Advanced technologies – new developments and economic feasibility for India

Lesley Sloss
Principal Environmental Consultant
IEA Clean Coal Centre

International Conference on Coal Based Power: Confronting Environmental Challenges
New Delhi, 17-19th March 2016

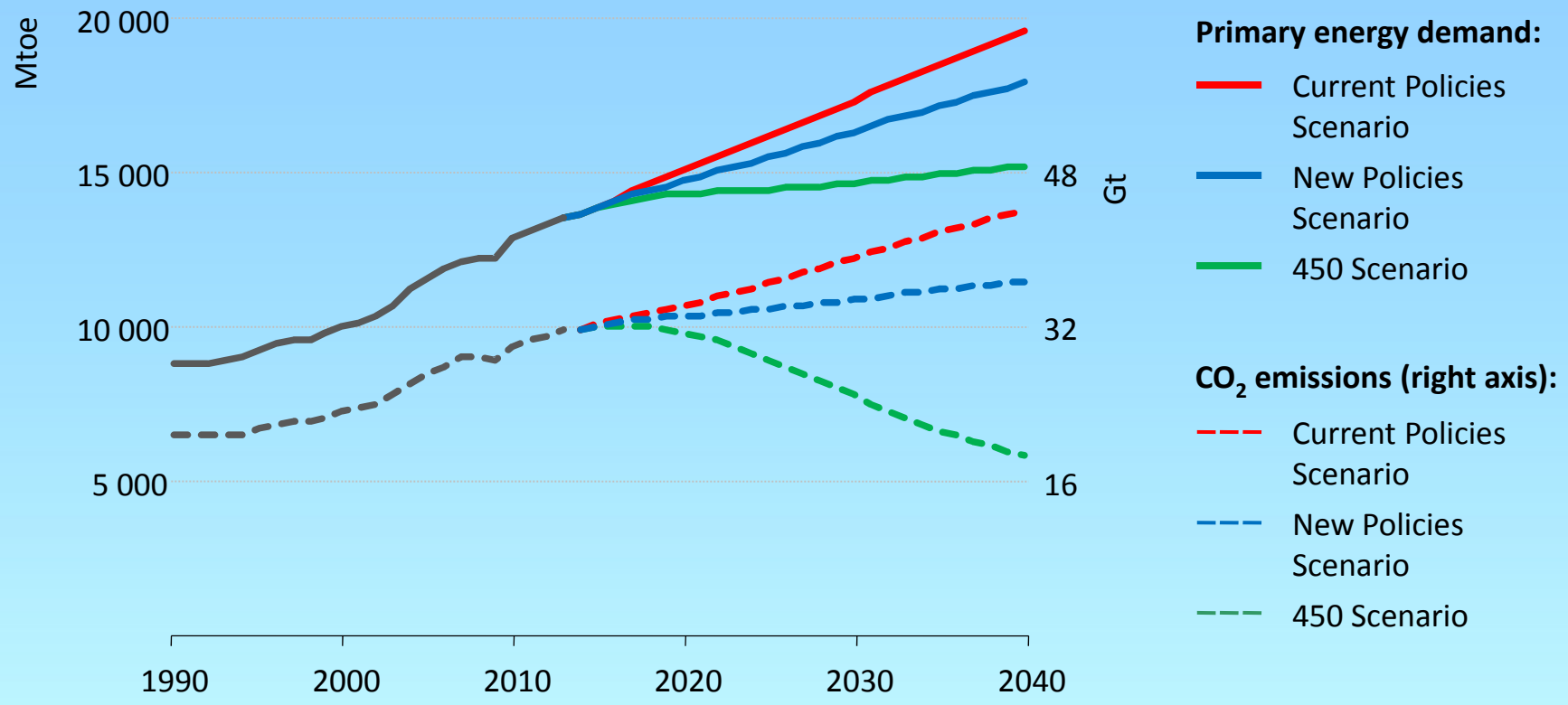
What does the IEA Clean Coal Centre do?

- Our output includes:
  - comprehensive assessment reports on all aspects of clean coal technology
  - Webinars
  - technical workshops on clean coal issues
  - Clean Coal Technologies Conference
- Capacity building activities and demonstration projects in developing countries with UNEP and US State Department

www.iea-coal.org

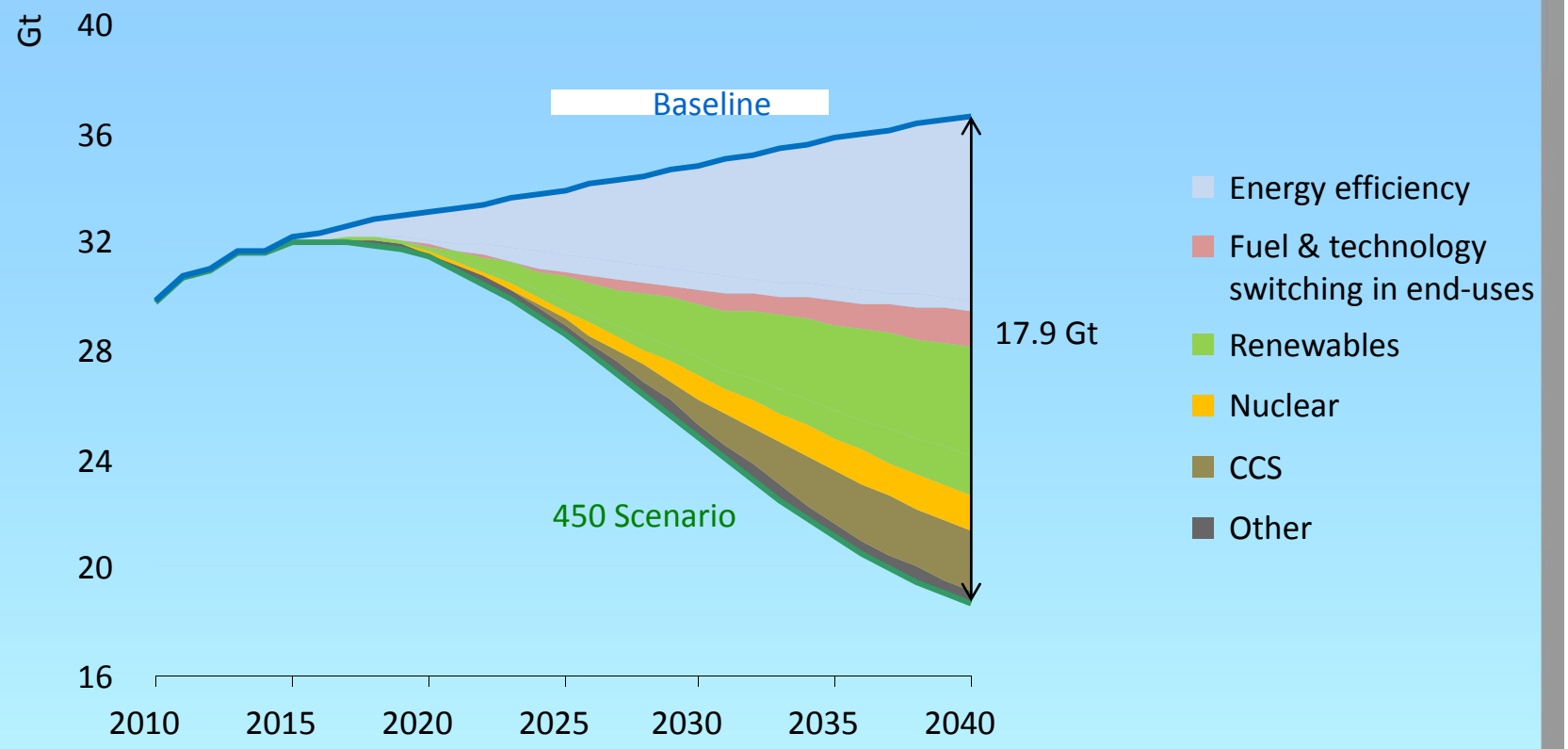
Energy demand will rise but policies determine emissions growth

World primary energy demand & CO_2 emissions by scenario



While global energy demand increases in all scenarios, government policies play a key role in dictating the degree of growth & decoupling with emissions levels

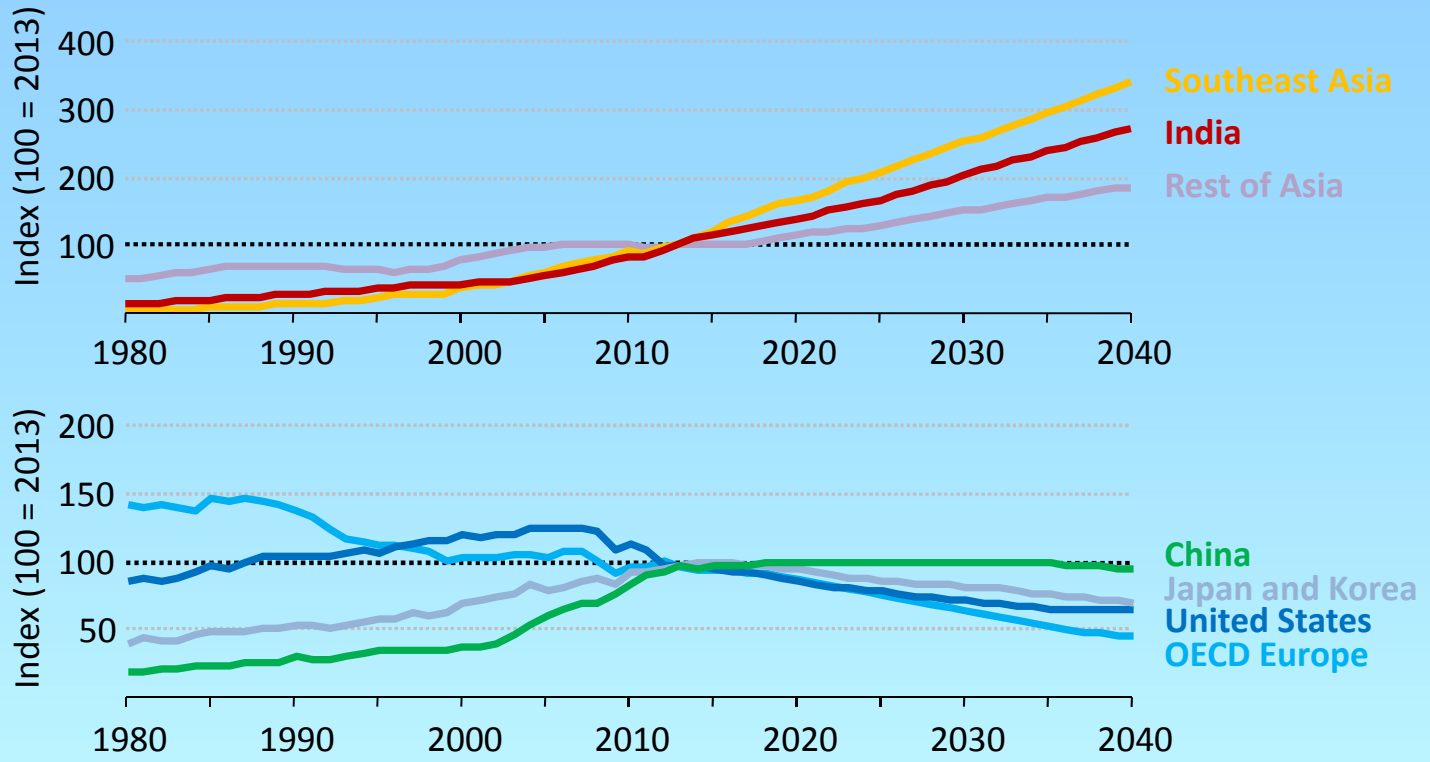
A 2 ° C pathway is still some further efforts away



A peak in emissions by around 2020 is possible using existing policies & technologies; technology innovation and RD&D will be key to achieving the longer-term goal

Asia drives global coal demand higher

Evolution of coal demand in key regions



Coal use in OECD countries peaked in 2007, so future growth hinges critically on the power sector in emerging economies, especially India, Southeast Asia & China

International Energy Agency
Secure Sustainable Together

World Energy Outlook 2015

INDIA ENERGY OUTLOOK

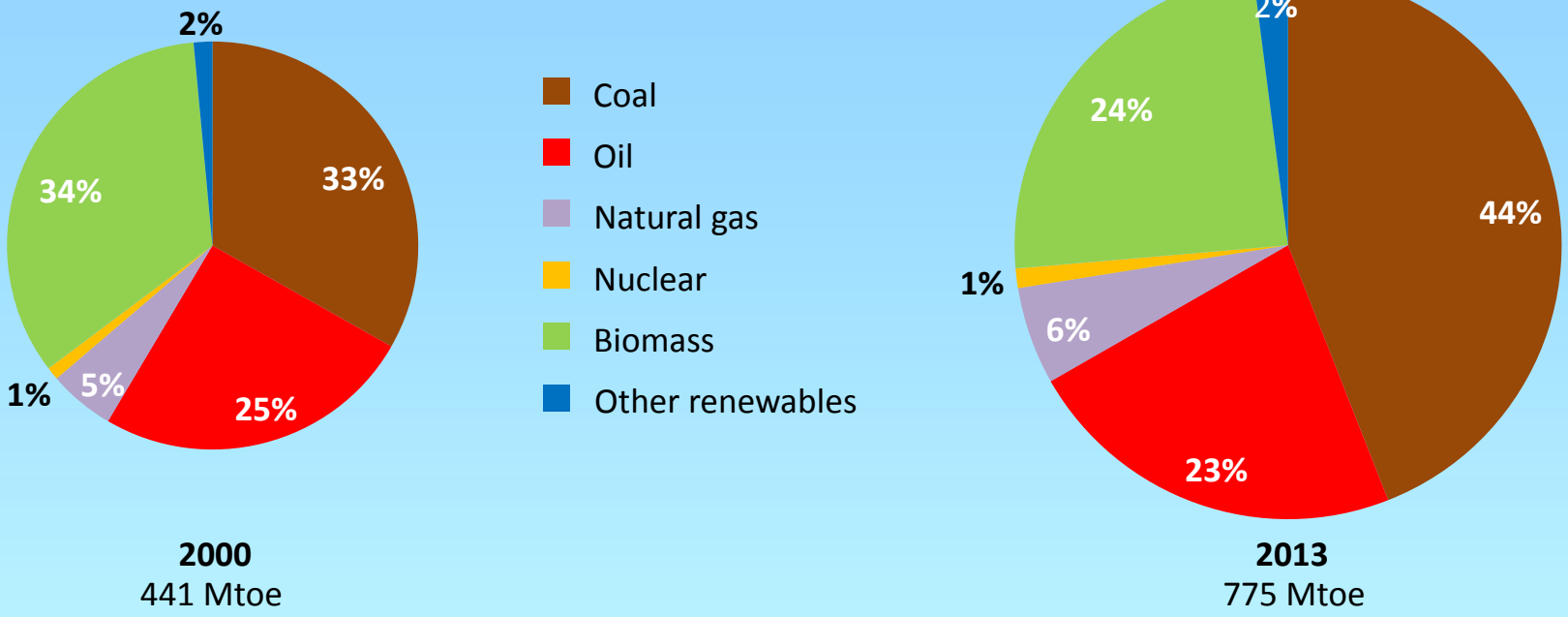
India in a fast-moving energy landscape

Energy at the heart of India's drive for development & modernisation

- 18% of the world's population in India use only 6% of its energy; scope for further growth is enormous
- Domestic reform efforts gain speed, but one in five remains without electricity

India: expanding energy demand led by coal

Primary energy demand in India by fuel



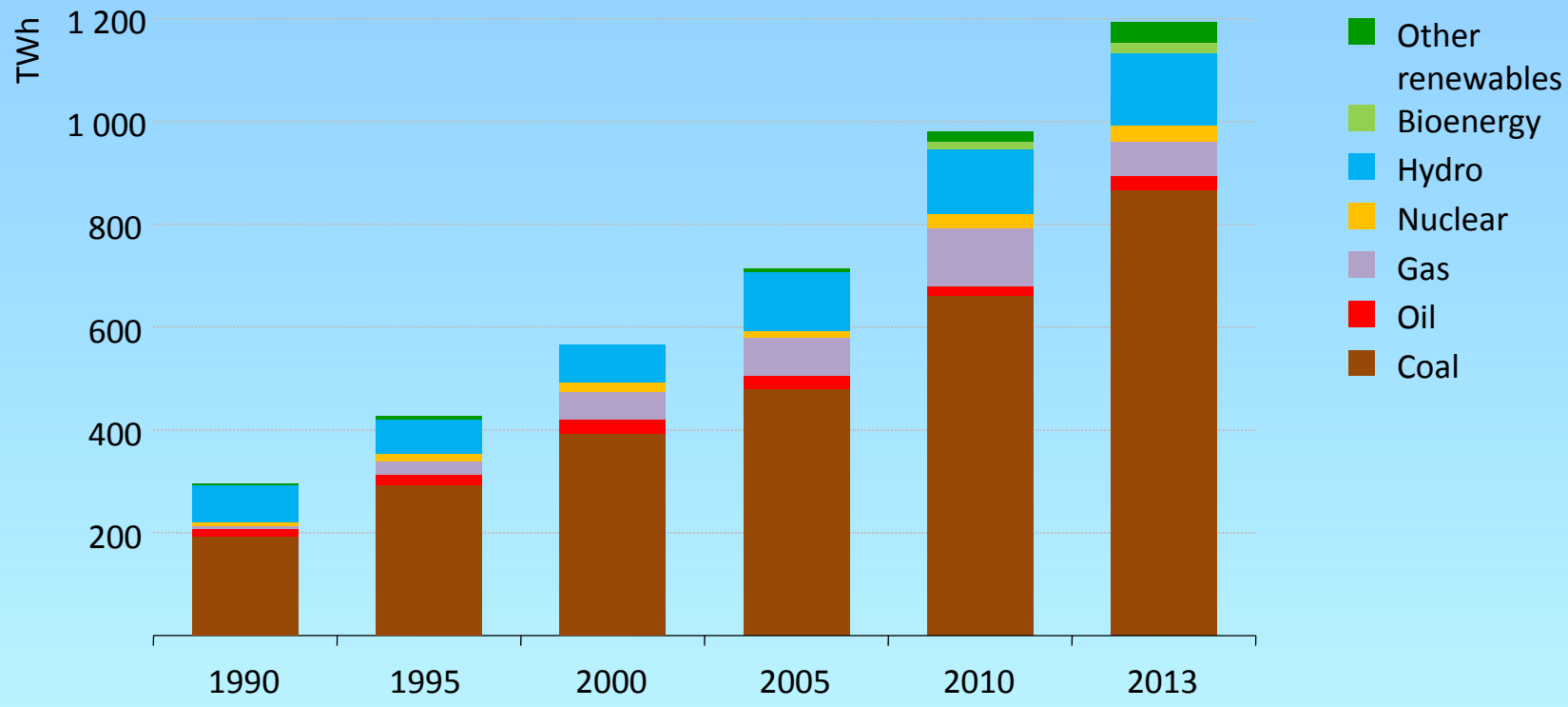
2000
441 Mtoe

2013
775 Mtoe

Almost three-quarters of Indian energy demand is met by fossil fuels, a share that has increased since 2000 notably because of a rapid rise in coal consumption

Coal remains the backbone of India's power sector

Total electricity generation in India by fuel



Coal makes up by far the largest share of power generation, but renewables are playing an increasingly important role

Efficiency of fossil fuel plants 2009-2011

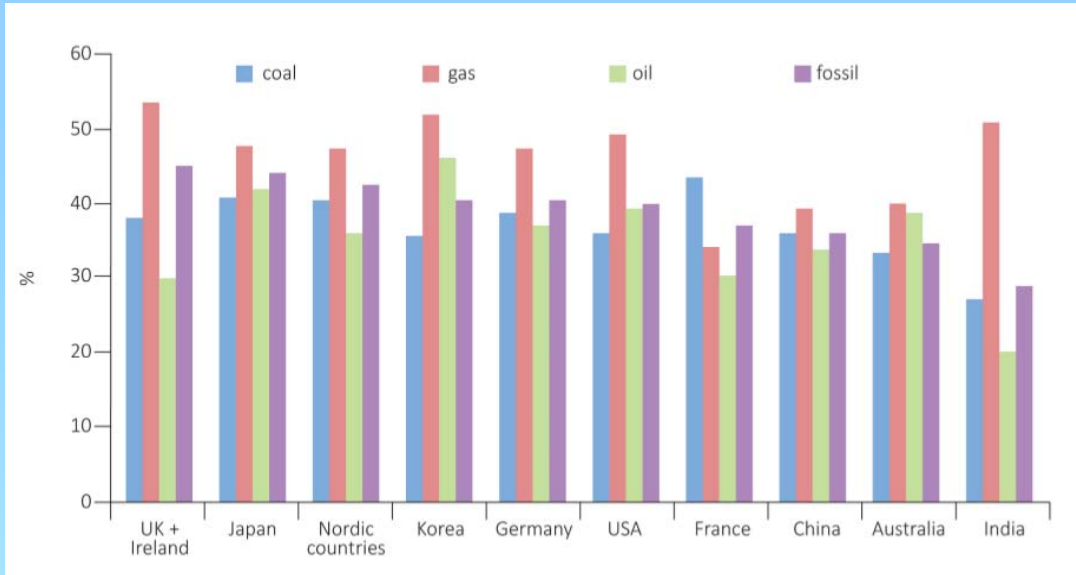
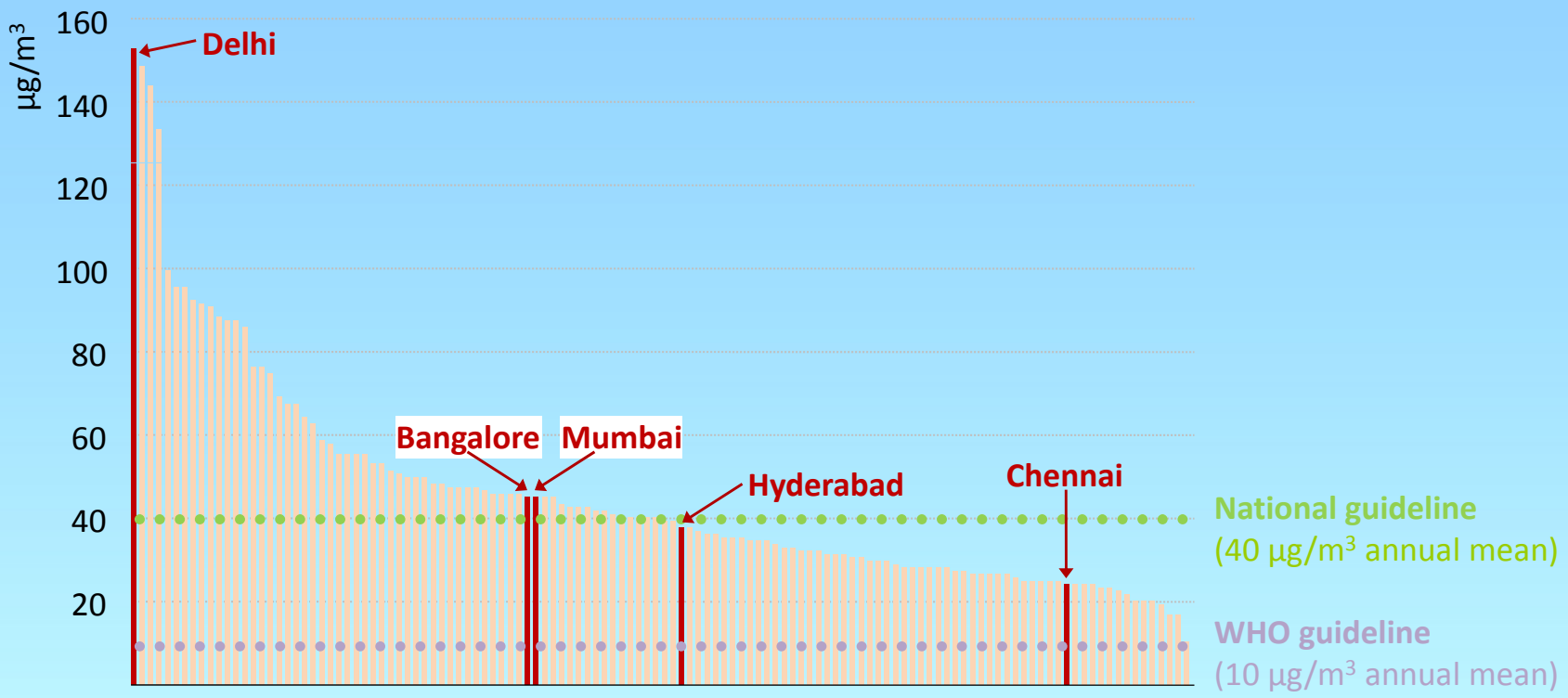


Table 1 Expected benefits in improving a typical 210 MW unit in India (Srivastava, 2010)

Description	Pre R&M	After R&M (target)	% improvement
Turbine heat rate, kcal/kWh	2240	2000	12
Boiler efficiency, %	82-84	85	
Unit heat rate, kcal/kWh	2700	2300-2500	7-14
CO_2 emissions, g/kWh	992	848-918	7-14

A worsening air quality in India's cities

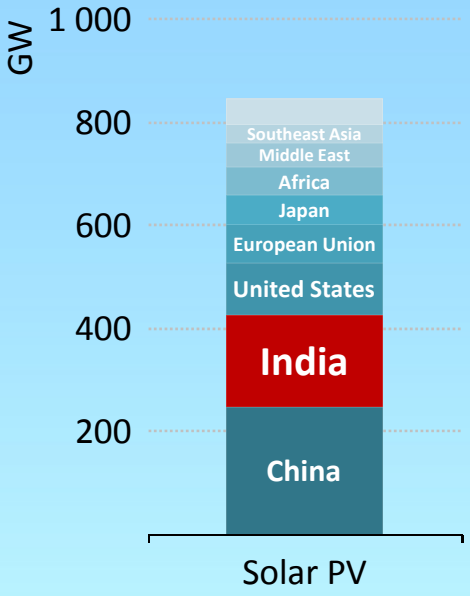
Average annual particulate matter concentration in selected cities in India



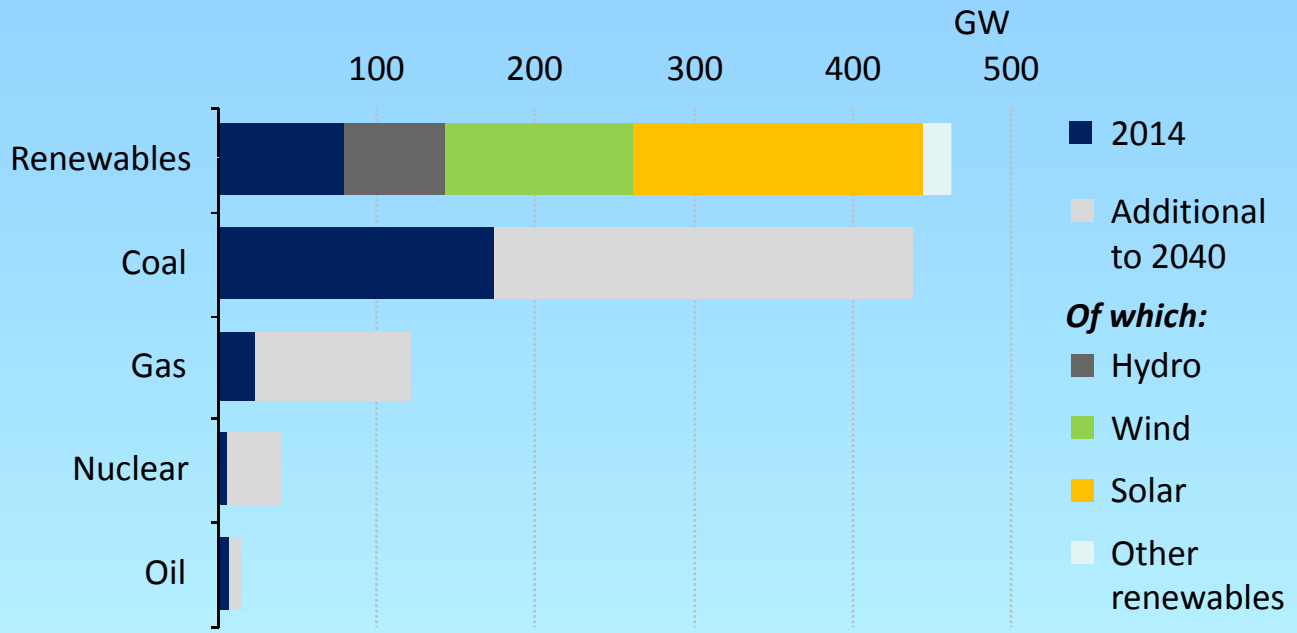
Rising fossil fuel combustion for power, industry & transport has led to low air quality in urban centres; use of solid biomass for cooking is also a major health issue

Renewables chart a new path to power in India

Change in global solar PV capacity 2014-2040



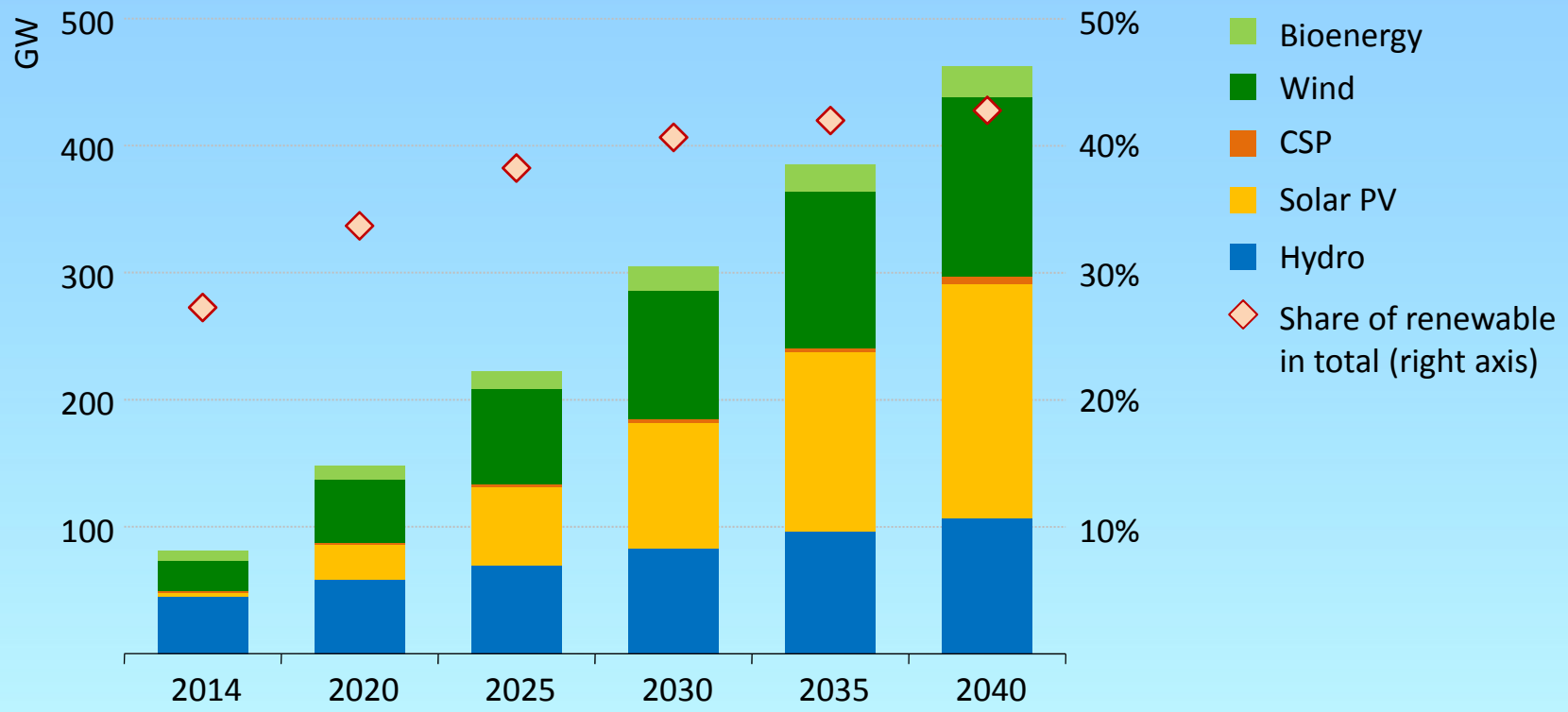
Installed power generation capacity in India by source



Renewables, led by solar and wind power, lead the way in India's power generation capacity additions, increasing the need for a more resilient grid

India: adding renewables for diversification

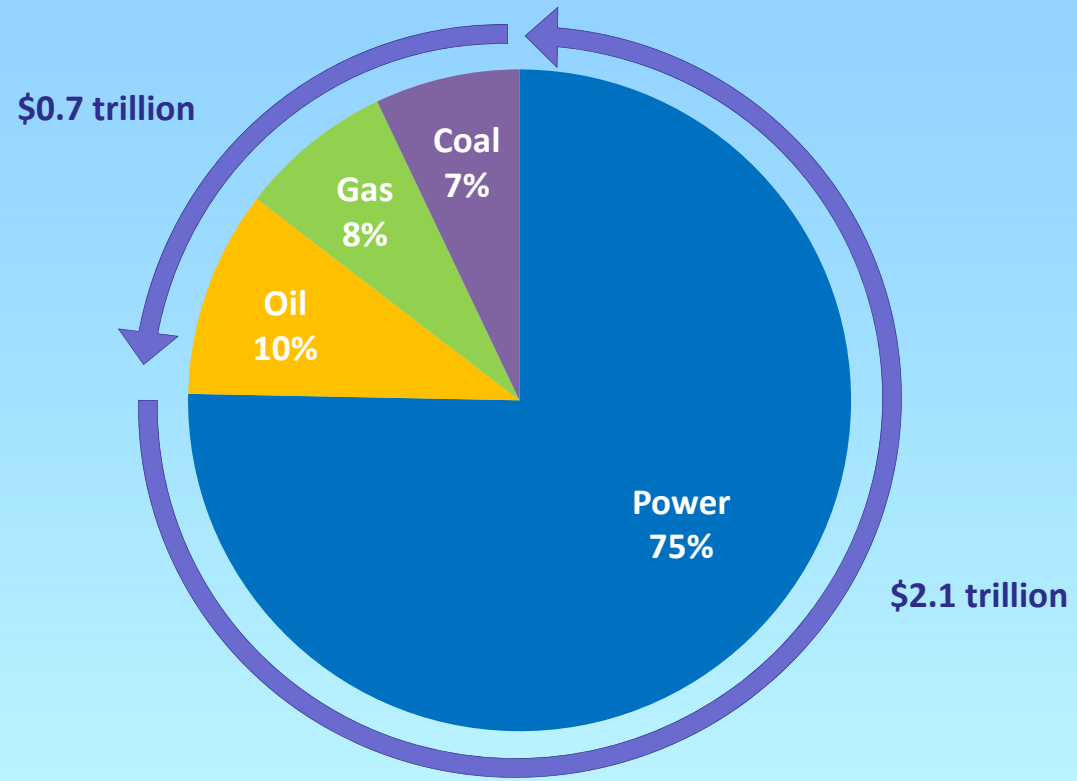
Renewable sources of power generation capacity in India



Renewables account for half of all new power generating capacity, increasing their share from 28% in 2013 to more than 40% by 2040

India: a huge commitment of capital

Cumulative investment in energy supply in India 2015-2040



Mobilising ₹7 lakh crore per year in energy supply investment is a constant challenge for Indian policy & regulation, but encouraging early signs are visible

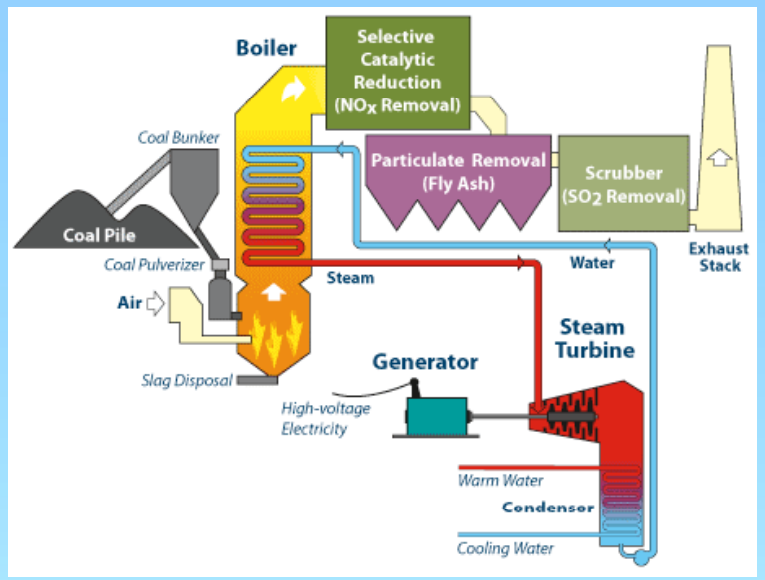
The importance of HELE technologies

High Efficiency, Low Emissions (HELE) technologies:

- Savings of 2.25 Gt carbon dioxide annually if all of the world's coal-fired power plants (with an average reported operating efficiency of 33%) were upgraded or replaced with state-of-the-art HELE units operating at an efficiency of 45%.

- This figure is greater than the current total carbon dioxide emissions of India, and corresponds to approximately 19% of the total annual emissions from the power sector globally

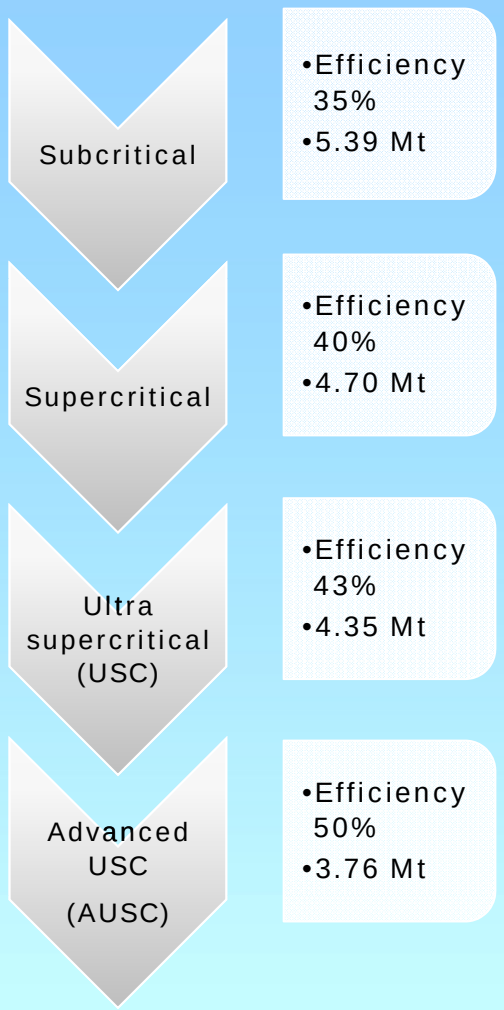
Super-critical boiler

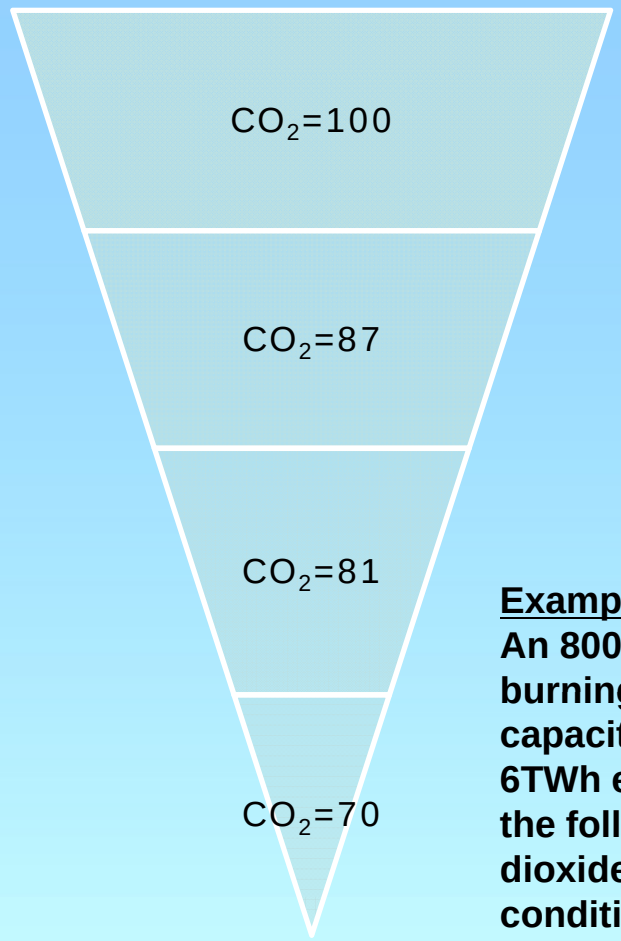


SC, USC and AUSC

	Superheater temperature and pressure	Material in high temperature components	Efficiency, LHV (net), hard coal, %	Coal consumption, gCOAL/kWh
Subcritical	≤540°C and <22.1 MPa	Low alloy CMn and Mo ferretic steels	<35	≥380
SC	540–580°C and 22.1–25 MPa	Low alloy CrMo steels and 9–12% Cr martensitic steel	35–40	380–340
USC	580–620°C and 22–25 MPa	Improved 9–12% Cr martensitic steels and austenitic steels	40–45	340–320
AUSC	700–725°C and 25–35 MPa	Advanced 10–12% Cr steels and nickel alloys	45–52	320–290

Potential carbon dioxide savings from HELE technologies





Example

An 800 MW_e power station boiler burning hard coal and operating at a capacity factor of 80% will generate 6TWh electricity annually and emit the following quantities of carbon dioxide, depending on its steam cycle conditions and corresponding efficiency (HHV).

Ultra-supercritical – Shanghai Waigaoqiao

By the end of 2012, the actual operation performances were:
(1) Annual average load rate: 81%
(2) Annual average net coal consumption (including FGD & SCR): 276 gce/kWh
(3) Annual average net efficiency (including FGD & SCR): 44.5%
(4) If the average net efficiency is converted into design conditions (full load), the net efficiency is : 46.5% (Measured net efficiency in 2013 is 46.7%)
(5) Annual average emissions(2013data):
Dust: 11.63mg/m^3;
SO_2: 17.71mg/m^3;
NOx: 27.25mg/m^3
(6) Self power consumption rate (2013data):2.0%

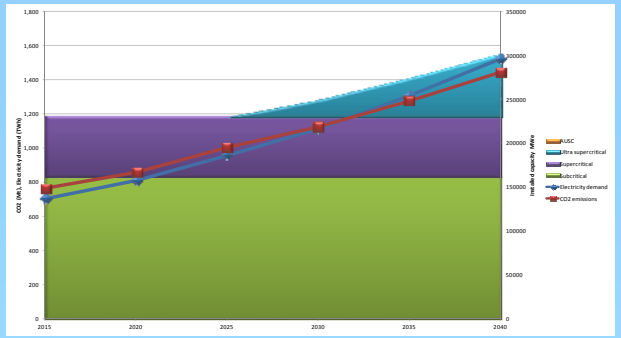
What can be achieved by phasing out subcritical coal power in India and moving to SC, USC, and AUSC?

.... And what are the costs?

HELE upgrade path through phased plant retirement

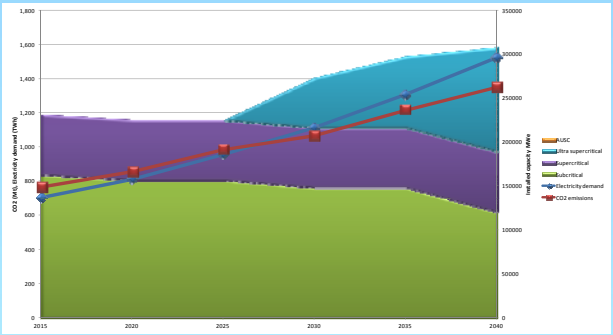
Base Case

Existing coal fleet with additional USC to meet demand (if required)



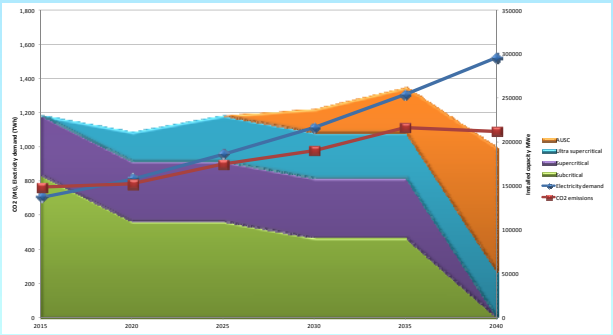
50 year retirement scenario

Review in 2020, 2030 and 2040. Retire capacity over 50 years old and replace with USC

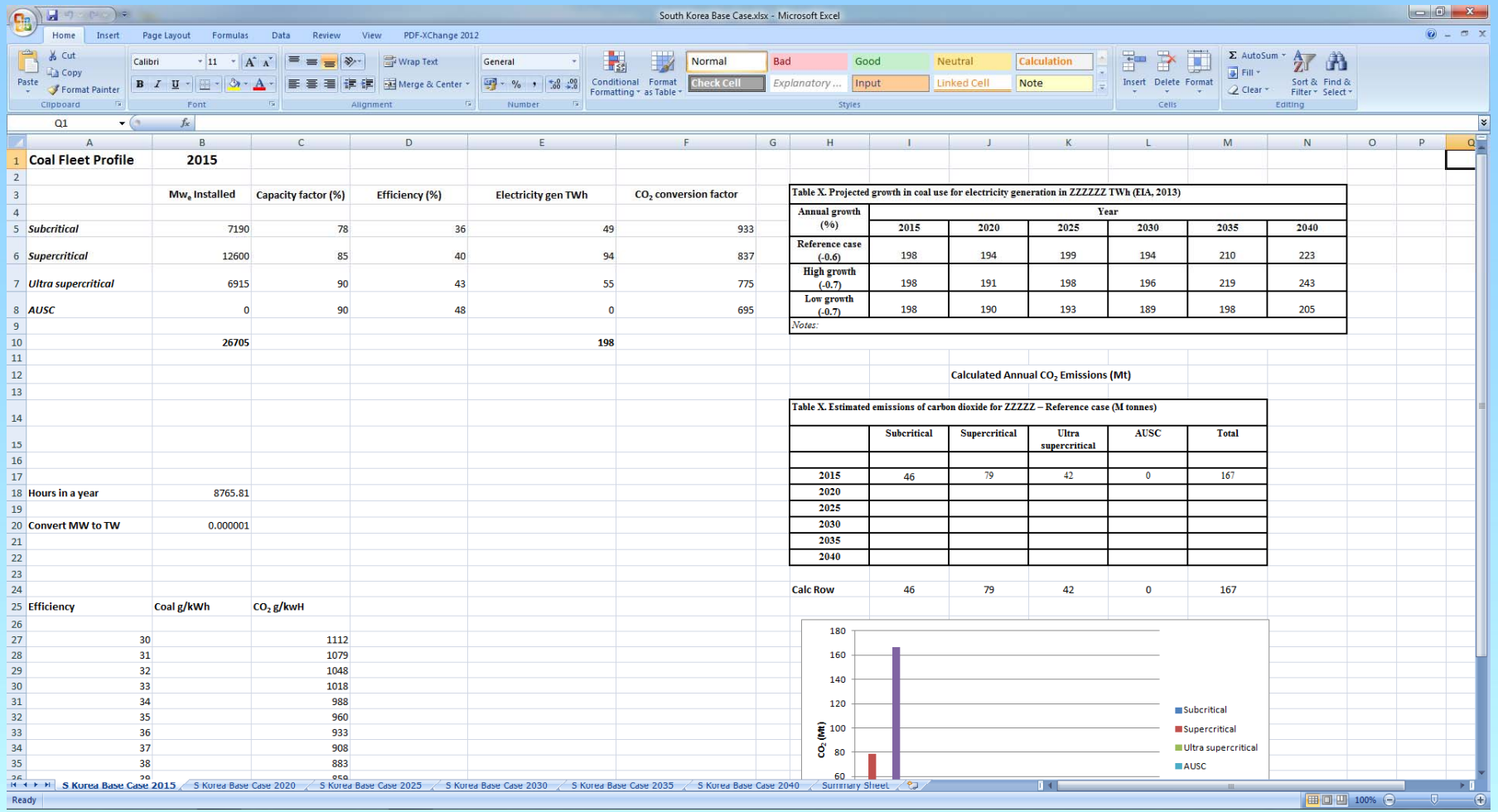


25 year retirement scenario

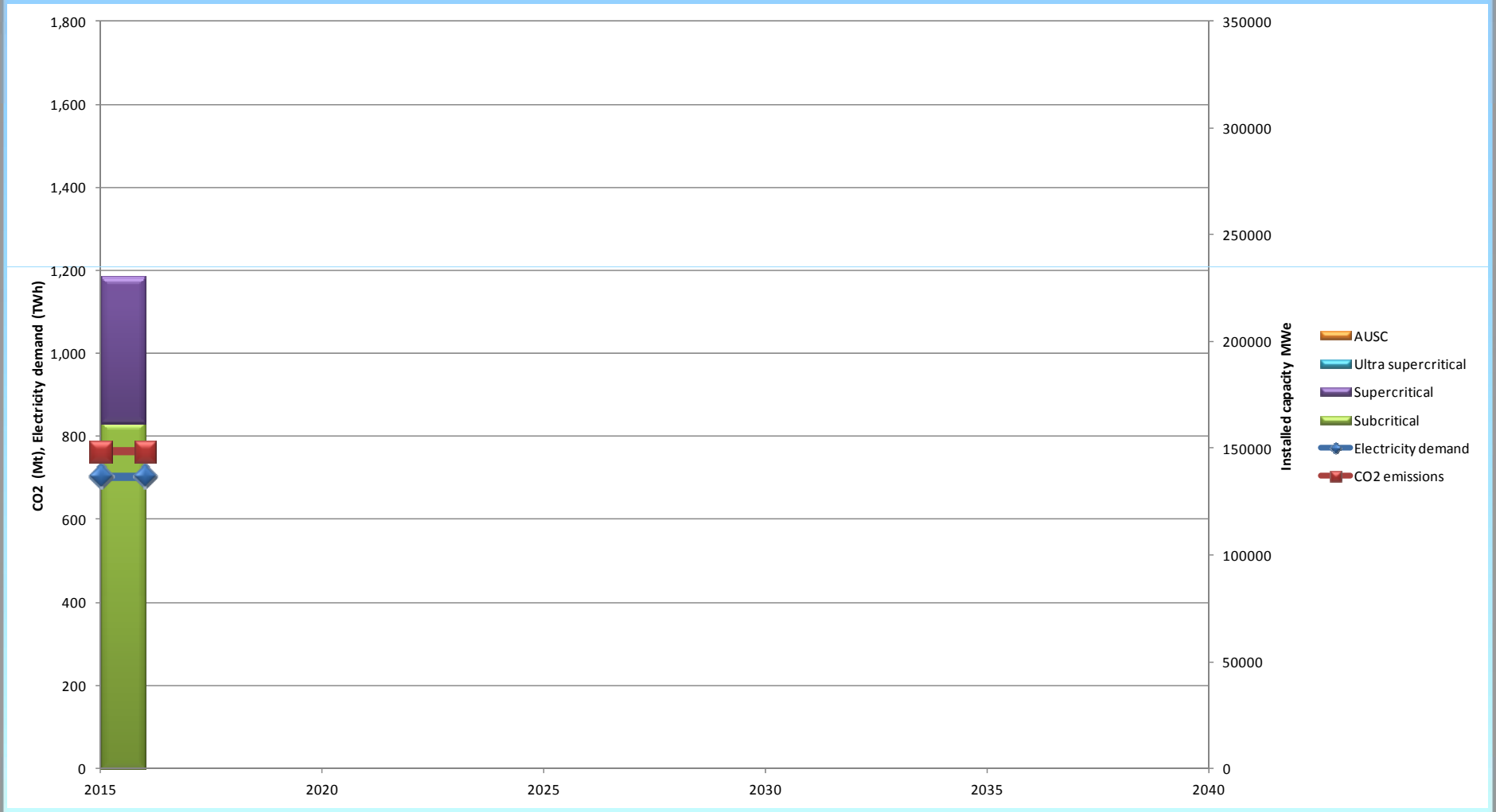
Review in 2020, 2030 and 2040. Retire capacity over 25 years old and replace with USC in 2020, AUSC in 2030 and 2040



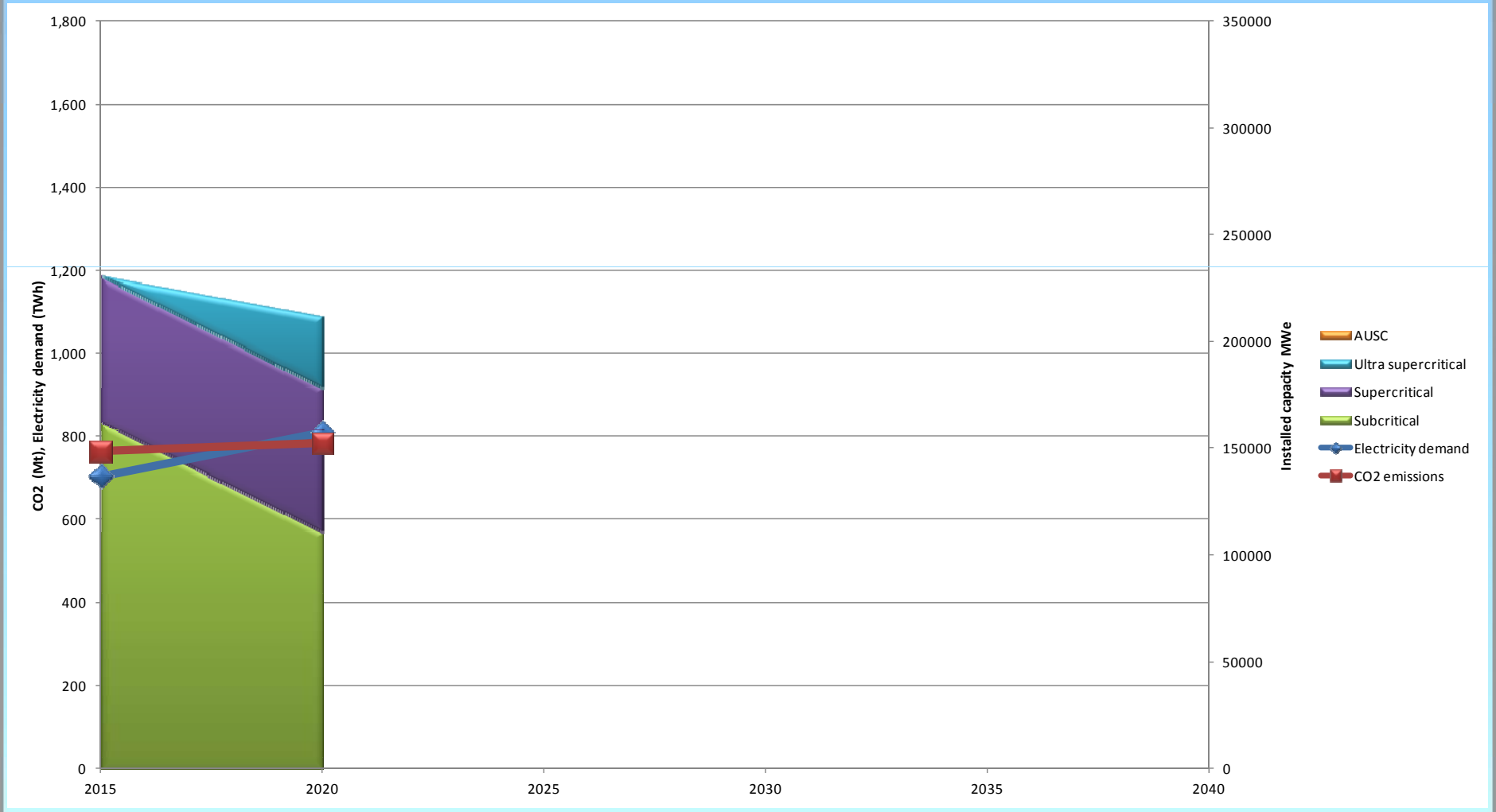
Spreadsheet modelling



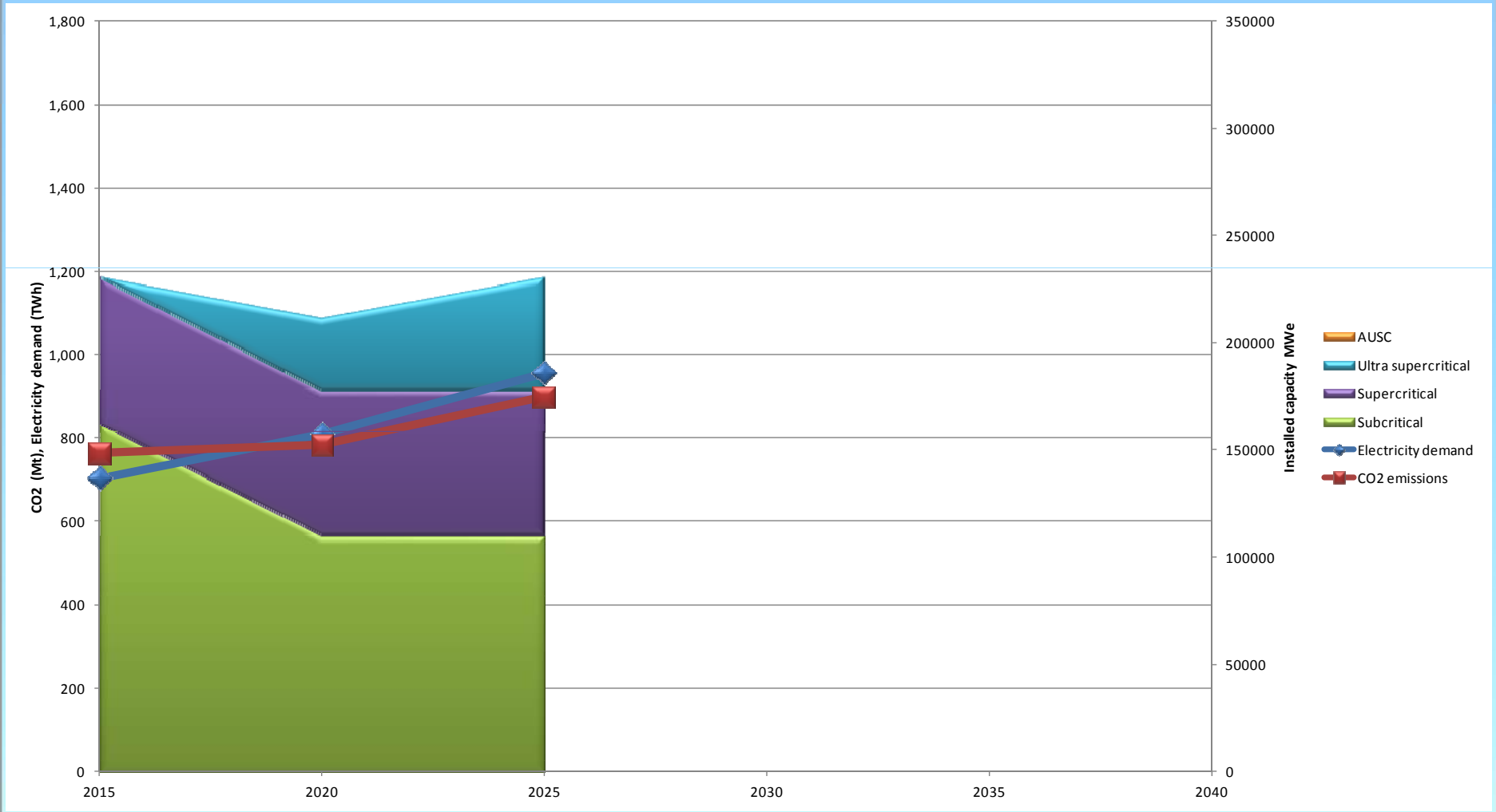
India – 25 year retirement scenario, 2015 - 2040



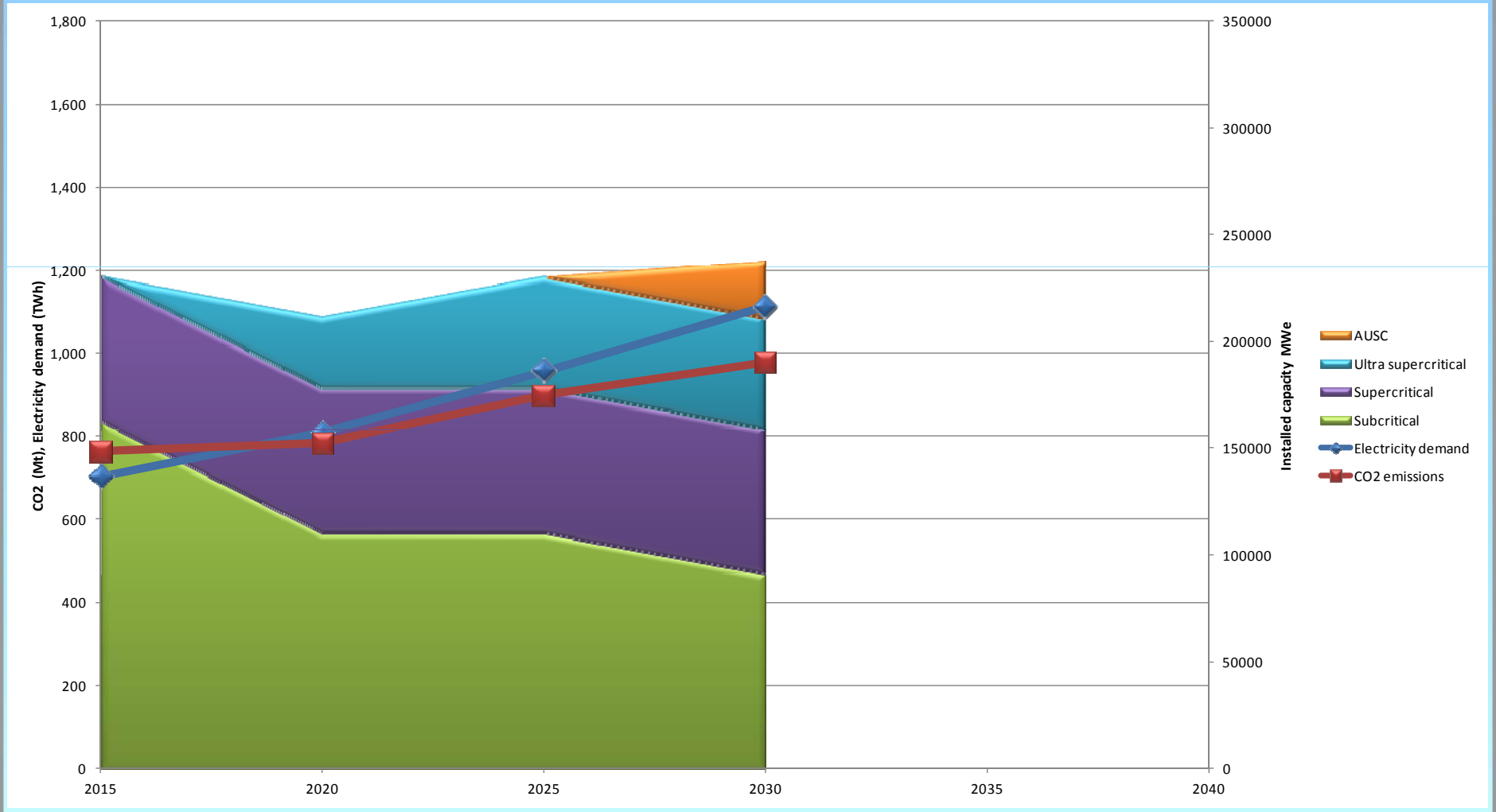
India – 25 year retirement scenario, 2015 - 2040



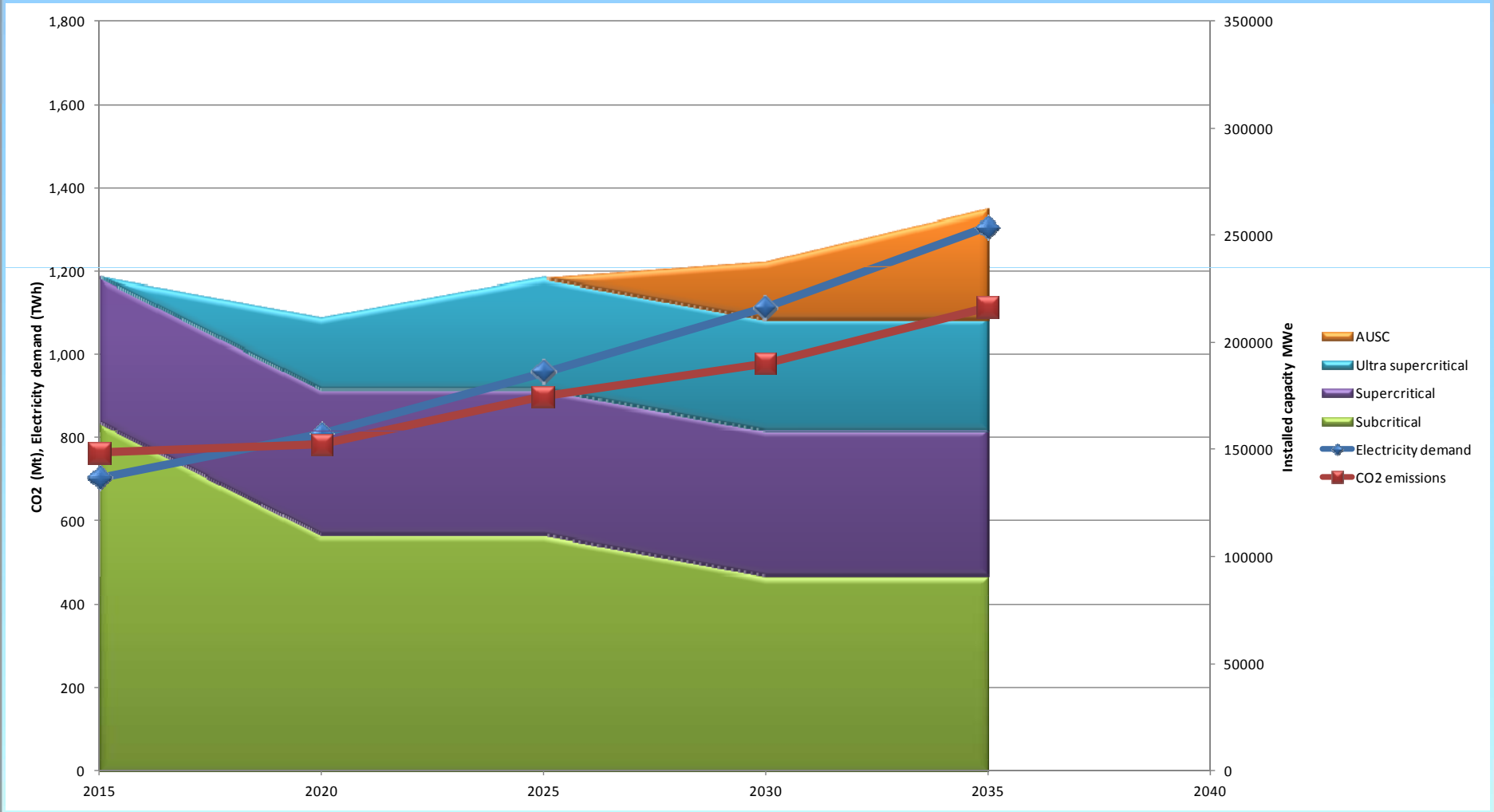
India – 25 year retirement scenario, 2015 - 2040



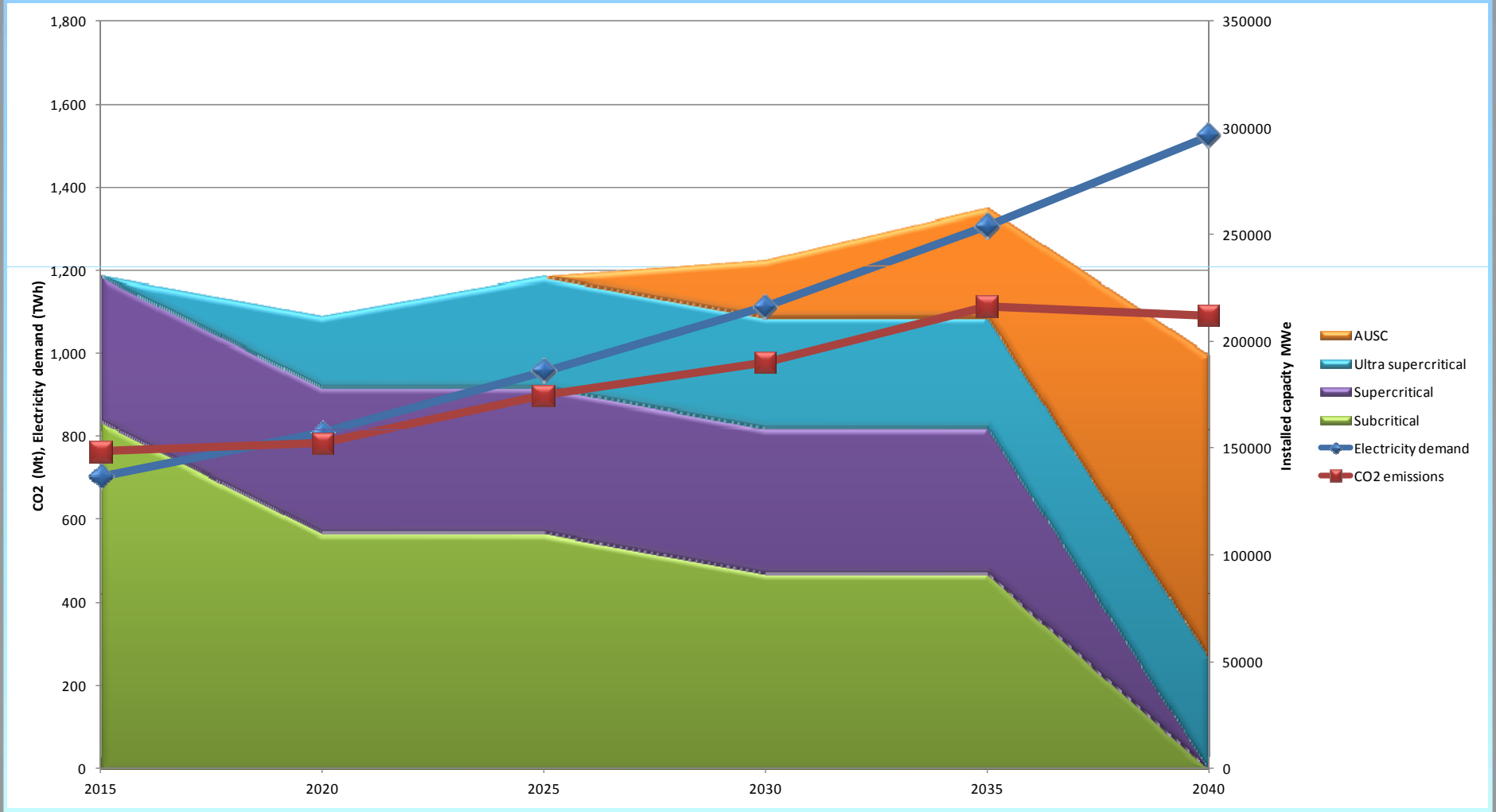
India – 25 year retirement scenario, 2015 - 2040



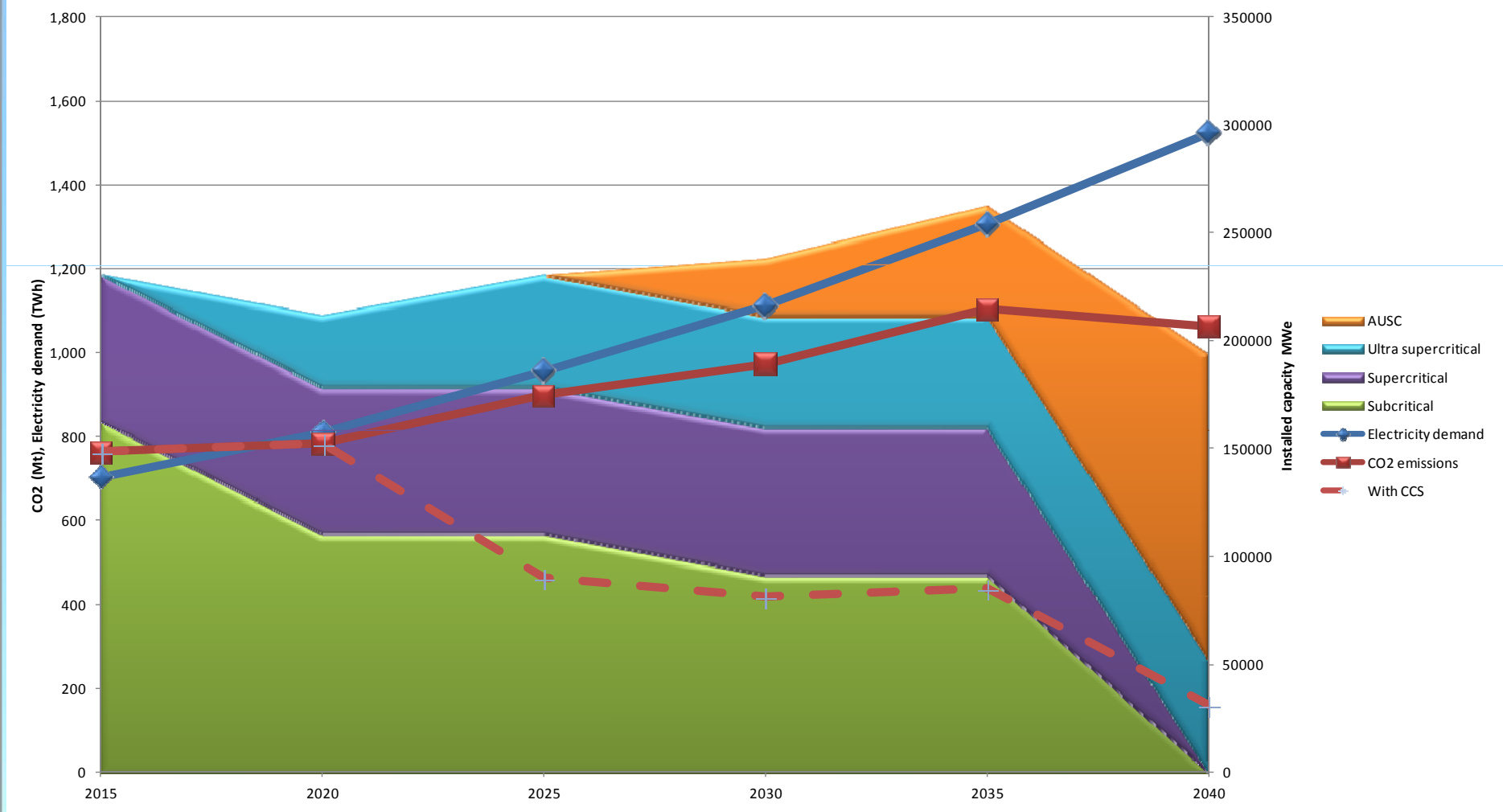
India – 25 year retirement scenario, 2015 - 2040



India – 25 year retirement scenario, 2015 - 2040



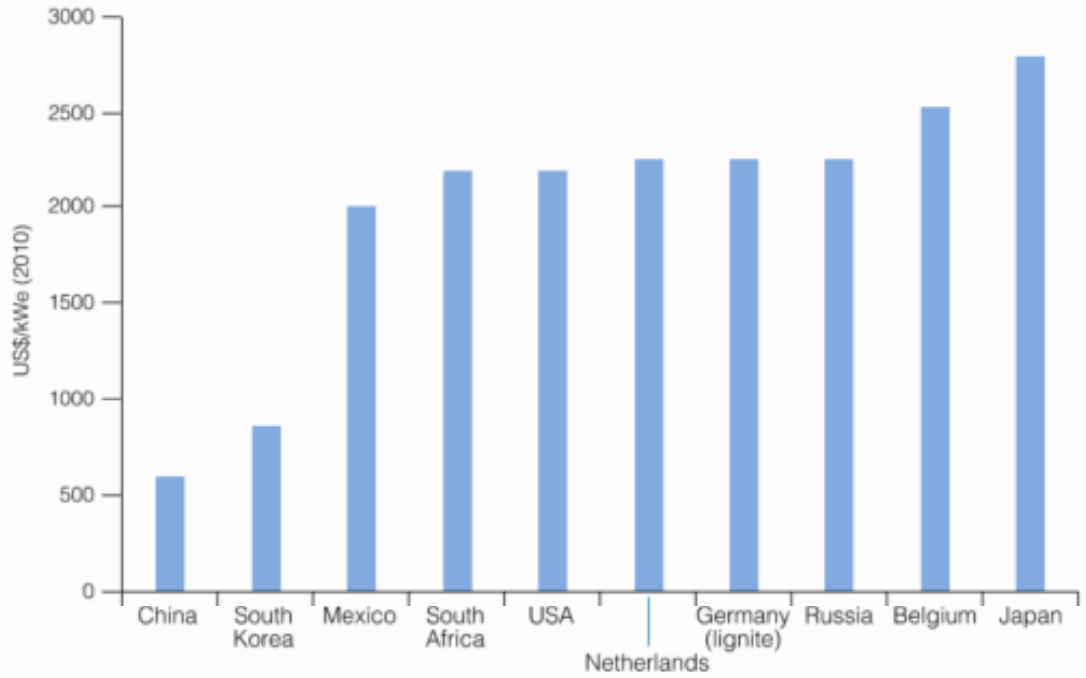
India – 25 year retirement scenario, 2015 – 2040
CCS emissions trend line (85% capture)



Key message for India

India has the fastest growing coal fleet after China. If HELE technology is implemented, significant savings can be made, but current policies on technology may not go far enough

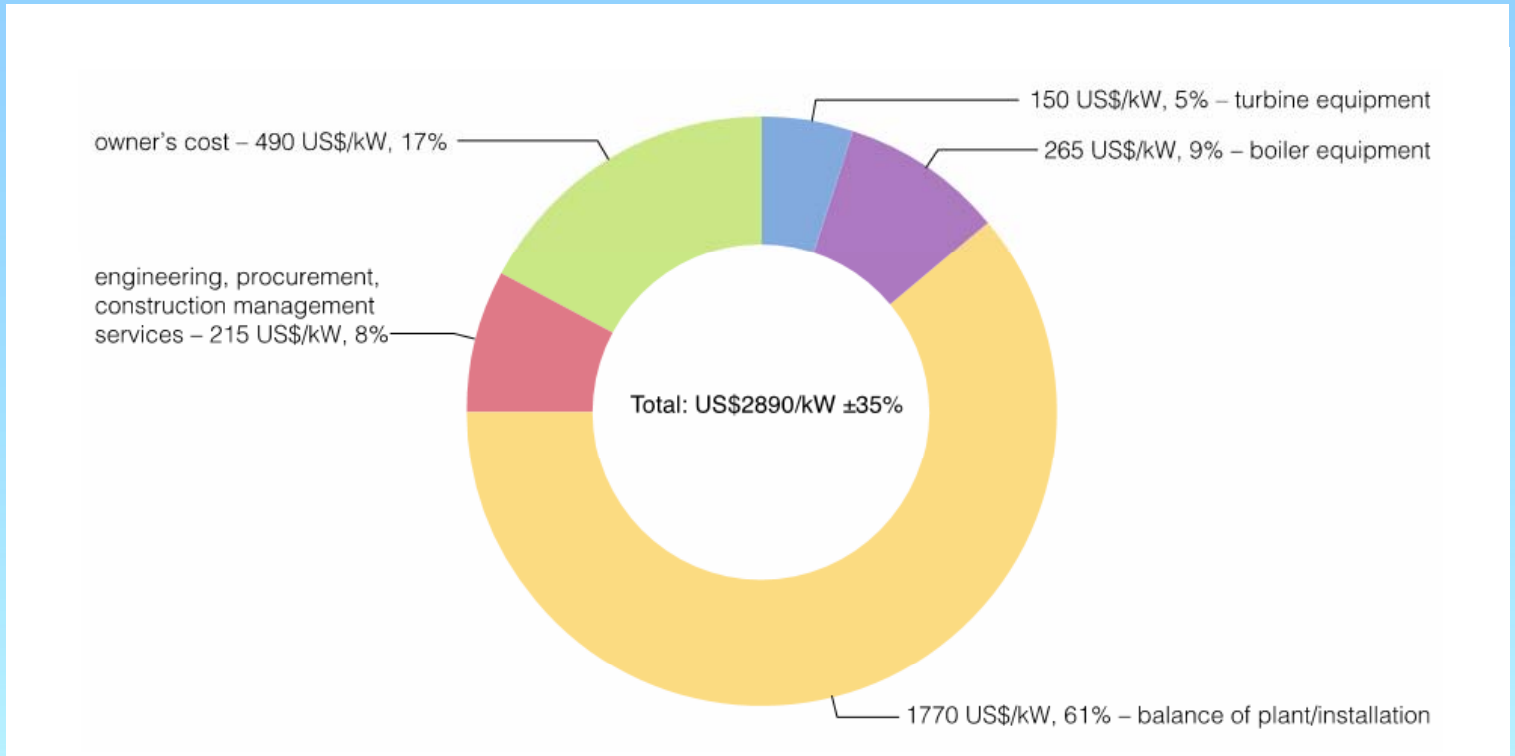
Overnight capex for new USC plants



Updated estimates for coal power plant capital and operating costs

	Plant characteristics			Plant costs (2012$)		
	Nominal capacity (MW)	Heat rate (Btu/kWh)		Overnight capital cost ($/kW)	Fixed O&M cost ($/kW-y)	Variable O&M cost ($/MWh)
Single unit advanced PC	650	8800		3246	37.80	4.47
Dual unit advanced PC	1300	8800		2934	31.18	4.47
Single unit advanced PC with CCS	650	12000		5227	80.53	9.51
Dual unit advanced PC with CCS	1300	12000		4724	66.43	9.51
Single unit IGCC	600	8700		4400	62.25	7.22
Dual unit IGCC	1200	8700		3784	51.39	7.22
Single unit IGCC with CCS	520	10700		6599	72.83	8.45

Capital cost breakdown for the construction of a 606 MWe pulverised coal fired plant 2010 data



Estimated costs of HELE capacity upgrades with and without CCS (2040 cumulative)

Country	HELE plant added to base case scenario (MWe)	Costs of added HELE plant without CCS (base case, US$ billion)	Costs of added HELE plant with CCS (base case, US$ billion)	HELE plant added in 50-year retirement scenario (MWe)	Costs of added HELE plant to 50-year retirement case without CCS (US$ billion)	Costs of added HELE plant to 50-year retirement case with CCS (US$ billion)	Additional capacity required from CCS derate to 50-year retirement scenario coal fleet (MWe)	Costs of additional capacity US$ billion
Australia	0	0.0	0.0	12500	36.7	59.1	3125	14.8
China	307347	901.8	1451.9	432347	1268.5	2042.4	108087	510.6
Germany	0	0.0	0.0	9171	26.9	43.3	2293	10.8
India	72000	211.2	340.1	119600	350.9	565.0	29900	141.2
Japan	0	0.0	0.0	4100	12.0	19.4	1025	4.8
Poland	0	0.0	0.0	15800	46.4	74.6	3950	18.7
Russia	3100	9.1	14.6	26900	78.9	127.1	6725	31.8
South Africa	20700	60.7	97.8	44500	130.6	210.2	11125	52.6
South Korea	3585	10.5	16.9	6785	19.9	32.1	1696	8.0
USA	0	0.0	0.0	246178	722.3	1162.9	61545	290.7
Base costs (US$/kW)								
Units without CCS	2934							
Units with CCS	4724							

Derate of 25% from CCS

Assume additional derate is also fitted with CCS

Pursuing a sustainable model for growth in India – IEA WEO comments

- **A continued focus on efficiency, low-carbon energy & high standards of pollution controls is vital to improve air quality**
- **India is among the most vulnerable countries to the impact of a changing climate, e.g. by exacerbating water stresses**
- **Increased energy use pushes up Indian CO_2 emissions, although per capita emissions remain 20% below world average in 2040**
- **Opening up new, long-term, low-cost financing options critical to direct investment towards cleaner, more capital-intensive projects**

Comments on India

- Will have to fastest growing coal fleet from 2020 onwards, with coal-sources electricity demand more than doubling by 2040
- Current fleet is mostly sub-critical but some SC plants are being built and this should increase in future – 13th 5-year plan may require all new plants to be at least SC
- USC and AUSC plants could allow CO_2 emissions to peak and decline by 2040
- High ash coals pose a challenge and warrant deeper analysis – water availability is also an issue

Conclusions

- India is growing and cleaning its new power
- A greater commitment to HELE technologies may be needed sooner to achieve significant results
- This will require significant investment