India's GHG Emissions Profile: Results of Five Climate Modelling Studies

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सत्यमेव जयते

Ministry of Environment & Forests
Government of India

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NCAER

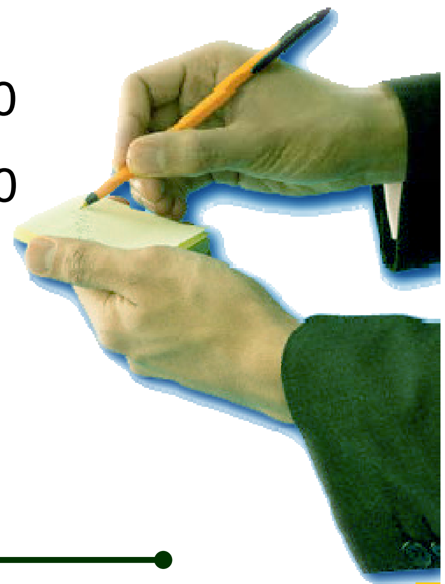
IRADe
Integrated Research and
Action for Development

McKinsey&Company

Agenda

Background

- Studies Undertaken
- Main Features of Model and Methodology
- Data Sources
- Illustrative Scenario Results
  - Assumptions
  - India's Per Capita GHG Emissions till 2030
  - India's Aggregate GHG Emissions till 2030
  - Plausibility of Results
- Some Other Interesting Results
- Conclusions



Background on Global Climate Change Debate

- Driven by results of complex computer models – climate models, macroeconomic models, energy-technology models, GHG concentration models, impact models – water resources, agriculture, coastal impacts, disease vectors, etc.

- A key element is GHG emissions profile of countries, esp. large developing countries – China, India, Brazil, South Africa

- So far, researchers from developed countries have been driving the debate through models that do not capture national realities

- Result has been several implausible estimates of India's future GHG emissions trajectory – leading to suggestions that the key to global climate stabilization is legally binding restraints on India's GHG emissions

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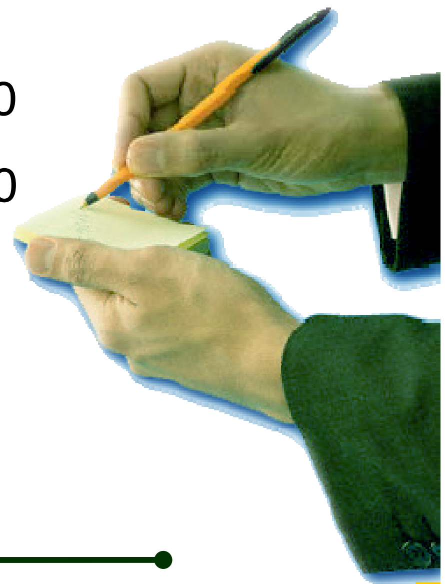

Studies Undertaken

Institutions and Models developed

- The institutions, and models developed by each are as follows:
  - NCAER (with Jadavpur Univ): National Computable General Equilibrium (CGE) Model (NCAER-CGE)
  - TERI: India MARKAL model (TERI-MoEF)
  - IRADe: Activity Analysis Model (IRADe-AA)
  - IIT Delhi: SWAT Hydrology Model (IITD-SWAT)
  - RMSI Delhi: AWSP Cropping Model (RMSI-AWSP)
- The first three are energy-economy models based on different methodologies, and may be used to simulate India’s GHG emissions trajectory
- The last two are climate change impacts models for water resources and agricultural crops respectively. Their results will be presented on another occasion

Studies Undertaken

This Compilation

- This presentation covers results of the first three models with respect to India's GHG emissions profile till 2030/31

- In addition, results of two other studies
  - TERI based on MARKAL, but with different assumptions presented at 14th UNFCCC Conference of Parties at Poznan in December 2008 (TERI-Poznan)
  - McKinsey and Company Bottom-up 10 sector study by are also reported

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Main Features of Models/Methodology (1/2)

NCAER-CGE

NCAER

- A top-down, sequentially dynamic, non-linear computable general equilibrium model, with market clearance and endogenous prices of commodities and factors, with 37 production sectors + government, and Coal, Oil, Gas, Hydro, Nuclear, and Biomass as primary energy resources

TERI-MoEF: (MARKAL)

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- Bottom-up linear programming model over defined period, with a detailed energy technologies matrix of >300 technologies, set of energy system technical and non-technical constraints, including limits to enhancement in energy efficiency of different technologies, 35 energy consuming subsectors + energy supply options including conventional and non-conventional, and Coal, Oil, Gas, Hydro, Nuclear, renewables, and traditional biomass as primary energy resources

IRADe-AA

IRADe
Integrated Research and Action for Development

- A linear programming model with sequential maximization of discounted sum of aggregate consumption for 3 years at a time for 30 years, with 34 activities with 25 commodities + Government, and Coal, Oil, Gas, Hydro, Nuclear, Wind, Solar and Biomass as primary energy resources

Main Features of Models/Methodology (2/2)

TERI-Poznan

- Identical to TERI-MoEF except that it assumes a lower GDP growth rate than the TERI-MoEF study; projects future energy prices (international and domestic) by in-house expert opinion, whereas TERI-MoEF uses the WEO, 2007 projections for international energy prices, and price indices from NCAER-CGE model for domestic energy prices. It is also much more conservative with respect to improvements in specific energy consumption, and assumes that there is little improvement in total factor productivity
  - The last set of divergent assumptions from TERI-MoEF seem to largely drive the differences in their results for the future CO_2 emissions path

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McKinsey & Company

- Factors in estimates of bottom up improvements in technology levers; analyses potential of a selected set from over 200 technologies. It includes 10 sectors: Power, Cement, Steel, Chemicals, Refining, Buildings, Transportation, Agriculture, Forestry, WASTE, and Coal, Oil, Gas, Hydro, Nuclear, Wind, Solar, Geothermal and Biomass as primary energy sectors

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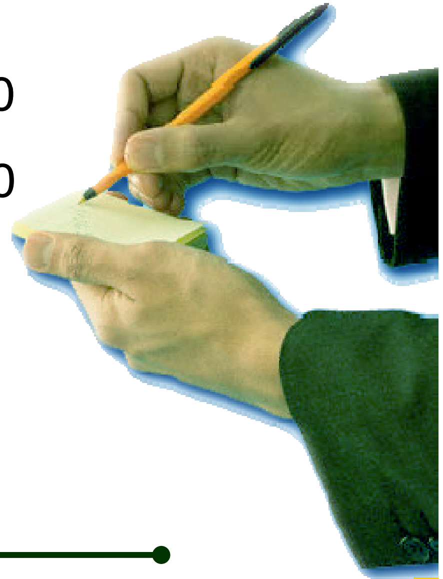

Data sources

Population	All models use projections of Registrar General of India (till 2026, extrapolated at same rates till 2030)
GHG emissions coefficients	All models use data from National Communication. McKinsey also uses IPCC values and own estimates for power sector
Domestic energy price projections	Endogenous in NCAER-CGE which feeds into TERI-MoEF, also endogenous for IRADe, own estimates for TERI-Poznan; not stated for McKinsey
CAGR of GDP	Endogenous for CGE (8.84%), feeds into TERI-MoEF, endogenous for IRADe (7.66%), assumed in TERI-Poznan (8.2%); exogenous in McKinsey (taken from Oxford econometric model at 7.52%)

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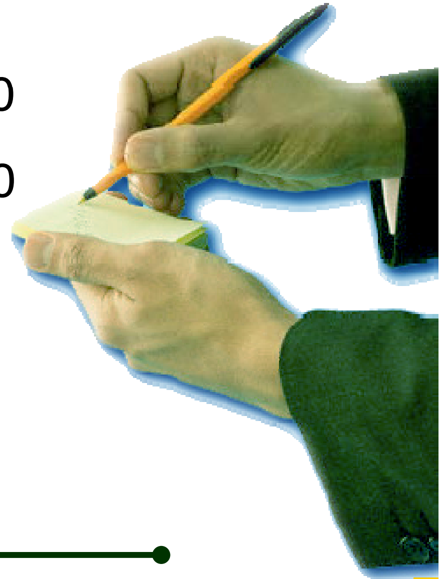

Illustrative Scenario Assumptions

- All models assume *no new GHG mitigation policies till 2030/31*
- **Technological change**: NCAER-CGE, TERI-MoEF, and IRADe-AA assume total factor productivity growth rate of 3.0%, and autonomous energy efficiency improvement of 1.5%, with TERI-MoEF limiting energy efficiency improvements in each technology to feasibility limits from expert opinion. TERI-Poznan considers energy efficiency improvements as per past trends and expert opinion, and very limited improvement in total factor productivity. McKinsey makes sector-by-sector assumption of technology mix (technological change is implicit in these assumptions)
- **Other assumptions**: TERI-MoEF uses Financial costs with 15% discount rate, IRADe and TERI-Poznan use Economic costs with 10% social discount rate

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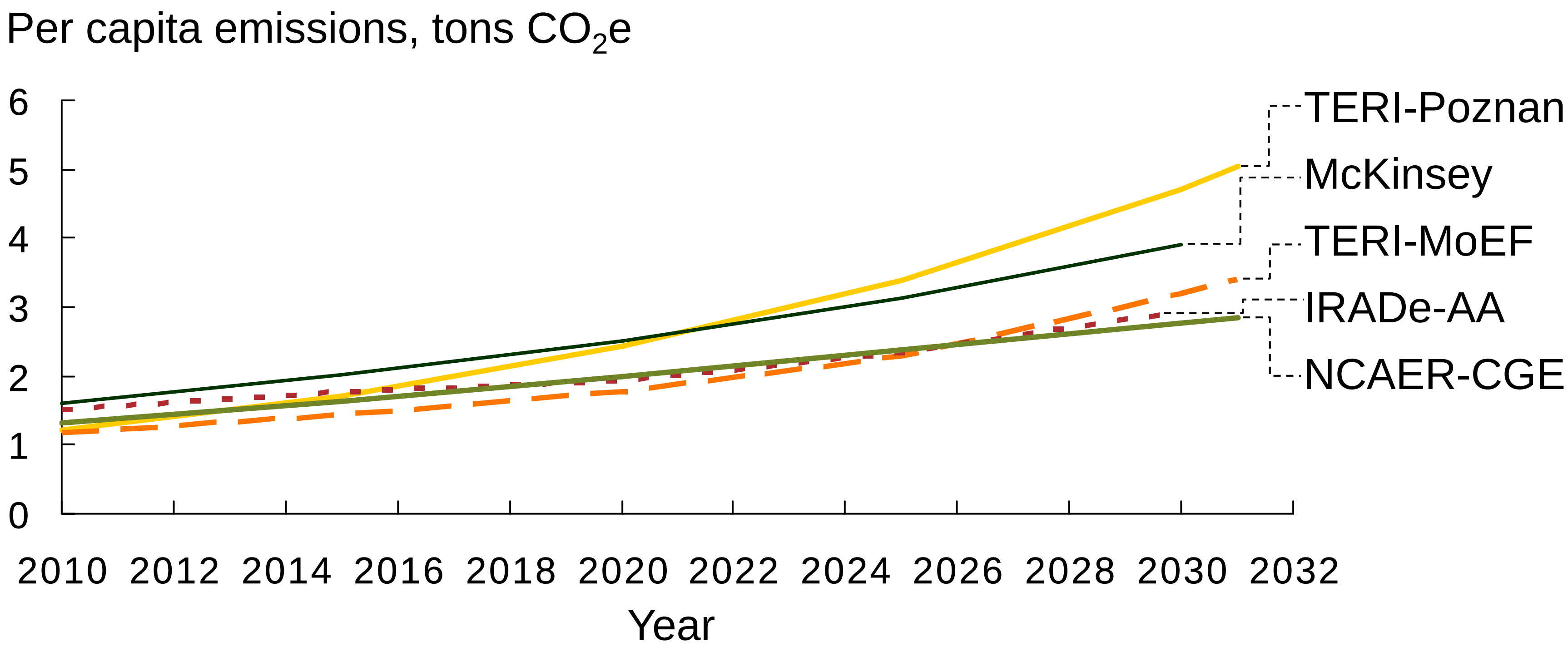
India's Per capita GHG emissions till 2030

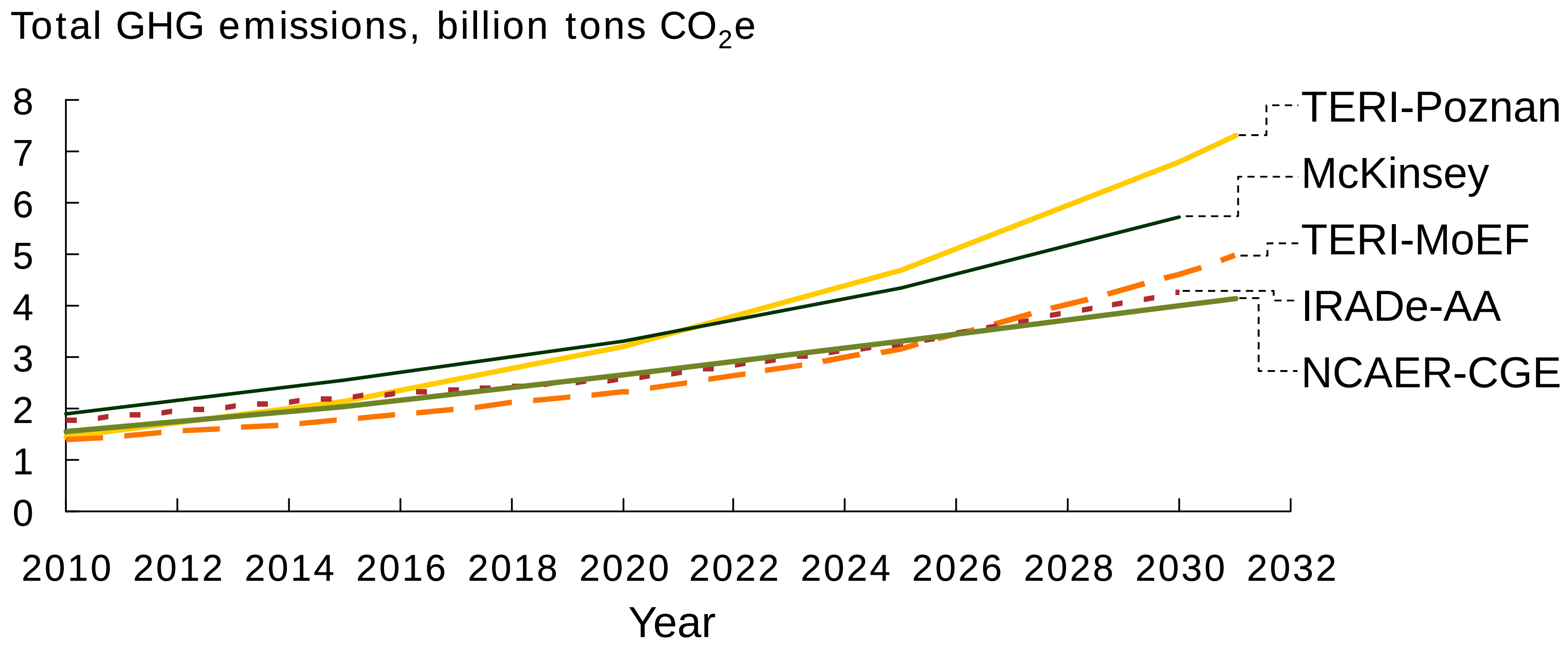
Per capita GHG emissions projections for India from 5 studies in Illustrative Scenarios (2010-2030)



The projections range from 2.77 tons/capita CO_2e (NCAER-CGE) to 5.0 tons/capita CO_2 (TERI-Poznan). Except for the last all studies indicate that India's per capita GHG emissions in 2030 will be below the 2005 global average of 4.22 tons!

India's Aggregate GHG emissions till 2030

Aggregate GHG emissions projections for India from 5 studies in Illustrative Scenarios (2010-2030)



The projections range from 4.0 billion tons CO_2e (NCAER-CGE) to 7.3 billion tons (TERI-Poznan)

Table 1: Results for illustrative scenarios (1/2)

	NCAER CGE Model	TERI MoEF Model	IRADe AA Model	TERI Poznan Model	McKinsey India Model
GHG emissions in 2030-31 (CO_2 or CO_2e) (billion tons)	❑ 4.00 billion tons of CO_2e	❑ 4.9 billion tons (in 2031-32)	❑ 4.23 billion tons	❑ 7.3 billion tons in 2031-32	❑ 5.7 billion tons (including methane emissions from agriculture); ranges from 5.0 to 6.5 billion tons if GDP growth rate ranges from 6 to 9 per cent
Per capita GHG emissions in 2030-31 (CO_2 or CO_2e)	❑ 2.77 tons CO_2e per capita	❑ 3.4 tons CO_2e per capita (in 2031-32)	❑ 2.9 tons CO_2e per capita	❑ 5.0 tons CO_2e per capita (in 2031-32)	❑ 3.9 tons CO_2e per capita (2030), all GHGs
CAGR of GDP till 2030-31, %	❑ 8.84%	❑ 8.84% (Exogenous – taken from CGE)	❑ 7.66% (Endogenous, 2010-11 to 2030-31)	❑ 8.2% 2001-2031 (Exogenous)	❑ Exogenous – 7.51% (2005-2030) from MGI Oxford Econometric model

Note: $ GDP at PPP is in 2003-2004 rates, except where noted separately

Table 1: Results for illustrative scenarios (2/2)

	NCAER CGE Model	TERI MoEF Model	IRADe AA Model	TERI Poznan Model	McKinsey India Model
Commercial energy use in 2030-31, mtoe	❑ 1,087 (Total commercial primary energy forms)	❑ 1,567 (Total commercial energy including secondary forms) in 2031-32	❑ 1,042 (Total commercial primary energy)	❑ 2,149 (Total commercial energy including secondary forms) in 2031-32	❑ NA
Fall in energy intensity	❑ 3.85% per annum (compound annual decline rate)	❑ From 0.11 in 2001-02 to 0.06 in 2031-32 kgoe per $ GDP at PPP	❑ From 0.1 to 0.04 kgoe per $ GDP at PPP	❑ From 0.11 in 2001-02 to 0.08 in 2031-32 kgoe per $ GDP at PPP	❑ Approximately 2.3% per annum between 2005 and 2030 (at PPP GDP, constant USD 2005 prices)
Fall in CO_2 (or CO_2e) intensity	❑ From 0.37Kg CO_2e to 0.15 Kg CO_2e per $ GDP at PPP from 2003-04 to 2030-31	❑ From 0.37 to 0.18 kg CO_2 per $ GDP at PPP from 2001-02 to 2031-32	❑ From 0.37 to 0.18 Kg CO_2 per $ GDP at PPP from 2003-04 to 2030-31	❑ From 0.37 to 0.28 kg CO_2 per $ GDP at PPP from 2001-02 to 2031-32	❑ Approximately 2% per annum between 2005 and 2030 (at PPP GDP, constant USD 2005 prices)

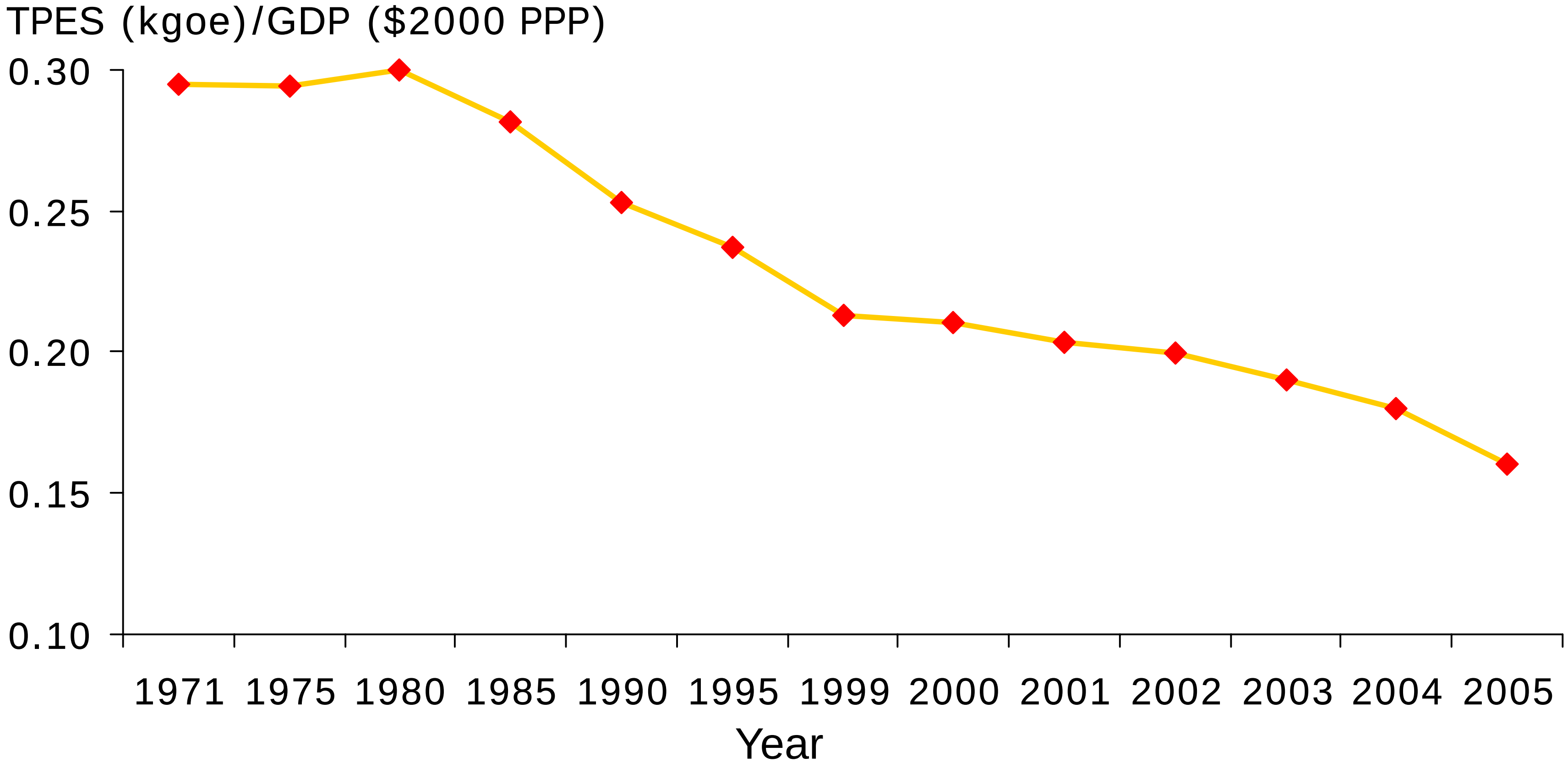
Each of the studies projects continuous decline in energy and CO_2 intensities of the economy till 2030

Note: $ GDP at PPP is in 2003-2004 rates, except where noted separately

Are the results on energy intensity and CO_2e intensity plausible?

Historical record of India's energy intensity

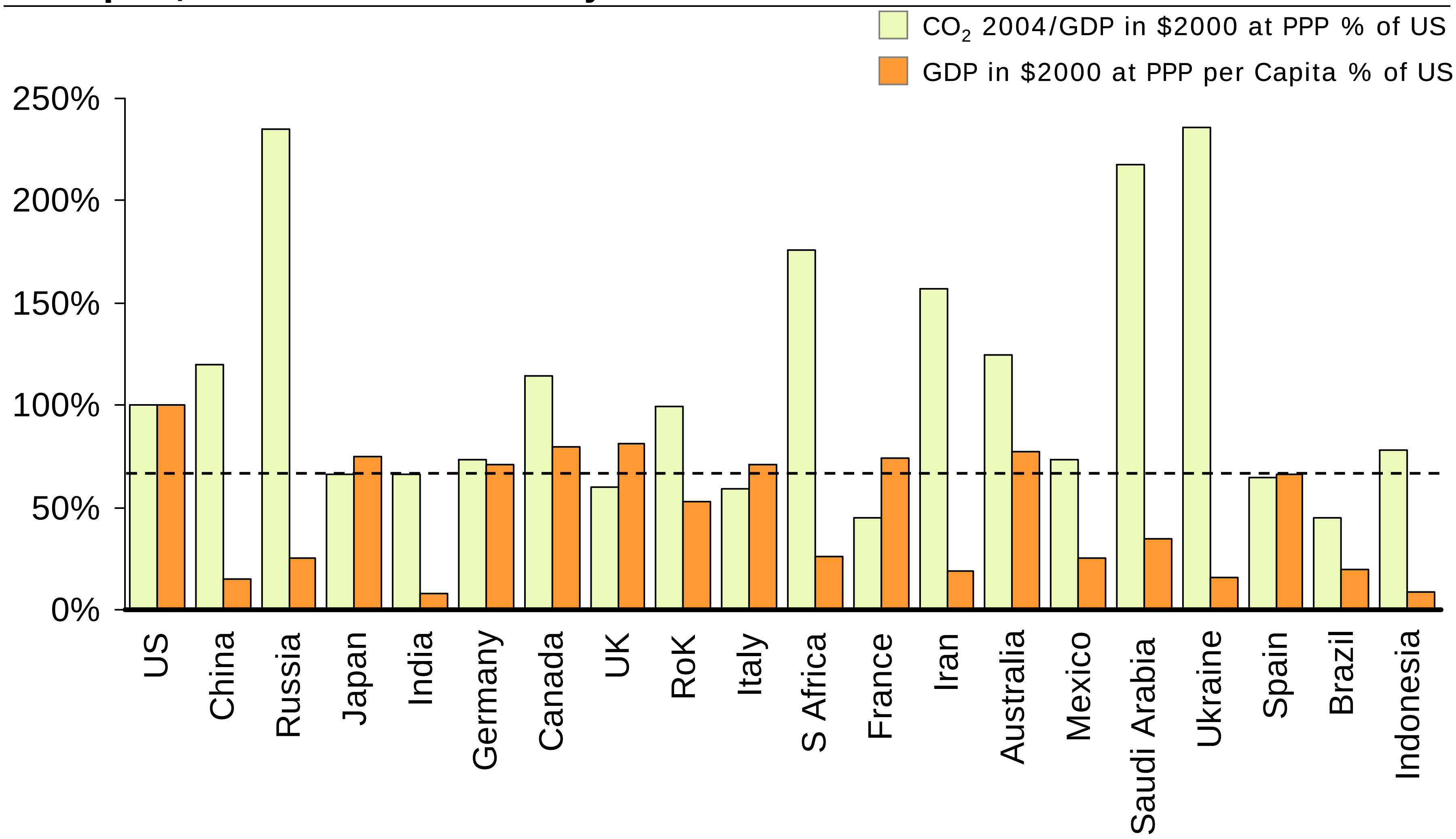
Energy intensity of GDP (kgoe/$ 2000 PPP) based on IEA data



India's energy intensity has declined continuously since 1990. At present, it is better than Germany's

Are the results on energy intensity and CO_2e intensity plausible?

The fossil fuel CO_2 intensity of the Indian economy in 2004 was the same as Japan; better than Germany



Data: "Growth and CO_2 Emissions – How do different countries fare?" : Roger Bacon and Soma Bhattacharya: World Bank, 2007

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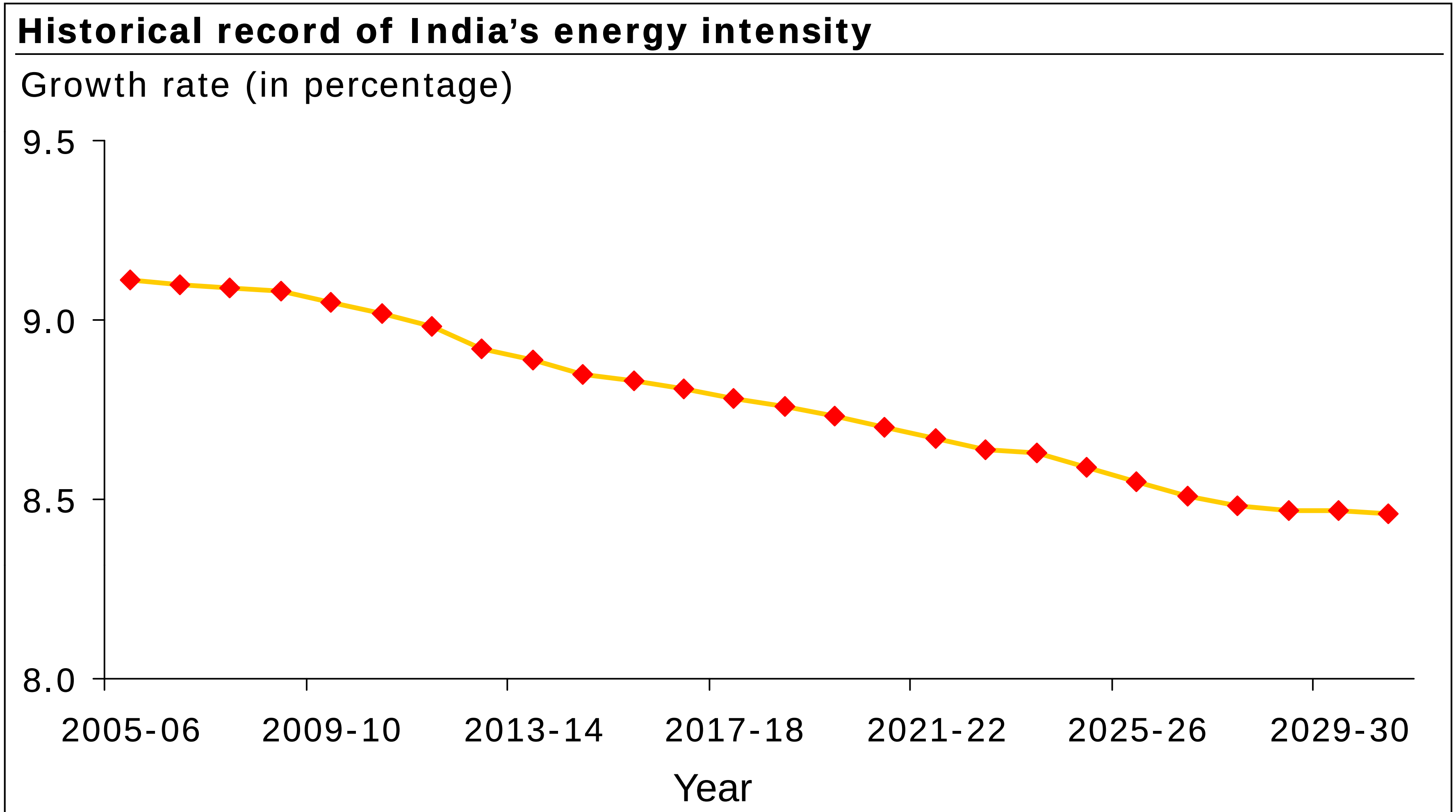
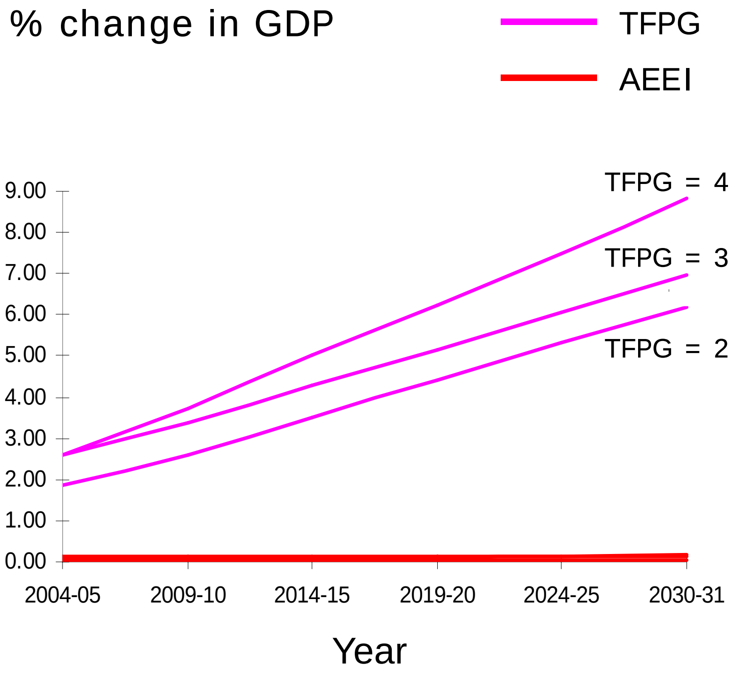
NCAER-CGE: GDP growth rate projections till 2030



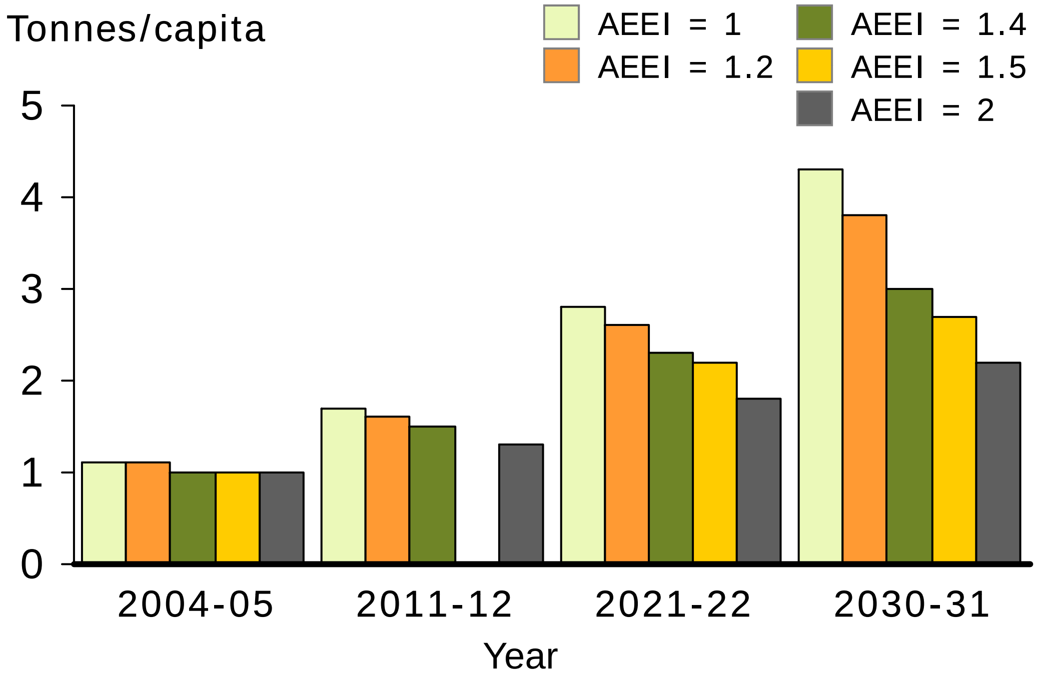
While GDP growth slows slightly till 2030, the CAGR of GDP remains high at 8.84%

Effect of varying technological change parameters

Effect of changing TFPG and AEEI on GDP



Effect of changing AEEI on per capita CO_2e emissions



Total Factor Productivity Growth (TFPG) has a dramatic positive effect on GDP growth, but the effect of autonomous energy efficiency (AEEI) improvement on GDP growth is negligible. Conversely, the effect of AEEI on per capita CO_2e emissions in 2030 is strong. Lesson: Energy efficiency improvement is the key to GHG mitigation, and factor productivity to economic growth!

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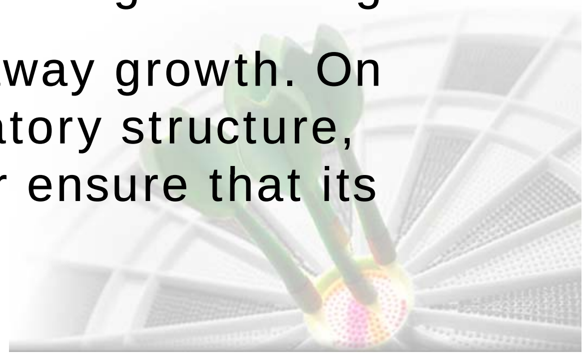
Conclusions

- Different models and approaches employing different methodologies and varying assumptions of technological change, GDP growth, and future energy prices give two consistent messages:
- First, India's per-capita GHG emissions will remain modest till 2030/31; 4 out of 5 models show that it will remain below the global average per-capita level in 2005, even without any new mitigation policies
- Second, that India's demonstrated decline in energy intensity, and associated GHG intensity, will continue till 2030/31
- This happens with high GDP growth rates over the period
- Another important conclusion is that the key to GHG mitigation is increased energy efficiency wrought by technological change
- India's GHG emissions are not poised for runaway growth. On the contrary, India's existing policy and regulatory structure, energy endowments, and consumer behaviour ensure that its growth will remain sustainable



"An ounce of practice is worth a ton of preaching"

– *MK Gandhi*


thank you