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# Sustainable Energy

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# Some climate observations

Natural GHG effect/H<sub>2</sub>O (almost 60 degrees Fahrenheit)

Scale of CO<sub>2</sub> doubling – degrees Centigrade

CO<sub>2</sub> is a cumulative issue because of residence time

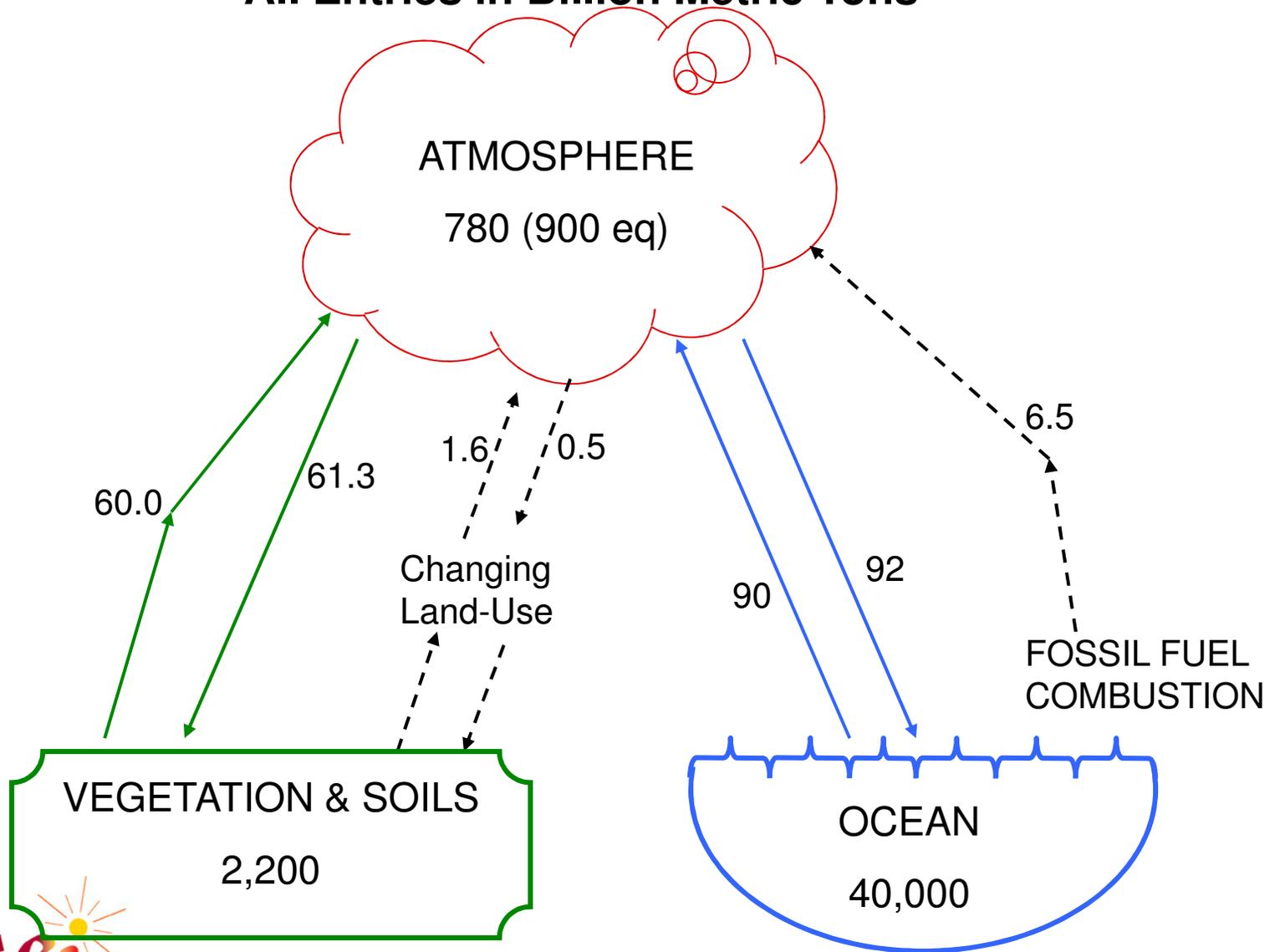
Scale of degrees Centigrade impact substantial

Measured T rise post-industrial (whatever the source, but very suggestive!)

Patterns of regional impact (poles, extreme weather,...) with some simple drivers

Note: 1 ppm CO<sub>2</sub> corresponds to about 2 gigatonnes carbon

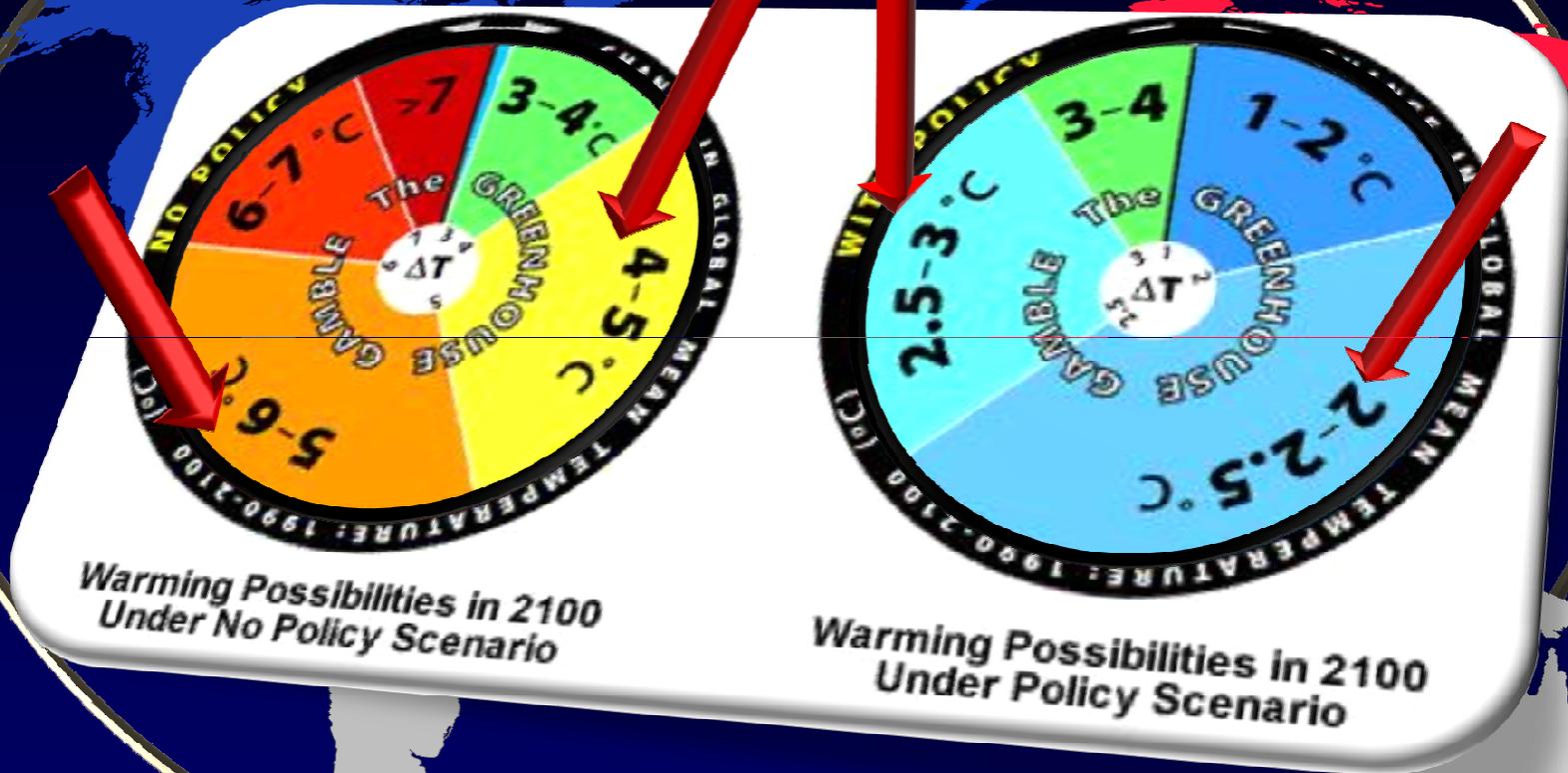
# Global Carbon Cycle (IPCC/EIA) All Entries in Billion Metric Tons



# It's later – and more serious -- than we think

Without Policy

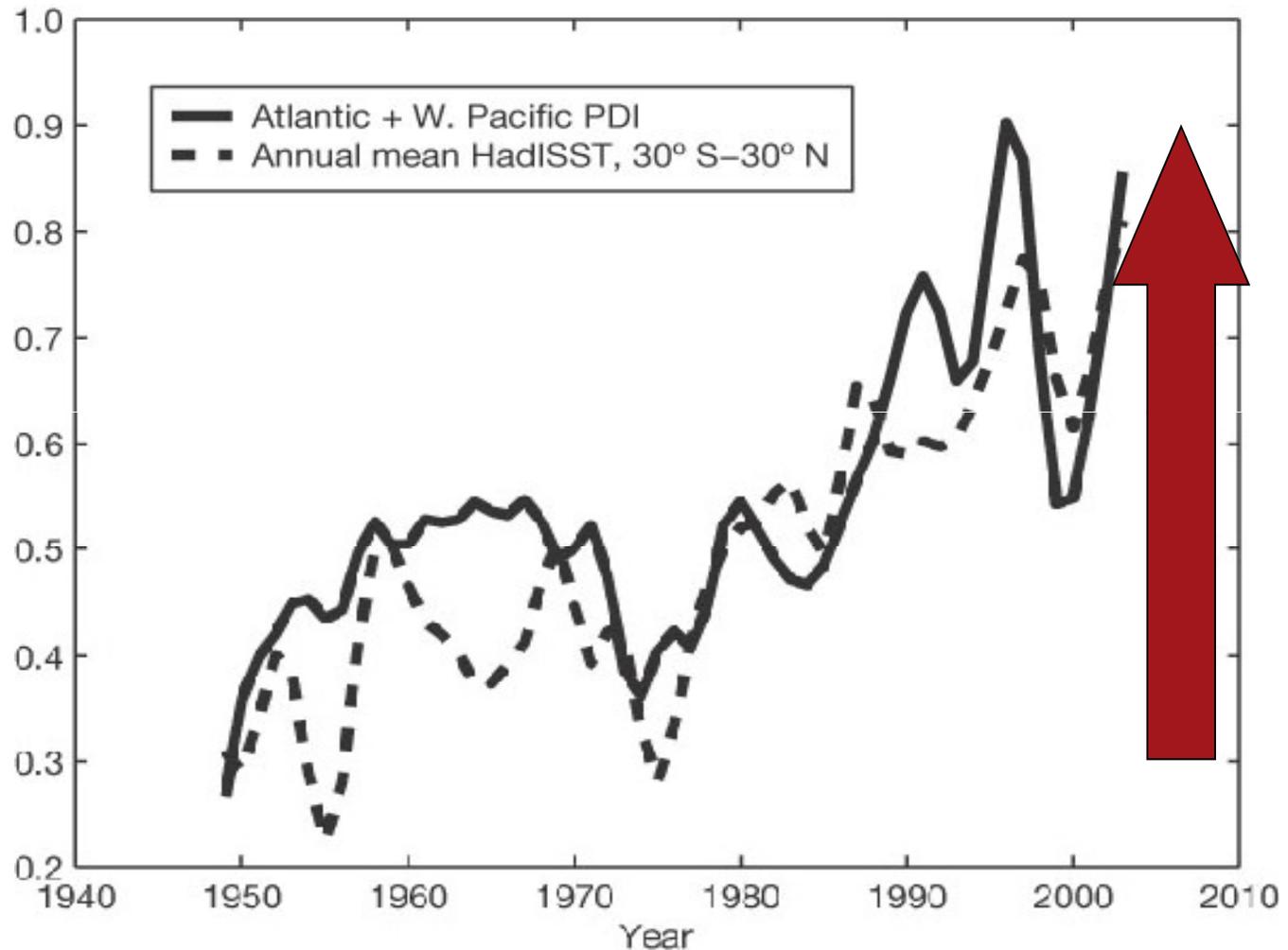
With Policy



# HURRICANES:

## INCREASING DESTRUCTIVENESS OVER THE PAST 30 YEARS?

**Power  
Dissipation  
Index (PDI)  
 $= T \int_0^{\infty} V_{\max}^3 dt$   
(a measure  
of storm  
destruction)**



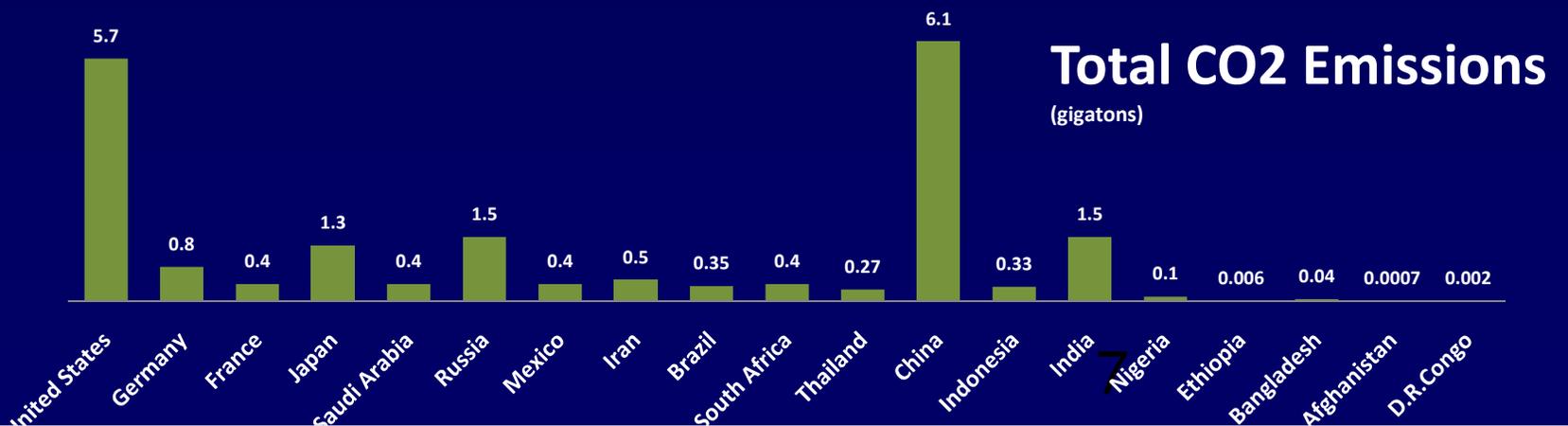
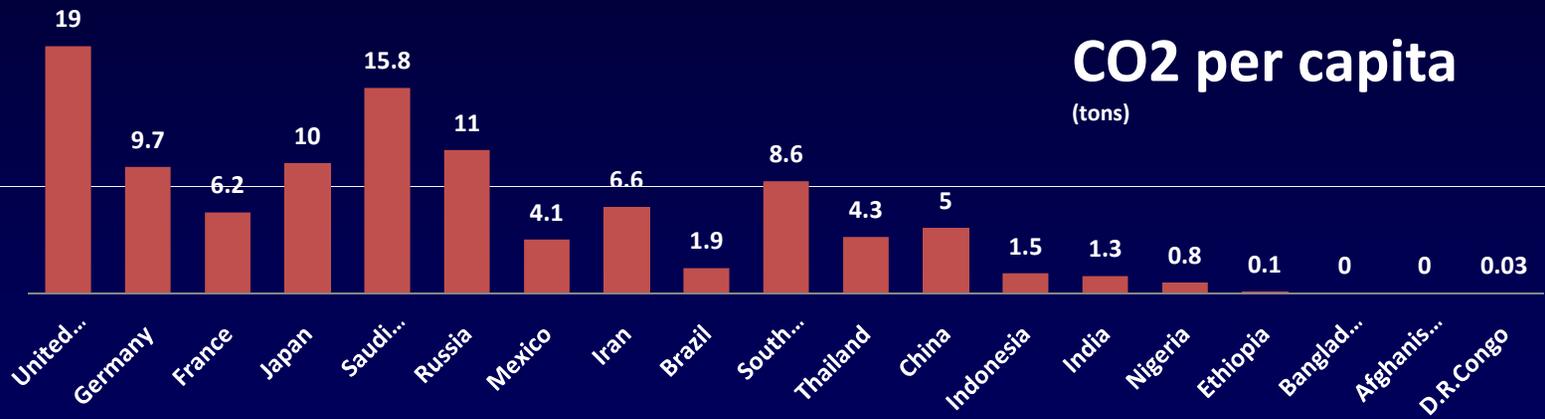
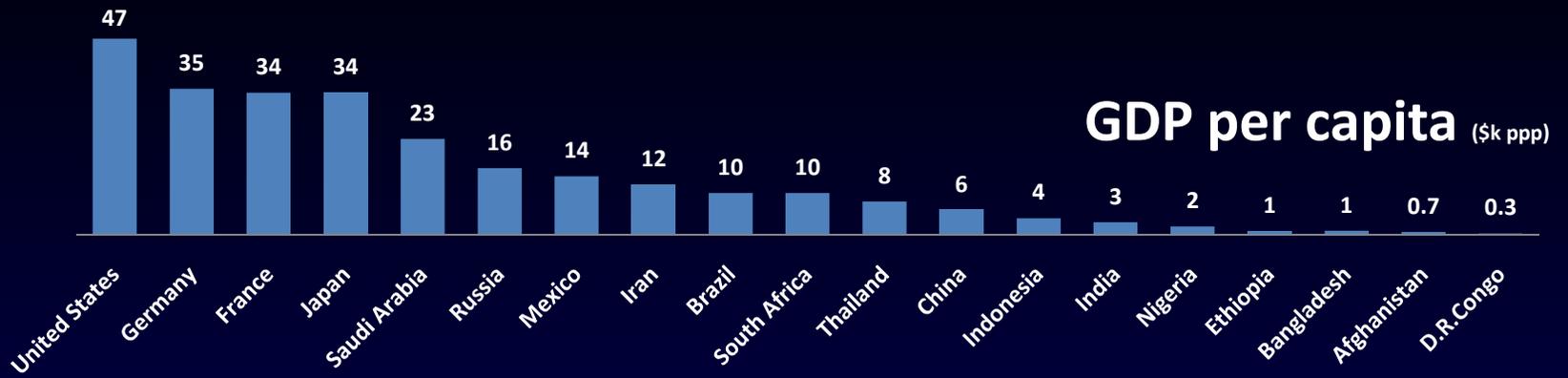
Reprinted by permission from Macmillan Publishers Ltd: Nature.  
Source: Emanuel, Kerry. "Increasing Destructiveness of Tropical  
Cyclones over the Past 30 years." *Nature* 436 (2005): 686-688. © 2005. 5



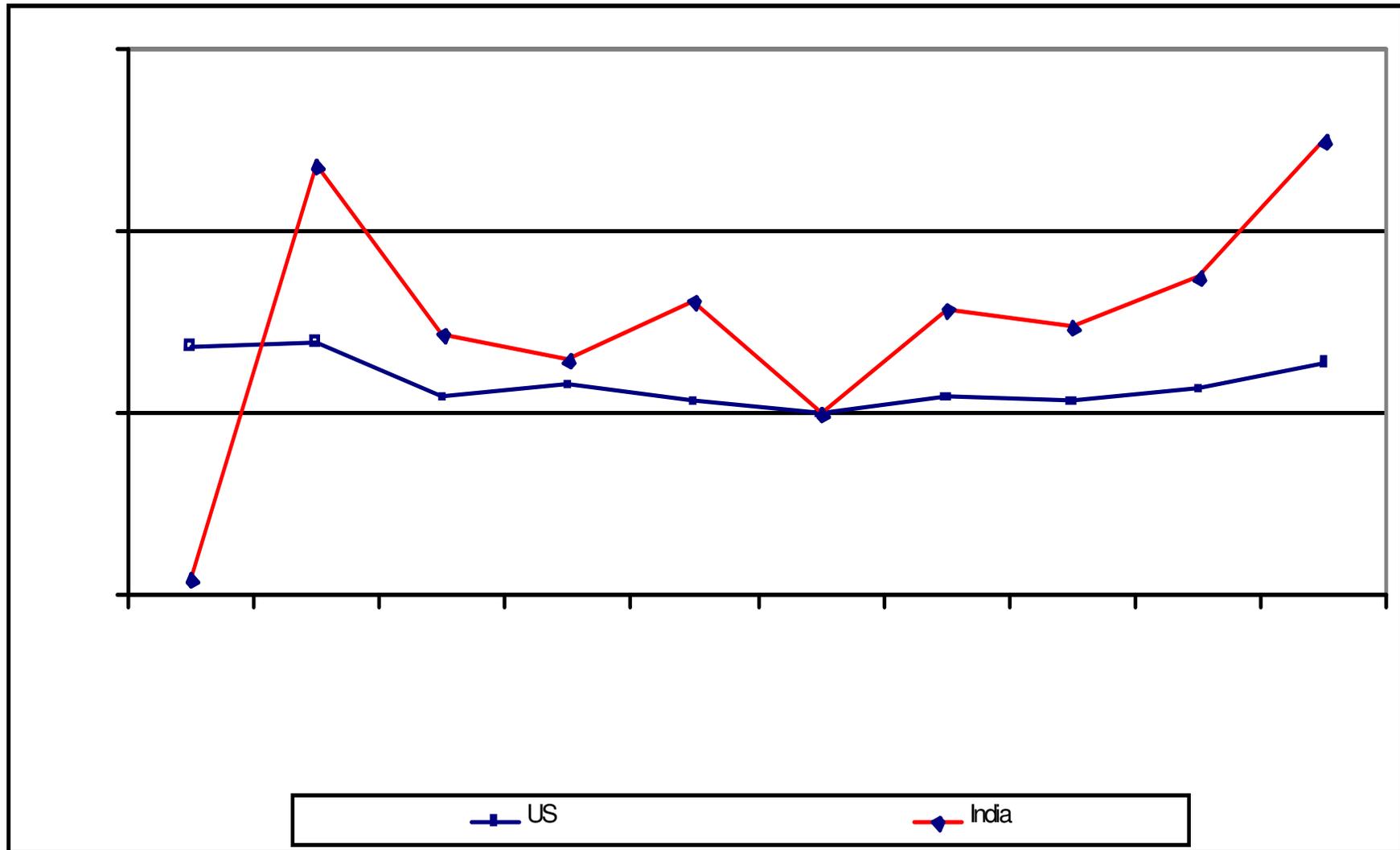
## Magnitude of CO<sub>2</sub>-eq Reductions Required

- BAU emissions in 2050: about 70 B tonnes CO<sub>2</sub>-eq
- 50% reduction from today: about 20 B tonnes,
  - About 2 tonnes/person
- Asymptote?

Roughly one  
tonne per person?



# Developing Countries Focus on Income Growth



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# Some observations

Unusual case of experts more worried than public! (Socolow, Princeton)

\* numeracy important: “Man would rather commit suicide than do arithmetic.” (G.B.Shaw/Gibbons)

\* anthropogenic emissions of CO<sub>2</sub>/GHG are on the scale to materially re-engineer the atmosphere, in a relatively short period (fraction of a century scale); natural variation also occurs

\* current understanding and simple arithmetic call for collective prudence in policy and behavior: a call for action, not inaction - indeed, onus should be on case for inaction, rather than the other way around!

## US Carbon Dioxide Emissions (EIA BAU)

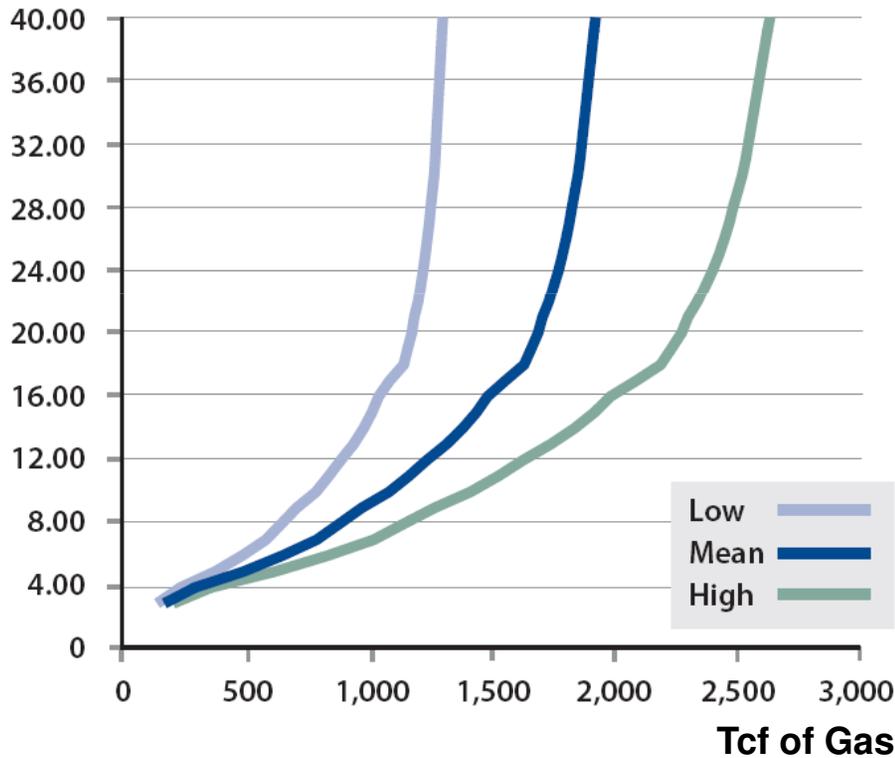
Millions of Metric Tons

|              | Residential + Commercial |             | Industrial  |             | Transportation |             | Total       |             |
|--------------|--------------------------|-------------|-------------|-------------|----------------|-------------|-------------|-------------|
|              | 2006                     | 2030        | 2006        | 2030        | 2006           | 2030        | 2006        | 2030        |
| Petroleum    | 153                      | 137         | 421         | 436         | 1952           | 2145        | 2526        | 2718        |
| Natural Gas  | 392                      | 483         | 399         | 433         | 33             | 43          | 824         | 959         |
| Coal         | 10                       | 9           | 189         | 217         | 0              | 0           | 289         | 226         |
| Electricity  | 1698                     | 2295        | 642         | 647         | 4              | 5           | 2344        | 2947        |
| <b>TOTAL</b> | <b>2253</b>              | <b>2924</b> | <b>1651</b> | <b>1733</b> | <b>1989</b>    | <b>2193</b> | <b>5983</b> | <b>6822</b> |
|              |                          | 1.1%/yr     |             | 0.2%/yr     |                | 0.4%/yr     |             | 0.6%/yr     |

## U.S. Gas Supply Cost Curve

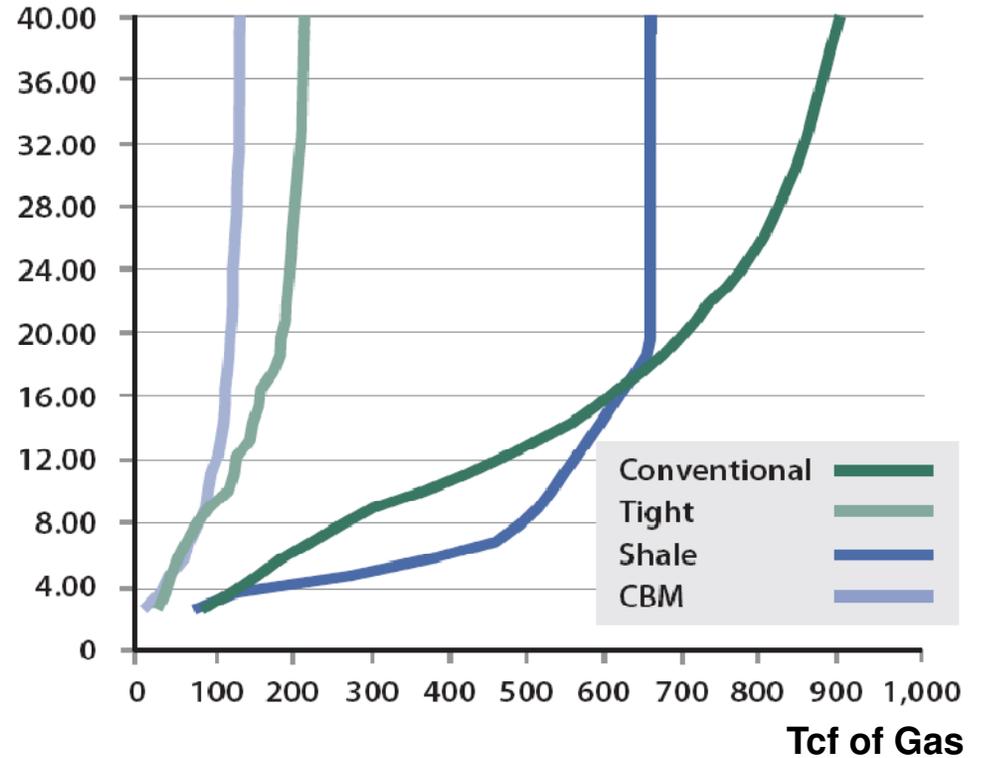
**Breakeven Gas Price\***

\$/MMBtu



**Breakdown of Mean U.S. Supply Curve by Gas Type Breakeven Gas Price\***

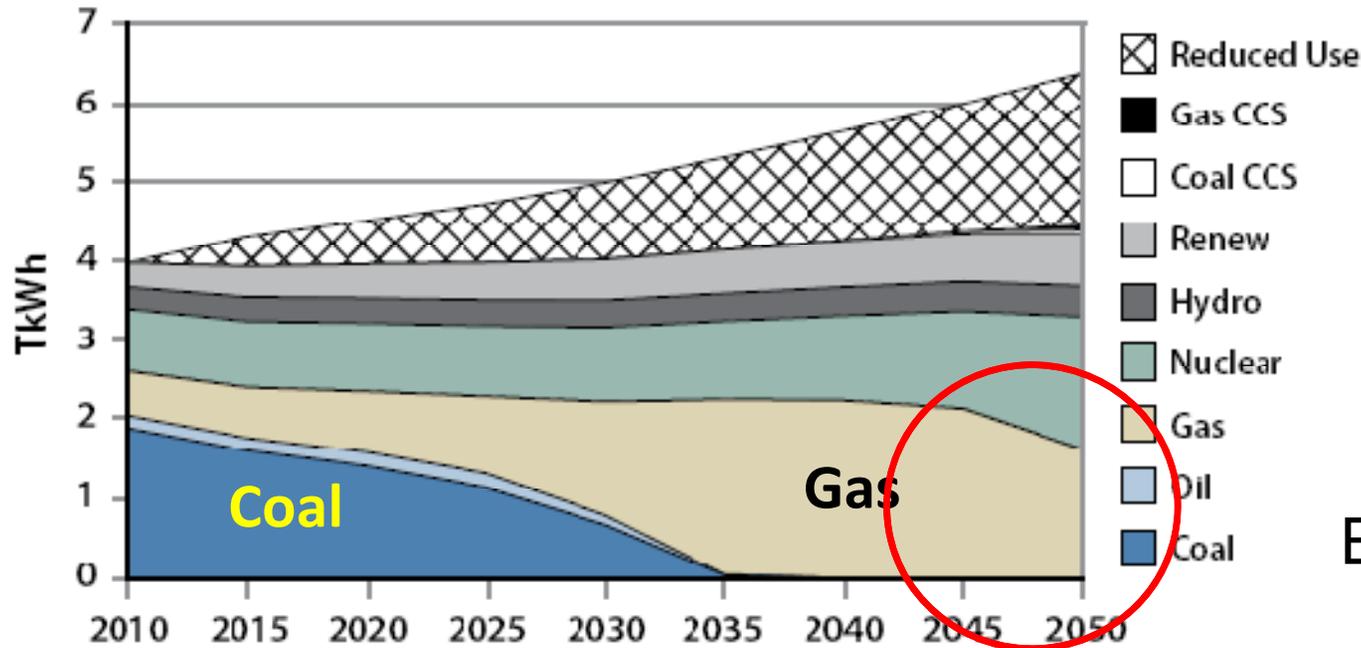
\$/MMBtu



\* Cost curves calculated using 2007 cost bases. U.S. costs represent wellhead breakeven costs. Cost curves calculated assuming 10% real discount rate, ICF Hydrocarbon Supply Model

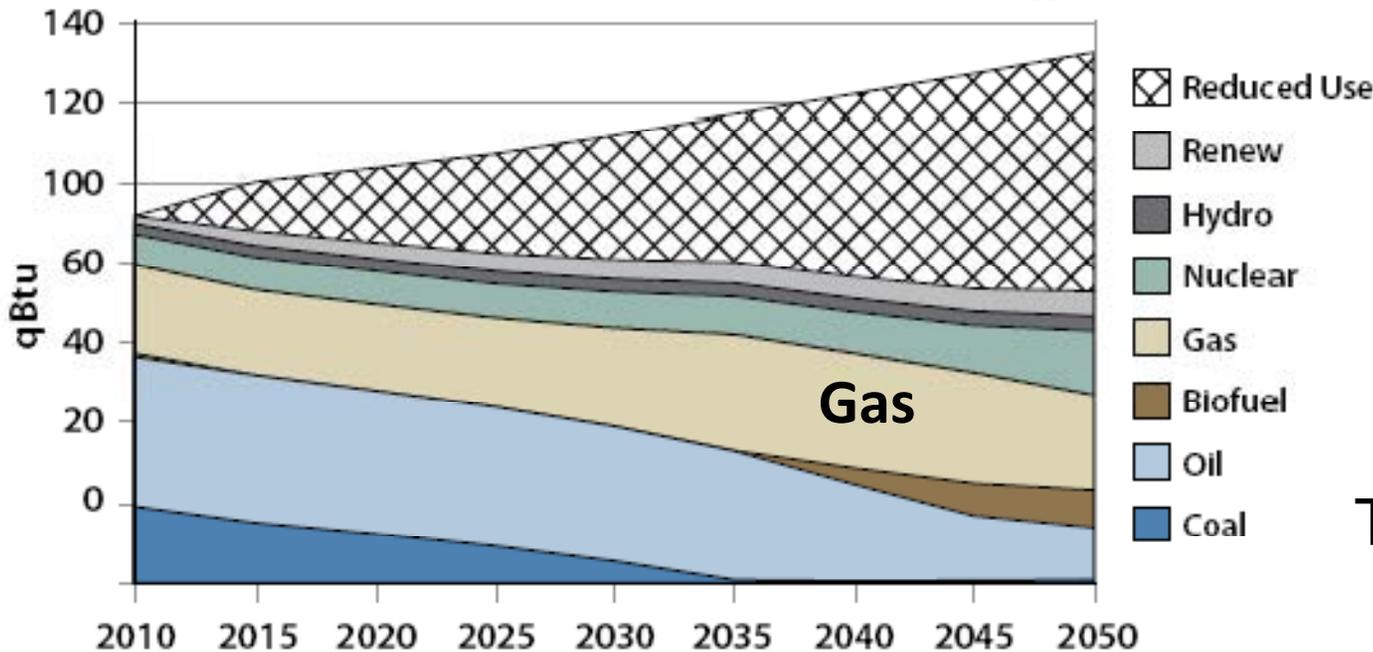


# MIT Future of Natural Gas Study



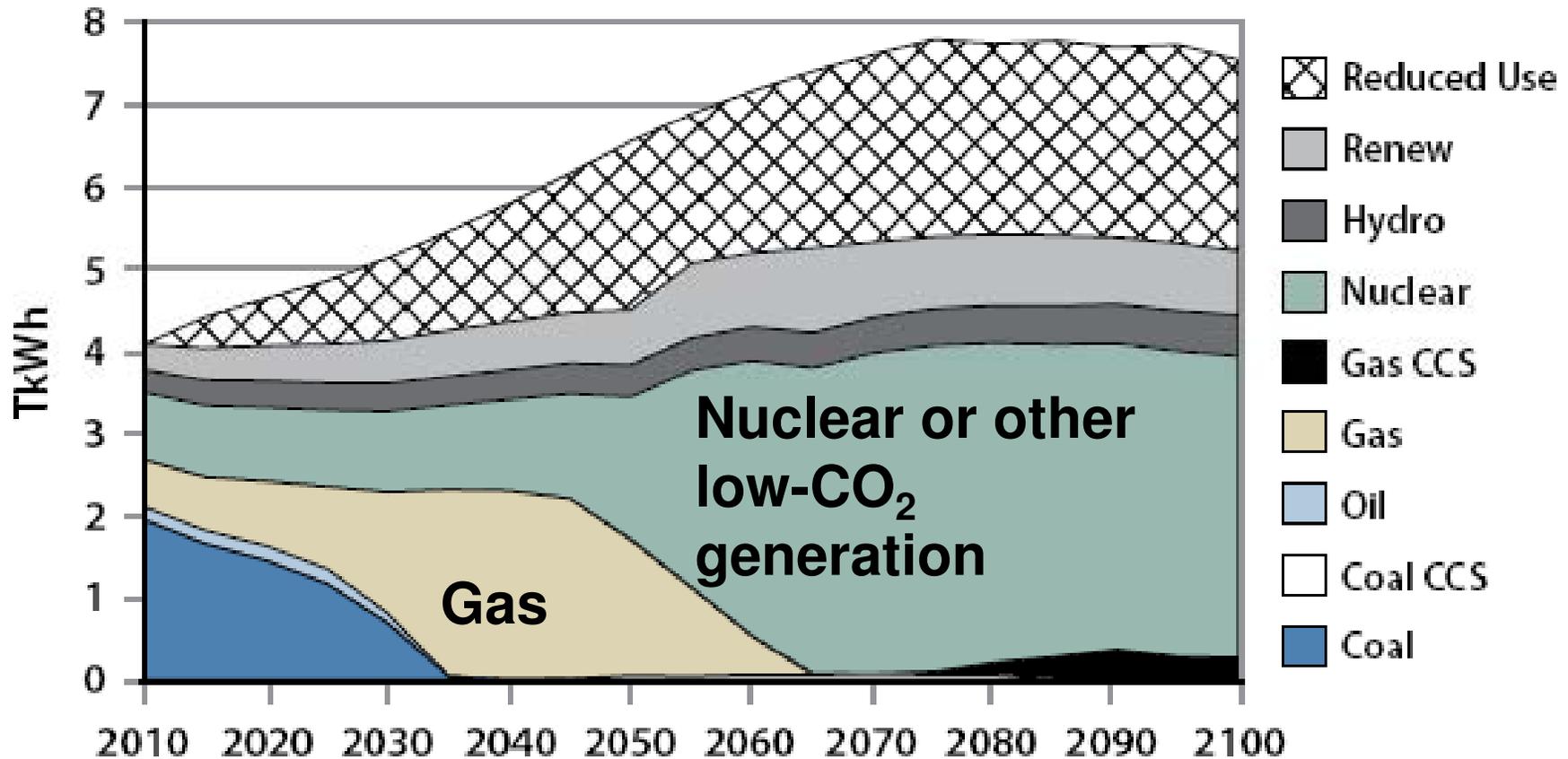
**Price-based mitigation**

50% by 2050  
No offsets



# Gas: A Bridge to ???

US power sector



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# Obama platform

- Climate policy elements
  - Economy-wide cap & trade
  - 1990 emissions levels by 2020 (14% reduction)
  - 80% reduction by 2050
  - Emissions credits auctioned
  - \$15B/year of auction revenue for clean energy RDD&D
- Major challenges
  - Financial crisis/deep recession
  - Regional differences/allocations?

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# Obama platform cont'd

- Efficiency programs
  - Federal energy consumption: -25% retrofit of Federal buildings in five years
  - National requirement for utility “decoupling” (authorities?)
  - Weatherize a million homes annually
  - Set national building efficiency goals

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# Obama platform cont'd

- International position
  - Re-engage and establish leadership after getting house in order
  - Convening role for G8+5 (China, India, Brazil, Mexico, South Africa)???
  - “China and Brazil must not be far behind”/time lag
  - Copenhagen? Cancun? ...?

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# Copenhagen Accord: Brazil, China, India, South Africa, USA

- Political vs treaty agreement
- Differentiated responsibilities acknowledged rationally
  - Different structure of national commitments, largely backed up by domestic legislative initiatives
  - Annex I/non-Annex I Kyoto construct largely superseded
  - Eliminate consensus straitjacket
  - Major emitters focus on **action**
- Start on transparency of monitoring and verification
- Critical role of adaptation acknowledged, with funds to least developed
- National responsibilities recorded for MANY countries
  
- Will UNFCCC process revive as central venue for negotiations? EU, Japan, Russia, Mexico, Indonesia,... position?
  - Major Economies Forum? G20? Other configurations of major emitters representing 80-90% of emissions?
- No real shot at 450 ppm CO<sub>2</sub>-eq?

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# Copenhagen Accord Registrations: Brazil, China, India, USA

- USA
  - CO2 emissions 17% below 2005 by 2020
  - 83% by 2050
  - Depends on Congressional action (above represent current discussions)
- China
  - 40-45% lower CO2/GDP by 2020
  - 15% non-fossil by 2020
  - 40M additional hectares forest by 2020
- India
  - 20-25% lower CO2/GDP by 2020
  - Near term implementation of standards on fuel efficiency and building energy use
  - 20% non-large-hydro renewables by 2020 (now 8%)
- Brazil
  - 36-39% less CO2 than BAU in 2020 (roughly 1994 levels)
  - Reduce deforestation by 80% vs historical practice in 2020
- EU
  - CO2 20% below 1990 levels by 2020
  - 30% if others play hard

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## Meeting US “commitments” to 2020?

- Demand reduction
  - Efficiency across sectors, but especially buildings and transportation
    - Electricity and NG for buildings, oil for transportation
- Displacement of existing coal (without CCS)
  - NG “repowering”
  - Bridge to somewhere?
    - Increased nuclear
    - Increased renewables/RES?
      - Intermittency? Unintended consequences?
- “Elephants in the room at UNFCCC negotiations!”
  - Nuclear and NG

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# Reshaping energy policy/DOE

- Authority to develop/implement energy policy
  - DOE has relatively little statutory or regulatory authority
  - Legislative process slow and yields mixed results
  - Congressional expansion of DOE authorities?
- Enhancing DOE energy technology innovation
  - Undersecretary for Science and Energy
  - Energy technology office reorganization from fuels to uses (e.g. transportation); portfolio approach around strategic objectives
  - Large scale demonstrations: Energy Technology Corporation with assured budgets and less management encumbrance
  - “Translational research” office (ARPA-E)
  - Innovation Hubs



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# Questions/Discussion

- Premise: there will be no comprehensive climate legislation for many years? If this proves to be correct:
- What should be the revised energy/climate strategy?
- What should be the policy with regard to intermittent renewables?
- How should we engage internationally?
- What should we do about DOE and energy technology innovation?

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Introduction to Sustainable Energy

Fall 2010

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