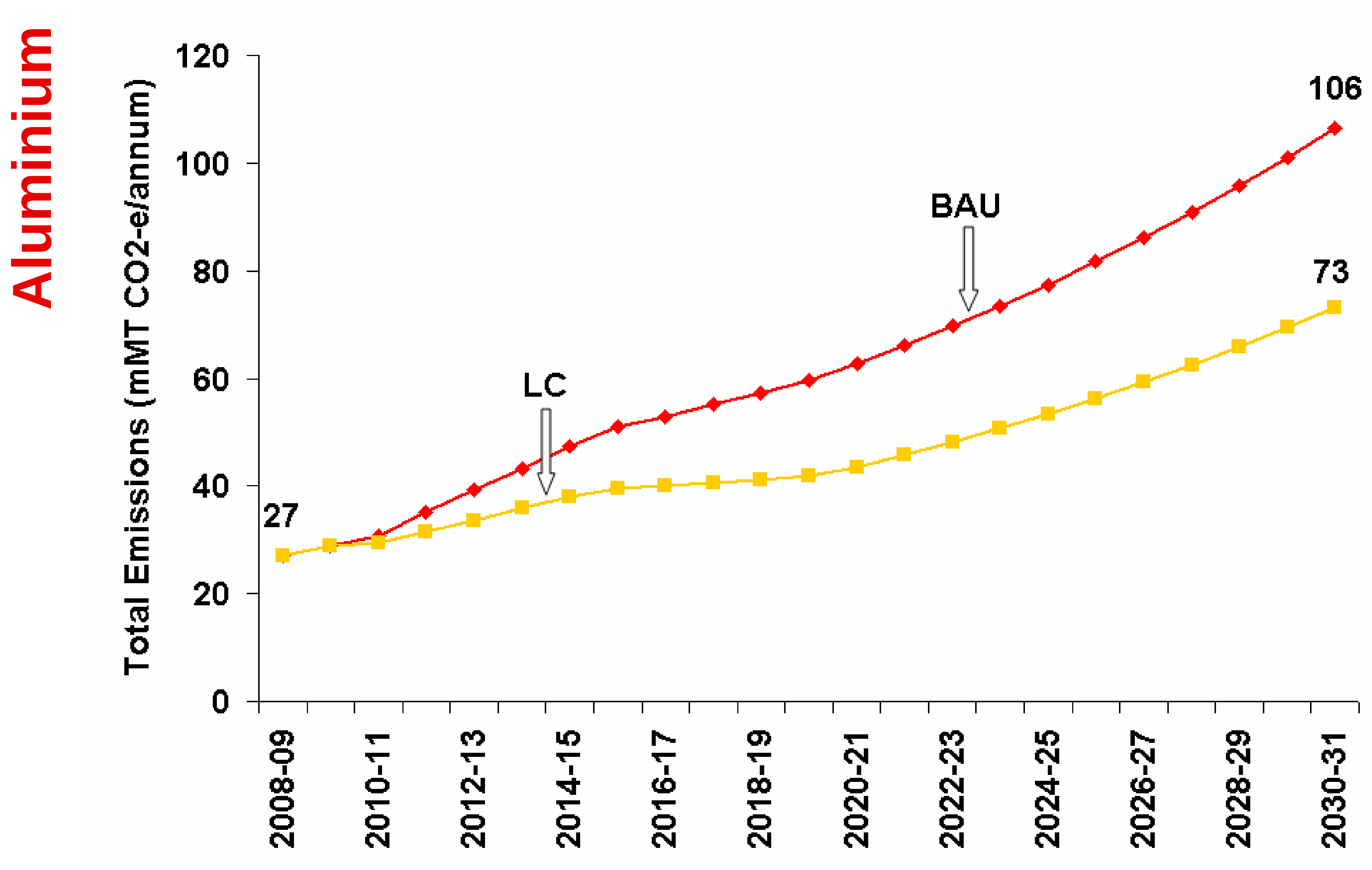


Emissions trajectory

Aluminium



Emissions trajectory

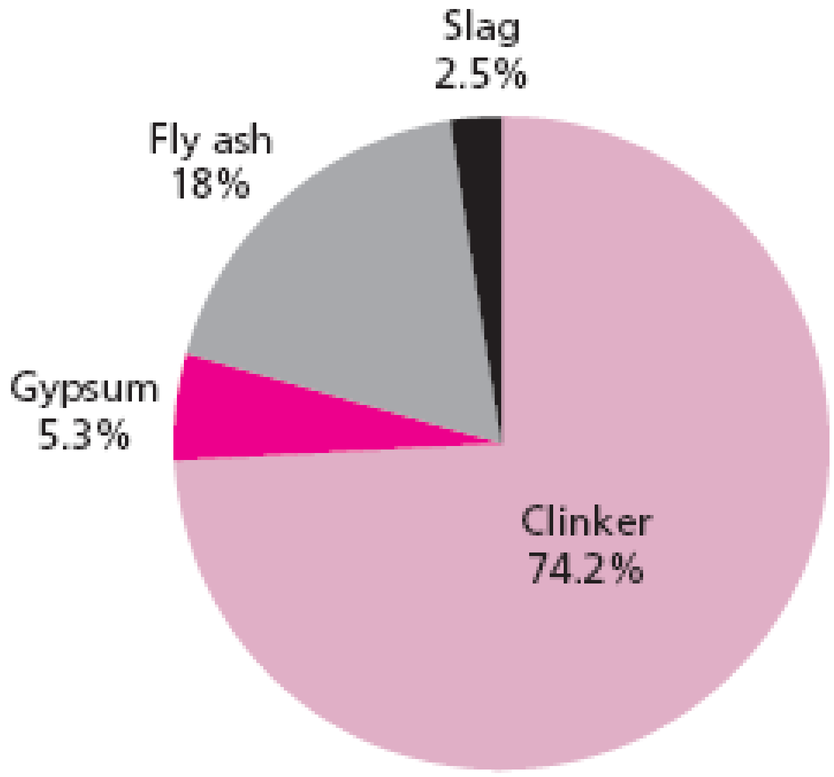


Cement

Cement

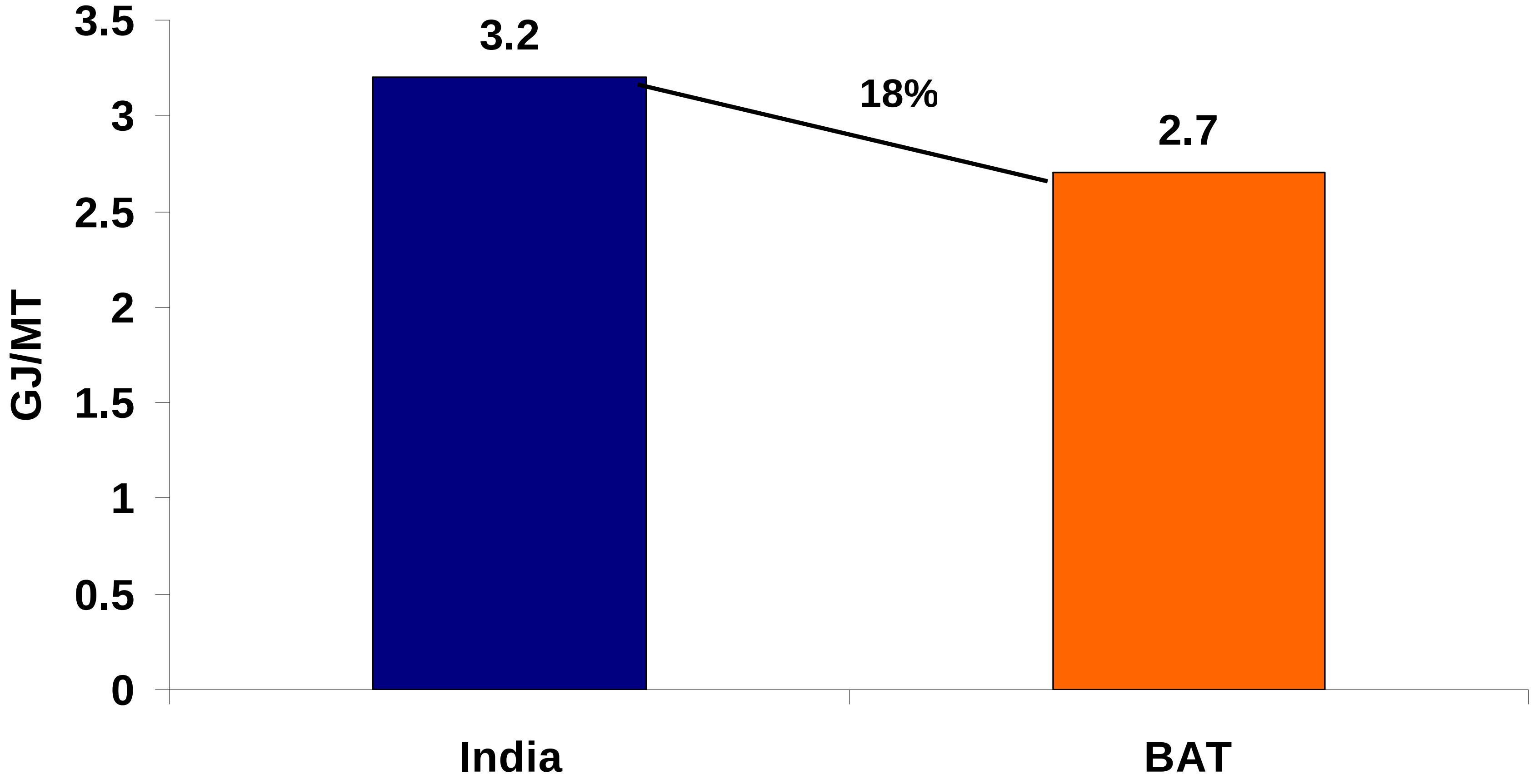
- **Sample:** Top six companies; **51% of total cement produced in the country**

Cement composition of plants surveyed



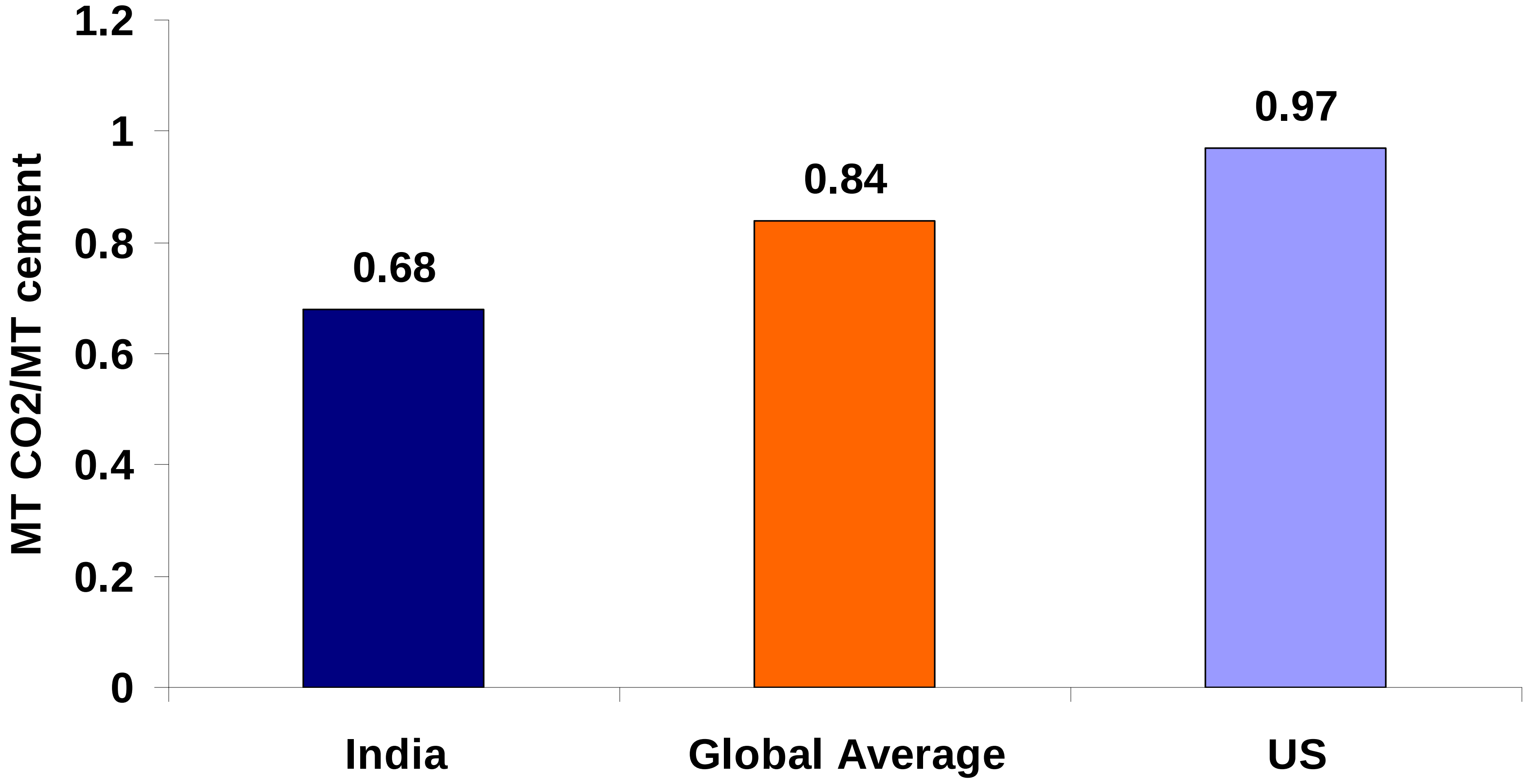
Primary energy consumption

Cement



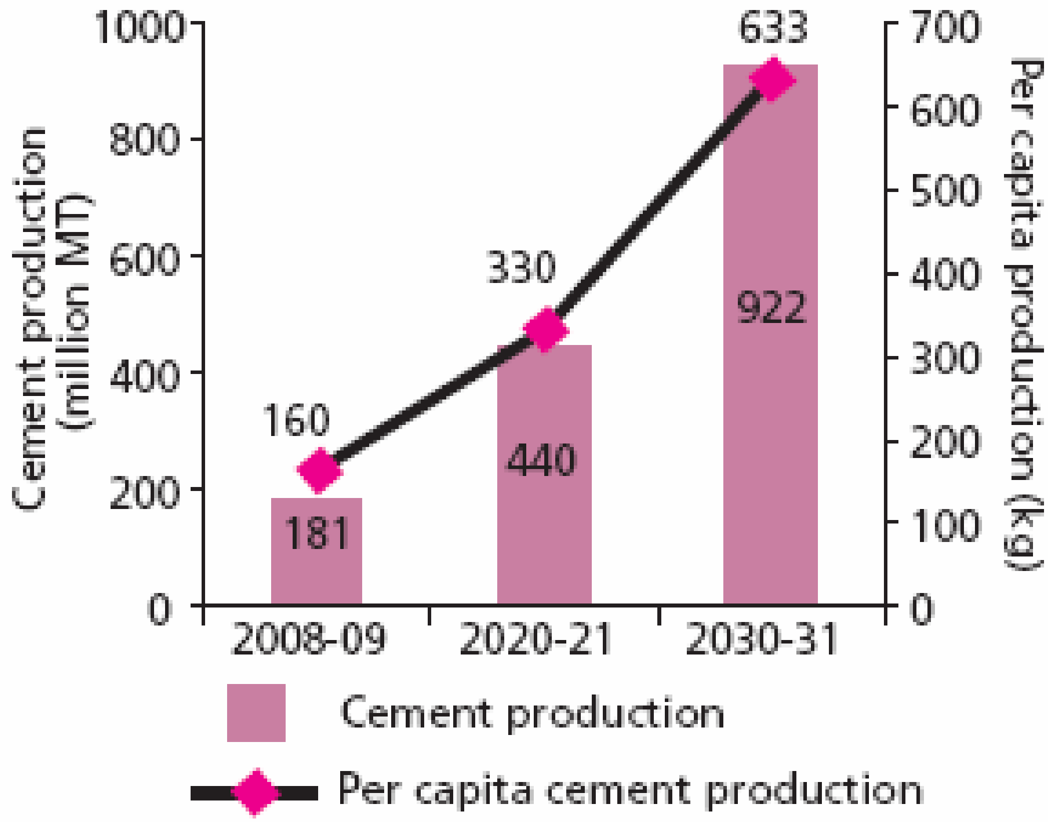
CO_2 emissions

Cement



Production projection

Cement



Per capita cement production in 2030-31 will be about 630 kg -- about the same as 2003 per capita consumption in China

Technology roadmap

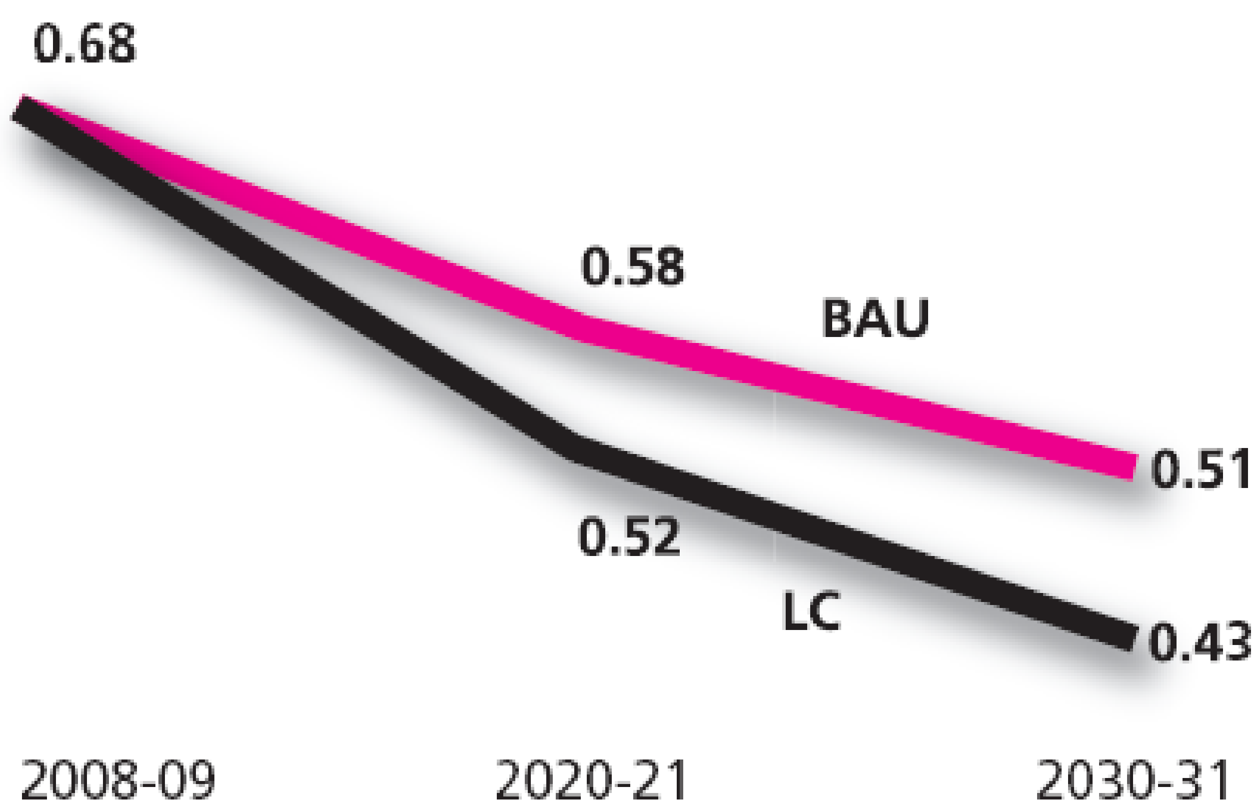
Cement

- **BAU**
  - Blended cement market share 95% (70% currently)
  - Blending proportion 40% (30% currently)
  - 10% substitution of kiln coal by alternate fuel – regulatory oversight needed
  - Incremental reduction in fuel and power consumption by 0.5% annually
- **LC**
  - Blending proportion reach 50% (30% currently) – thermal treatment and regulatory changes required
  - Waste heat recovery unit of 3 MW/mMT clinker capacity

Emissions intensity

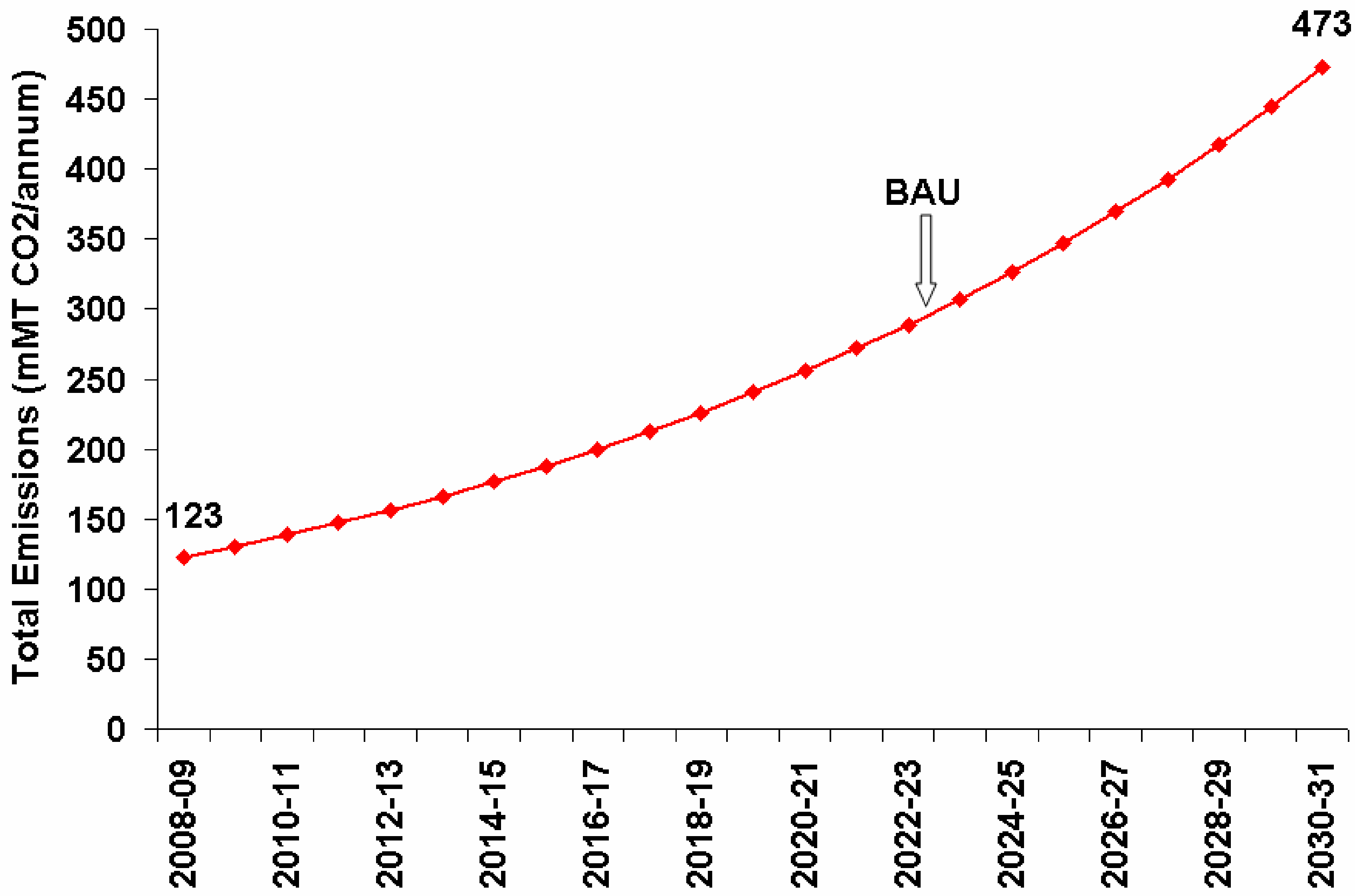
Cement

MT CO_2/MT cement



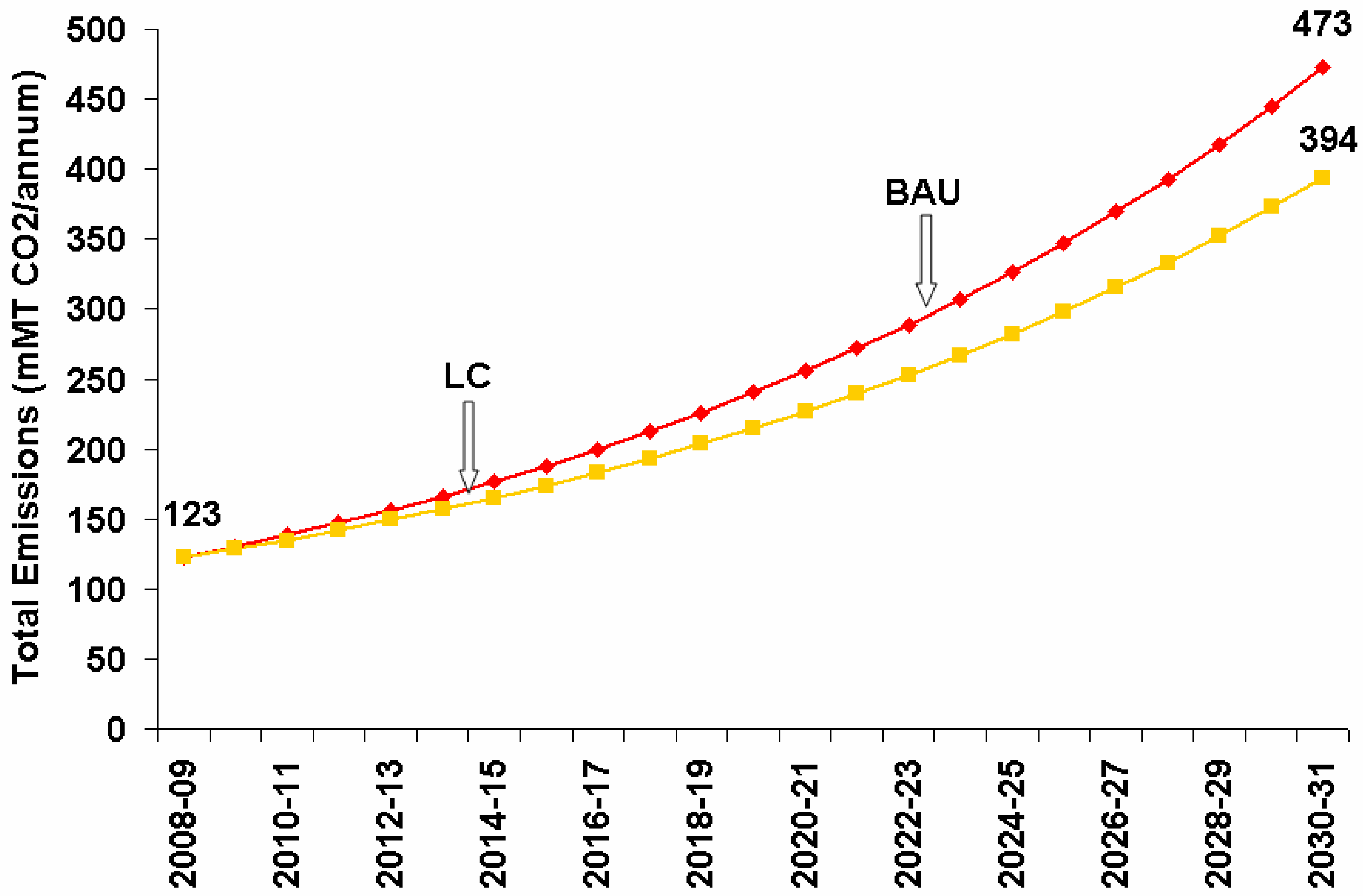
Emissions trajectory

Cement



Emissions trajectory

Cement

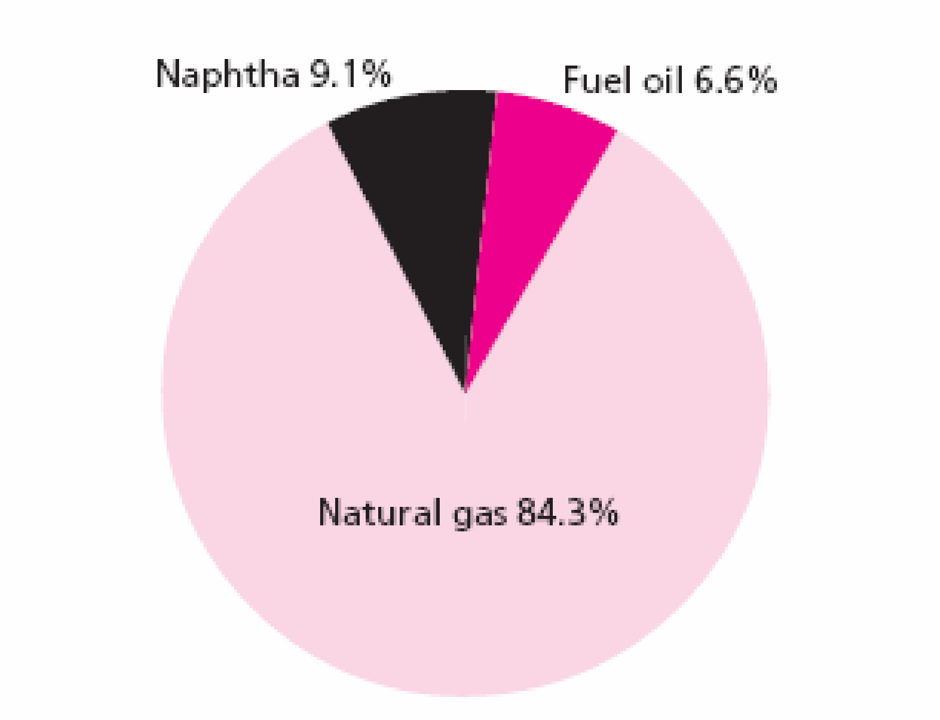


Fertilizer (urea only)

Fertilizer

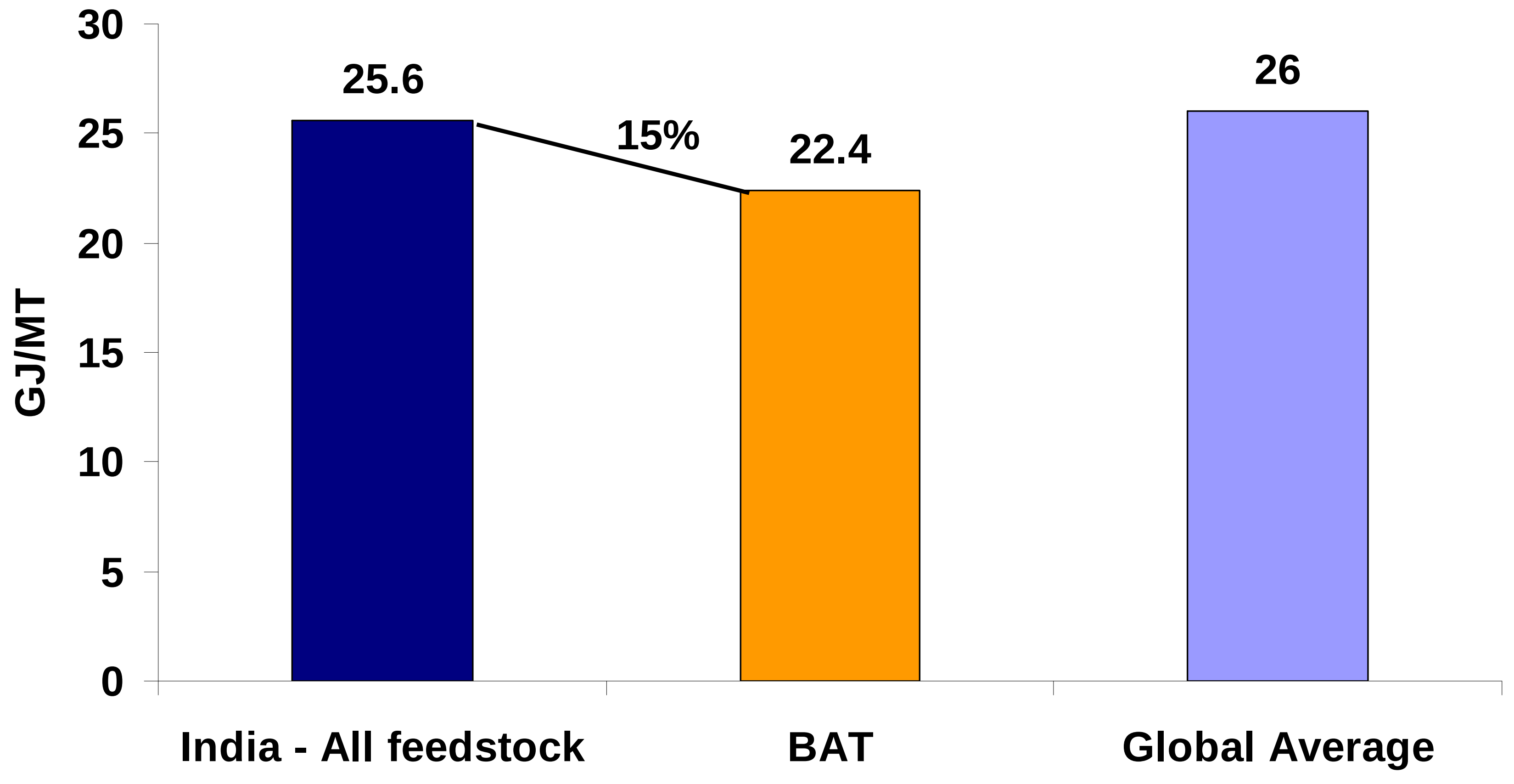
- **Sample:** Eight companies; 14 plants; **68% of total urea produced in the country**

<u>Feedstock of plants surveyed</u>



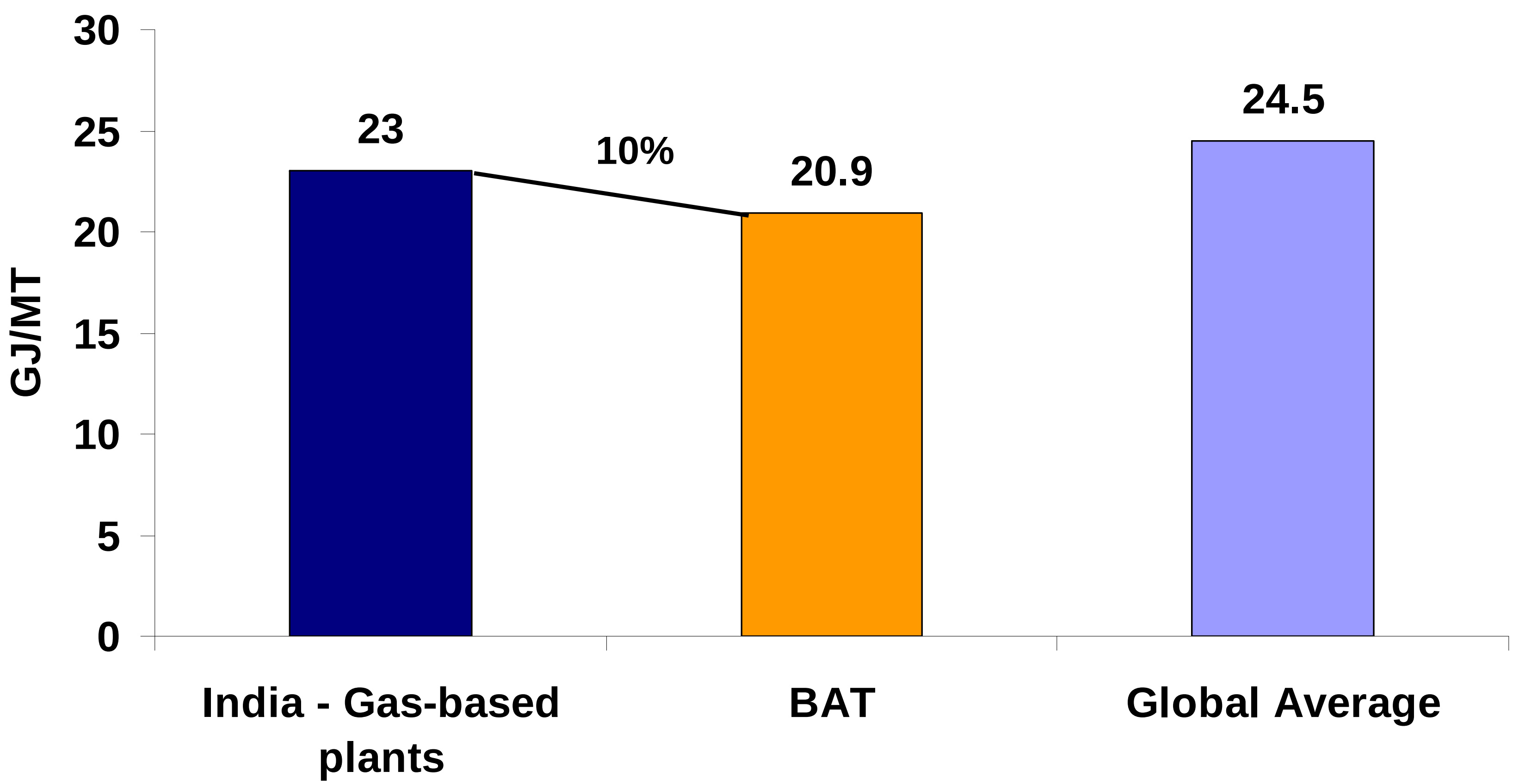
Primary energy consumption

Fertilizer



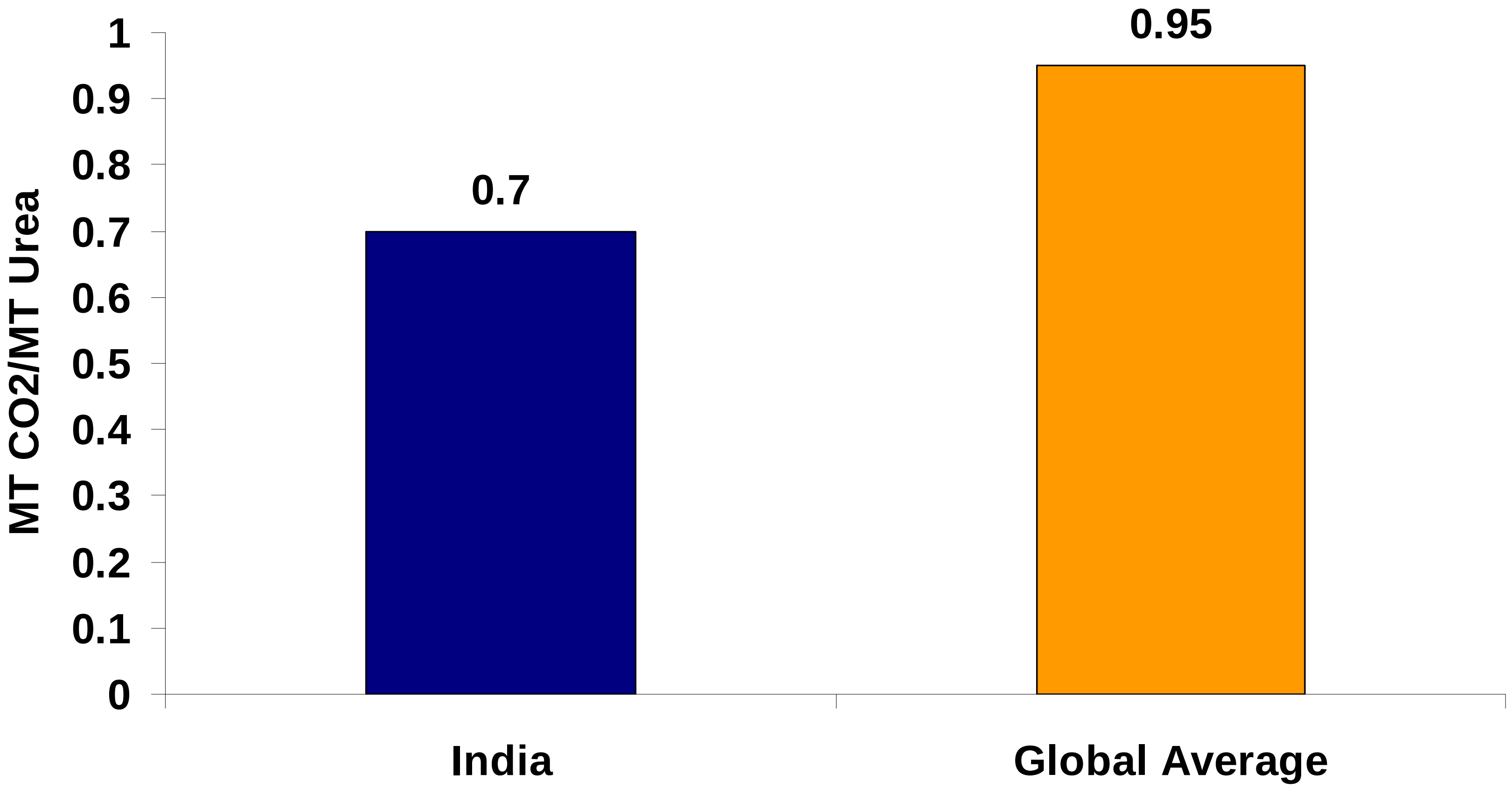
Primary energy consumption

Fertilizer



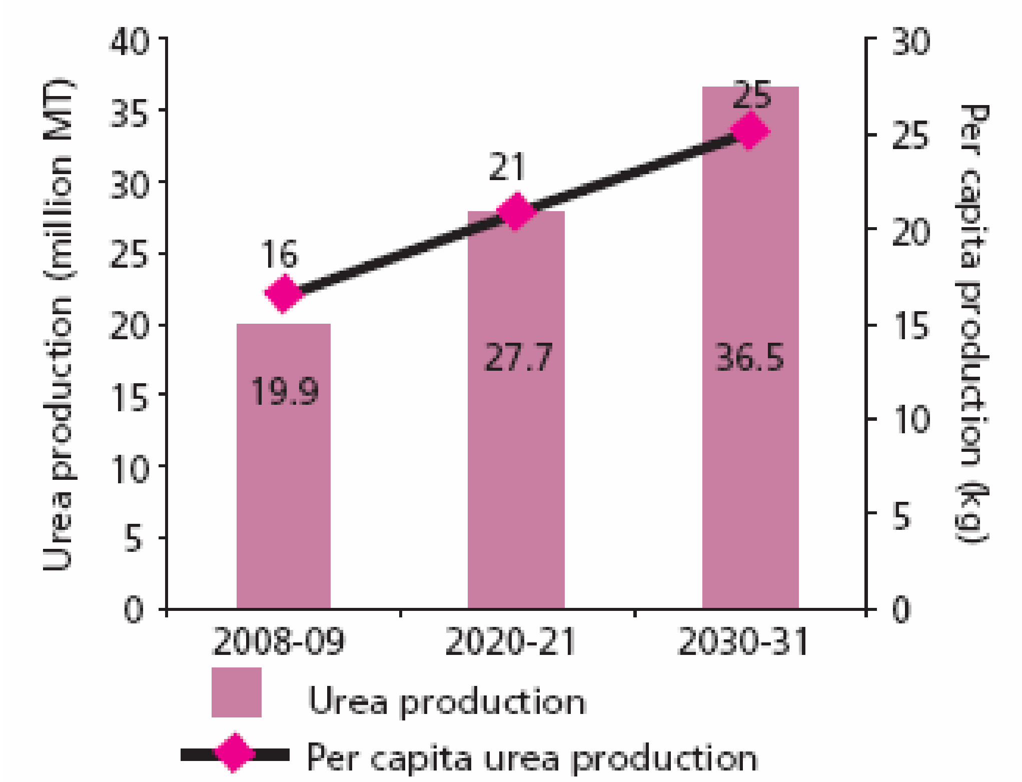
CO_2 emissions

Fertilizer



Production projection

Fertilizer



India currently imports 25% of the urea demand. We have projected 3% annual growth in production; however, industry believes this may not possible due to the non-availability of gas

Technology roadmap

Fertilizer

- **BAU**
  - – NPS (2006-2010) envisages conversion of all plants to natural gas, but availability is still 25% below allocation; we assume about 10% of urea will still be produced from naptha and fuel oil; all new capacity addition will be based on natural gas
  - – New plants operating at India best – which is also current BAT
  - – Old plants reach current BAT by 2030-31 (0.6% reduction annually)

Technology roadmap

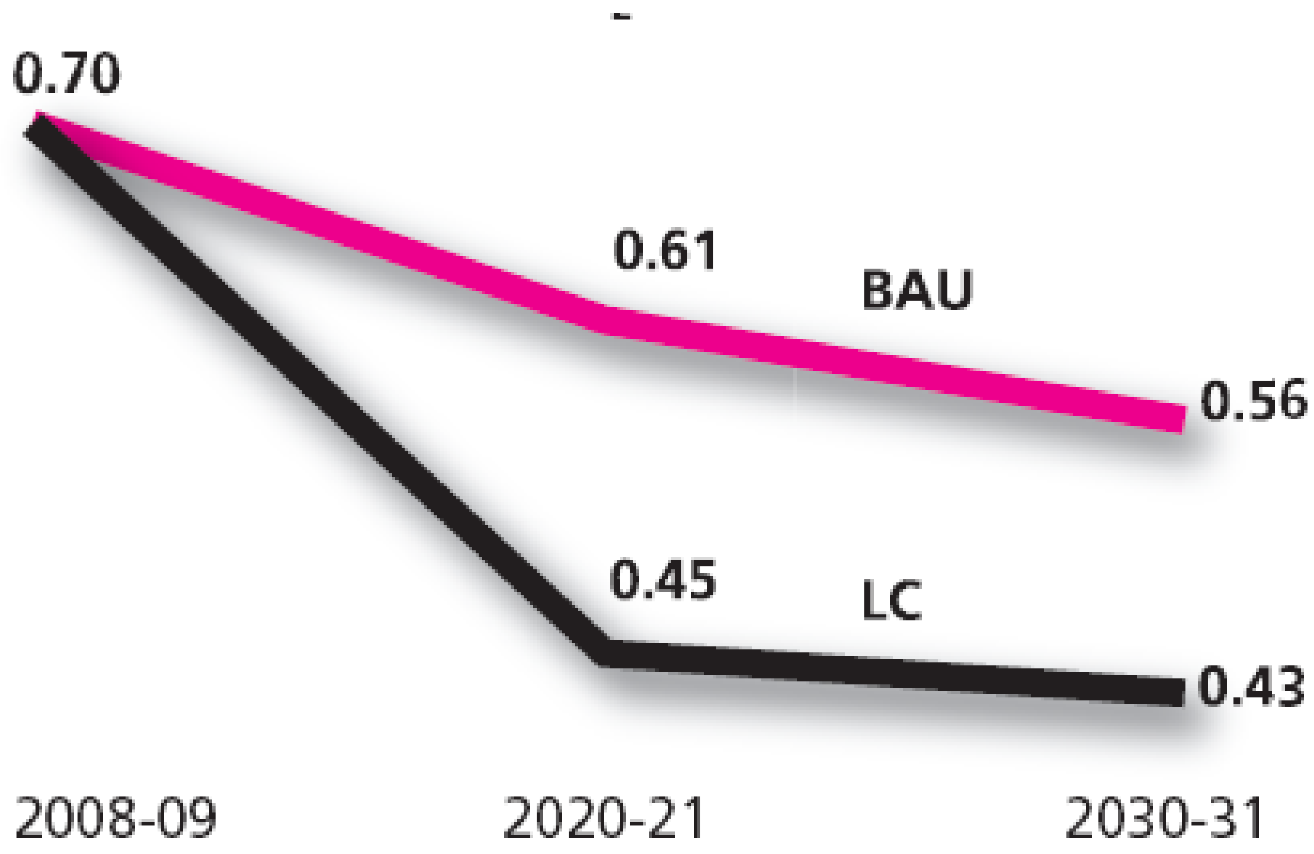
Fertilizer

- **LC**
  - All natural gas feedstock from 2015 onwards
  - Govt. has set an ambitious target of reducing energy consumption 10% below current BAT through research in high-pressure primary reformers and shift catalysts, membrane-based CO_2 removal, low-pressure synthesis catalysts and solid oxide fuel cells for captive power generation etc. We assume new plants after 2020 operate at 10% below current BAT

Emissions intensity

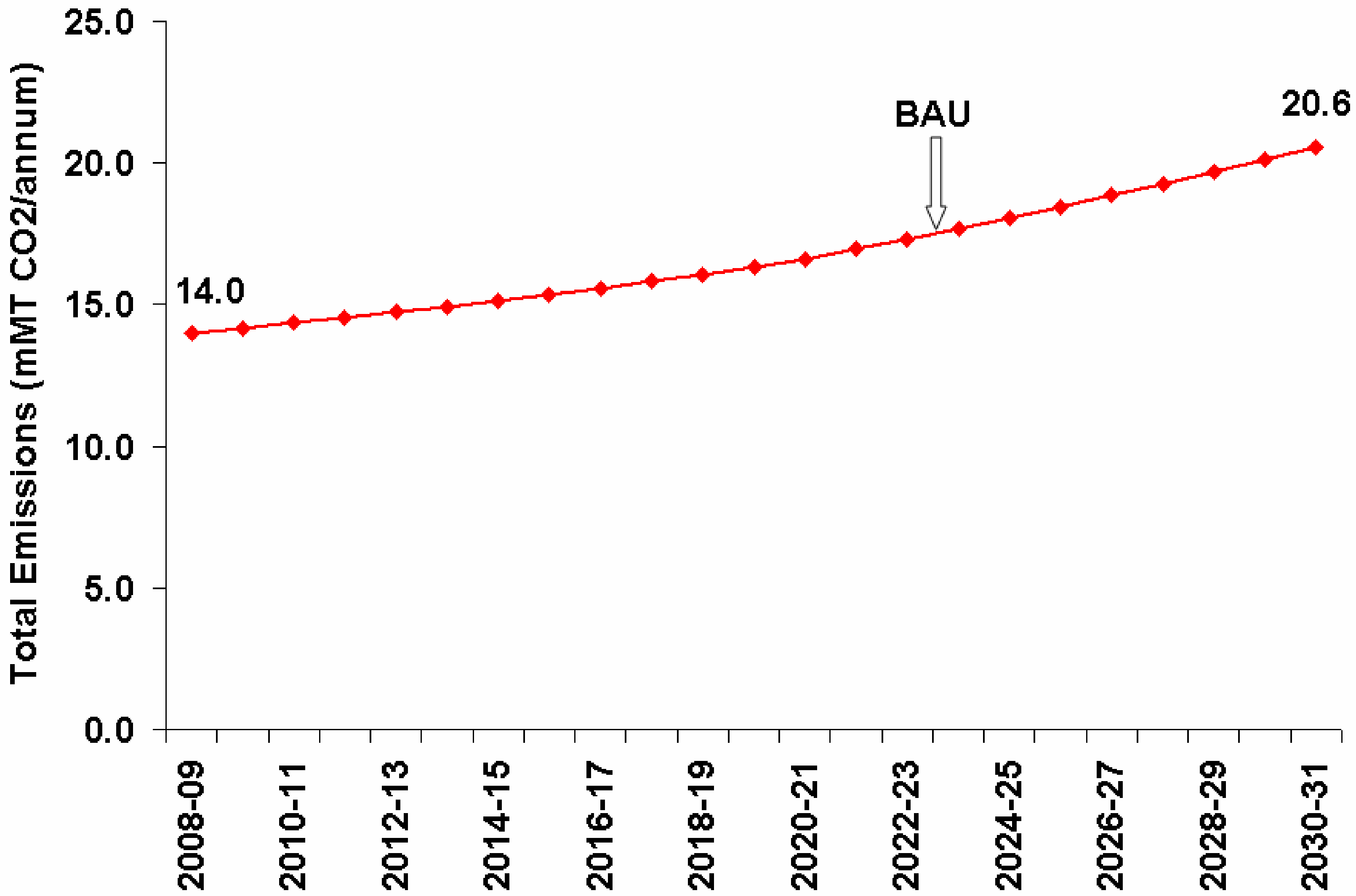
Fertilizer

MT CO_2/MT Urea



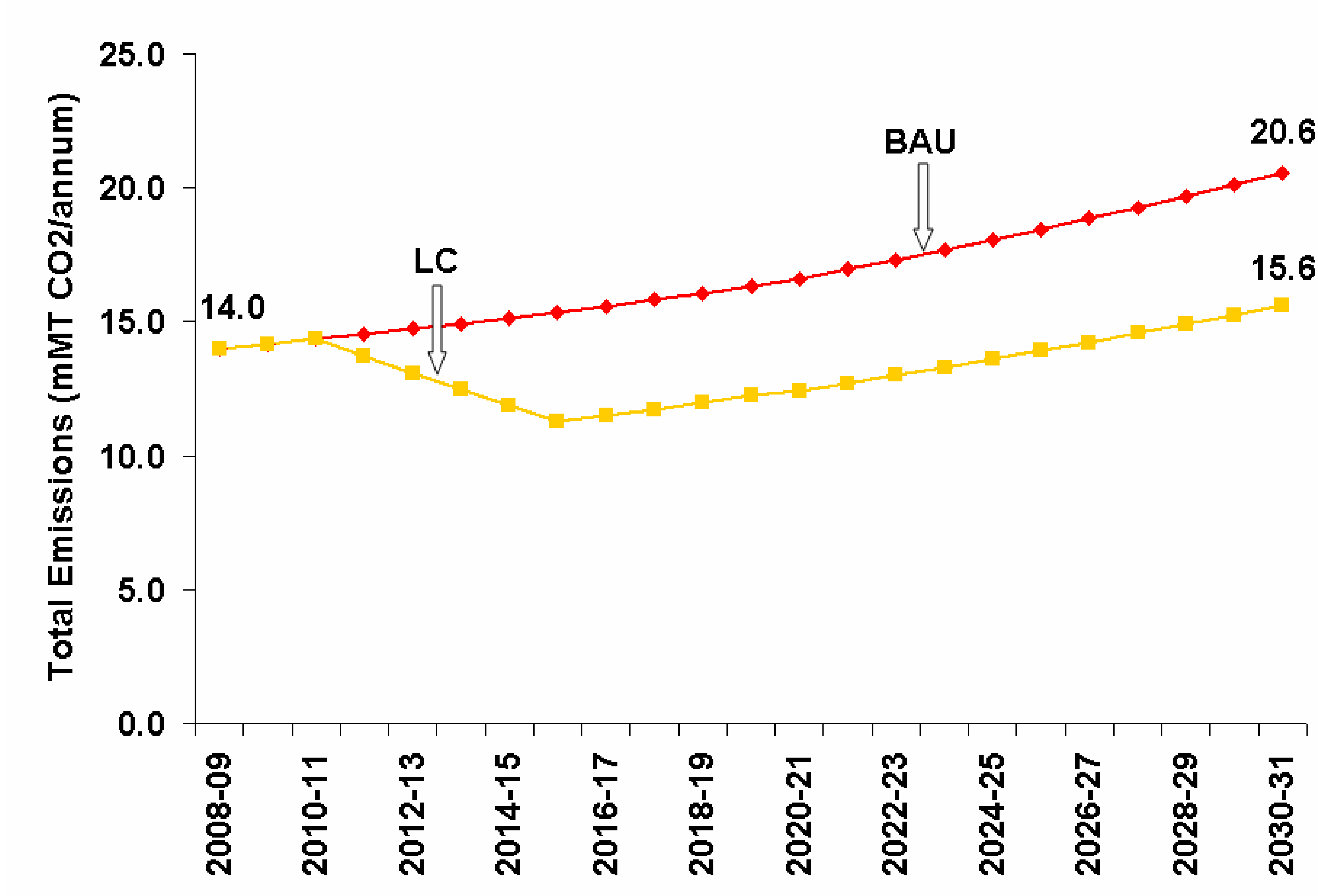
Emissions trajectory

Fertilizer



Emissions trajectory

Fertilizer



Emissions trajectory

Fertilizer

- The cumulative emissions avoided in LC over BAU between 2008-09 & 2030-31 is about 83 mMT of CO_2. **Mainly due to feedstock switch**

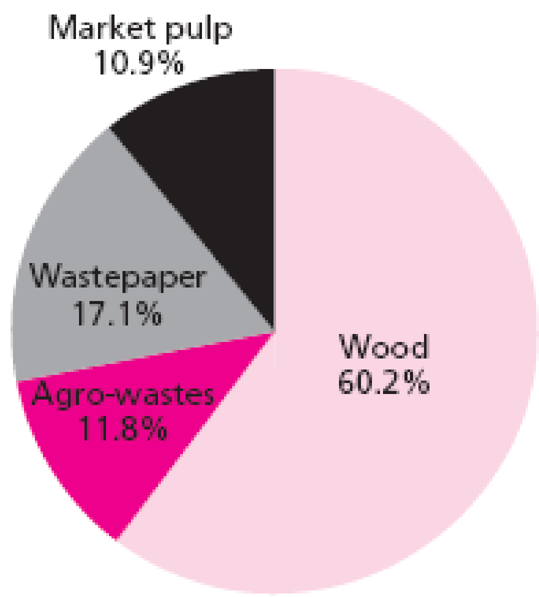
- Even without technology improvements, the cumulative emissions avoided is about 80 mMT if all heavy feedstock-based plants are phased out by 2012.

Paper and pulp

Paper and Pulp

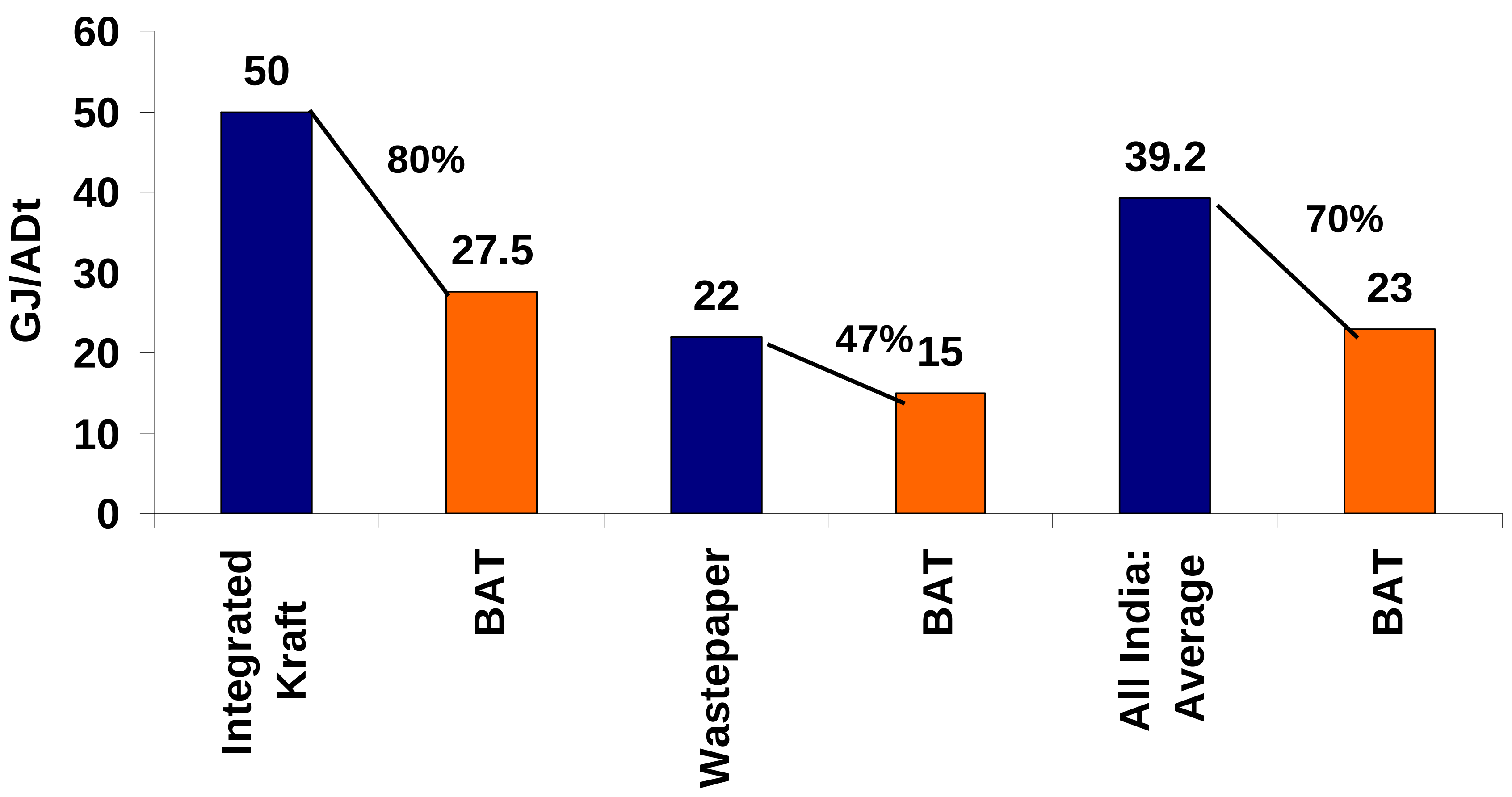
- **Sample:** Eight companies; 18 plants; **one-third of total paper produced in the country**

Pulp composition of plants surveyed



Primary energy consumption

Paper and Pulp

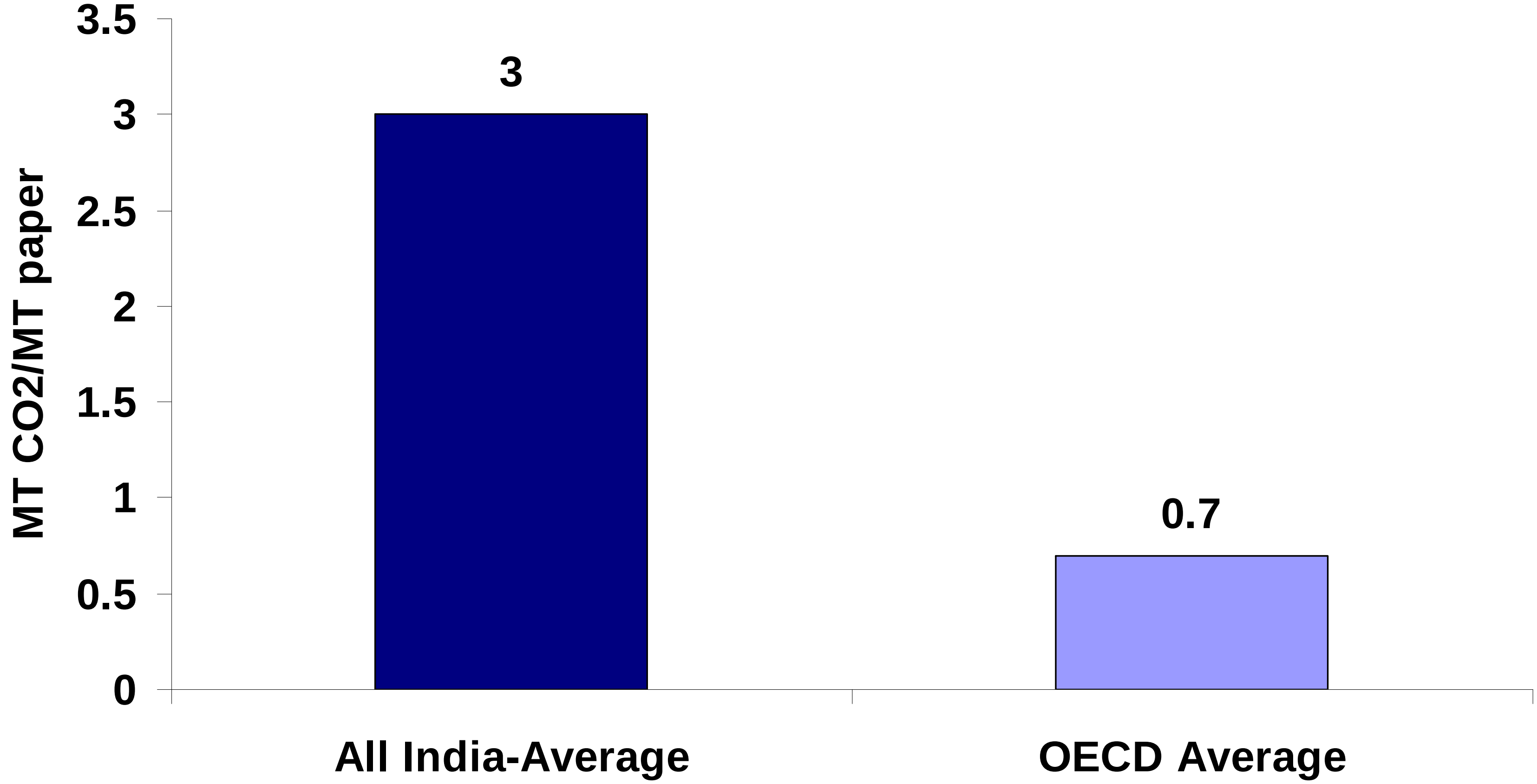


Primary energy consumption

- High primary energy consumption because of:
  - Small mill size (one-seventh the average capacity of a European mill);
  - Multiple raw materials;
  - Multi-product nature of plants;
  - Large number of old plants

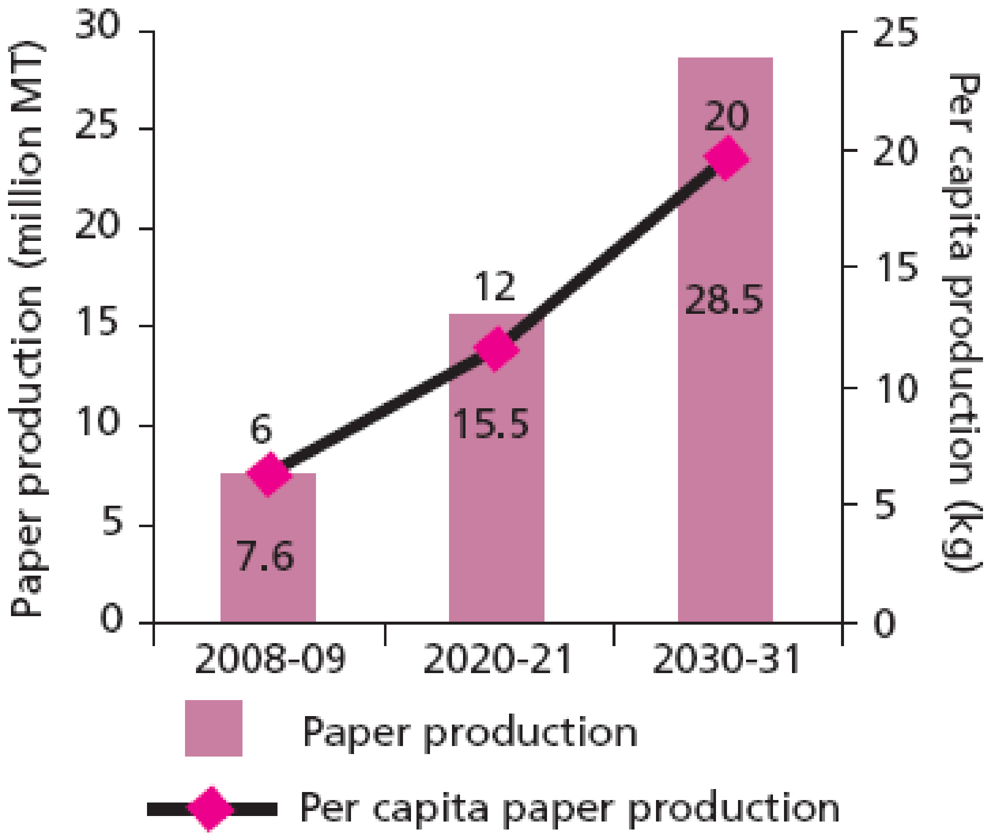
GHG emissions

Paper and Pulp



Production projection

Paper and Pulp



Per capita paper production (2030-31): 20 kg

One-fifteenth of current per capita consumption in the US.

Technology roadmap: BAU

Paper and Pulp

- 50% paper from wastepaper, reducing the energy and GHG intensity significantly
- Kraft mills specific energy consumption reduced to 40 GJ/ADt (50 GJ/ADt currently) by planned increase in the size and change in technology ("Duel C" digesters, 7 effect evaporators, advanced paper m/c)
- Wastepaper mills too reduce specific energy consumption to 15 GJ/ADt by increasing mill size and advanced paper m/c

Technology roadmap: LC

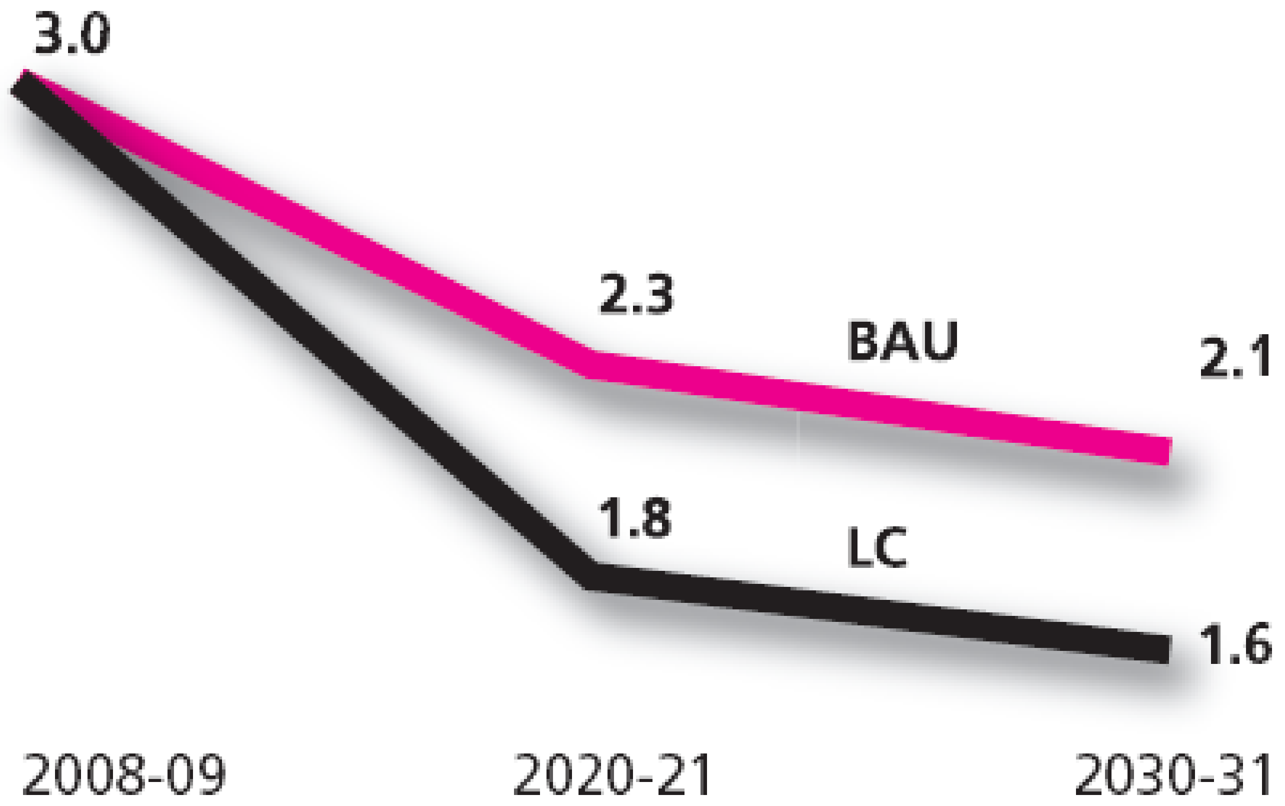
Paper and Pulp

- Kraft mills specific energy consumption can be reduced to 30-35 GJ/ADt (50 GJ/ADt currently) but will require: regulation on mill size (minimum 0.3 mMTpa), retirement of 2.0 mMTpa capacity, high capacity-high speed advanced paper m/c, continuous digesters, BLS gasification etc.
- Newsprint production from 80% wastepaper, advanced CMP plants and high capacity-high speed advanced paper m/c

Emissions intensity

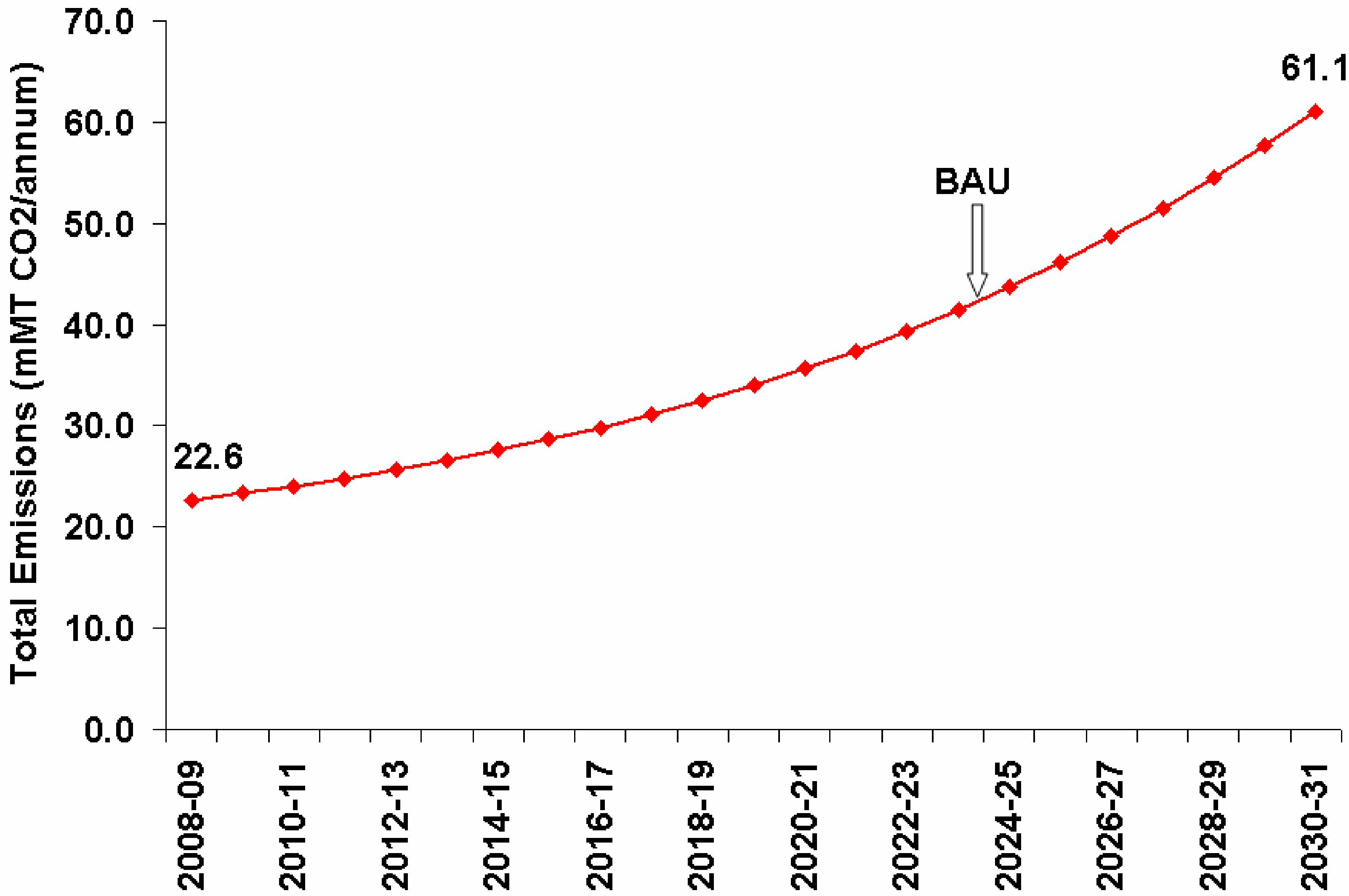
Paper and Pulp

MT CO_2/ADt paper



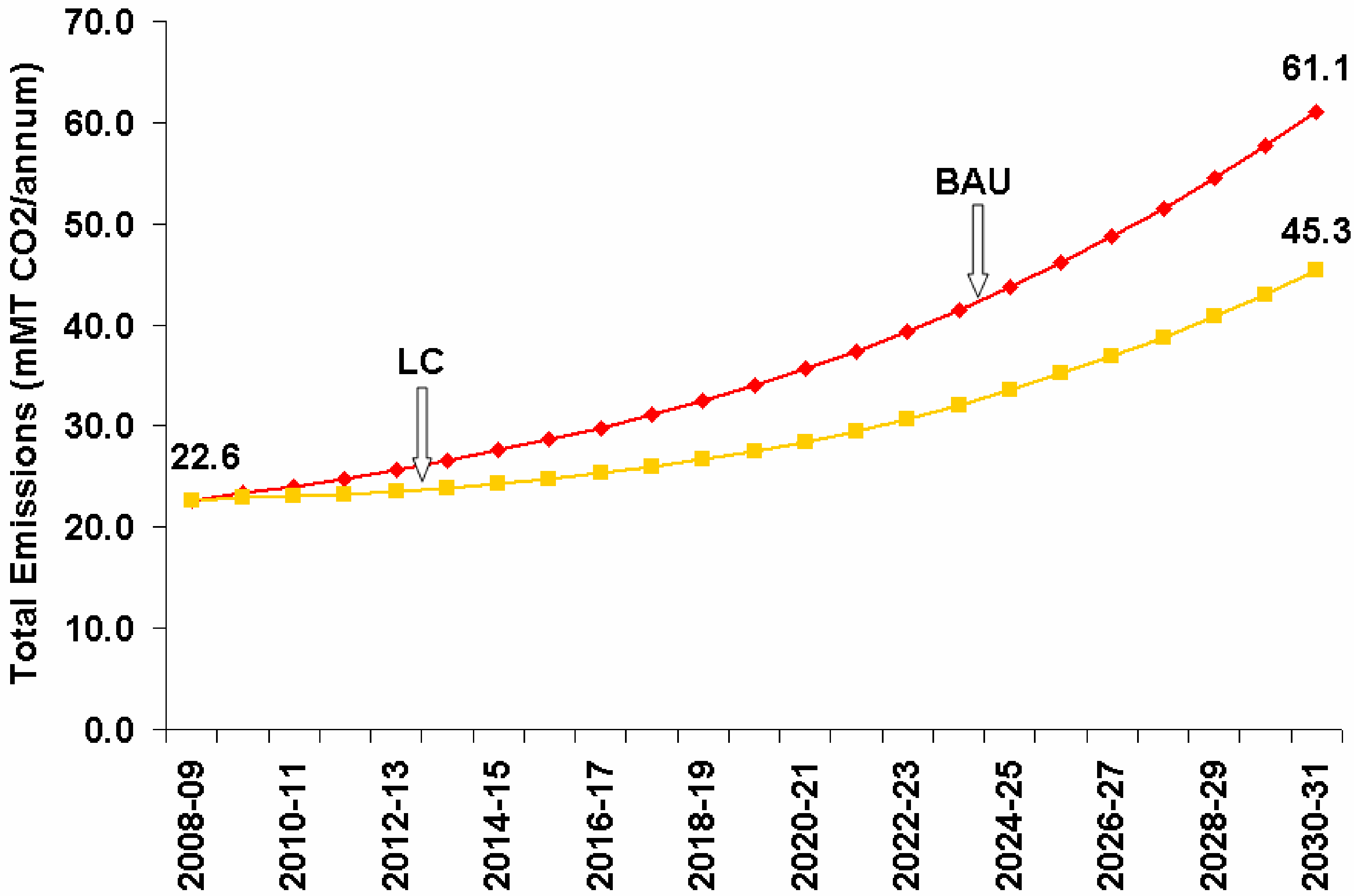
Emissions trajectory

Paper and Pulp



Emissions trajectory

Paper and Pulp

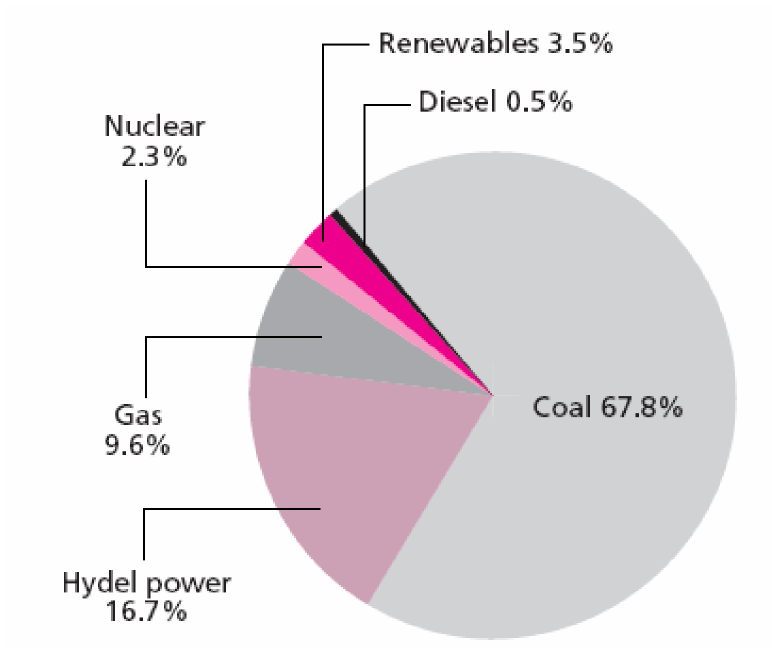


Power sector

Power Sector

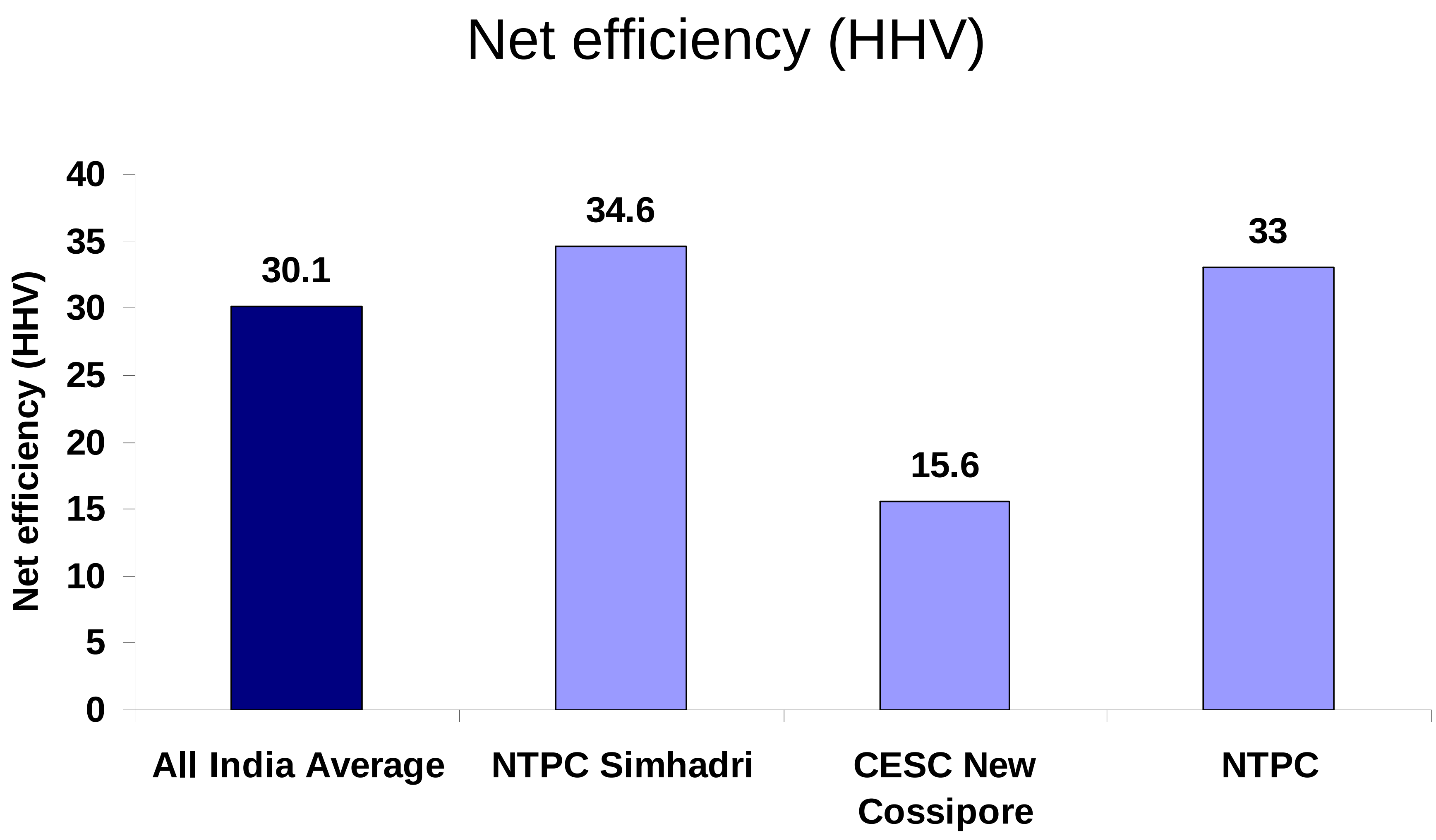
- **Sample:** 81 coal-fired plants, 8 lignite-fired plants and 42 gas-fired plants -- more than 90 per cent of the coal, lignite and gas fired power generation capacity in the country

Power generation: 2007-08



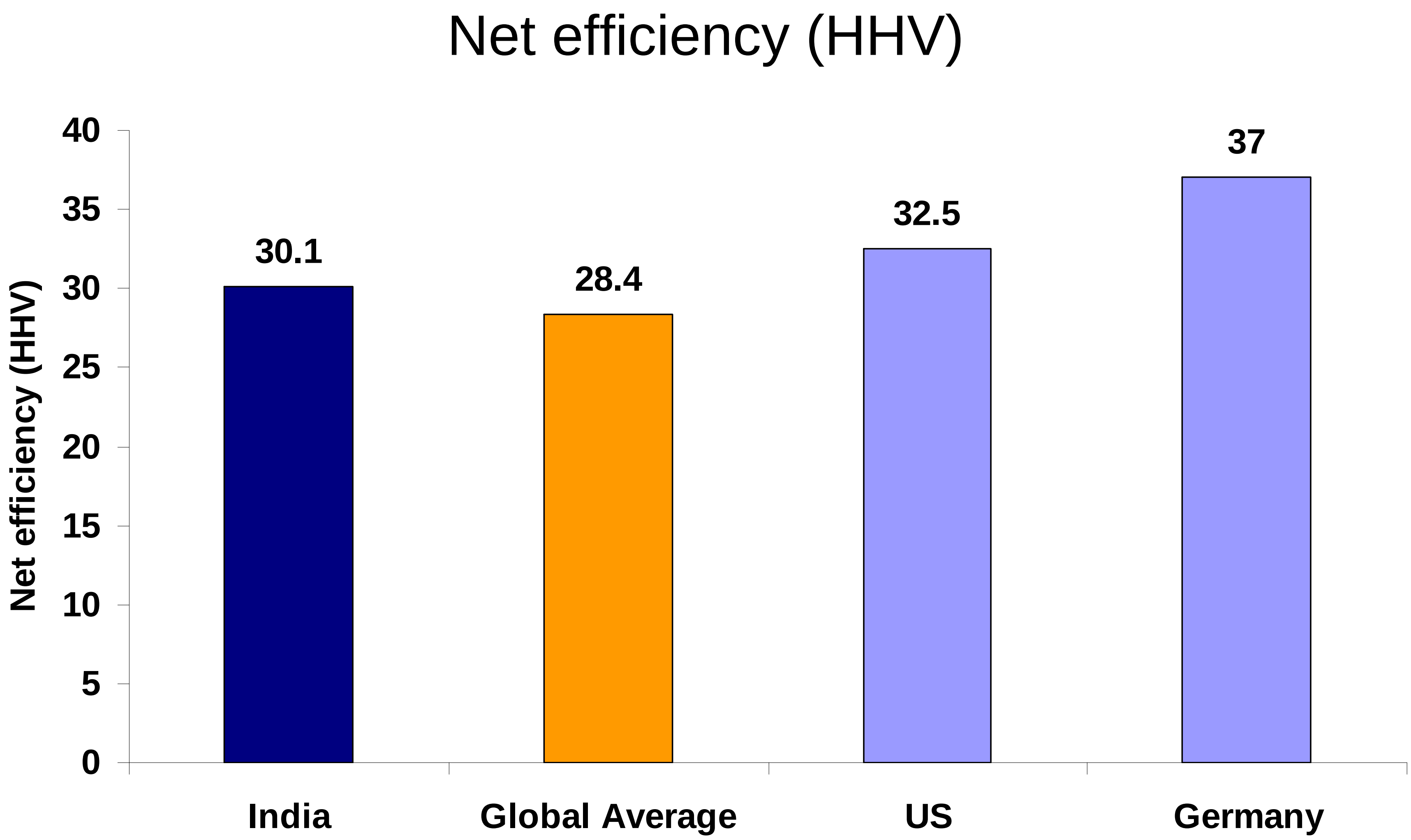
Coal and lignite plants

Power Sector



Coal and lignite plants

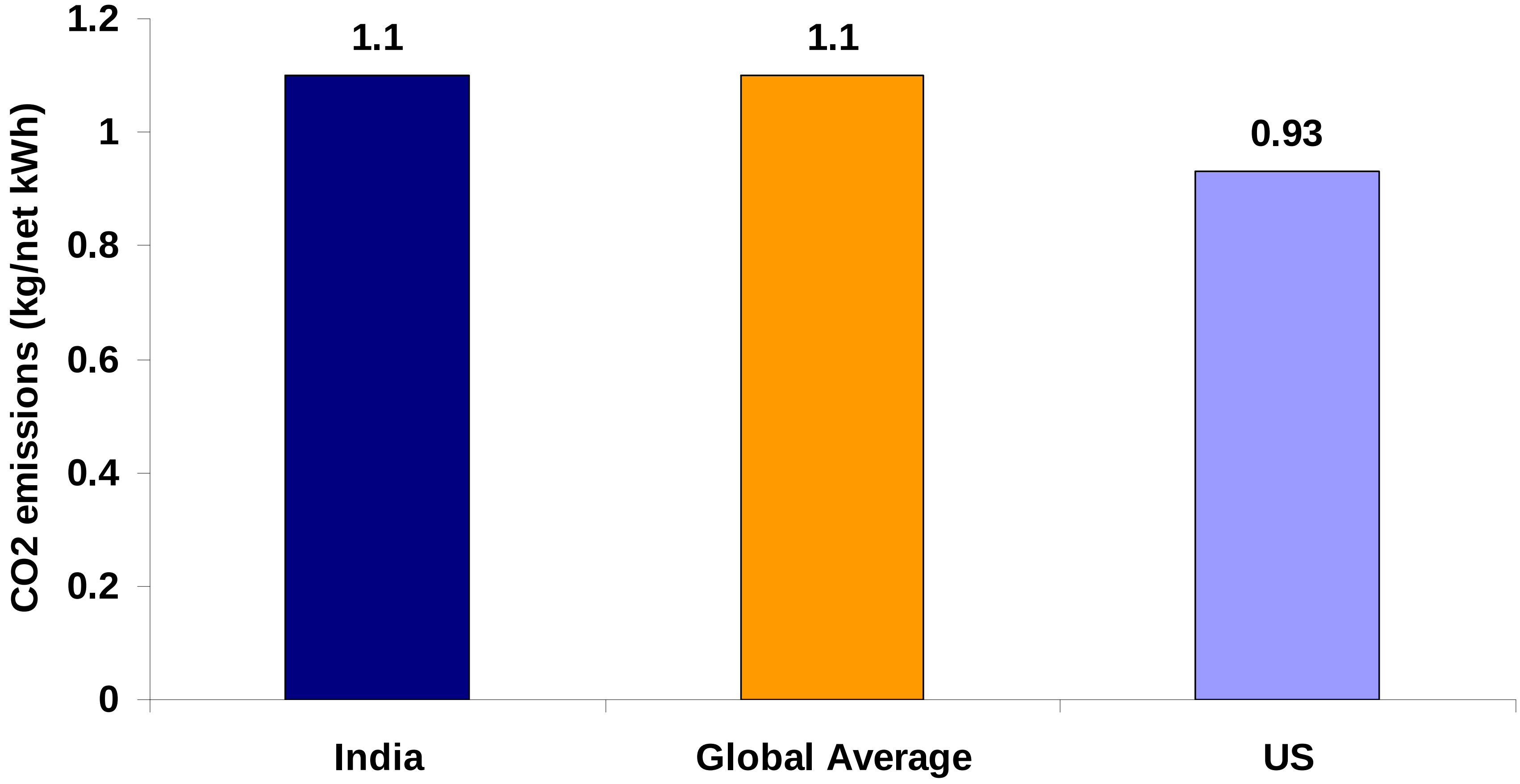
Power Sector



Coal and lignite plants

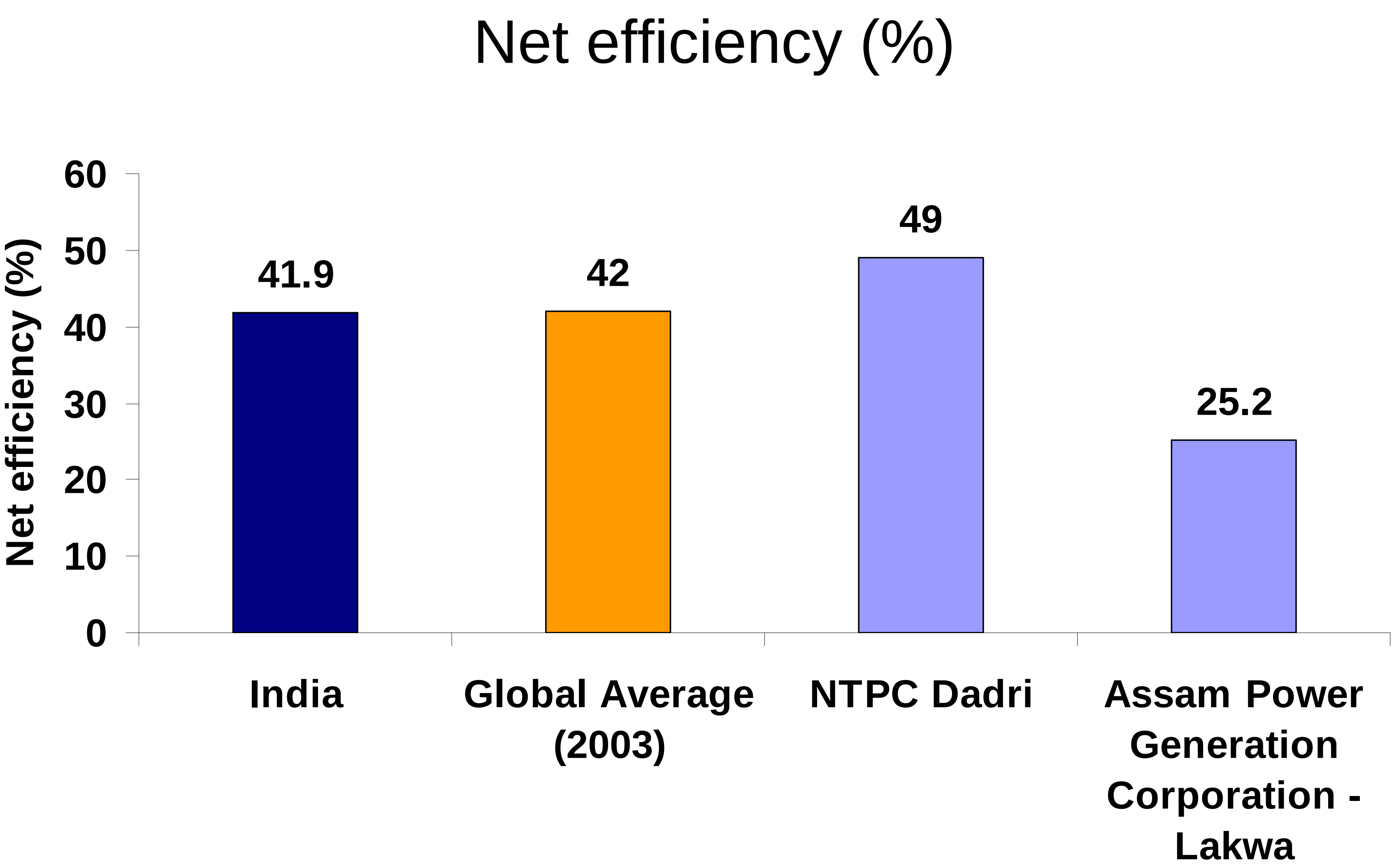
Power Sector

Specific CO_2 emissions



Gas-fired plants

Power Sector



Thermal power

Power Sector

- Efficiency lower than what is possible with advanced steam parameters and better grid and load management practices

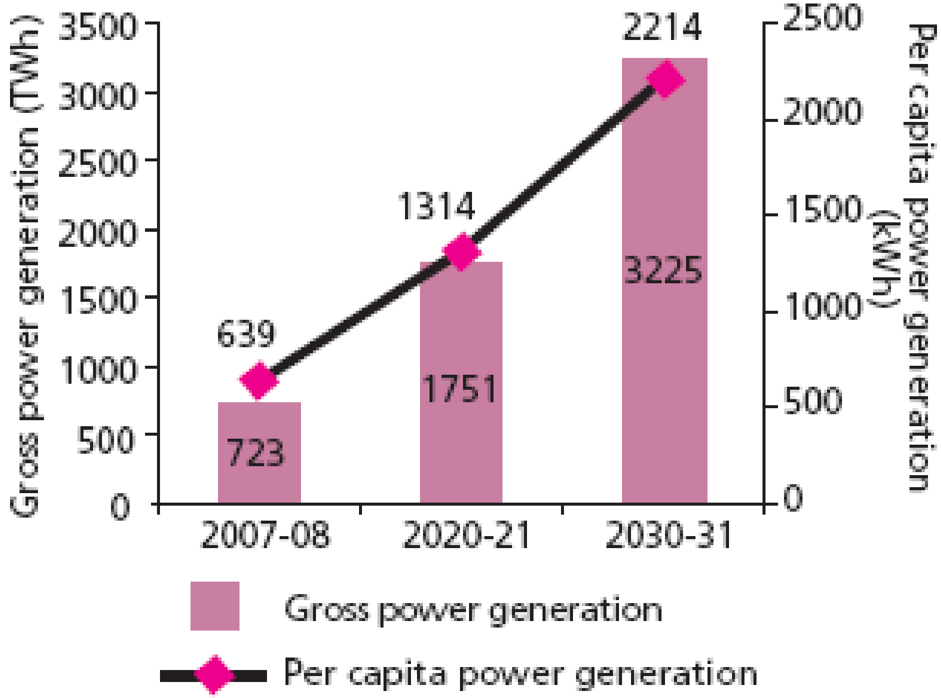
- However, coal quality (gone down over the years) and high temperature and humidity are limiting factors

- **NTPC Sipat** – India's first supercritical plant (1,980 MW) – net efficiency of 33.8% (HHV) and net specific CO_2 emissions of 0.96 kg/kWh (NTPC Simhadri, 34.6% and 0.94 kg/kWh)

Power generation projection

Power Sector

- Falling elasticity between gross power generation and GDP; 8% growth rate – Integrated Energy Policy



- *India's per capita gross power generation in 2030 about one-seventh of **current** per capita power generation in the US.*

Technology roadmap: BAU

Power Sector

- Proportion of gas to total power generation constant (9.6%) – capacity 50,000 MW in 2030-31
- Hydro growth 4% per annum (last 20 years' trend)
- Nuclear 30,000 MW – government push
- Onshore wind – 40,000 MW in 2030-31 (6% pa)
- Biomass – 20,000 MW (5,000 MW each from agro waste and bagasse cogeneration; 10,000 MW wood)
- Small hydro: 8,000 MW (past trend)
- Solar – 20,000 MW
- **Rest from coal** - improved efficiency in existing stock; 30% supercritical till 2020; after 2020 only supercritical plants

Technology roadmap: LC

Power Sector

- Gas, hydro, nuclear, onshore wind – same as BAU
- Biomass – 50,000 MW (5,000 MW each from agro waste and bagasse cogeneration; 40,000 wood)
- Small hydro: 15,000 MW (entire capacity)
- Solar – 100,000 MW
- Offshore wind: 50,000 MW
- **Rest from coal** - improved efficiency in existing stock, retirement of 10,000 MW capacity; 80% supercritical till 2020; after 2020 only supercritical/ ultra supercritical plants

Installed capacity

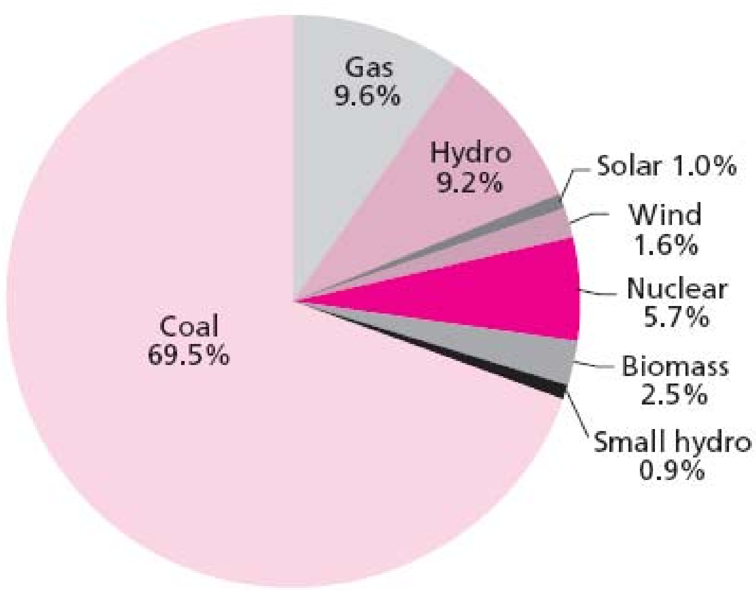
Power Sector

	2008-09 (in MW)	2030-31 (in MW)	
		BAU	LC
Coal-based power plants	81,606	3,40,000	2,80,000
Gas & oil-based power plants	18,256	50,700	50,700
Large Hydropower plants	36,885	84,500	84,500
Nuclear power	4,120	30,000	30,000
Solar PV	0	10,000	55,000
Solar thermal (CSP)	0	4000 – without storage 2000 – with storage	7,500 – without storage 15,000 – with storage
Onshore wind	10,891	40,000	40,000
Offshore wind	0	0	50,000
Biomass	1,752	20,000	50,000
Small hydropower plants	2,430	8,000	15,000
Total	1,56,000	5,89,200	6,77,700

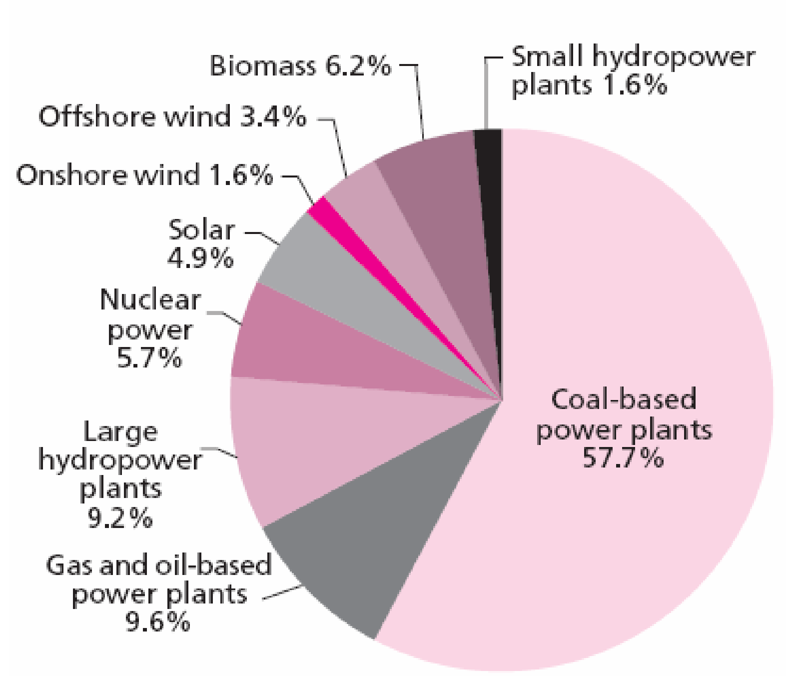
Power generation

Power Sector

BAU



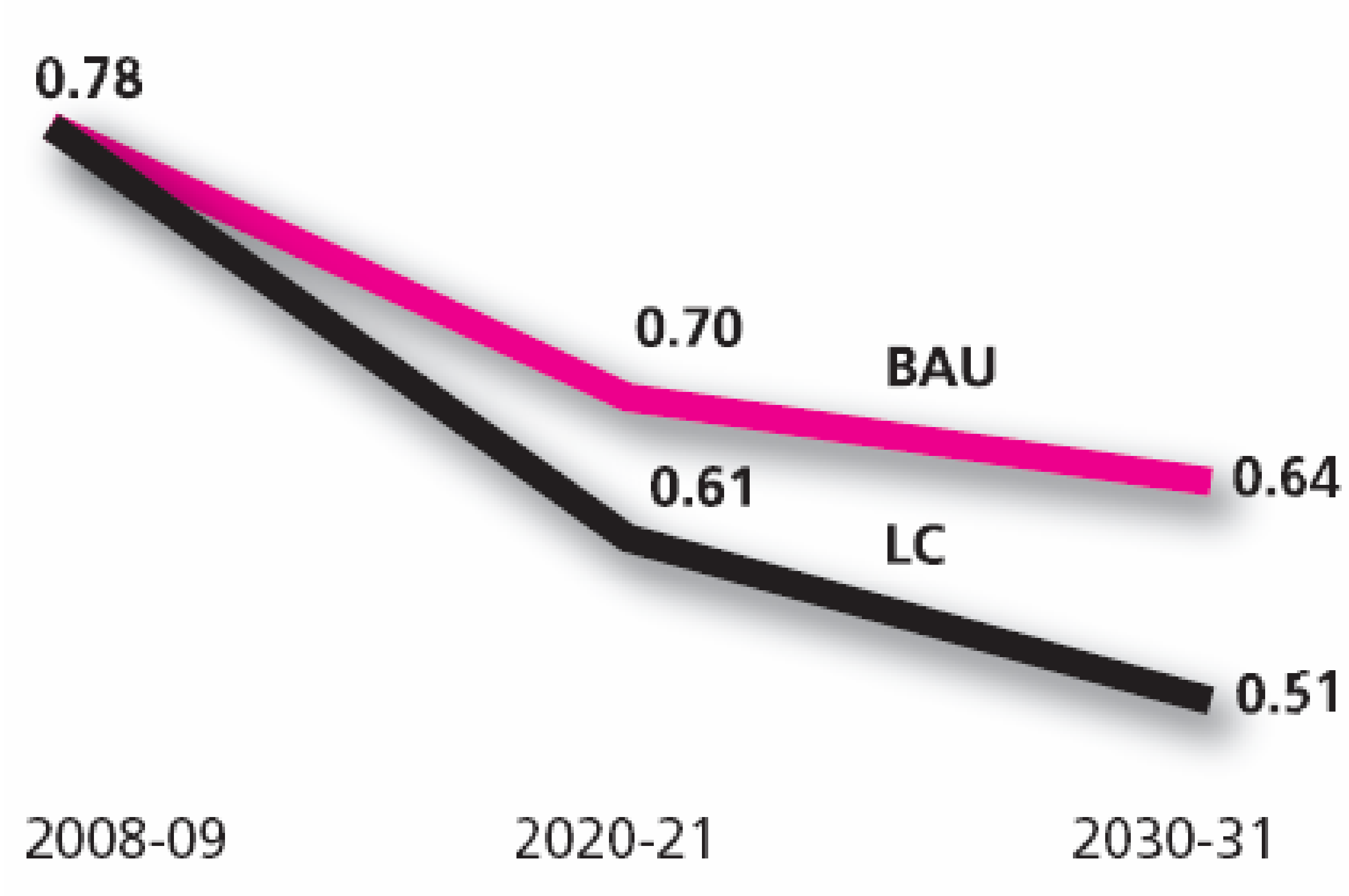
LC



Emissions intensity

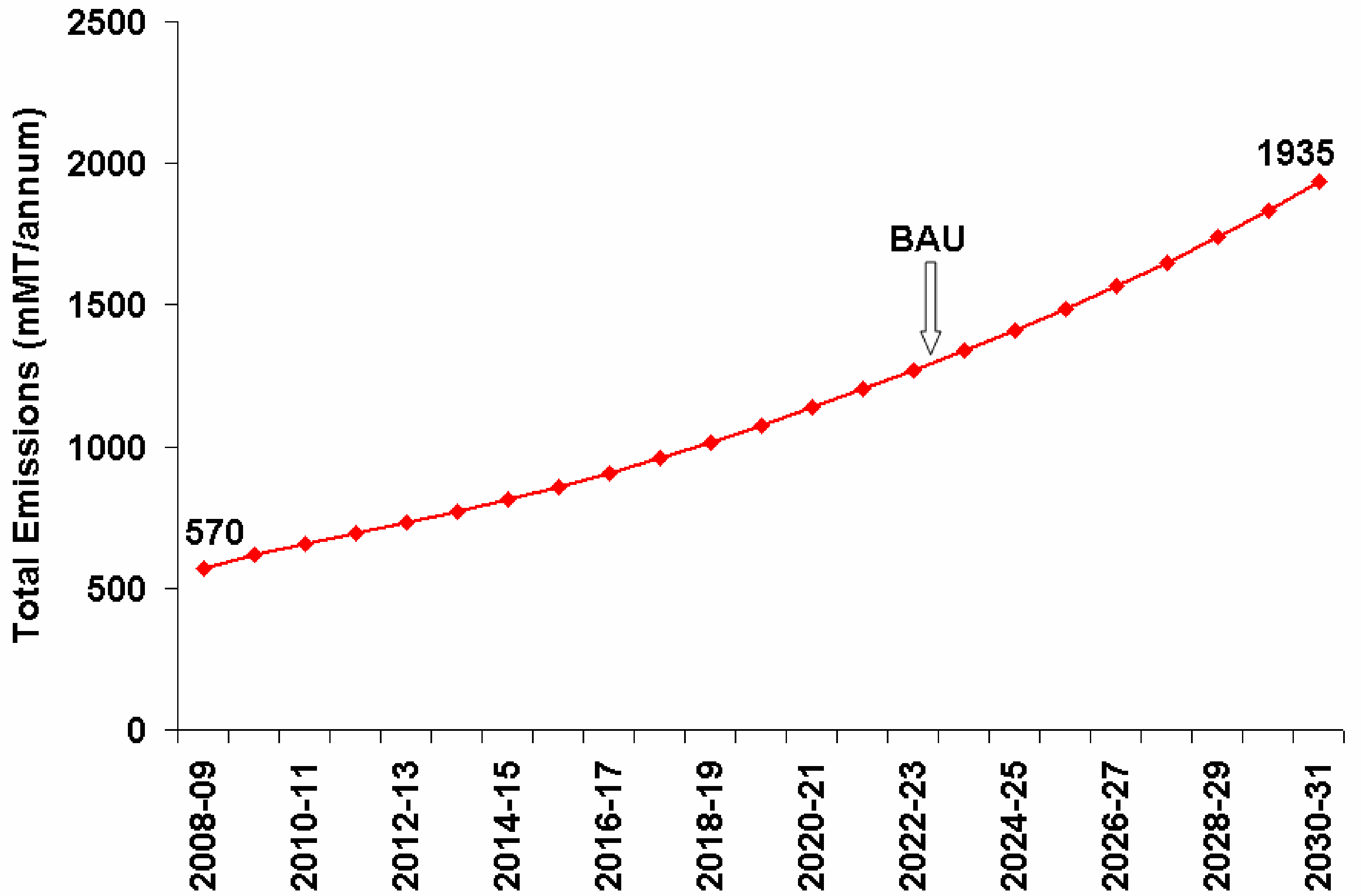
Power Sector

Kg CO_2/net kWh



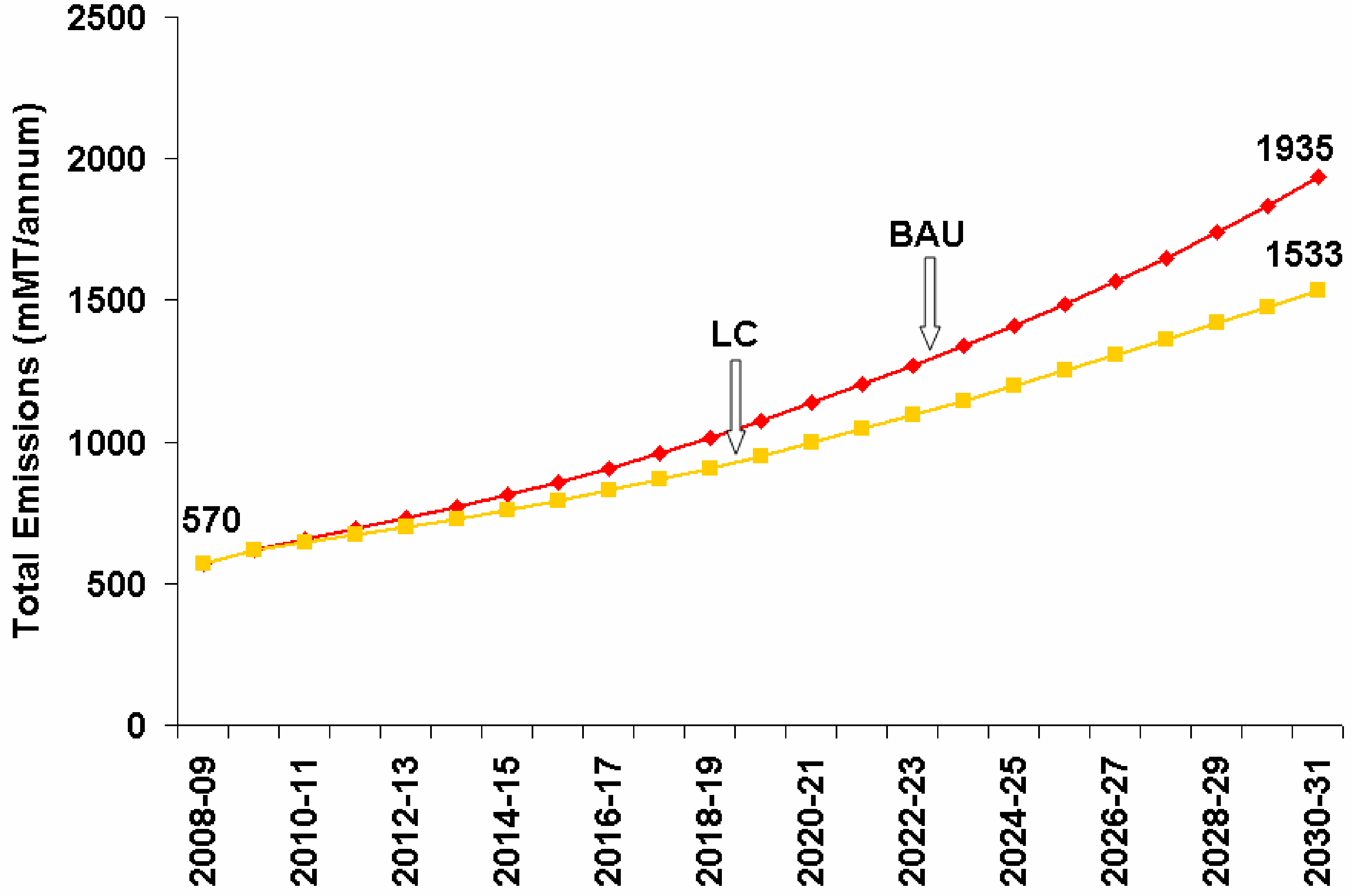
Emissions trajectory

Power Sector



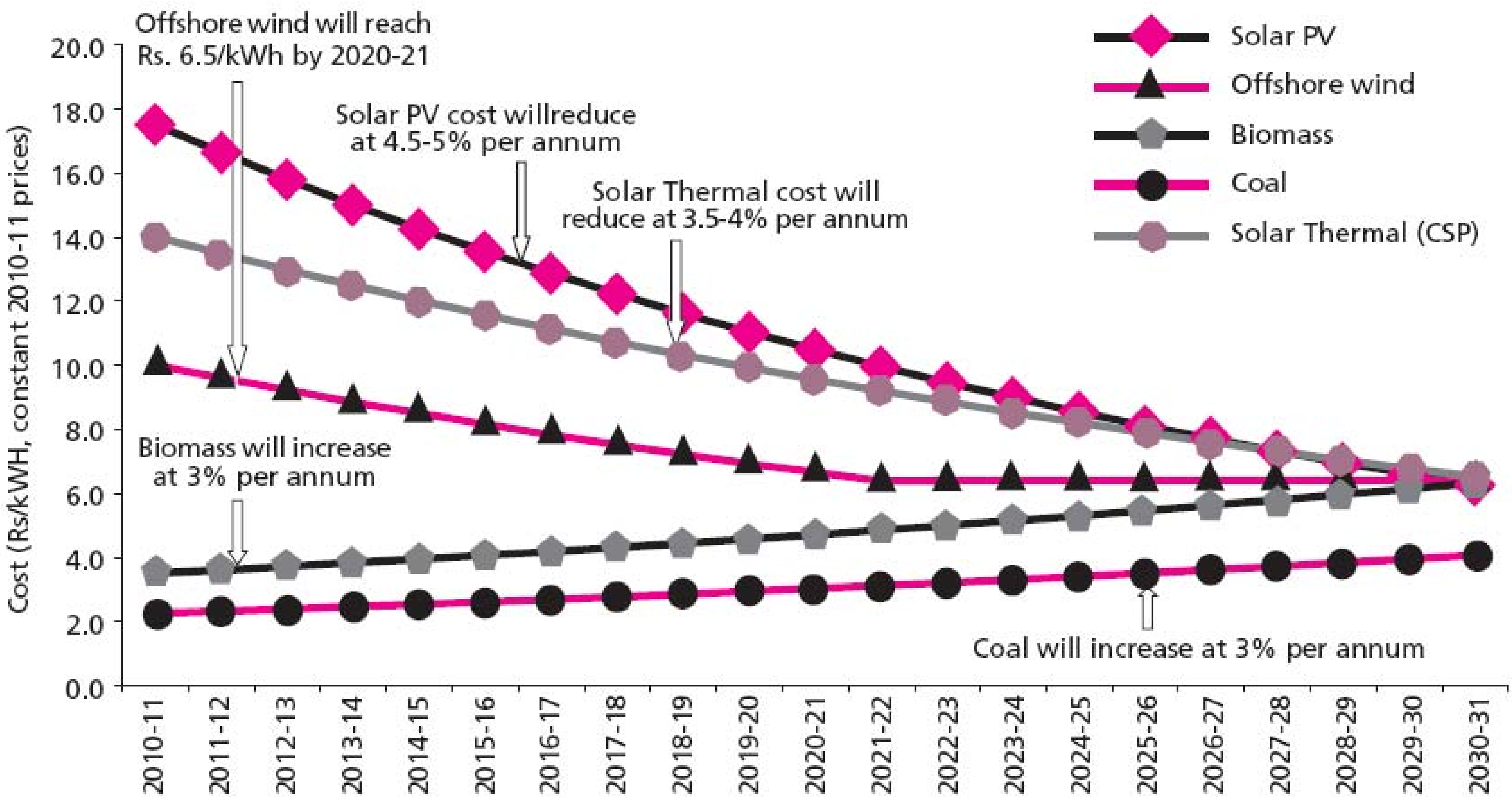
Emissions trajectory

Power Sector



Cost of low carbon

Power Sector



Cost of low carbon

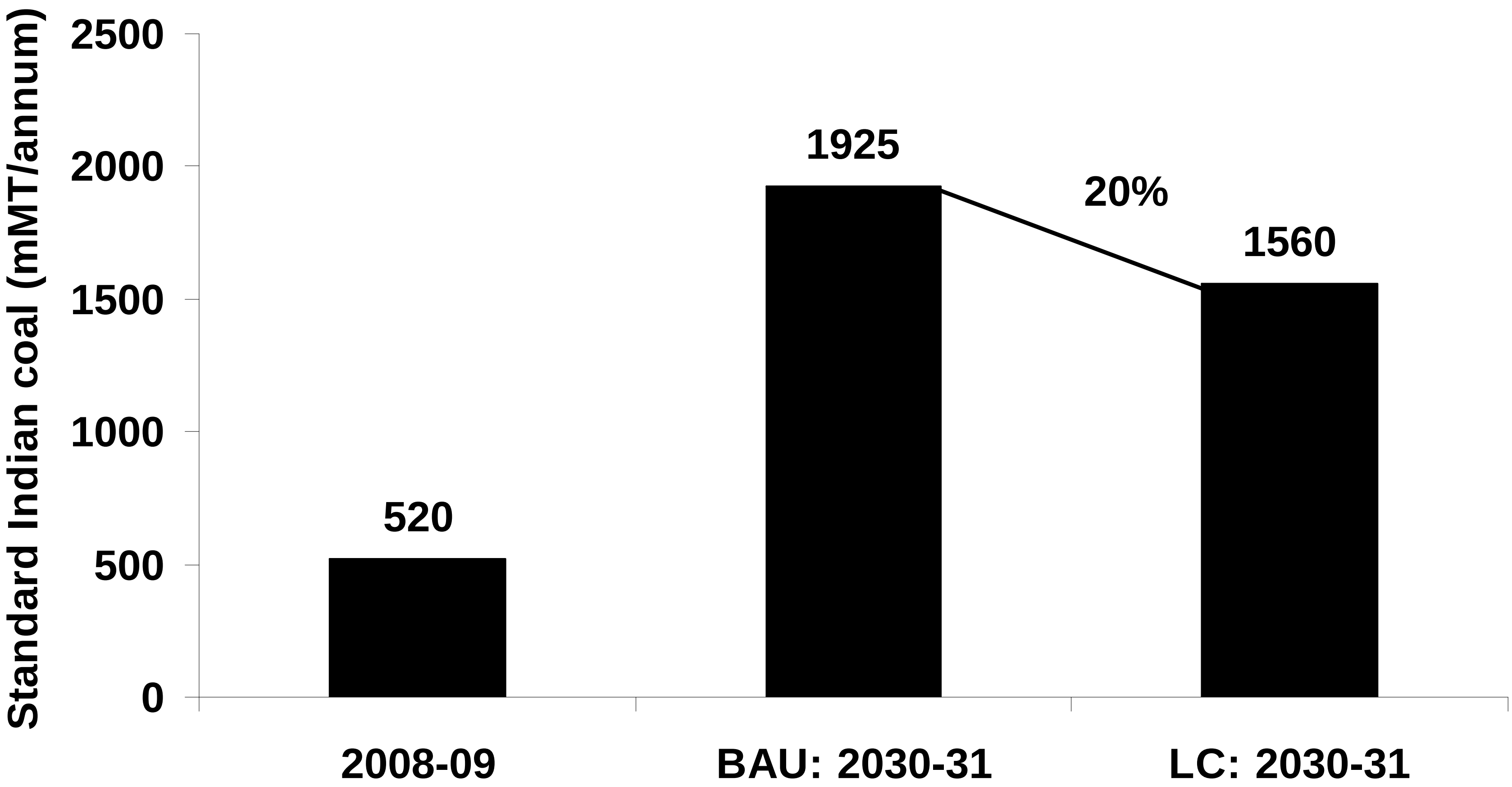
Power Sector

- Cumulative emissions avoided by opting for LC over BAU is 3.4 billion MT CO_2 @ US $60 / tonne CO_2 avoided
- This is 3- 4 times the price of CERs under CDM

Resources and resource constraints

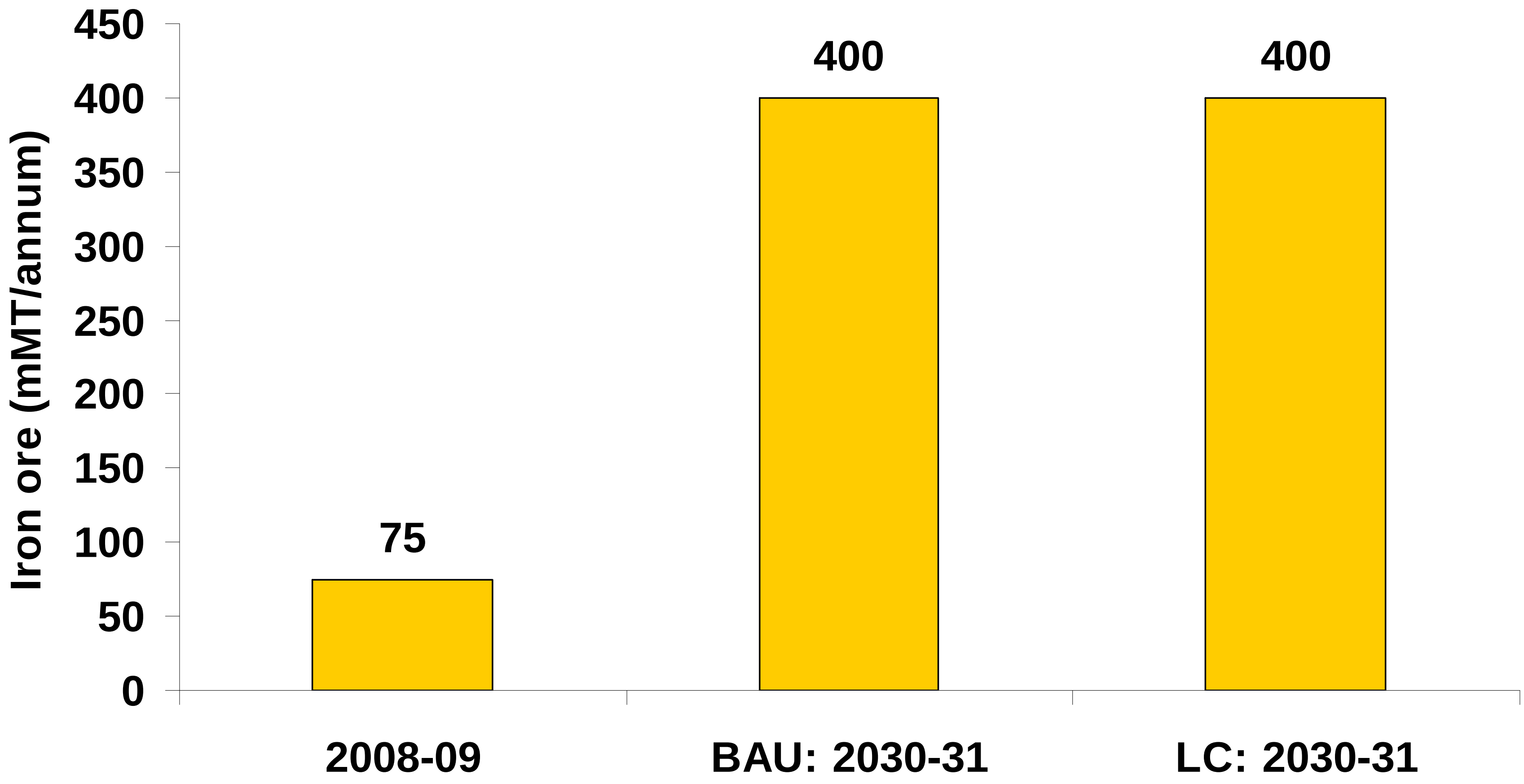
Coal

Minerals



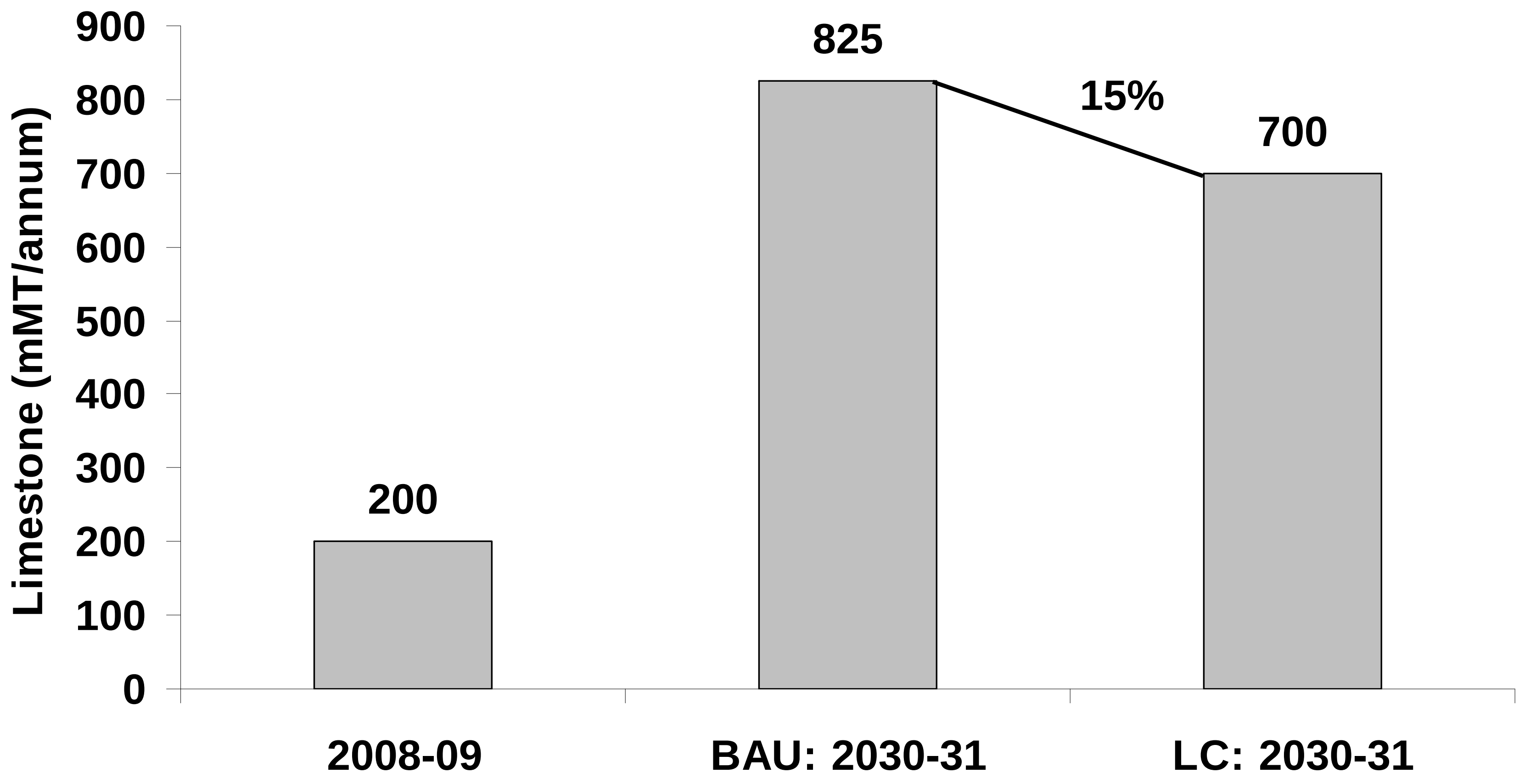
Iron ore

Minerals



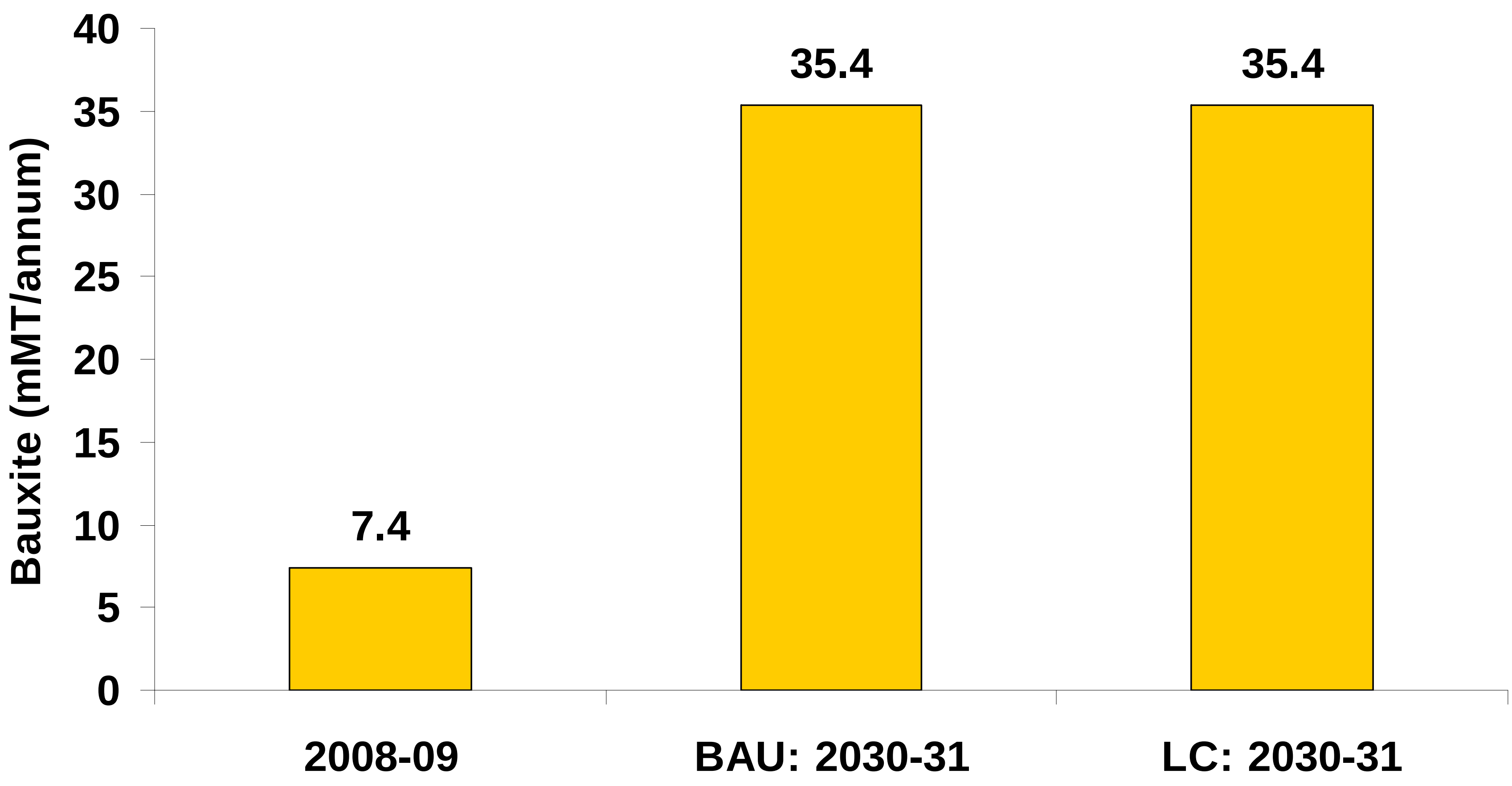
Limestone

Minerals



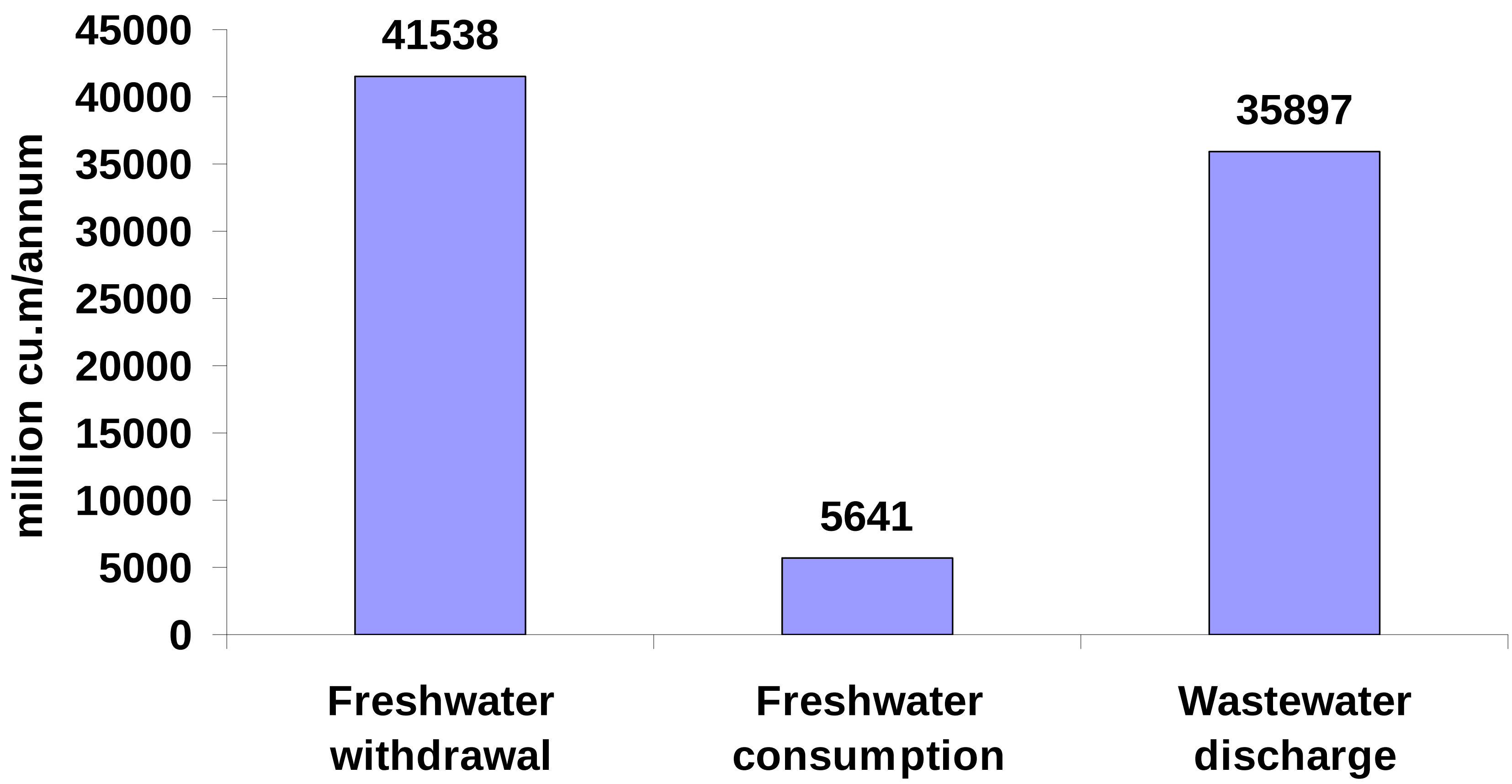
Bauxite

Minerals



Freshwater: 2008-09

Freshwater



Freshwater: 2008-09

Freshwater

WATER WITHDRAWAL

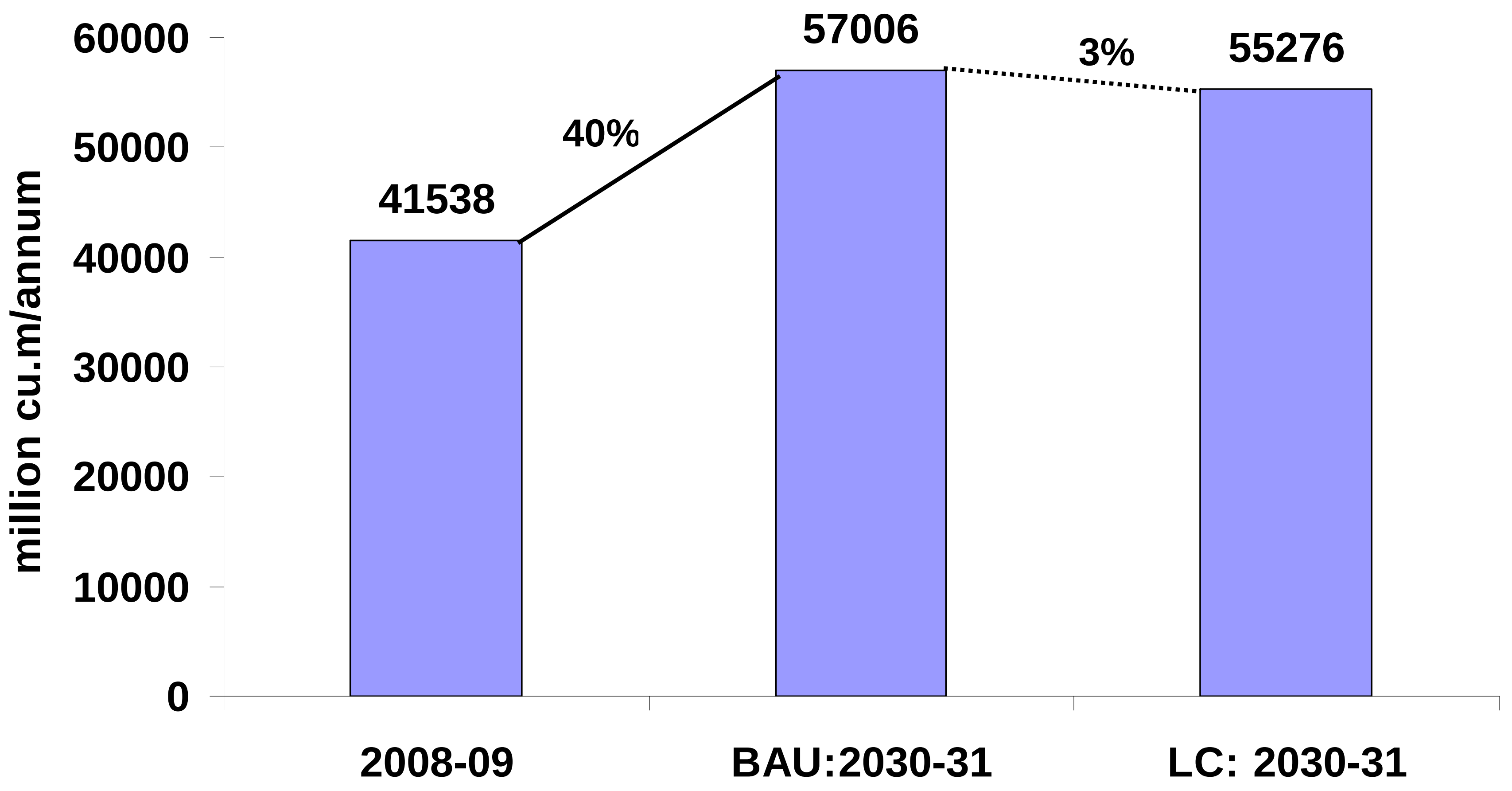
- **2008-09: 41,538 million cubic meter/year**
- **1.1 billion peoples' daily water need (100 lpcd)**

WATER CONSUMPTION

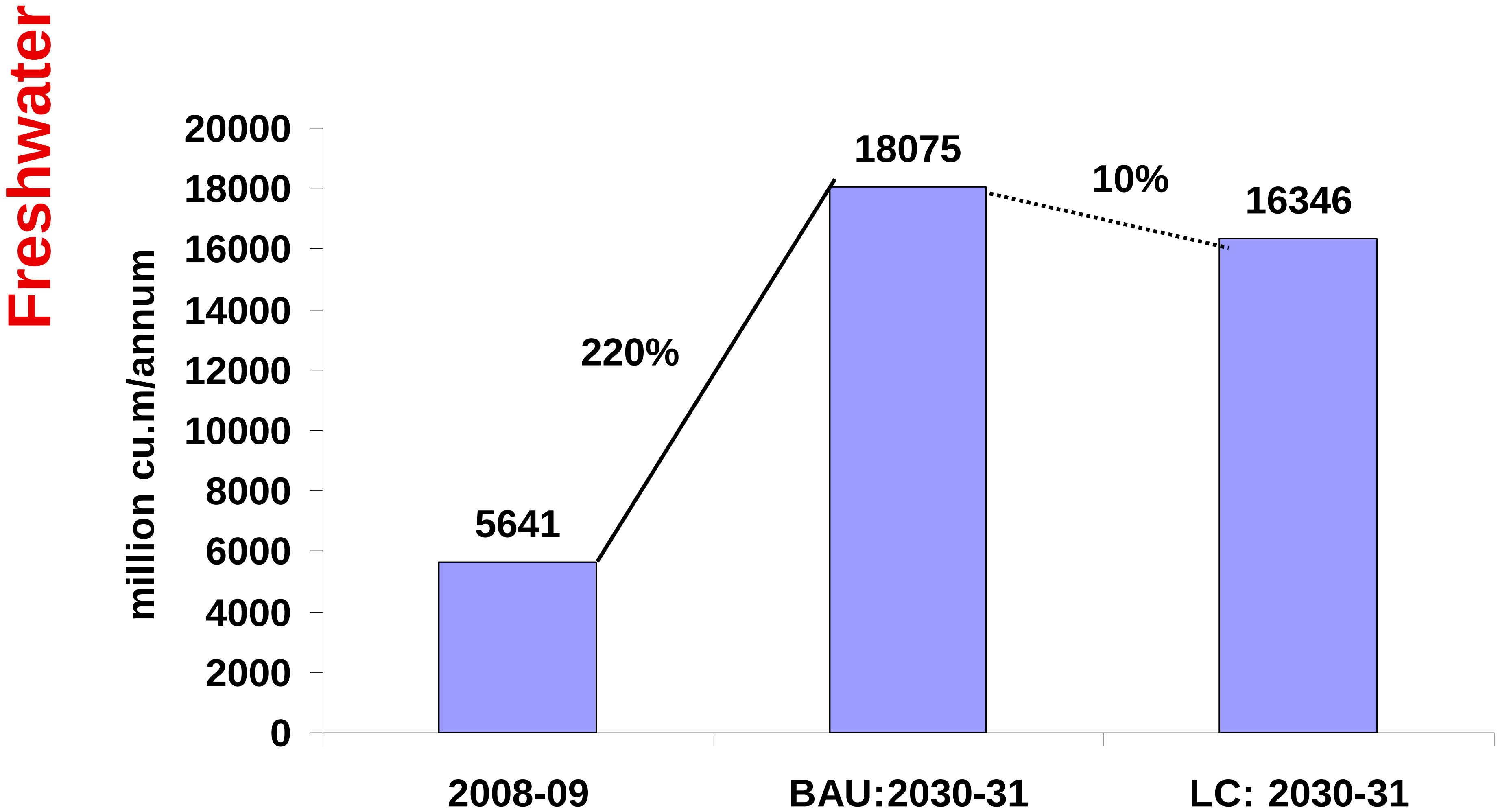
- **2008-09: 5,641 million cubic meter/year**
- **A billion peoples' daily drinking and cooking need (15 lpcd)**

Freshwater withdrawal

Freshwater



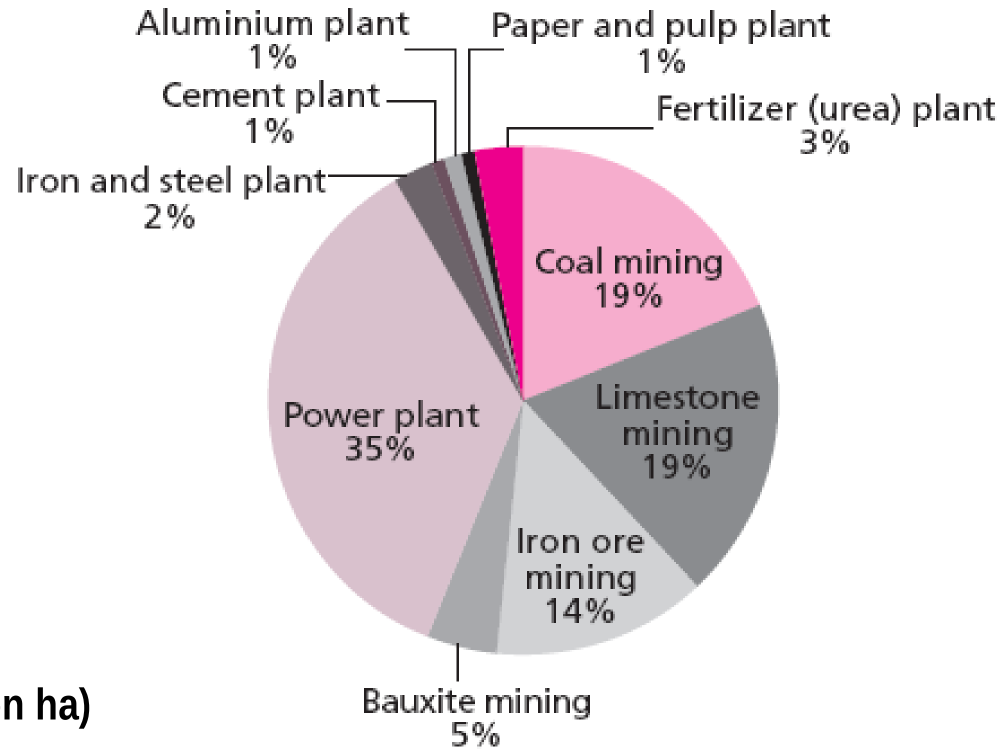
Freshwater consumption



Land: 2008-09

Land

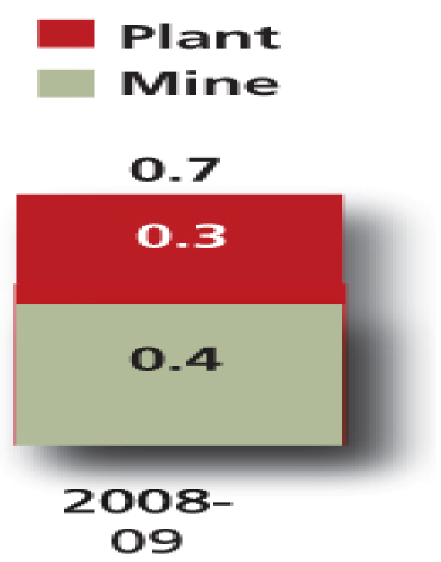
Land currently occupied by six sectors (million ha)



Additional land required

Land

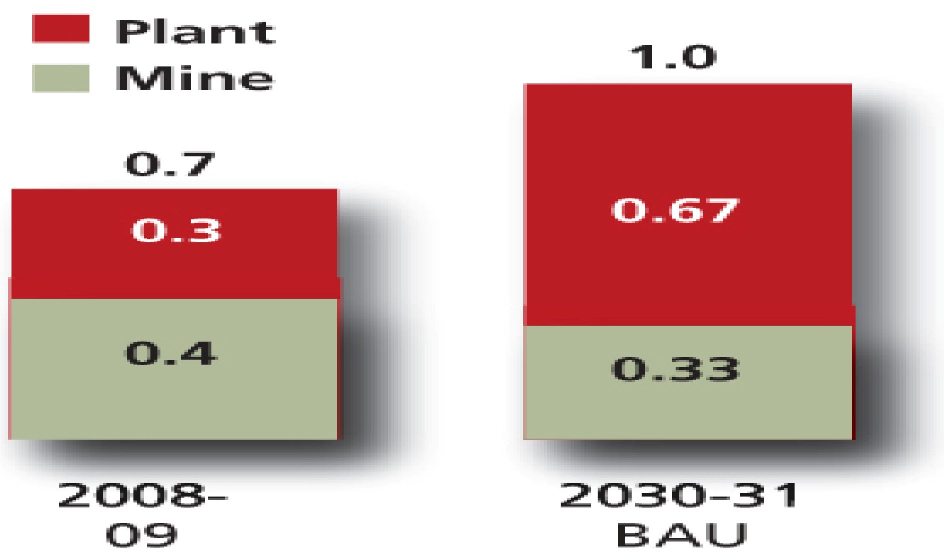
Additional land required *(million hectares)*
excluding land required for biomass



Additional land required

Land

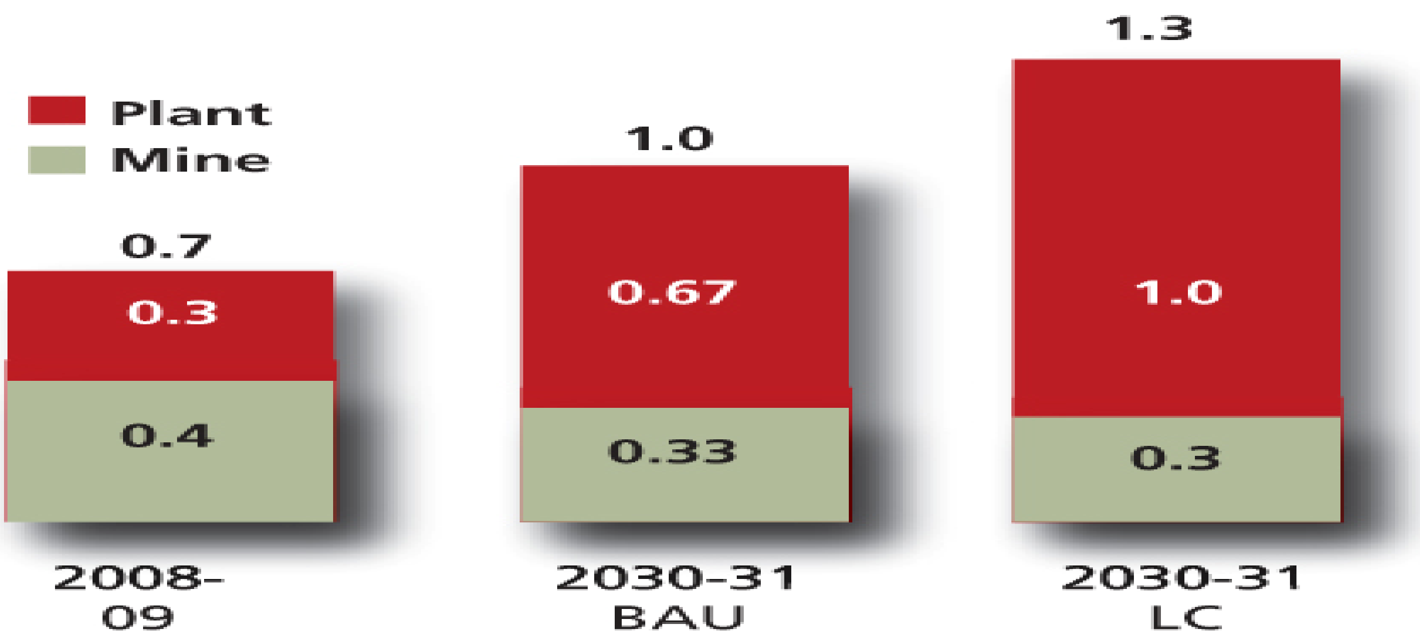
Additional land required *(million hectares)*
excluding land required for biomass



Additional land required

Land

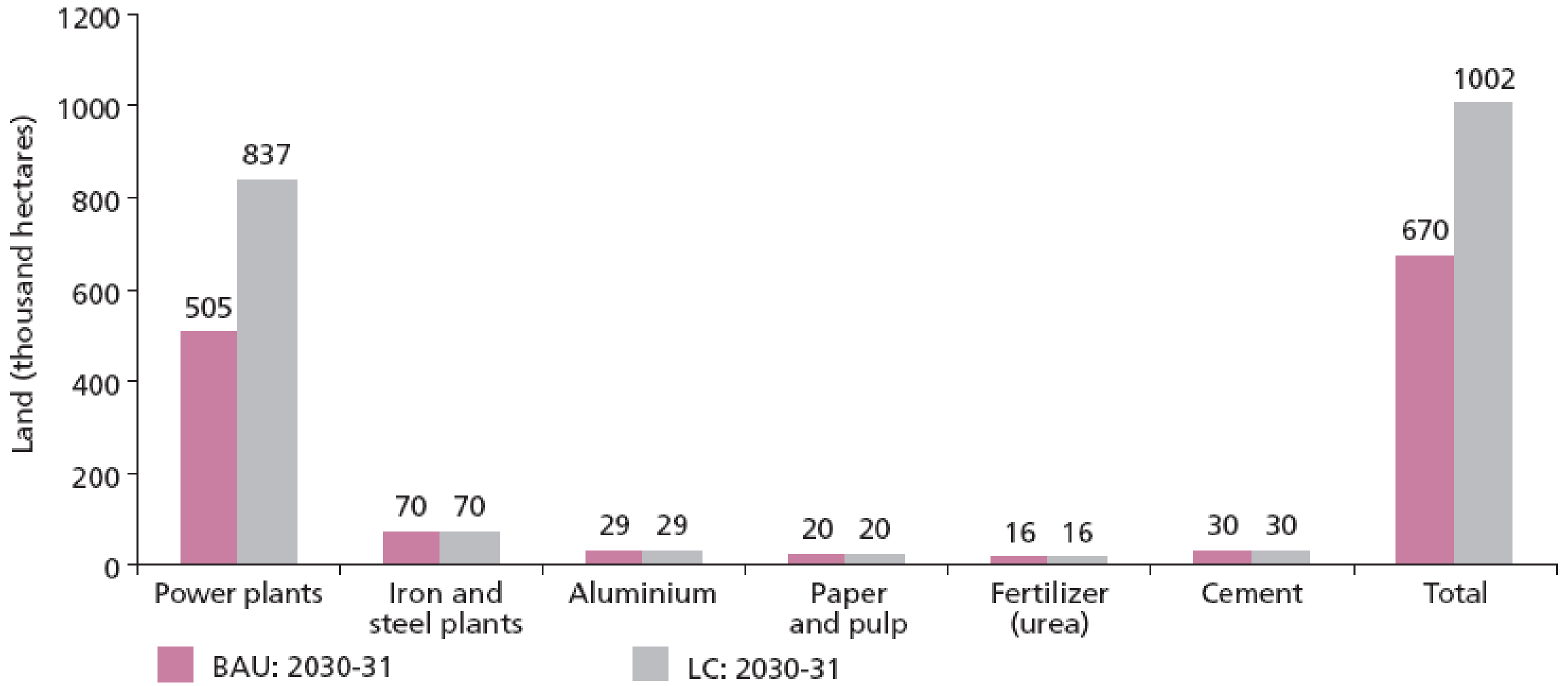
Additional land required *(million hectares)*
excluding land required for biomass



Additional land required

Land

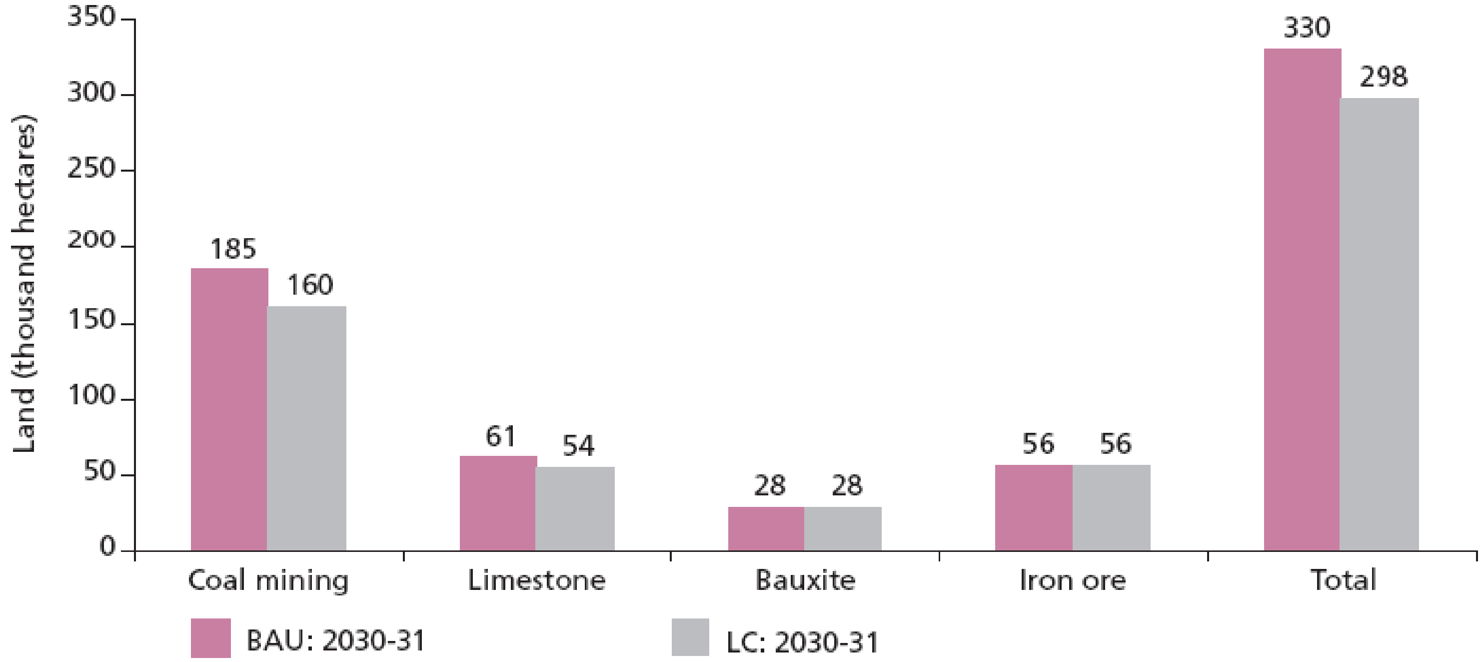
Additional land required for plants *(million hectares)*



Additional land required

Land

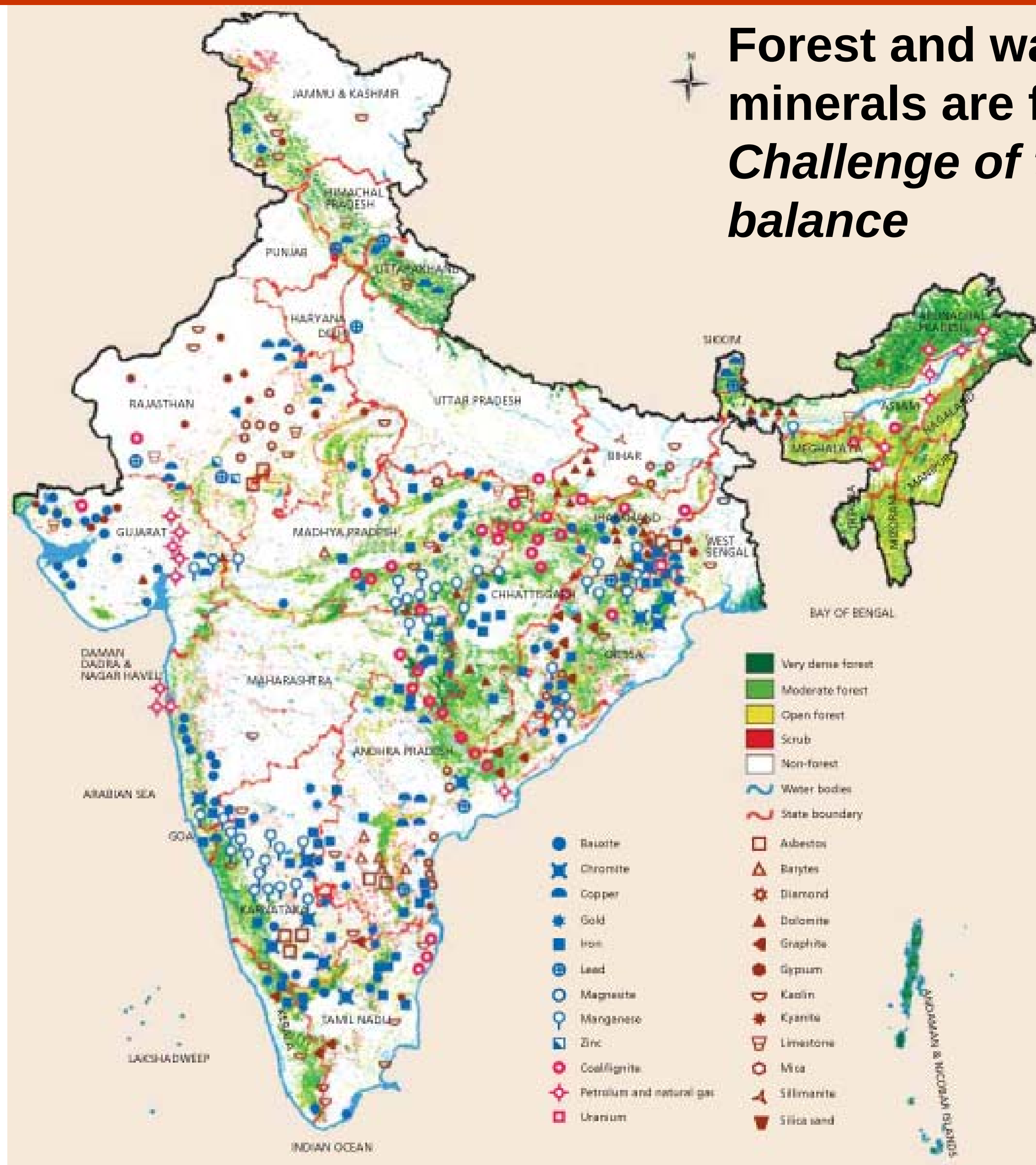
Additional land required for mines *(million hectares)*



Land, forest, water……

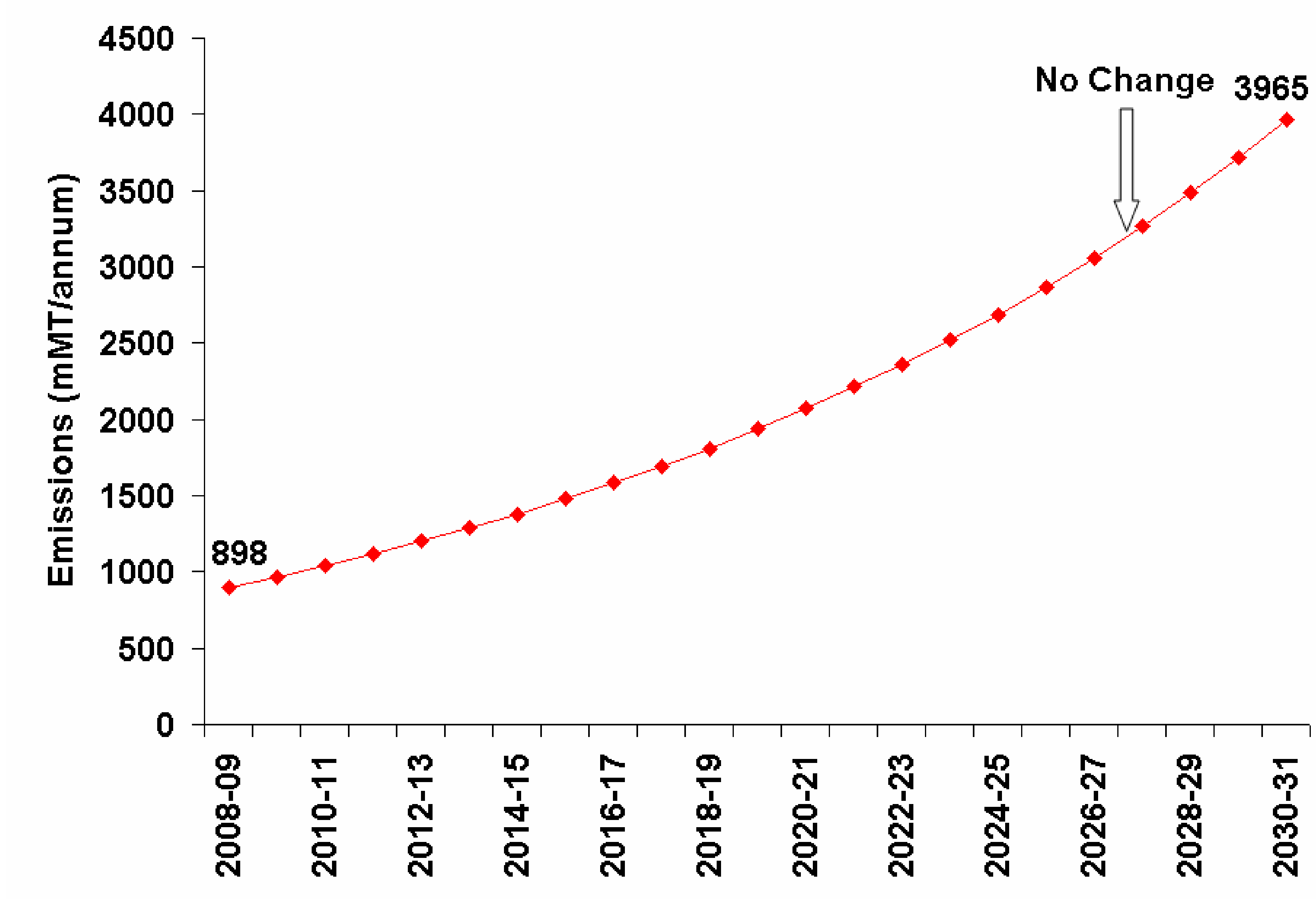
Land

Forest and water is where minerals are found.
Challenge of the old balance



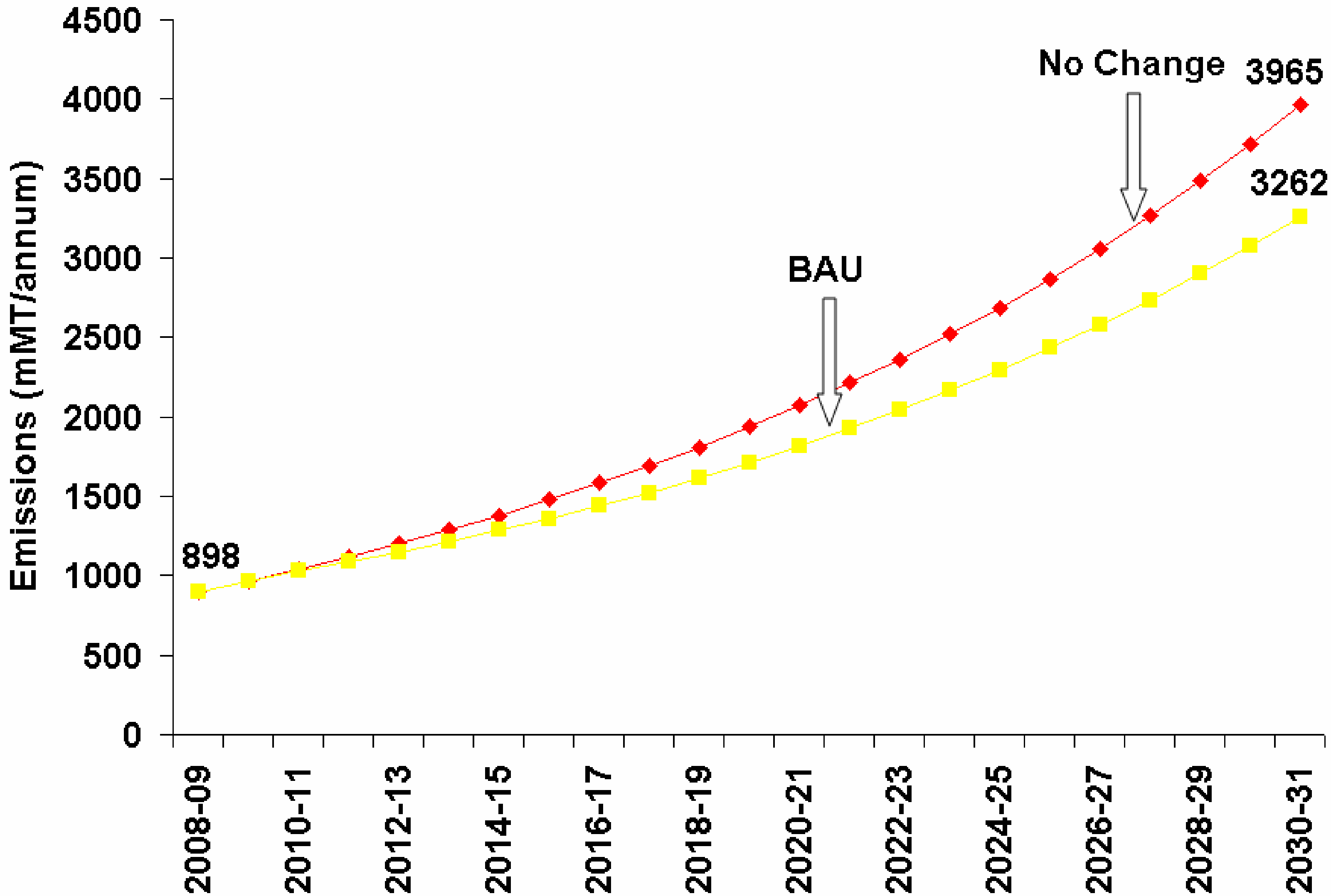
GHG emissions scenario

Low carbon growth



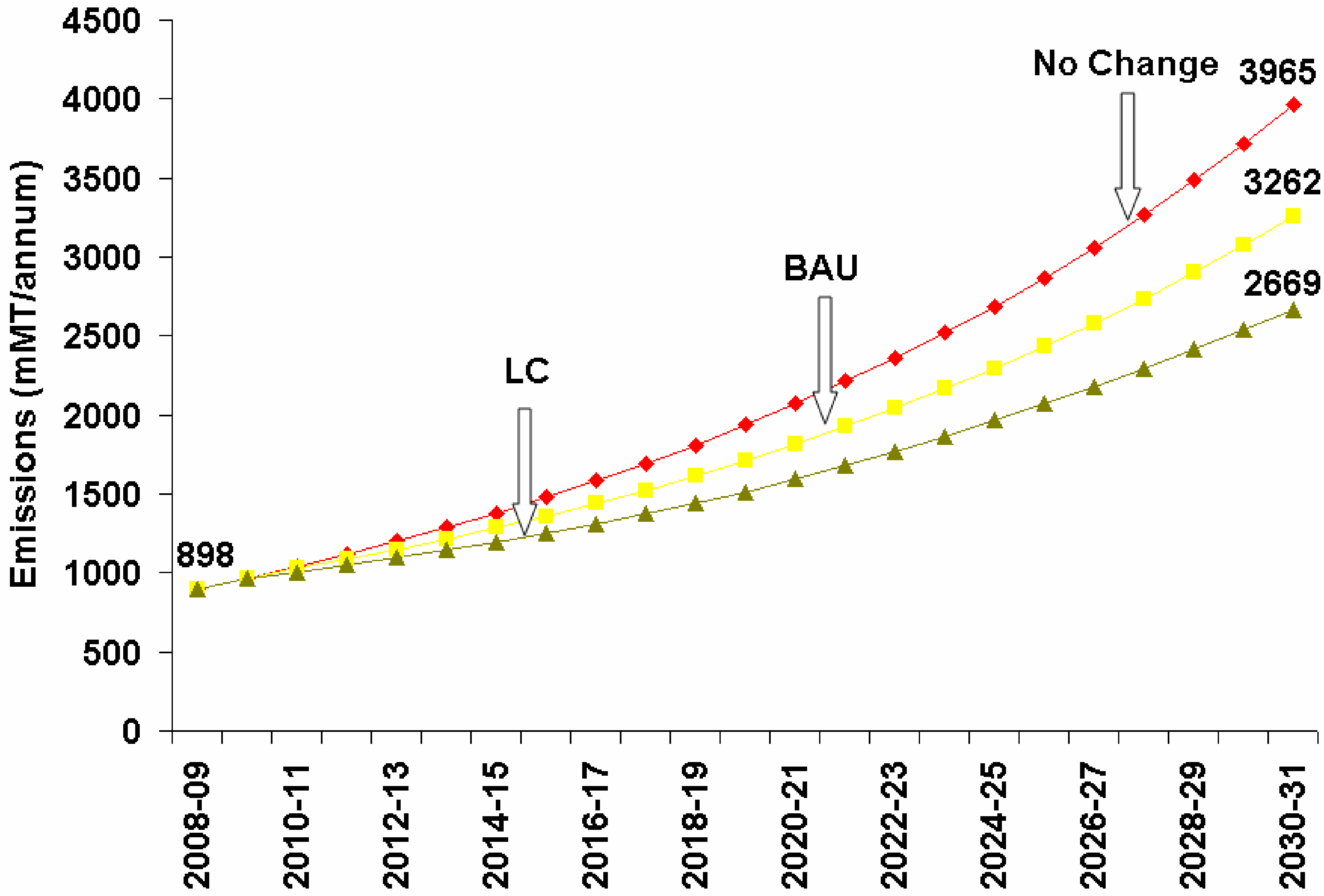
GHG emissions scenario

Low carbon growth



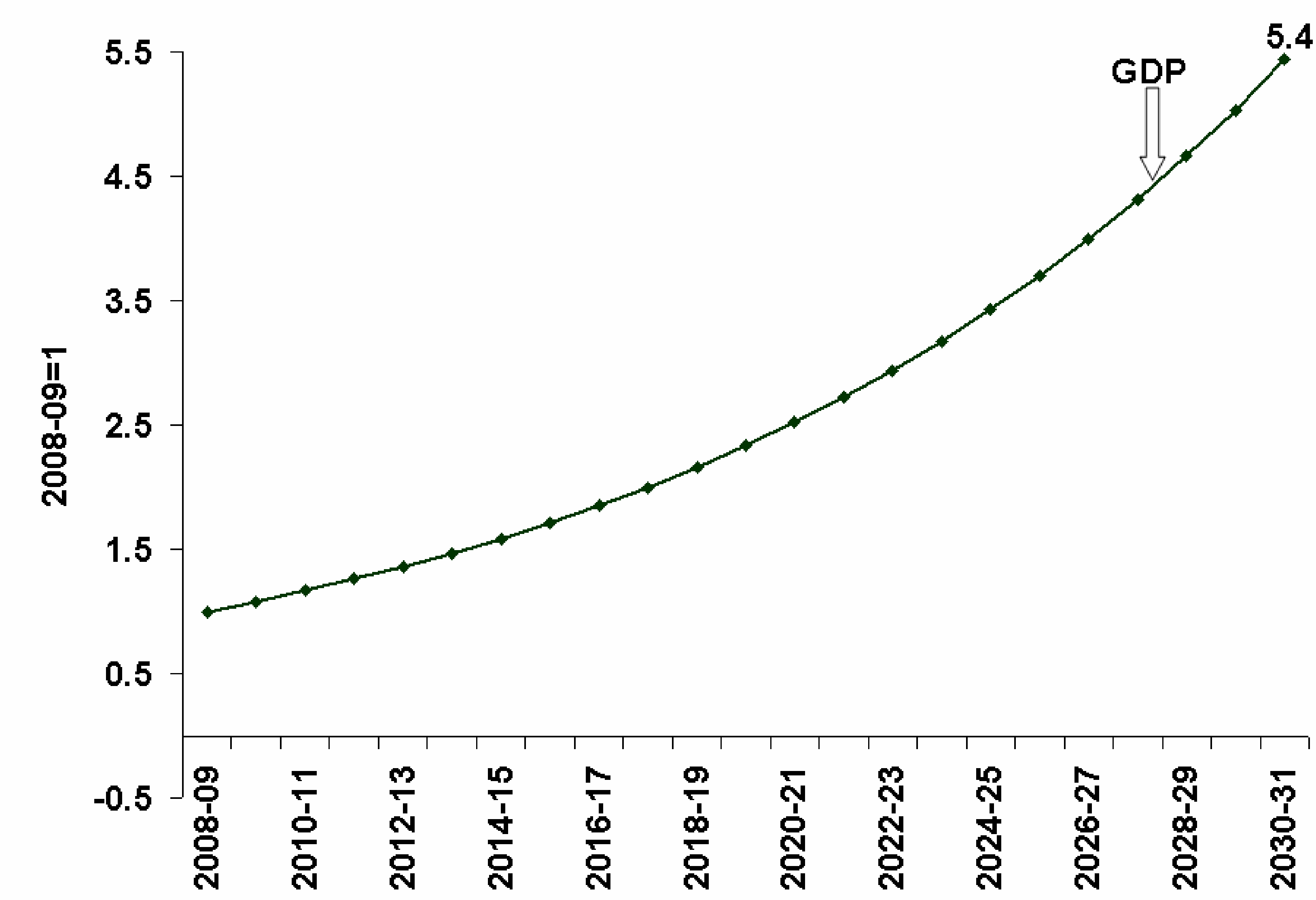
GHG emissions scenario

Low carbon growth



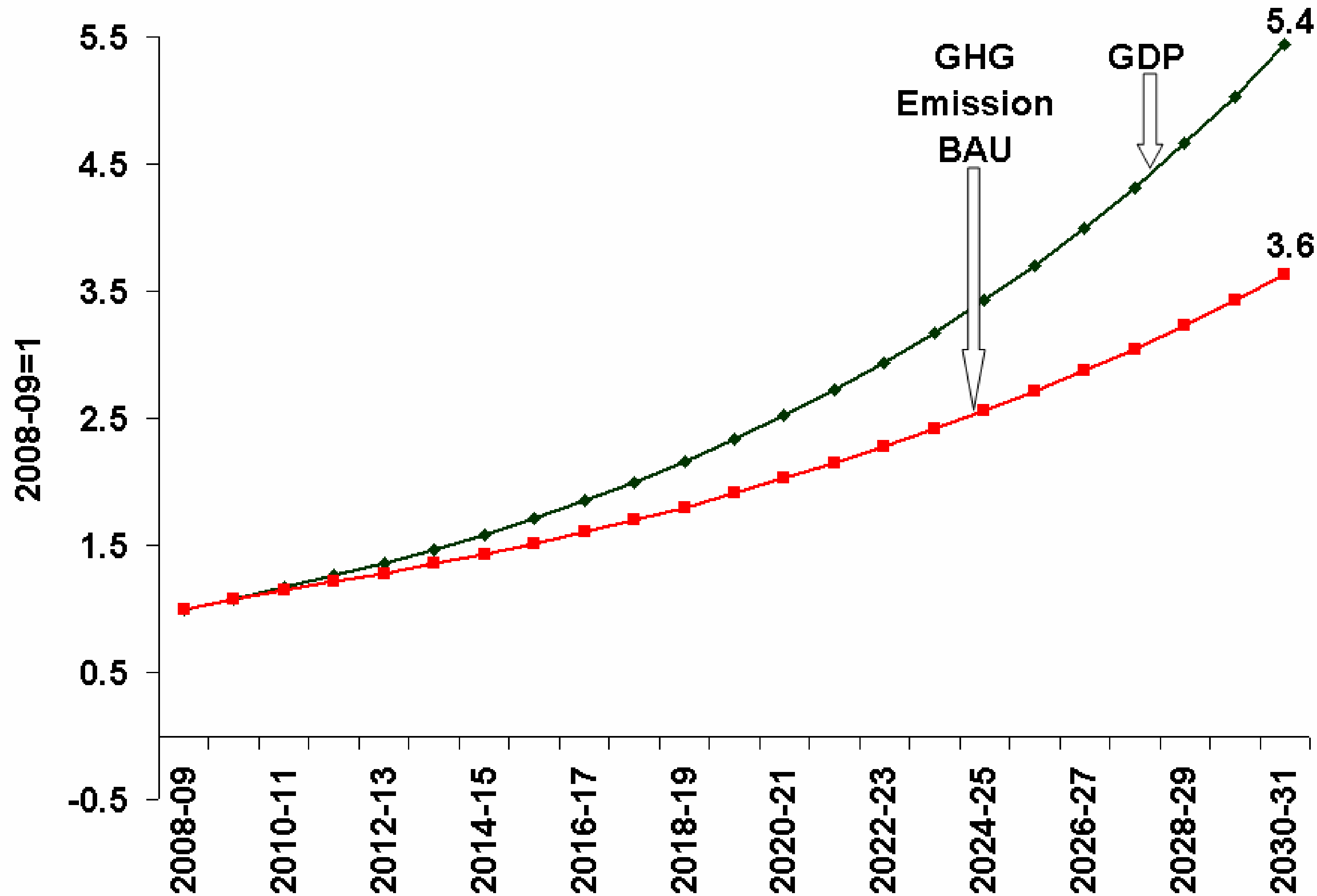
Emissions intensity of GDP

Low carbon growth



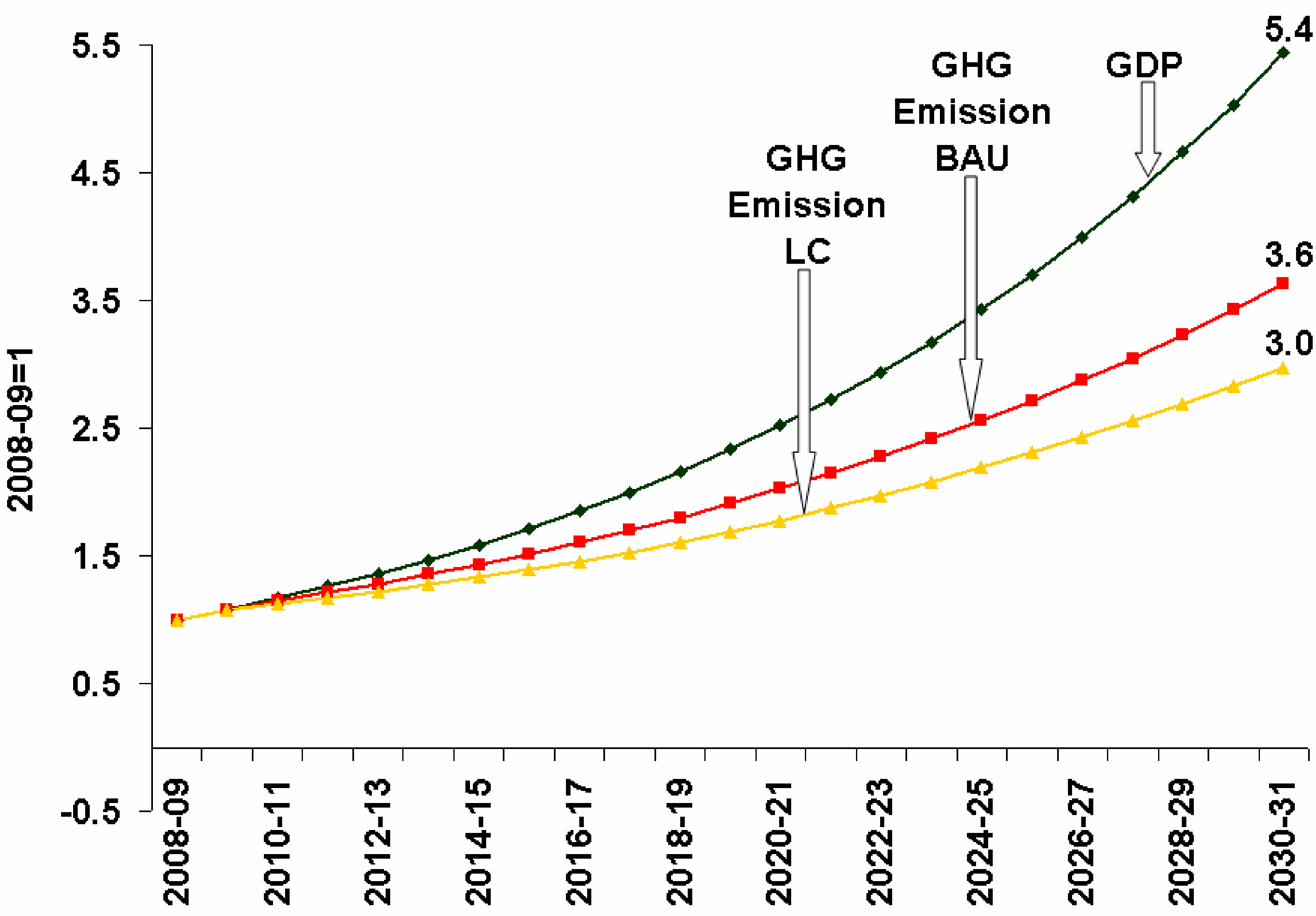
Emissions intensity of GDP

Low carbon growth



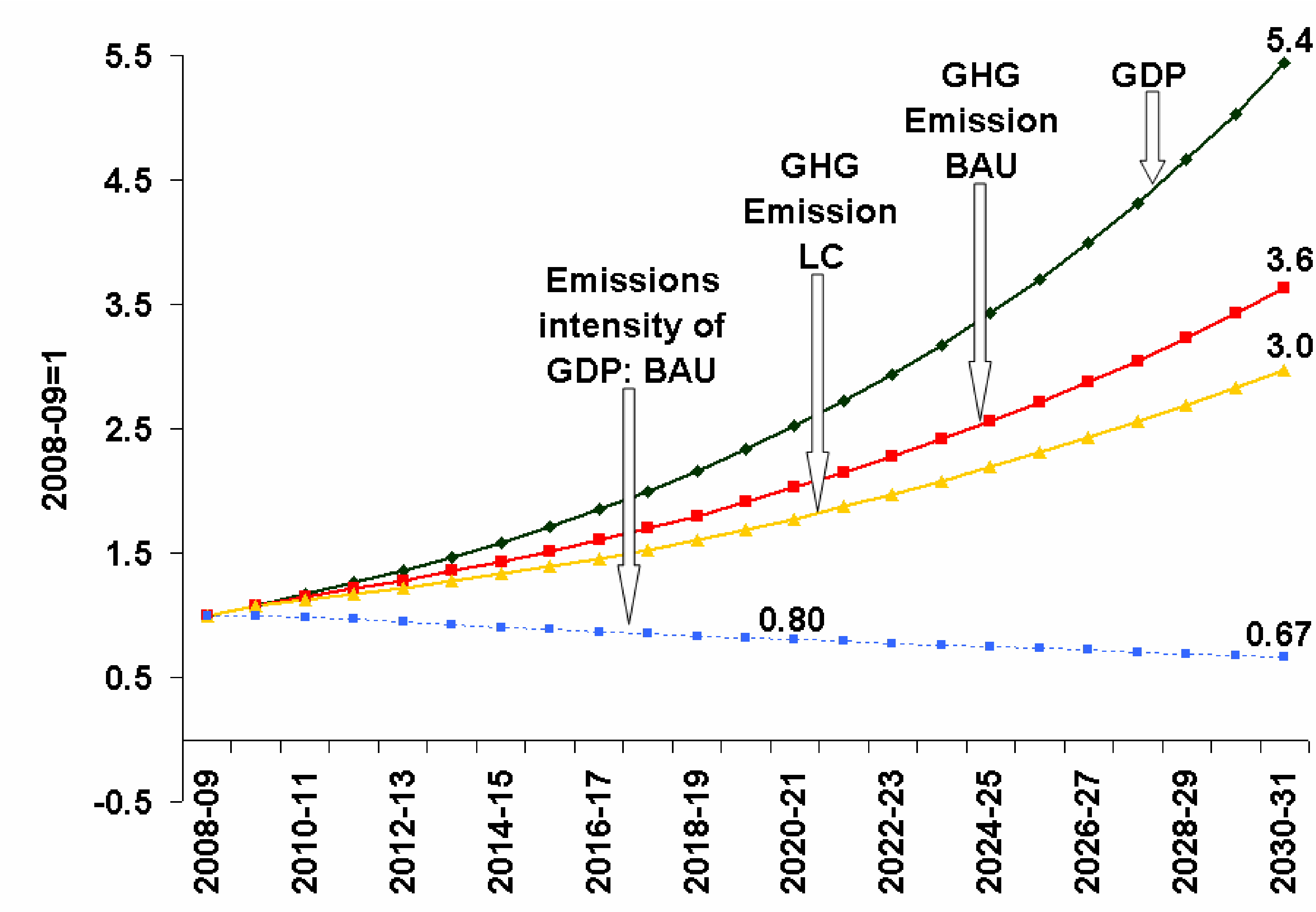
Emissions intensity of GDP

Low carbon growth



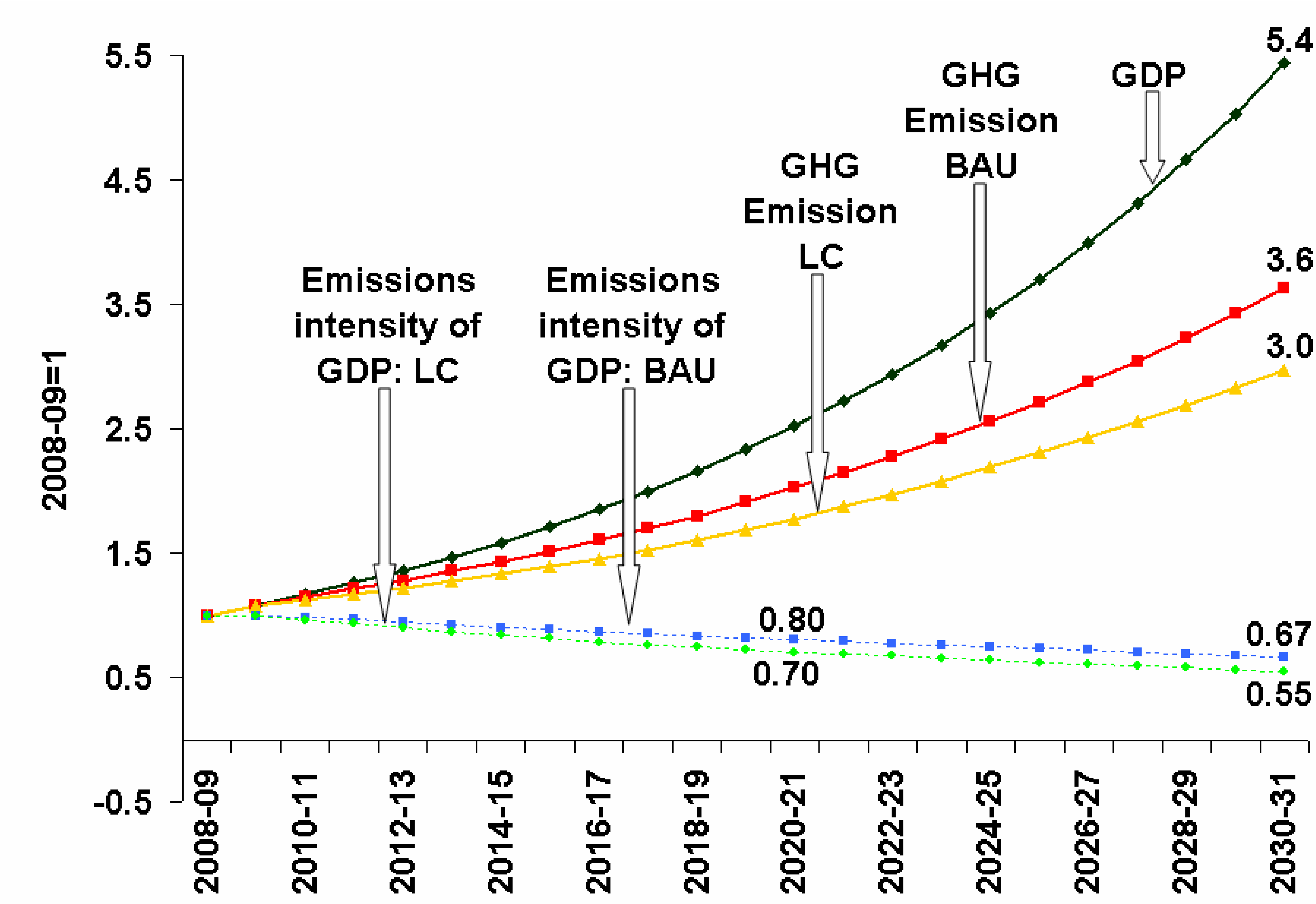
Emissions intensity of GDP

Low carbon growth



Emissions intensity of GDP

Low carbon growth



What the future looks like

Low carbon growth

- In both BAU and LC, major reductions in emissions intensity will be achieved by 2020-21.
- After 2020-21, in steel, aluminium and fertilizer the emissions intensity stagnates; in paper and cement, the reduction is moderate and largely because of change in raw material.
- By 2020-21, aluminium, cement and fertilizer will operate at BAT levels; steel and paper will operate at highest possible levels considering the structure, technology and limitations.
- Everything in power sector depends on how ambitious we are in deploying low/no-carbon technologies. Cost is the factor.

What the future looks like?

Low carbon growth

- Reducing emissions post 2020 will be a challenge.
- By 2020, we will exhaust all ‘low hanging’ options as well as high-end commercialized technologies.
- Post 2020 new, high-cost and not yet commercially available technologies will be required to reduce emissions significantly. And it will be expensive.

What are the implications of this study for international negotiations?