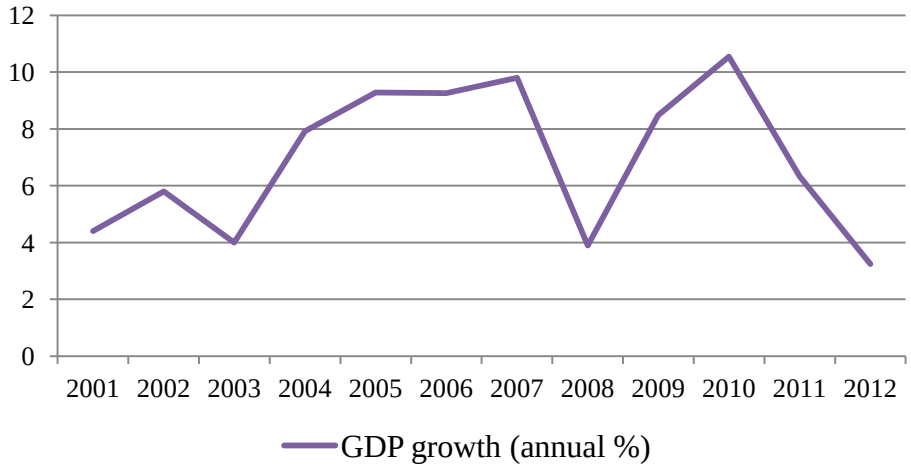
Climate Change: Implications from Macroeconomic Models for India
April 14, 2014

Macro Workstream

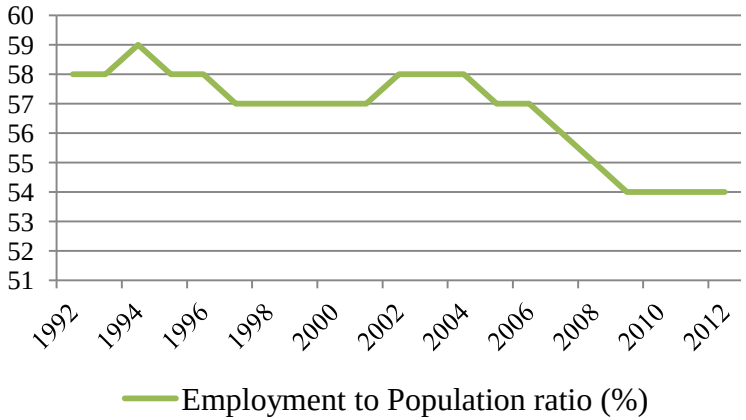
ICRIER, April 14th, 2014

Macroeconomic Indicators

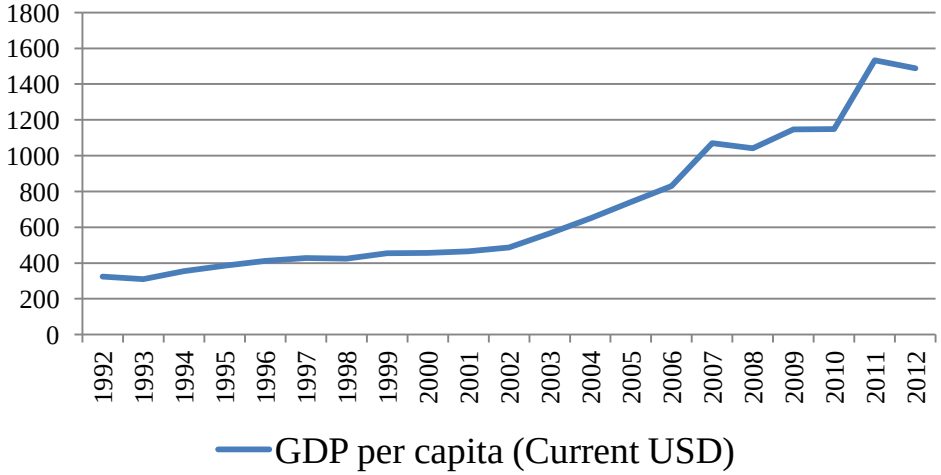
GDP growth (annual %)



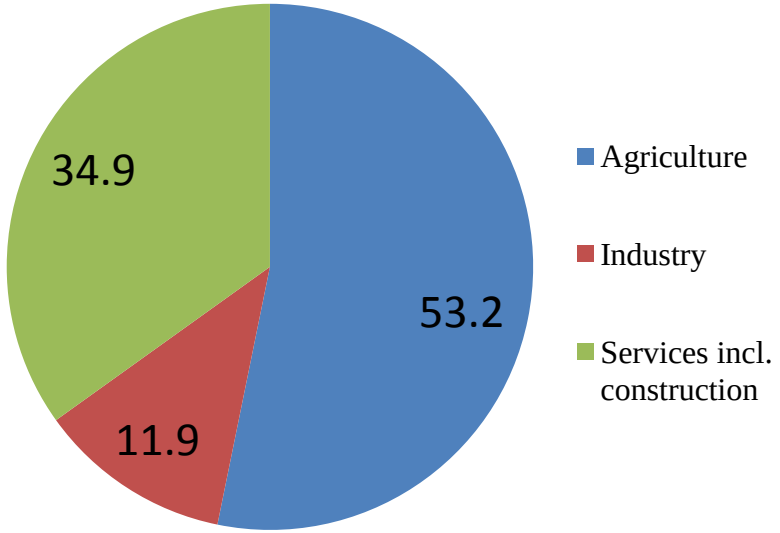
Employment to Population ratio (%)



GDP per capita (Current USD)



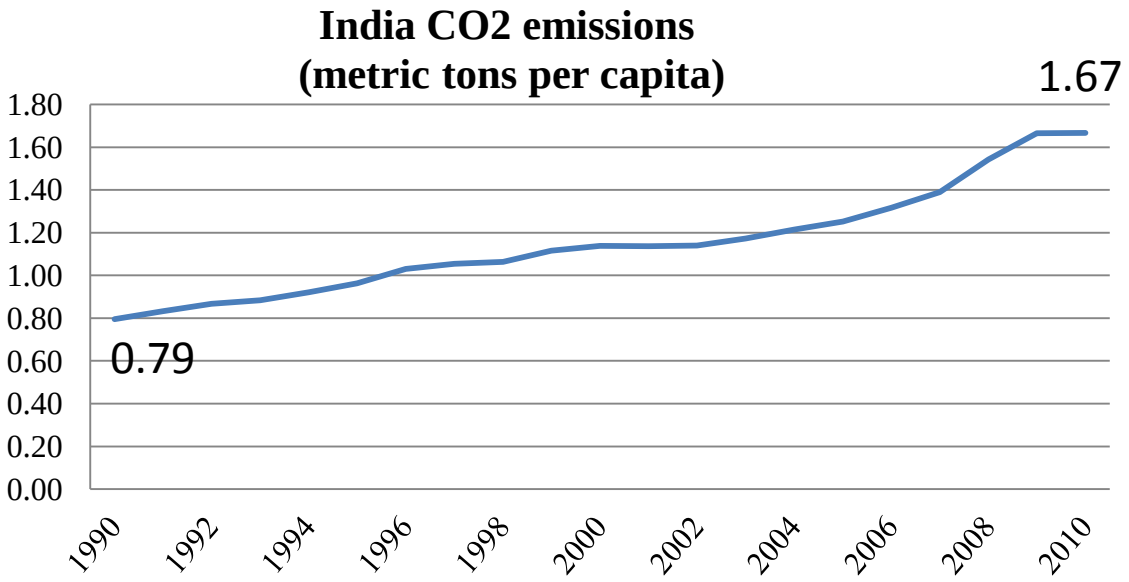
Share in Employment (%)

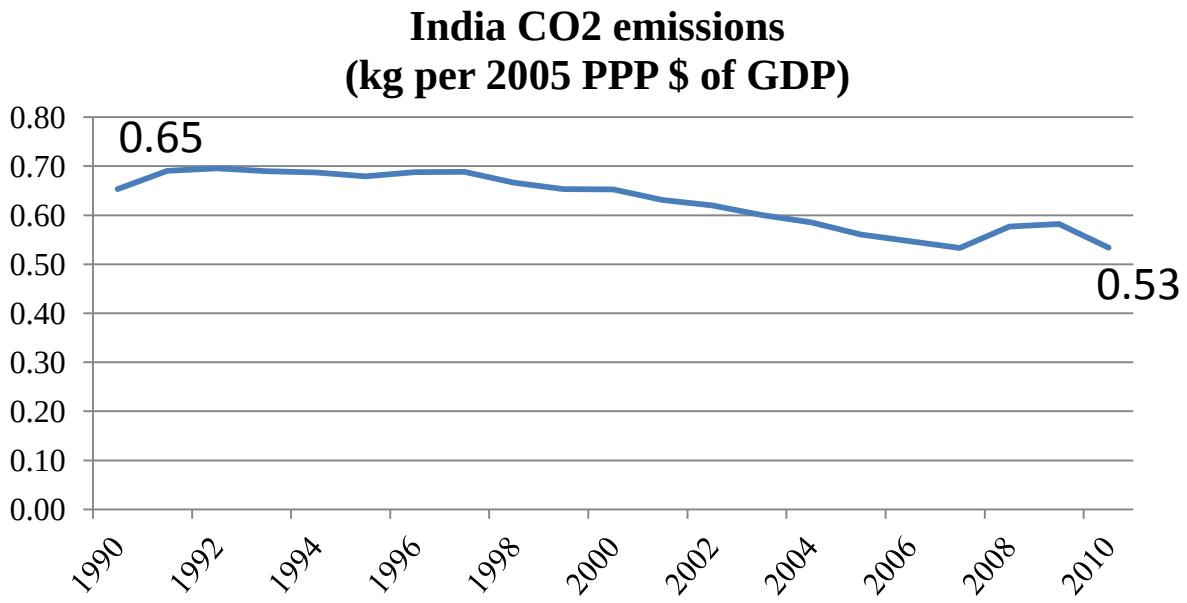


Economic Growth, Sustainability and Climate Change

- ***Current paradigm*** - sustaining economic growth and promoting inclusiveness
- ***Commitment:*** voluntary mitigation goal of reducing the emissions intensity of its Gross Domestic Product (GDP) by 20–25 per cent, over 2005 levels, by 2020
- Assessment of Macro models , incorporating climate change

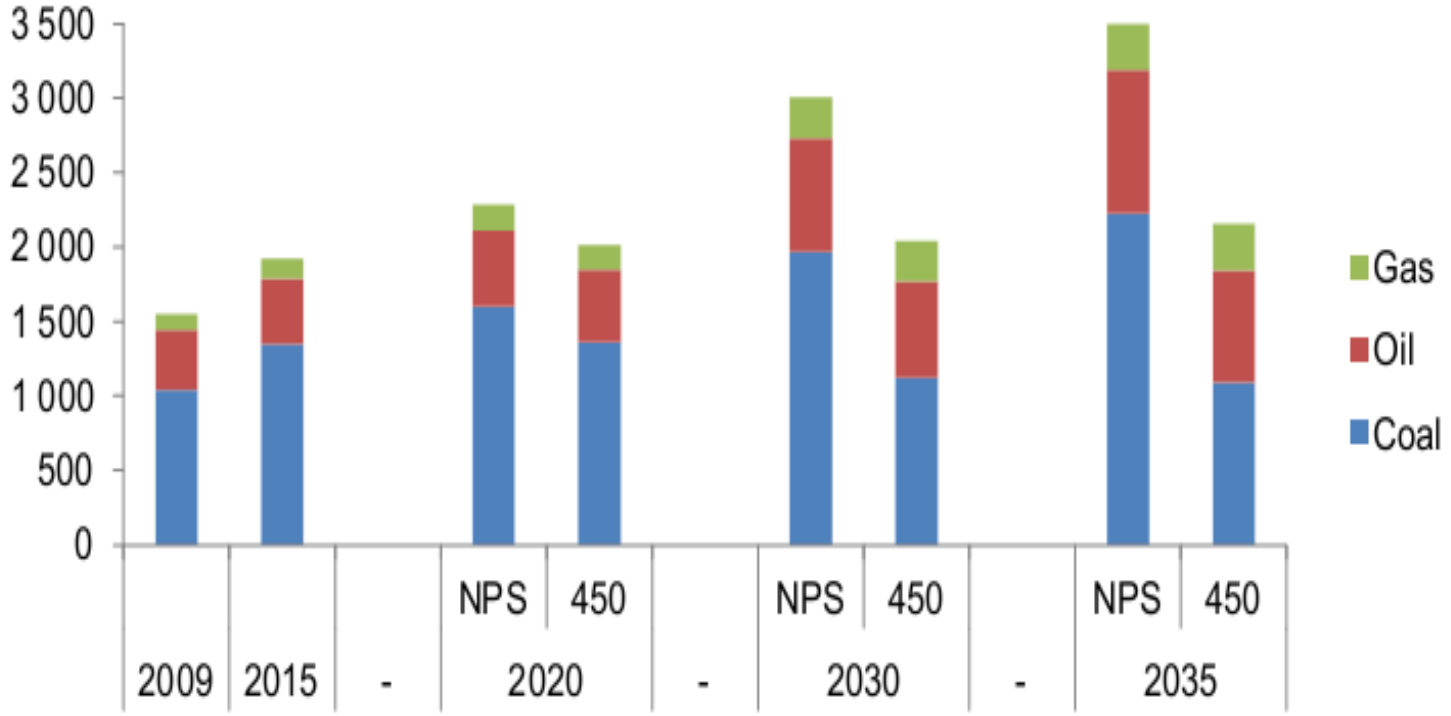
Emission Indicators





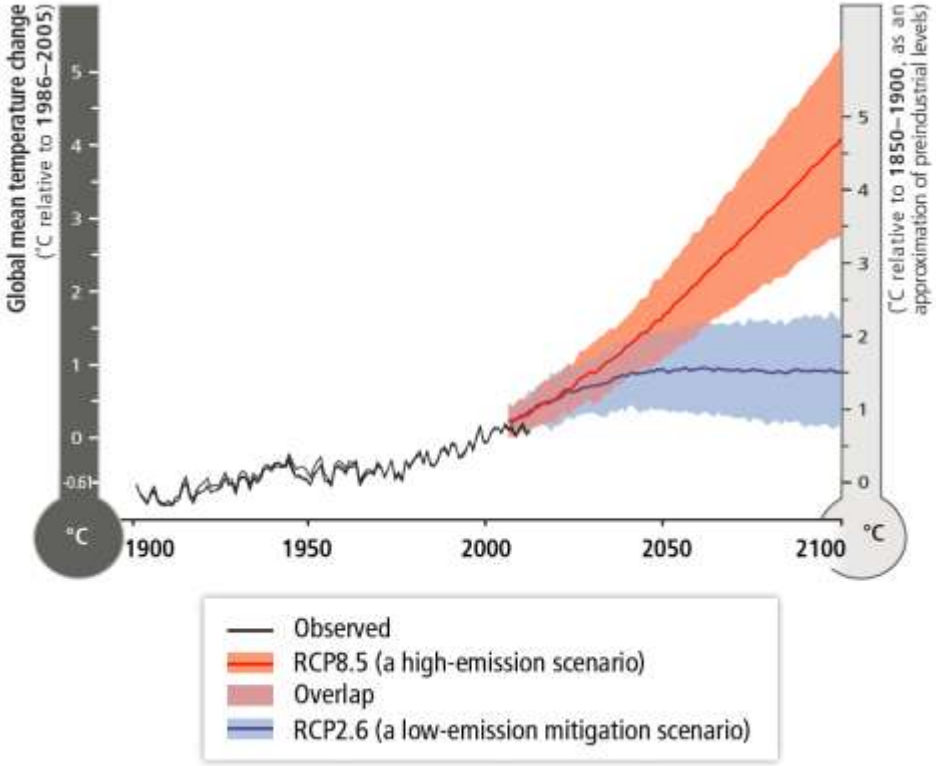
Carbon emissions in India 1990-2035 (MtCO2)

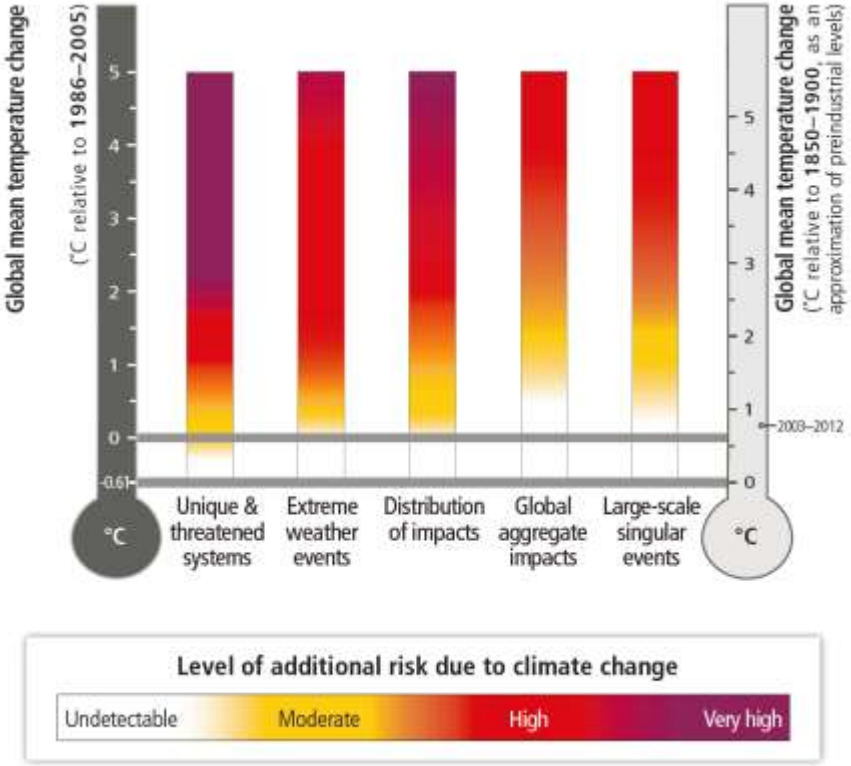
Figure 8 • Carbon emissions in India, 1990-2035 ($MtCO_2$)

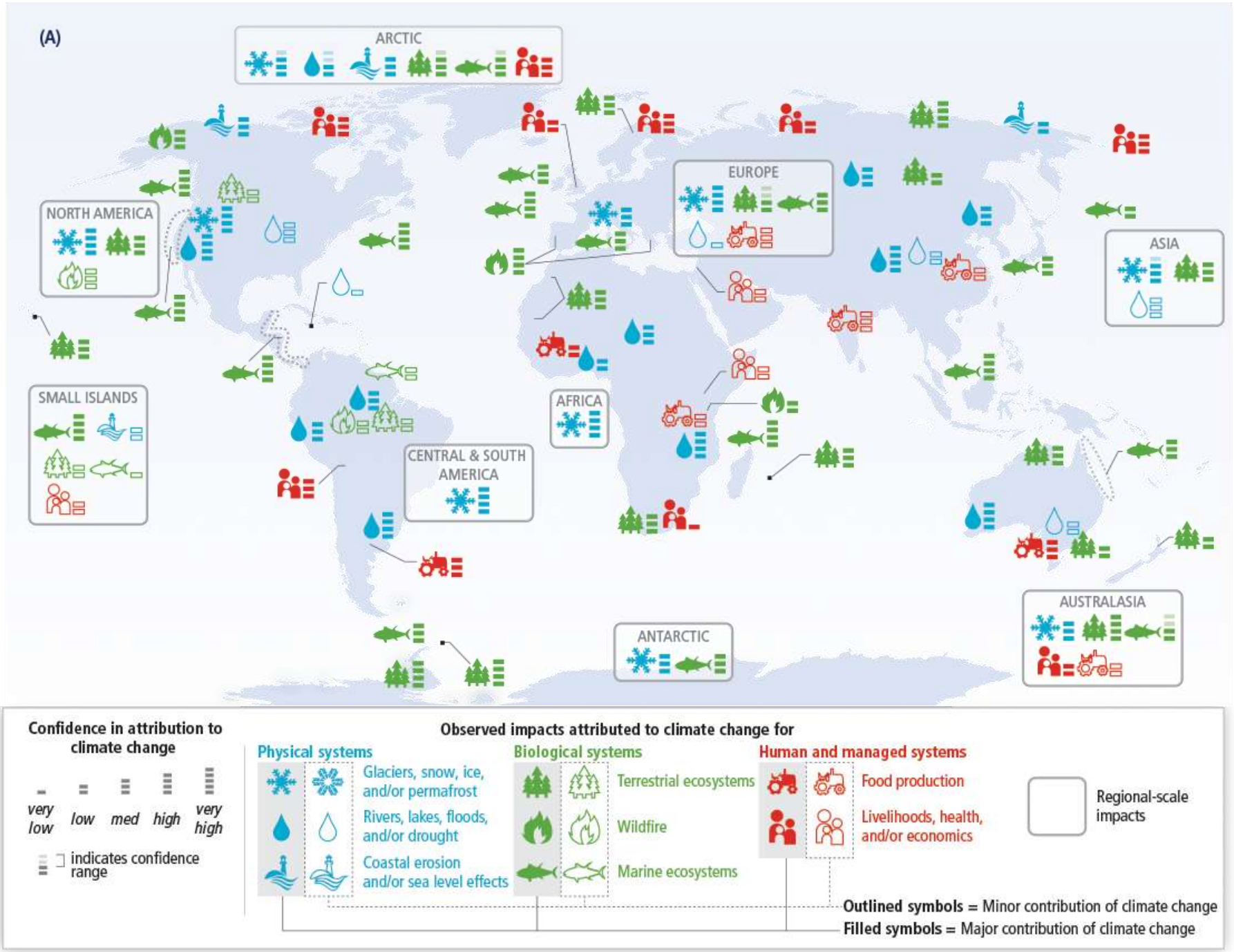


Source: IEA, 2011a.

Source: Understanding Energy Challenges in India Policy, Players and Issues. OECD/IEA, 2012

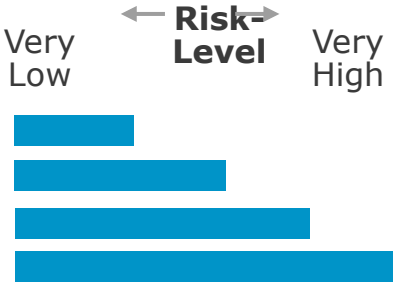

Global mean temperature change
(°C relative to 1986–2005)
°C
1900
1950
2000
2050
2100
(°C relative to 1850–1900, as an approximation of preindustrial levels)
Observed
RCP8.5 (a high-emission scenario)
Overlap
RCP2.6 (a low-emission mitigation scenario)


Global mean temperature change
(°C relative to 1986–2005)
2003–2012
Unique & threatened systems
Extreme weather events
Distribution of impacts
Global aggregate impacts
Large-scale singular events
Level of additional risk due to climate change
Undetectable
Moderate
High
Very high

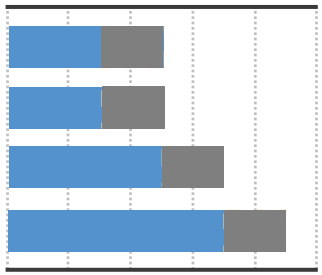

(A)
ARCTIC
NORTH AMERICA
EUROPE
ASIA
SMALL ISLANDS
AFRICA
CENTRAL & SOUTH AMERICA
AUSTRALASIA
ANTARCTIC
Confidence in attribution to climate change
very low
low
med
high
very high
indicates confidence range
Observed impacts attributed to climate change for
Physical systems
Glaciers, snow, ice, and/or permafrost
Rivers, lakes, floods, and/or drought
Coastal erosion and/or sea level effects
Biological systems
Terrestrial ecosystems
Wildfire
Marine ecosystems
Human and managed systems
Food production
Livelihoods, health, and/or economics
Regional-scale impacts
Outlined symbols = Minor contribution of climate change
Filled symbols = Major contribution of climate change

Projected Risks for Asia

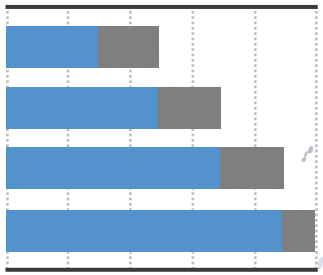
Present
Near Term (2030-2040
Long Term (2080-2100) **2°C** **4°C**



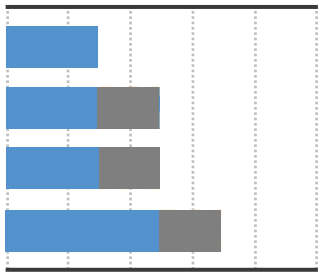
Increased Flood Damage to Infrastructure , Livelihoods, and Settlements



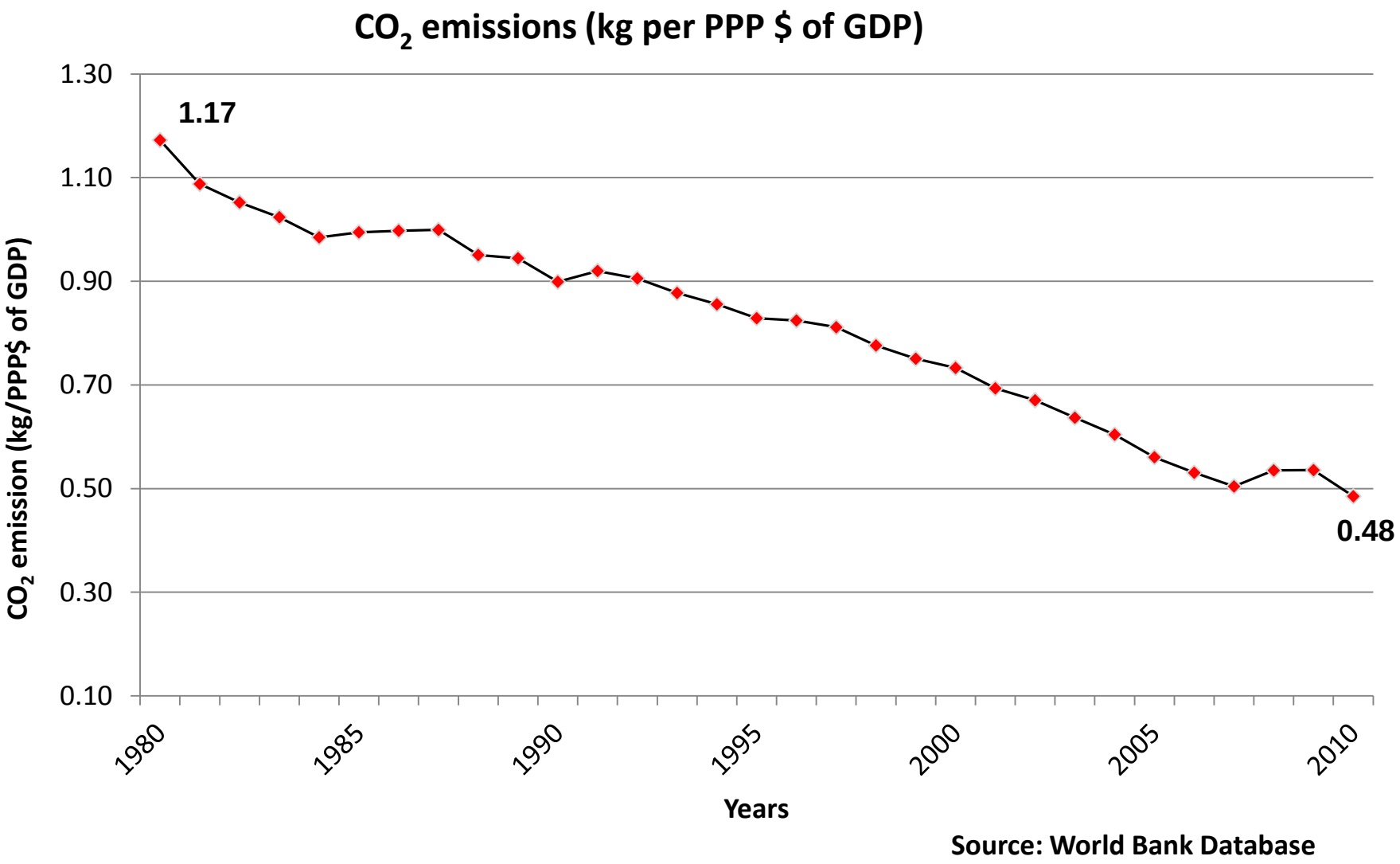
Heat-Related Human Mortality



Increased Drought-Related Water and Food Shortage



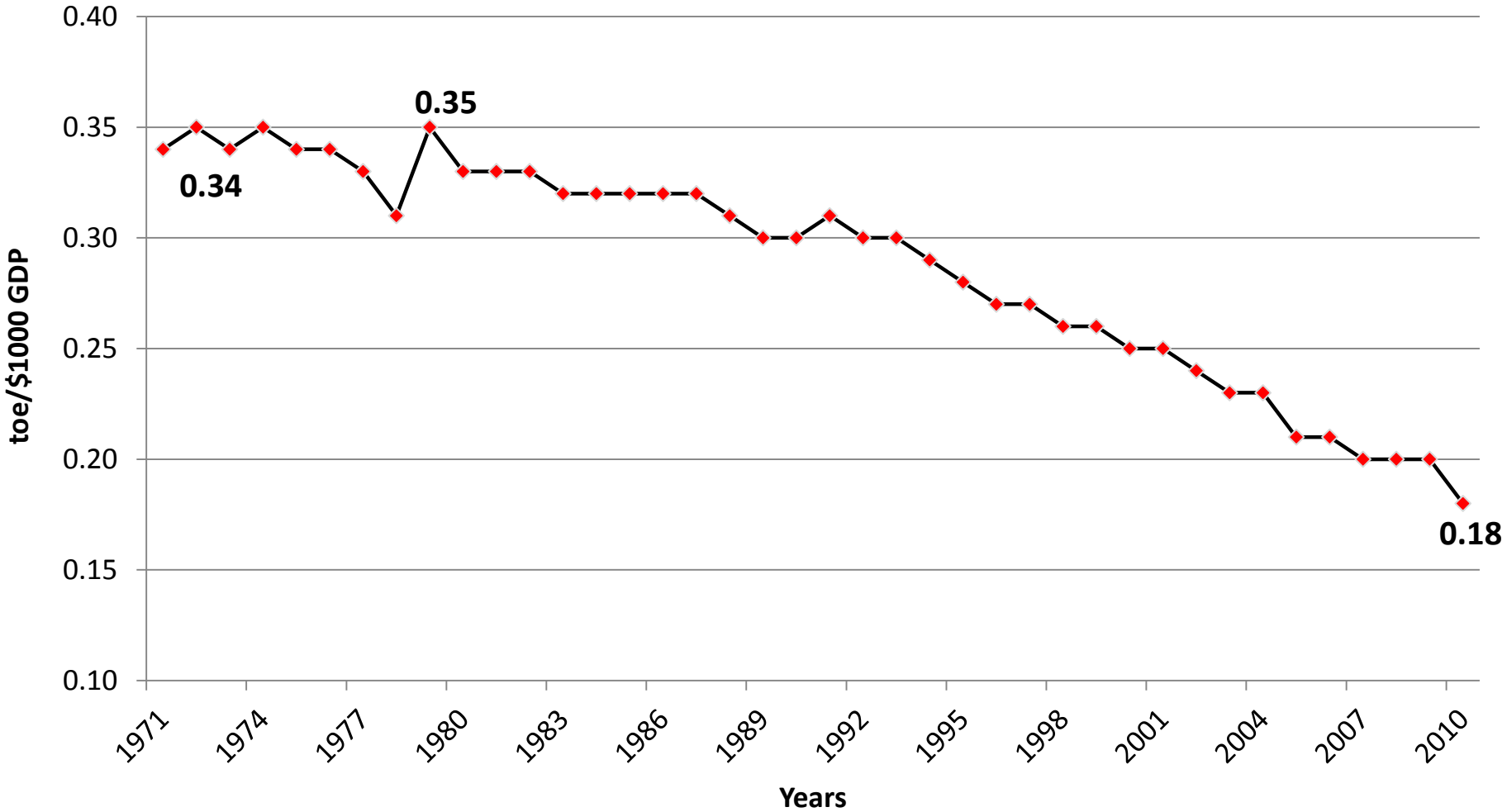
India's Carbon Intensity (1980 – 2010)



Source: World Bank Database

India's Energy Intensity (1971 – 2010)

Tonnes of oil equivalent (toe) per thousand 2000 US dollars of GDP calculated using PPPs

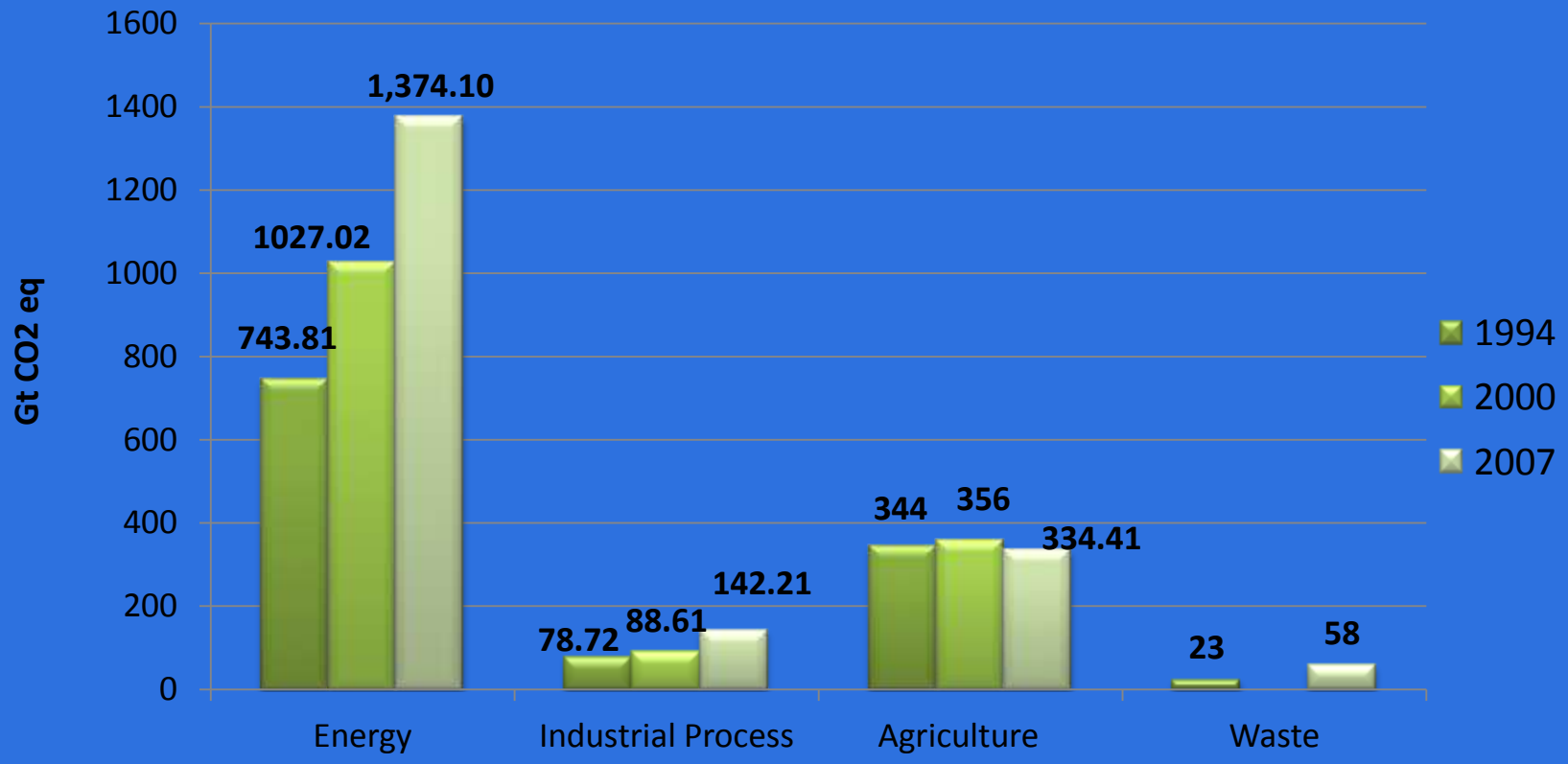


The ratios are calculated by dividing each country's annual TPES by each country's annual GDP expressed in constant 2000 prices and converted to US dollars using purchasing power parities (PPPs) for the year 2000.

Source: OECD database; available through OECD's iLibrary

India's Sectoral GHG Emission (1994, 2000 and 2007)

- **1994 - India's Ist National communication to UNFCC on GHG Emission**
- **2000 - India's 2nd National communication to UNFCC on GHG Emission**
- **2007 - INCCA* Prepared an inventory of GHG emission for the year2007**



Source: India's Second National Communication to UNFCC, 2012

***India : Greenhouse Gas Emission 2007, INCCA Indian Network for Climate Change Assessment, 2007**

Economic Growth, Sustainability and Climate Change

What are the emerging pathways ?

With a special focus on:

Synergies (co-benefits, low regret strategies)

trade-offs (GDP, emission constraints, poverty)

Coverage of available studies:

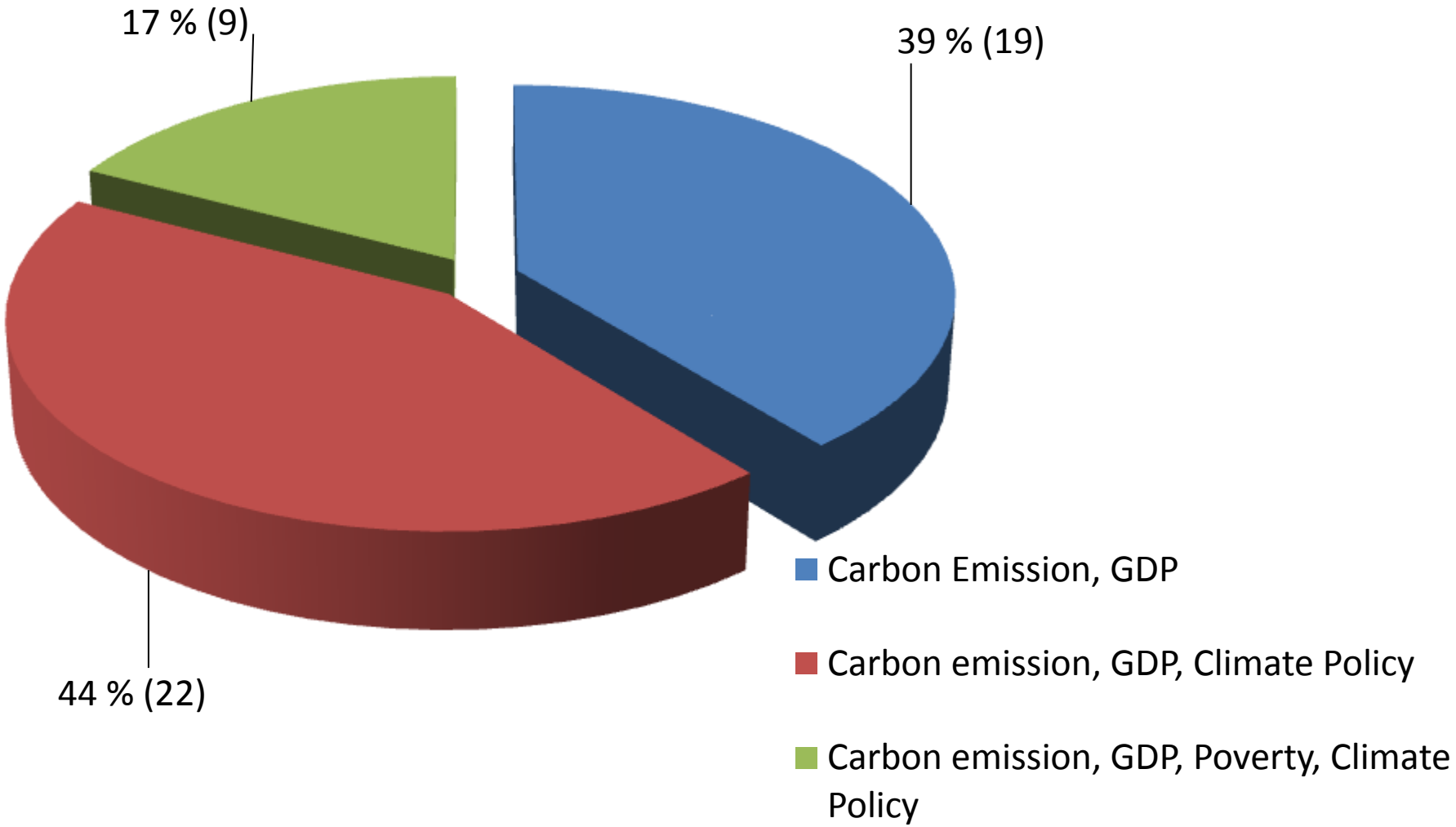
- 50+ peer reviewed journal articles, book chapters, reports
- 3 energy economy models supported by Ministry of Environment and Forests ; (released in 2009)

  Aim: build GHG emissions profile till 2030-31.

  Energy economy and impact model combinations :

  Linear Programming (LP); Computable General Equilibrium (CGE);
- Studies from independent researchers and organisations, prior and post this set
- Low carbon expert group (Planning Commission)

Aspects of the papers reviewed



Note: Percentage of paper reviewed with the mentioned three main aspects
Figure in Parenthesis represents the number of papers

Assumptions, methodology, findings and limitations

Descriptions from 8 recent studies

Study	***Model Type***	*Time frame*	***Energy efficiency***
Gaba et al. (2011)	Engineering-based bottom-up model	2007-2031	In particular electricity generation
Parikh et al. (2014)	LP- Activity analysis model	2010-2050	Autonomous EE improvements 1 – 1.2% pa
NCAER-CGE (Pohit et al 2009)	Sequential, CGE model (37Sectors)	2010-2030	Autonomous EE improvement 1.5% pa
Shukla et al. (2008)	Mix of models ; integrated modelling framework for LCS	2005-2032	Across sectors, special mention of industrial production technology
Saveyn et al. (2012)	CGE - GEM-E3 global model.	2005-2050	Yes
Chaturvedi and Shukla (2013)	Global Change Assessment Model (GCAM- IIM)	2005-2095	Emphasis on end use energy efficiency
Shukla and Chaturvedi (2012)	Global Change Assessment Model (GCAM- IIM)	2005-2095	Low carbon technologies in electricity generation
IEG-CGE (Pradhan and Ghosh 2012)	Recursive dynamic CGE; building on DART	2005 - 2050	In OECD scenario leads to energy intensity of GDP falling by 85% between 2005-2050 with climate mitigation policy; 38% by 2020

Descriptions from 8 recent studies

Study	*Scenario*
Gaba et al. (2011)	**Five Year Plans** fully implemented; **Delayed Implementation** as per historical performance; **All-Out Stretch** –FYP, with rise in EE & and low carbon energy
Parikh et al. (2014)	**Accelerated Visionary Development** policies for human well-being. **Carbon budget scenarios (corresponding to 2 deg C stabilization target)**
NCAER-CGE (Pohit et al 2009)	**BAU Reference** scenario: No new mitigation policies or scenarios
Shukla et al. (2008)	**Base** - GDP gr. 8%; target for stabilization (650 - 550 ppm CO_2e); **Carbon tax -** target 550 – 480 ppm CO_2e **Sustainable society: C**umulative carbon budget for 2013–2050.
Saveyn et al. (2012)	3 **Asian Modeling Emission scenarios - For carbon price path** - **Low -**CO2 Price $10; **Middle** CO2 Price $30 **High** - CO2 Price $50
Chaturvedi and Shukla (2013)	**6 scenarios: 1 reference and 2 climate mitigation With reference assumptions for end use EE improvement & Advanced assumptions**
Shukla and Chaturvedi (2012)	**BAU with and without targets** for clean energy sources in electricity generation. **Carbon price with and without such clean energy electricity targets**
IEG-CGE (Pradhan and Ghosh 2012)	**BAU: OECD growth scenario** (4.3% in 2050); **Higher growth scenario (**5.9% in 2050) **2 policy regimes (for** temp. at 2 deg C) - i. Global carbon tax; ii. Emissions

Model Power and Model Limitations

What is included: energy efficiency, health costs, leadership

Equilibrium properties: Unemployment, capacity gaps

Cross-border flows: Trade, finance, capital

Carbon policy – tax, emissions trading, revenue use

Model Power : What is included?

Study	***Health Costs***
Gaba et al. (2011)	Not included
Parikh et al. (2014)	
NCAER-CGE (Pohit et al 2009)	Not included
Shukla et al. (2008)	Not modelled; however, benefits of improved air quality through reduced SO2 is one indicator for a low carbon society
Saveyn et al. (2012)	Not included
Chaturvedi and Shukla (2013)	Significant co-benefits of EE improvements in terms of energy security from reduced import bills, Reduced local air pollutants.
Shukla and Chaturvedi (2012)	Possibility of reduced health cost due to improved air quality as a co-benefit – but not explicitly modelled
IEG-CGE (Pradhan and Ghosh 2012)	Not included

Model Power : What is included?

Study	***Role of cross border flows (trade, finance)***
Gaba et al. (2011)	Regional trade in lower-carbon energy sources recommended for low carbon pathway
Parikh et al. (2014)	
NCAER-CGE (Pohit et al 2009)	
Shukla et al. (2008)	Sustainability scenario also assumes a high degree of regional cooperation among the countries in southern Asia for energy and electricity trade and effective use of shared water and forest resources.
Saveyn et al. (2012)	
Chaturvedi and Shukla (2013)	
Shukla and Chaturvedi (2012)	Additional gains in hydro and wind potentials from regional cooperation with neighbouring countries. A larger south Asian market for energy and electricity in which Indian firms would have a greater opportunity to participate in joint ventures.
IEG-CGE (Pradhan and Ghosh 2012)	

In-built transitions: Avenues for Action?

Study	
Gaba et al. (2011)	**T & D loss reduction most cost-effective** - Approx. 20% reduction in CO2 from grid electricity with reduction in T & D losses, construction of supercritical power plants
Parikh et al. (2014)	Some options for meeting global carbon budget corresponding to 2 deg C target **Increase in share of renewables in total generation** by 0.18% per year
Shukla et al. (2008)	**Mitigation mainly in electricity sector** - initially due to fuel switching up to 2030, beyond which due to CCS in power generation, steel and cement industry.
Saveyn et al. (2012)	Increase in share of **natural gas.**
Chaturvedi and Shukla (2013)	**End use EE** significant impact on transportation and building sectors
Shukla and Chaturvedi (2012)	**Setting clean energy electricity generation targets** internalises co-benefits from reduced air pollution, increased energy security and reduced climate change risks
IEG-CGE (Pradhan and Ghosh 2012)	Creation of a **CCS, thermal electricity** sector

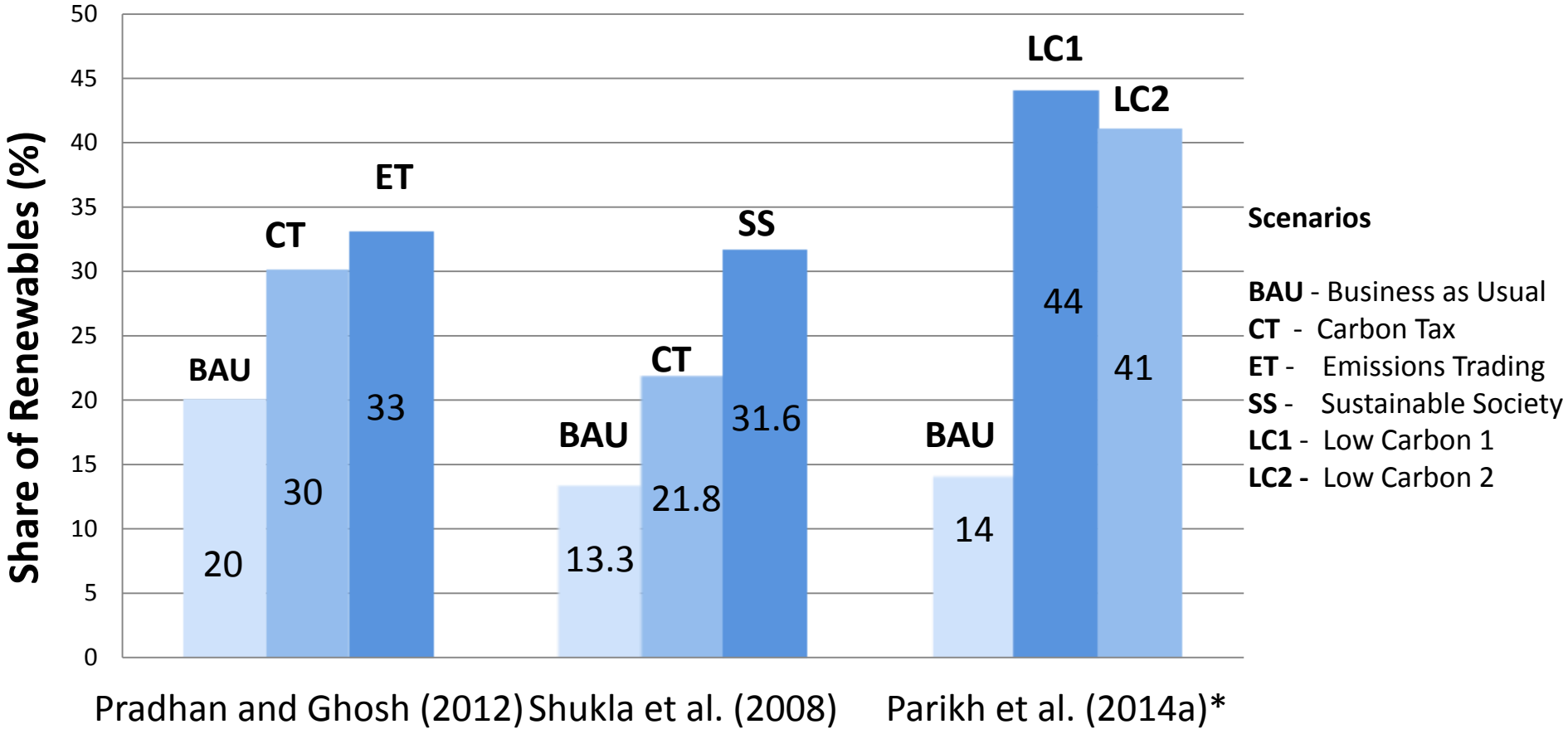
In-built transitions: Avenues for Action?

Study	
Gaba et al. (2011)	Tighter **mandatory energy efficiency standards for household appliances** lowers electricity consumption by a third.
Parikh et al. (2014)	Increase in share of railways in freight movement from 35% in 2010 to 67% by 2050 **Reducing petroleum product inputs** in transport sector by 2% per year
Shukla et al. (2008)	Higher adoption of renewables, specially biomass, and improvements in device efficiencies also responsible for mitigation.
Saveyn et al. (2012)	**Interventions in transport** and some highly energy intensive sectors (**metal and chemical industries**) contribute most.
Chaturvedi and Shukla (2013)	Substantial shift towards electricity consumption esp. for transport and industrial sectors, with a stringent climate policy.
Shukla and Chaturvedi (2012)	Low carbon technologies compete among themselves and substitute each other, thereby enhancing the need for subsidy or carbon price; e.g. **Solar electricity, requires subsidy throughout the century to achieve its targets**
IEG-CGE (Pradhan and Ghosh 2012)	

Descriptions from 8 recent studies

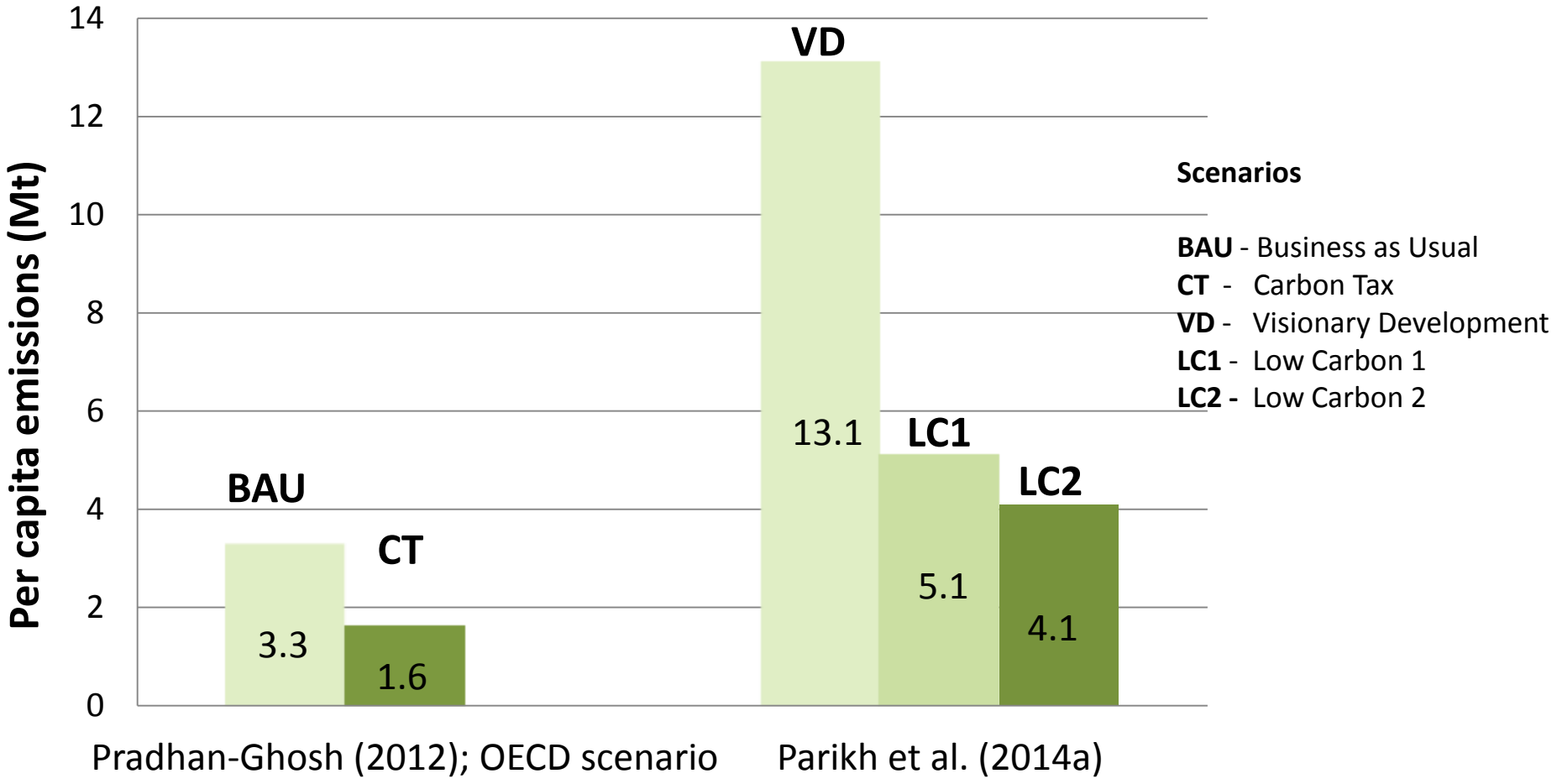
Study	***Carbon policy and revenues***
Gaba et al. (2011)	
Parikh et al. (2014)	
NCAER-CGE (Pohit et al 2009)	
Shukla et al. (2008)	In CT scenario – in 2050 Carbon tax increases to $100/tCO2 and GDP decreases by 1.35% compared to 2005. **Tax revenues from the carbon tax are invested back into the economy**. **Carbon tax for penetration of renewables**
Saveyn et al. (2012)	
Chaturvedi and Shukla (2013)	Carbon tax leads to reduction of final energy demand (net of rebound effect from EE improvements)
Shukla and Chaturvedi (2012)	Feedback effects of subsidy and taxes on current and future GDP are not included in the present analysis.
IEG-CGE (Pradhan and Ghosh 2012)	**Emissions trading permits**; Global Carbon tax on coal, oil and gas products: **carbon prices rise more post 2040**, since abatement opportunities more in earlier years (Partially from

% Share of renewable energy in total energy, with and without climate policy in 2050



** Parikh et al. (2014a) - share of renewables in total electricity generation*

Per capita emissions in 2050



Model Limitations: What is not included?

Leadership and collective action premiums	Model scenarios and assumptions on the in-built dynamics have implications for governance and institutional measures, but do not explicitly model these. Emissions tend to peak around 2035 - 2040, with a climate policy regime in place (e.g. Pradhan and Ghosh at 2.1 MT per capita in 2040)

Model Limitations: What is not included?

Long term impacts; Looking beyond the short term	Transferring resources (carbon tax revenues or capital inflows) to the weaker sections of society or subsidising other sectors of the economy could reduce (or reverse) the adverse effect. **Forecasting issues**: Structural uncertainties, non-assignment of probabilities; non marginal changes Changes in ***international prices of fossil fuels*** are modelled using future price projections, and usually ***remain invariant to policy scenarios*** In most India models, domestic energy prices are endogenous (NCAER-CGE, MoEF – IRADe, TERI MoEF). In general, ***price elasticity as based on Indian data tends to be low; w***hile the international price projections (exogenous) usually assume some escalations.

Model Limitations: What is not included?

Discussion of non-equilibrium properties with involuntary unemployment; Capacity gaps	Most models assume **full employment** with intersectoral mobility in case of factors of production. **Alternative closure assumptions** in the CGE framework could for instance be built in, but generally not seen. Similarly, ***subsidies*** are also part of the price equation, ***and not looked at separately***. Overall impacts through a carbon tax which changes (raises) prices are the common approach.

No last word on welfare changes!

Paper	Time frame	Emission reduction	Economic Loss
Kirit S. Parikh (2011)	2005-2050	Cumulative carbon emission reduces from 337 Gt in base case to 133-156 Gt under constrains	12.5% loss in GDP
Shukla et al. (2008)	2005-2032	Decrease in cumulative emission 62.6 billion tCO2.	1.35% loss in GDP
Shukla and Dhar (2011)	2005-2050	Decrease in cumulative emission around 60.8 billion ton	6.7% loss in GDP

Paper	Time frame	Emission reduction	Economic Loss
Shukla et al. (2009)	2010-2030	Reduced carbon emissions around 5.1 billion-ton of CO2	1% economic growth each year to the region sustained over a 20 year period.
Calvin et al. (2012)	2005-2020	Emissions per unit of GDP falls to 20–25% below 2005 levels in 2020	
Murthy et al. (1997)	1990-2020	CO2 emissions reduces from 5.8% to 4.8%	
Pradhan and Ghosh (2012)	2010-2030	Target fixed at 450 ppm; corresponding to long term temp rise of 2 deg C	**Decline of 1.1 – 1.3% in GDP growth rate, except for 2045-2050**

Table 1 : Mitigation Options and Potential:

Emissions of selected electricity supply technologies (gCO2eq/kWh)

Options	Lifecycle emissions* (gCO2eq/kWh)
Currently Commercially Available Technologies	
Coal – PC	820
Gas - Combined Cycle	490
Biomass – CHP	230
Hydropower	24
Nuclear	12
Concentrated Solar Power	27
Solar PV - rooftop	41
Solar PV - utility	48
Pre-commercial Technologies	
CCS - Coal - PC	220
CCS - Coal	200
IGCC-CCS - Gas - Combined Cycle	170

*** Represents the median value**

Source: As reported in IPCC, AR5, WG III calculations

Is a low carbon transition pathway consistent with attaining the goals set for the economy?

- 25% emission intensity reduction over 2005 levels

  possible by 2020 with GDP growth rate of 8-9% in short term (Interim report, Expert Committee, Planning Commission)

  29% (WB 2011), 24-25% (Parikh 2014)
- Critical challenges of poverty reduction in the near and medium term; resource constraints to economic growth already identified – energy, water and land use.
- Climate change a threat multiplier, adding to constraints, and competition over resources under BAU
- Low carbon path offers potential economic gains, apart from climate mitigation benefits
- Energy security : EE improvements, share of renewables
- Health Co-benefits: Air pollution major issue already in cities
- Technological innovation and its attendant implications for investment gains; impacts on quality of life (varying extent in most models)

Learning: A strong climate policy can induce transitional change

Discussion