# Linking Climate Policy With Development Strategy:
## Options for Brazil, China, and India

**An Introduction to the Project by**


**John P. Holdren**

President and Director

**THE WOODS HOLE RESEARCH CENTER**

Teresa & John Heinz Professor of Environmental Policy

**HARVARD UNIVERSITY**


**Woods Hole Research Center Side Event**

**14th Conference of the Parties to the UNFCCC**

**Bali, 10 December 2007**

## Overarching Project Goal

Identify, analyze, and promote high-leverage approaches and corresponding policies for simultaneously reducing greenhouse-gas emissions below business-as-usual projections while advancing other development goals in Brazil, China, and India.

# Project structure

- Coordinated by the Woods Hole Research Center in cooperation with the Energy Technology Innovation Policy Project of the John F. Kennedy School of Government, Harvard University

- Conducted in collaboration with partner institutions in the Brazil, China, and India, under the guidance of an international advisory committee

- Funded by the William and Flora Hewlett Foundation

# Partner institutions & lead participants

BRAZIL

*Instituto de Pesquisa Ambiental da Amazônia* (P Moutinho)

CHINA

*Institute of Environmental Economics, Renmin University* (ZOU Ji); *China Automotive Technology and Research Center* (TIAN Dongmei ); *Institute of Thermoengineering Physics, Chinese Academy of Sciences* (WANG Bo )

INDIA

*Indian Institute of Technology - Bombay* (R Banerjee); *The Energy and Resources Institute (TERI)* (W N Kishore); *Indian Institute of Science - Bangalore* (N H Ravindranath); *Indian Institute of Management* – Ahmedabad (P R Shukla)

# Coordinating institution team leaders

WOODS HOLE RESEARCH CENTER

| | |
|---|---|
| Project leaders: | John P. Holdren and Joan Diamond |
| Brazil leader: | Daniel Nepstad |
| India leader: | Kirk R. Smith (visiting from UC Berkeley) |
| China leaders: | John P. Holdren and Kirk R. Smith |

HARVARD J. F. KENNEDY SCHOOL OF GOVERNMENT

| | |
|---|---|
| Project leader: | Kelly Sims Gallagher |
| China leaders: | Hongyan HE Oliver and ZHAO Lifeng |
| India leader: | Ambuj Sagar |

# International Advisory Committee

- Prof John P. Holdren, USA
- Prof José Goldemberg, Brazil
- Prof ZOU Ji, China
- Dr Ajay Mathur, India

# Motivation

The sponsors and participants hope to…

- Increase awareness of what is already being done in major developing countries to mitigate global climate change while achieving other societal goals.
- Advance the prospects for implementing additional high-leverage approaches having this character.
- Compare situations, perspectives, challenges, and opportunities in Brazil, China, and India to identify transferable insights, mutual interests, possibilities for cooperation within and beyond this set of countries.

# Why Brazil, China, and India?

- They represent
  - 40% of world population
  - 27% of Gross World Product (ppp)
  - 24% of world fossil carbon emissions
  - 23% of world primary energy use
- They are leaders among developing countries in economic growth, technological innovation, with large “win-win” potential for climate-change mitigation.
- The coordinating organizations -- Woods Hole Research Center & Harvard’s Kennedy School of Government – have long-standing ties to relevant research centers and governmental agencies in the focus countries.

# Brazil, China, India Comparisons, 2005

| | *Brazil* | *China* | *India* |
|---|---|---|---|
| Population, millions | 186 | 1306 | 1100 |
| GDP/pers, 2005$ (ppp) | 11200 | 7300 | 3700 |
| Total energy supply, EJ | 9 | 80 | 28 |
| Oil consumption, EJ | 4 | 15 | 5 |
| Oil imports, Mb/d | 0.1 | 3.4 | 1.7 |
| Electricity generation, TWh | 405 | 2475 | 679 |
| Fossil C emitted in $CO_2$, MtC | 91 | 1400 | 313 |

ppp = at purchasing-power parity, EJ = exajoules, TWh = terawatt-hours, MtC = megatons of carbon in $CO_2$. Total energy supply includes biomass fuels. Electricity generation is gross, not net. World figures: population 6420 million, ppp-GWP $58.7 trillion, total energy 515 EJ, oil 172 EJ, electricity 18184 TWh, fossil C emissions 7500 MtC

# Project research focuses for all countries

1. Identification and elaboration of one or more key intersections where development goals and greenhouse-gas mitigation opportunities overlap
2. Estimation of potential GHG reductions for specific opportunities, compared to accepted baseline scenarios, to the extent possible.
3. Assessment of the barriers (technological, economic, infrastructural, political) to achieving these savings.
4. Identification of the elements of strategies for overcoming those barriers.

# Country / sectoral focuses

BRAZIL

- Avoided deforestation

  additional benefits in water management, fire reduction, bio-diversity preservation, local jobs in sustainable community forestry

CHINA

- Motor-vehicle fuel efficiency, advanced coal technologies

  additional benefits in air-pollution reduction, reduced oil dependence

INDIA

- Advanced coal technologies, electricity transmission, distribution, & end-use; biomass gasification for heat & power; household/institutional cookstoves

  additional benefits in reductions in indoor and outdoor air pollution, reduced oil dependence, biomass-based regional economic development

# The costs and benefits of reducing carbon emissions from deforestation and forest degradation in the Brazilian Amazon

**Daniel Nepstad**

**Linking Climate Policy With Development Strategy:**
**Options for Brazil, China, and India**

Support: William and Flora Hewlett Foundation

The Woods Hole Research Center

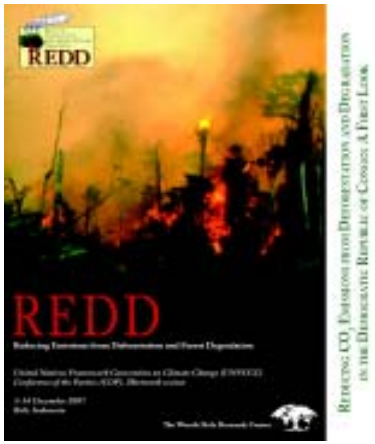
IPAM - INSTITUTO DE PESQUISA AMBIENTAL DA AMAZÔNIA

UFMG

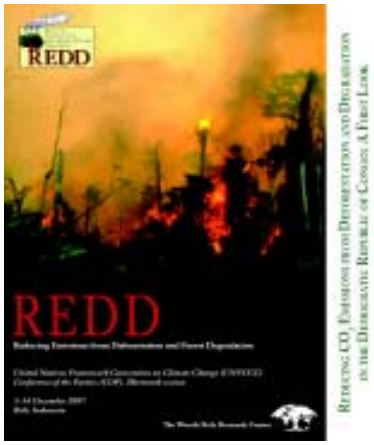
With:

Britaldo Soares-Filho (Univ. Federal Minas Gerais)
Frank Merry (Woods Hole Research Center)
Paulo Moutinho (Instituto de Pesquisa Ambiental da Amazonia)
Steve Schwartzman (Environmental Defense)
Oriana T. Almeida (Universidade Federal do Para, IPAM)
Sergio Rivero (UFPa)
Maria Bowman (WHRC)

# Publications available here

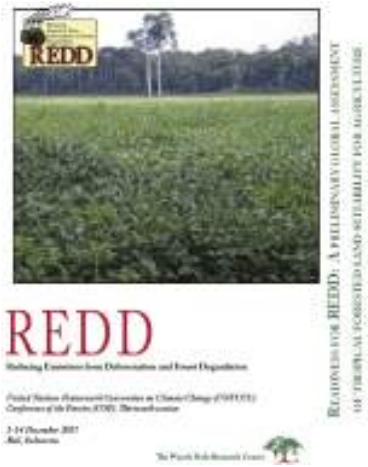



Brazilian Amazon



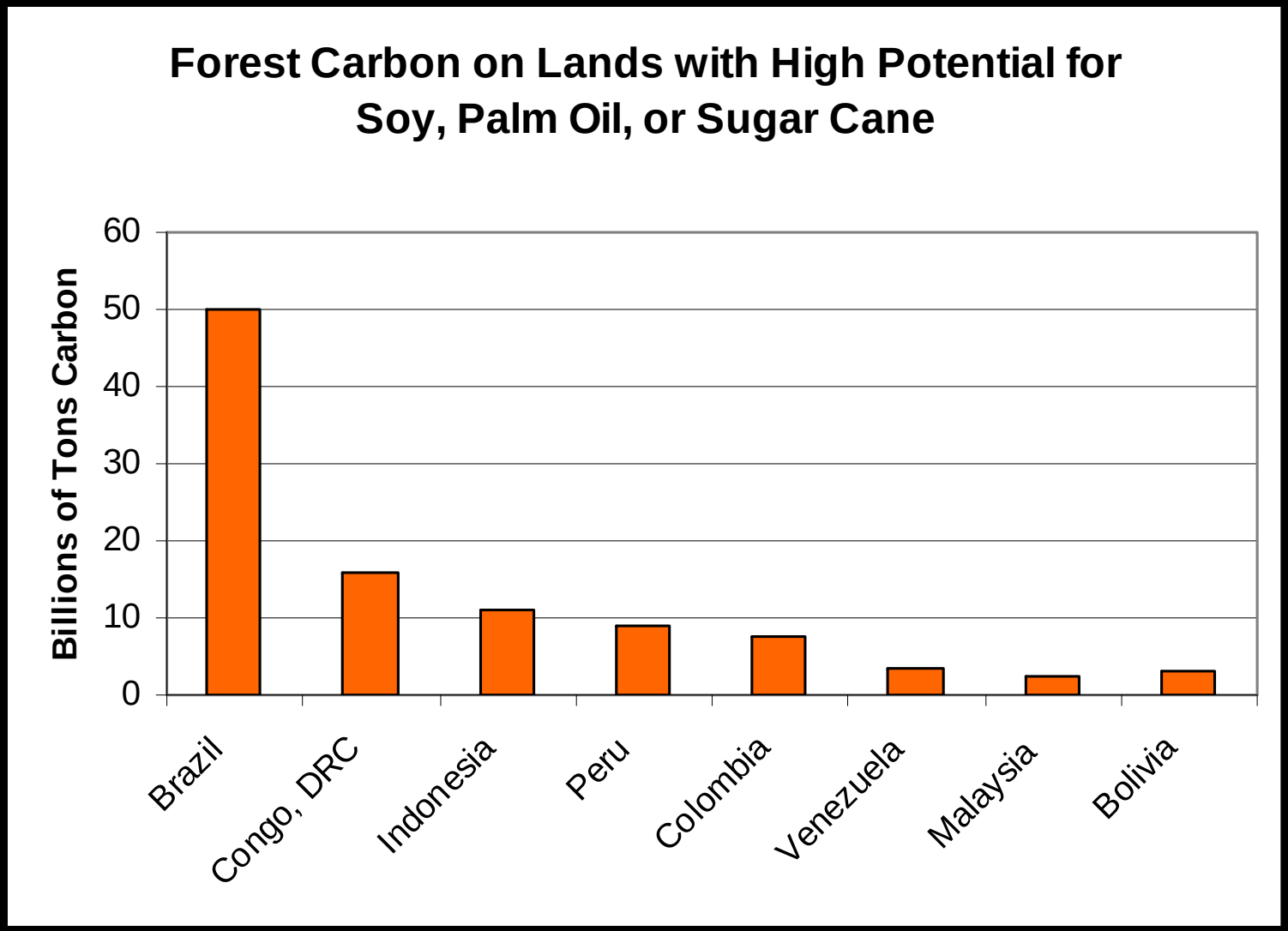

DR of Congo

ALOS forest mapping




Crop suitability

whrc.org/BaliReports


Forest Carbon on Lands with High Potential for Soy, Palm Oil, or Sugar Cane
Billions of Tons Carbon
60
50
40
30
20
10
0
Brazil
Congo, DRC
Indonesia
Peru
Colombia
Venezuela
Malaysia
Bolivia

How much will REDD cost?

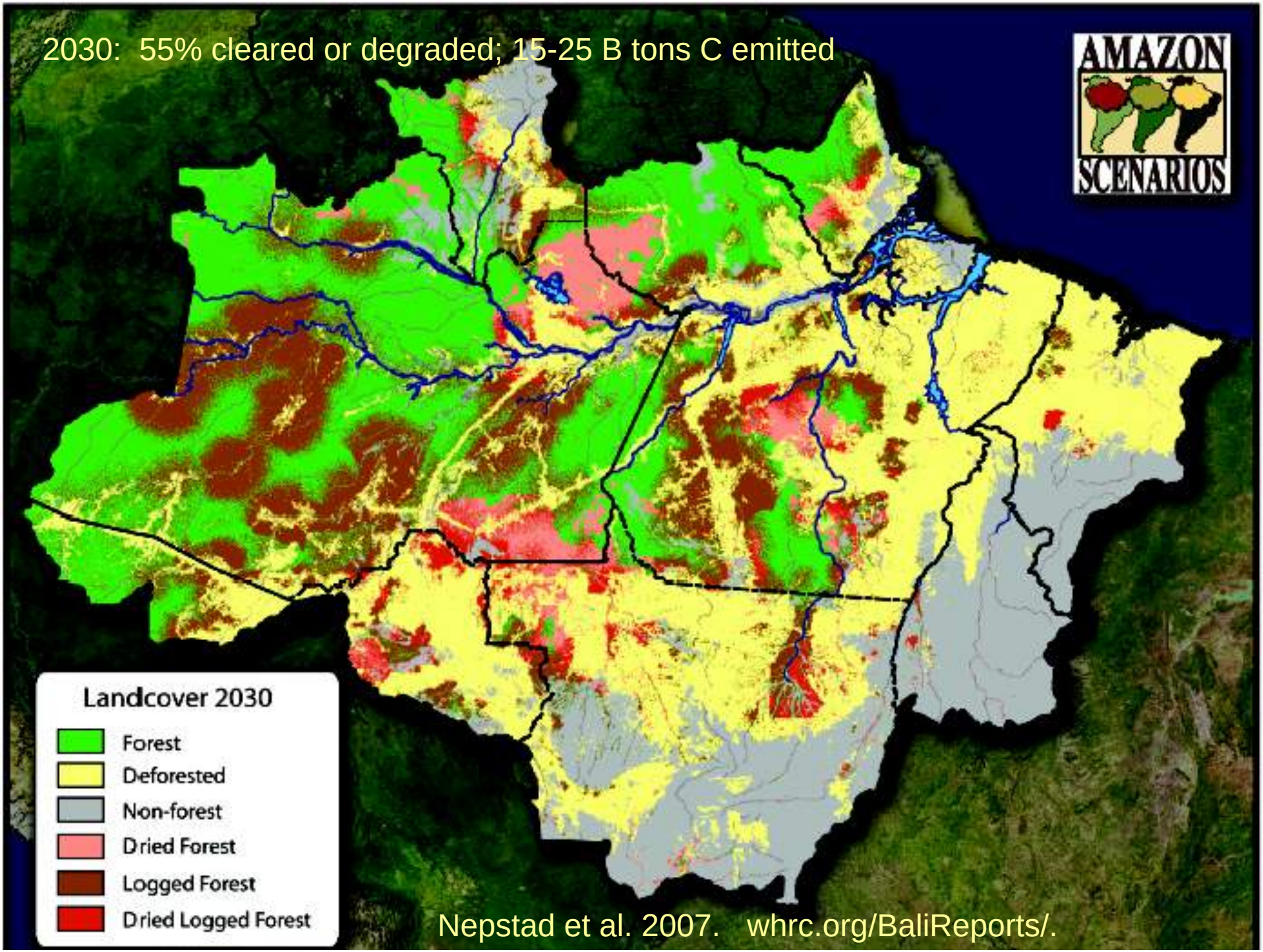
Most of the estimates from global models—tens of $B per year

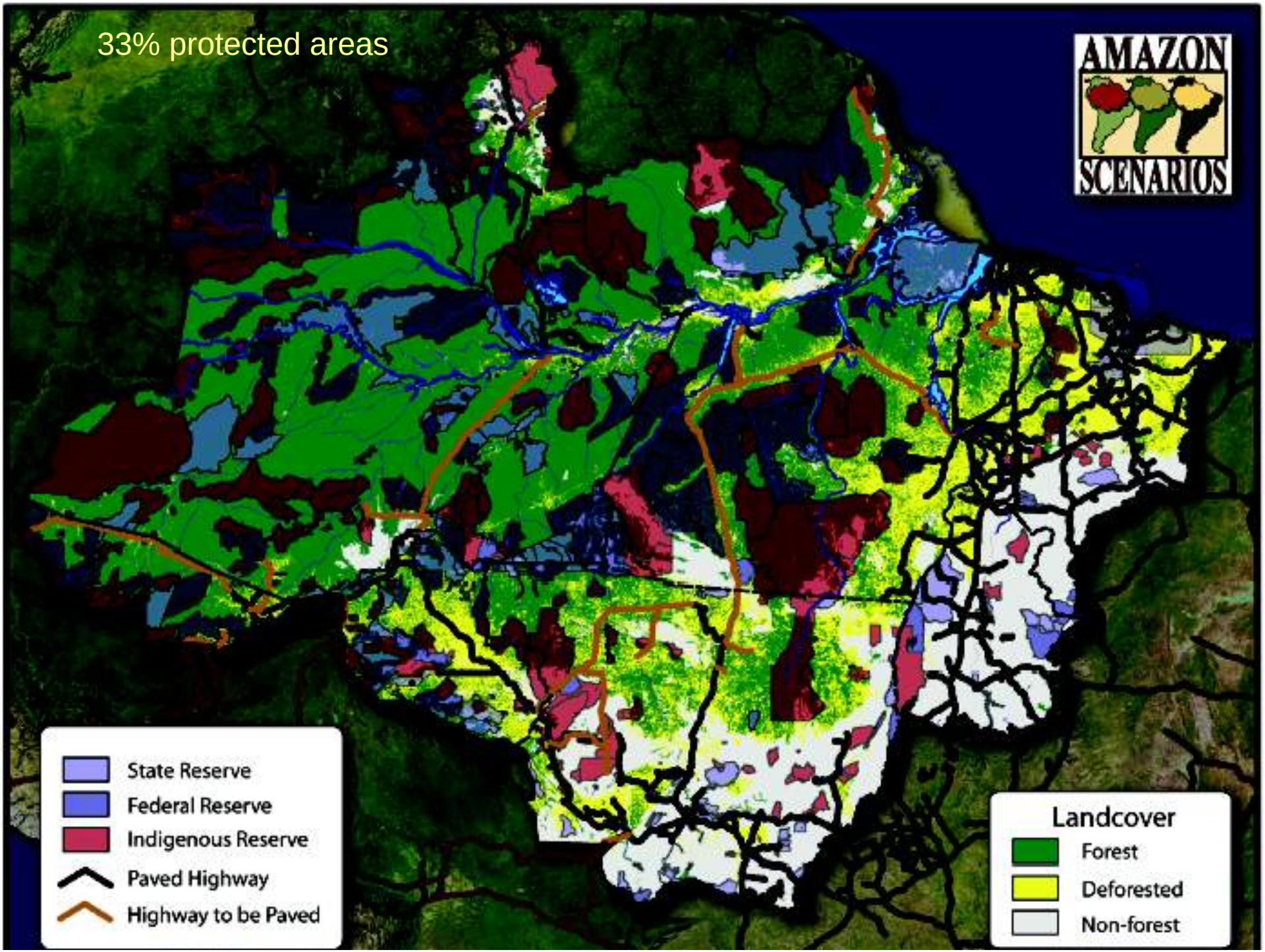
We provide an estimate of the cost of REDD building from the ground up

Two approaches:

1. Opportunity costs of reducing forest clearing (using spatial rent models)

2. Illustrative example of actual costs for compensating (a) Forest People, (b) the Private Sector, and (c ) the Government


2030: 55% cleared or degraded; 15-25 B tons C emitted
AMAZON
SCENARIOS
Landcover 2030
Forest
Deforested
Non-forest
Dried Forest
Logged Forest
Dried Logged Forest
Nepstad et al. 2007. whrc.org/BaliReports/.


33% protected areas
AMAZON
SCENARIOS
State Reserve
Federal Reserve
Indigenous Reserve
Paved Highway
Highway to be Paved
Landcover
Forest
Deforested
Non-forest

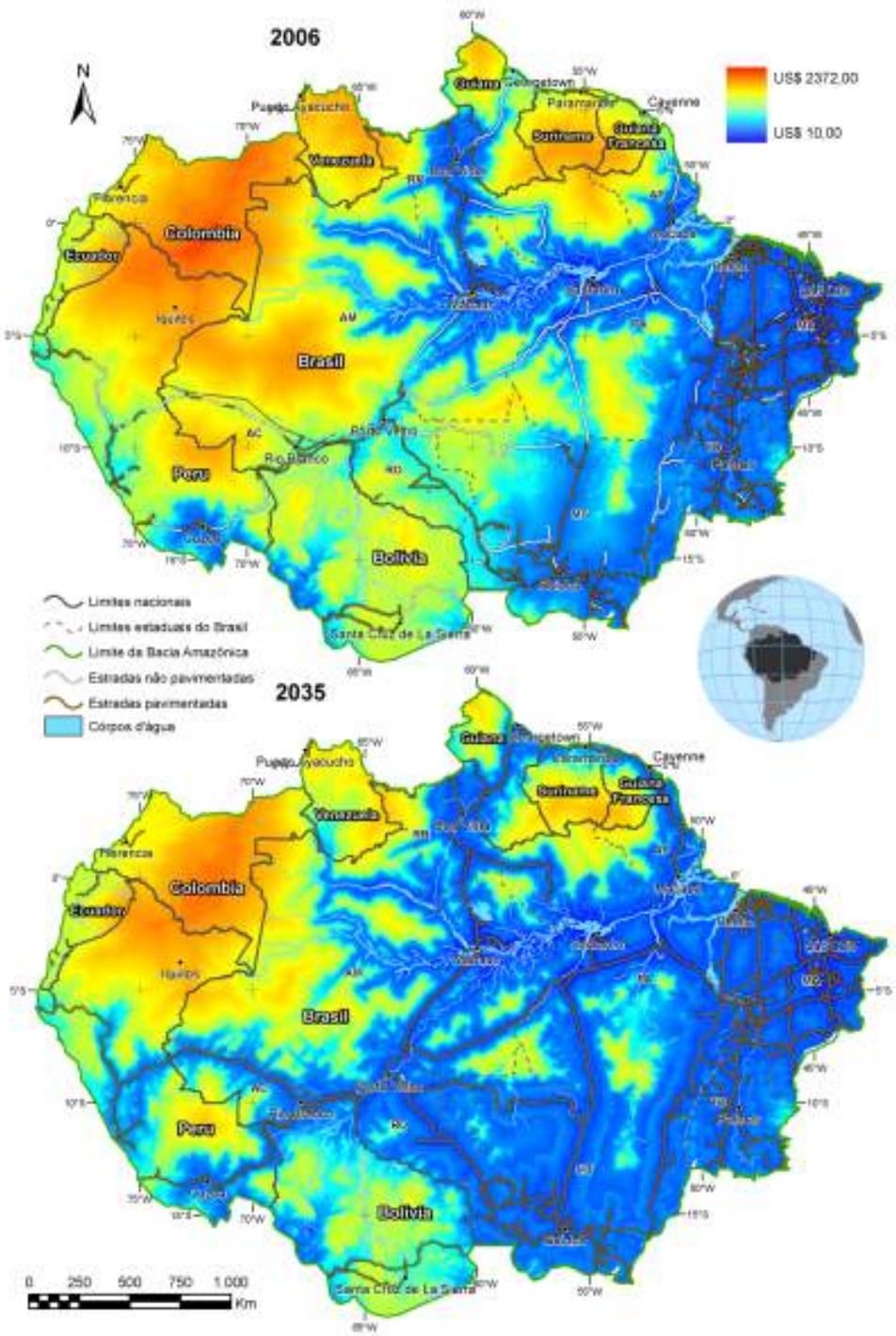
Approach 1:  Opportunity Costs

Net Present Value of deforestation-dependent activity (soy, cattle) divided by associated reduction in carbon stock

*with and without potential revenues from sustainable forest management*

*NPV for 30-yrs with schedule of highway paving*

# Opportunity costs of foregone profits from soy

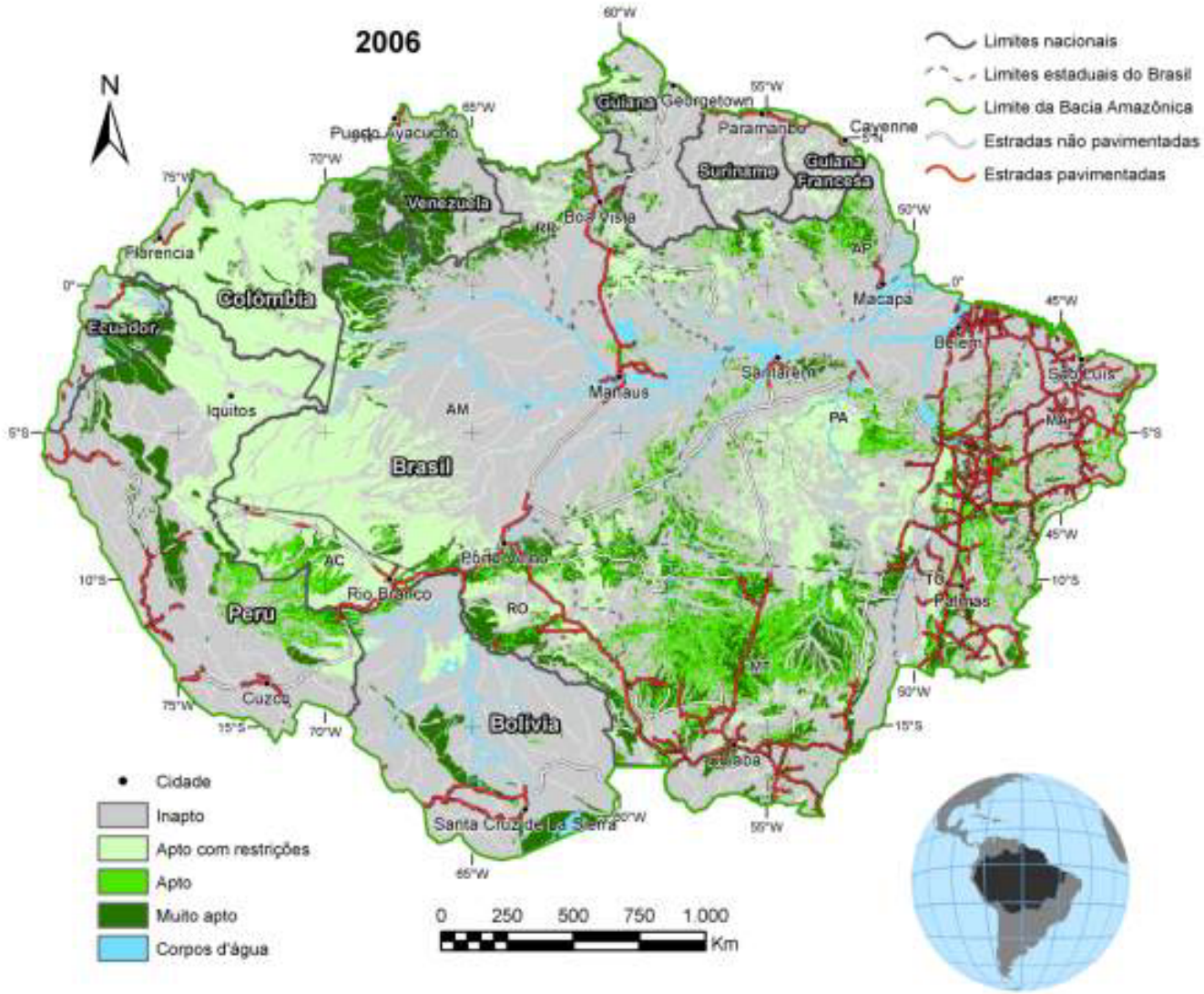



The costs of transporting soybeans to the nearest international port in 2006 and 2035, with projected highway paving.

Other model components:
-yield
-other costs (fertilizer, inputs)

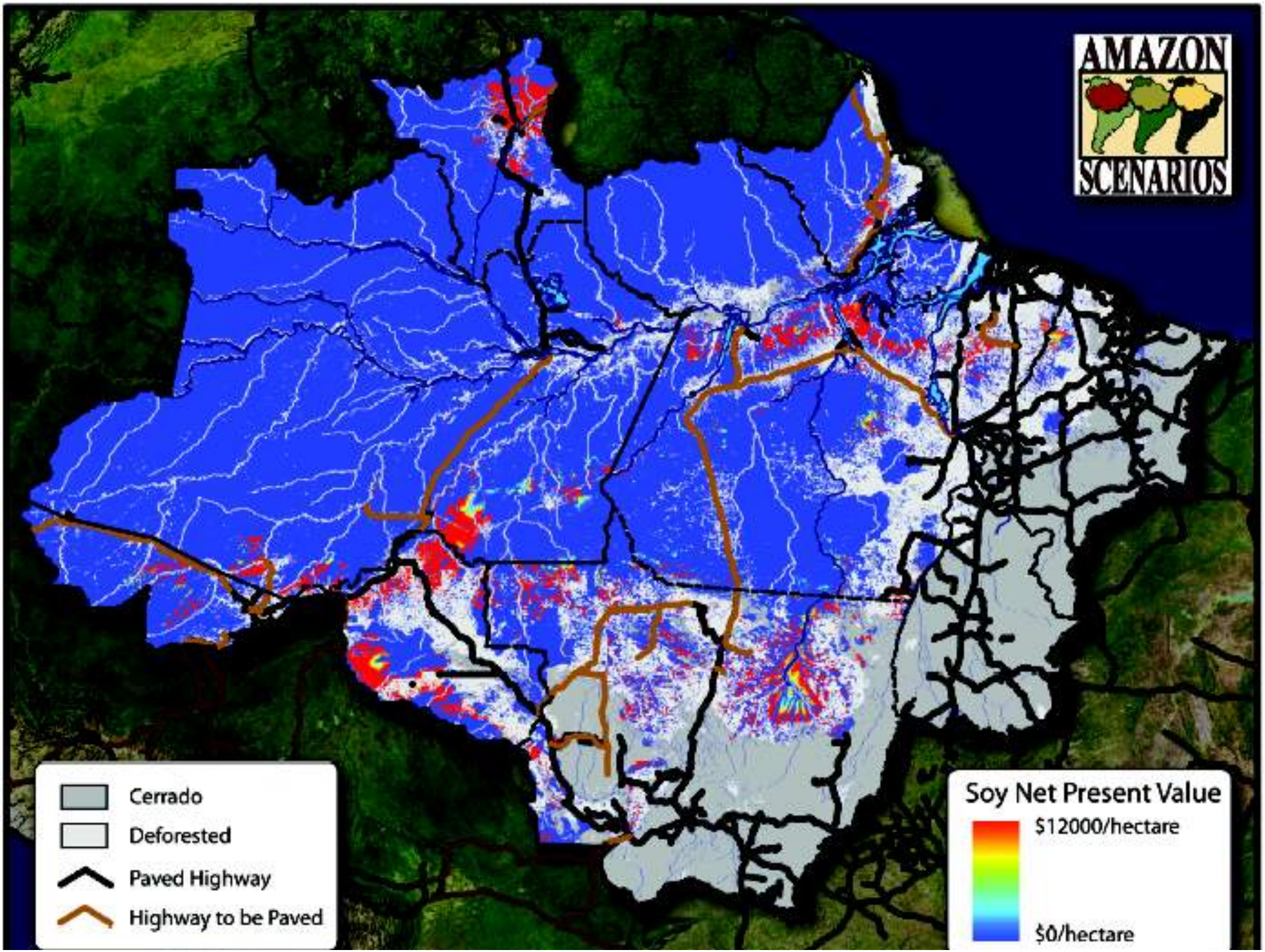
From: Vera Diaz et al. 2007 Ecol Econ, Soares-Filho et al. 2006 Nature

# Soil suitability for soy:  slope, soil quality, inundation




Nepstad et al. in press Phil Trans. R. Soc.

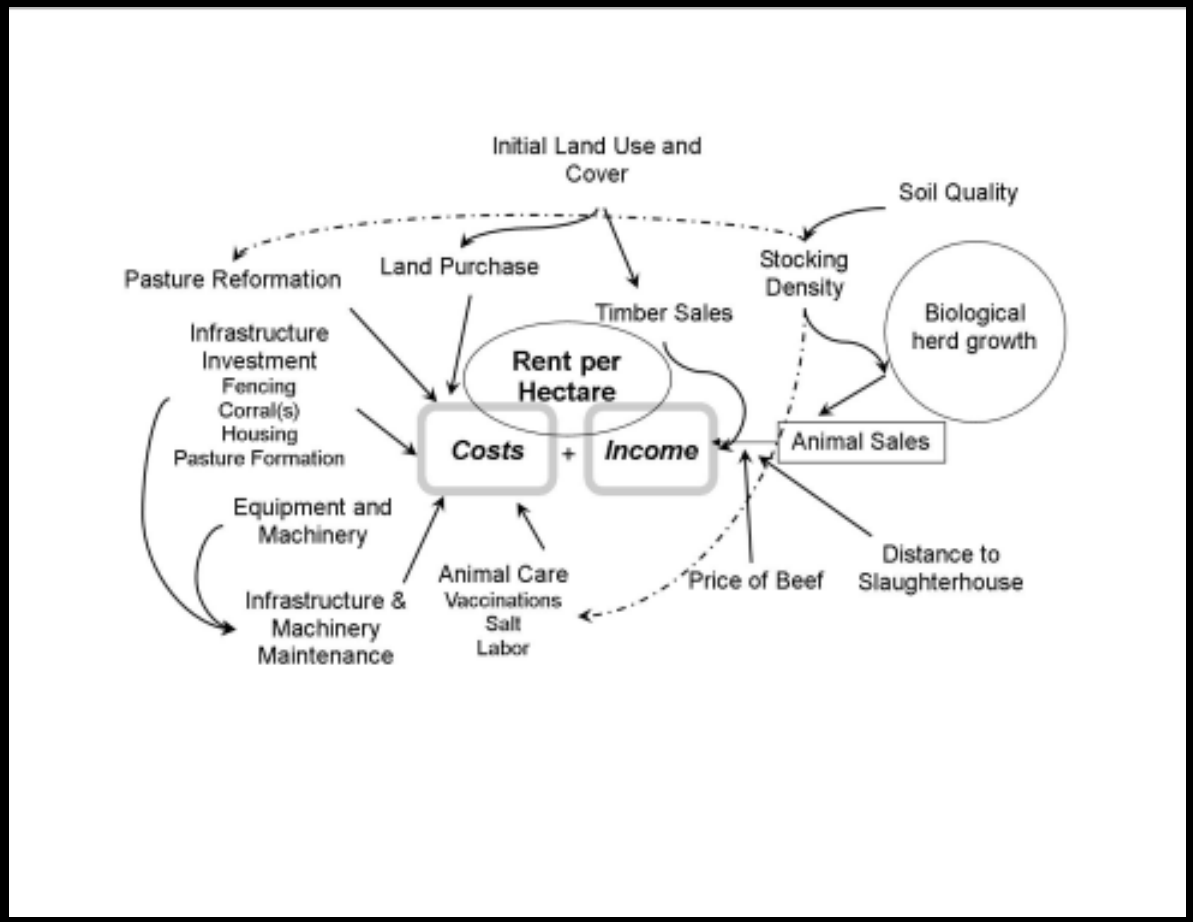
Whrc.org/BaliReports/


AMAZON
SCENARIOS
Cerrado
Deforested
Paved Highway
Highway to be Paved
Soy Net Present Value
$12000/hectare
$0/hectare

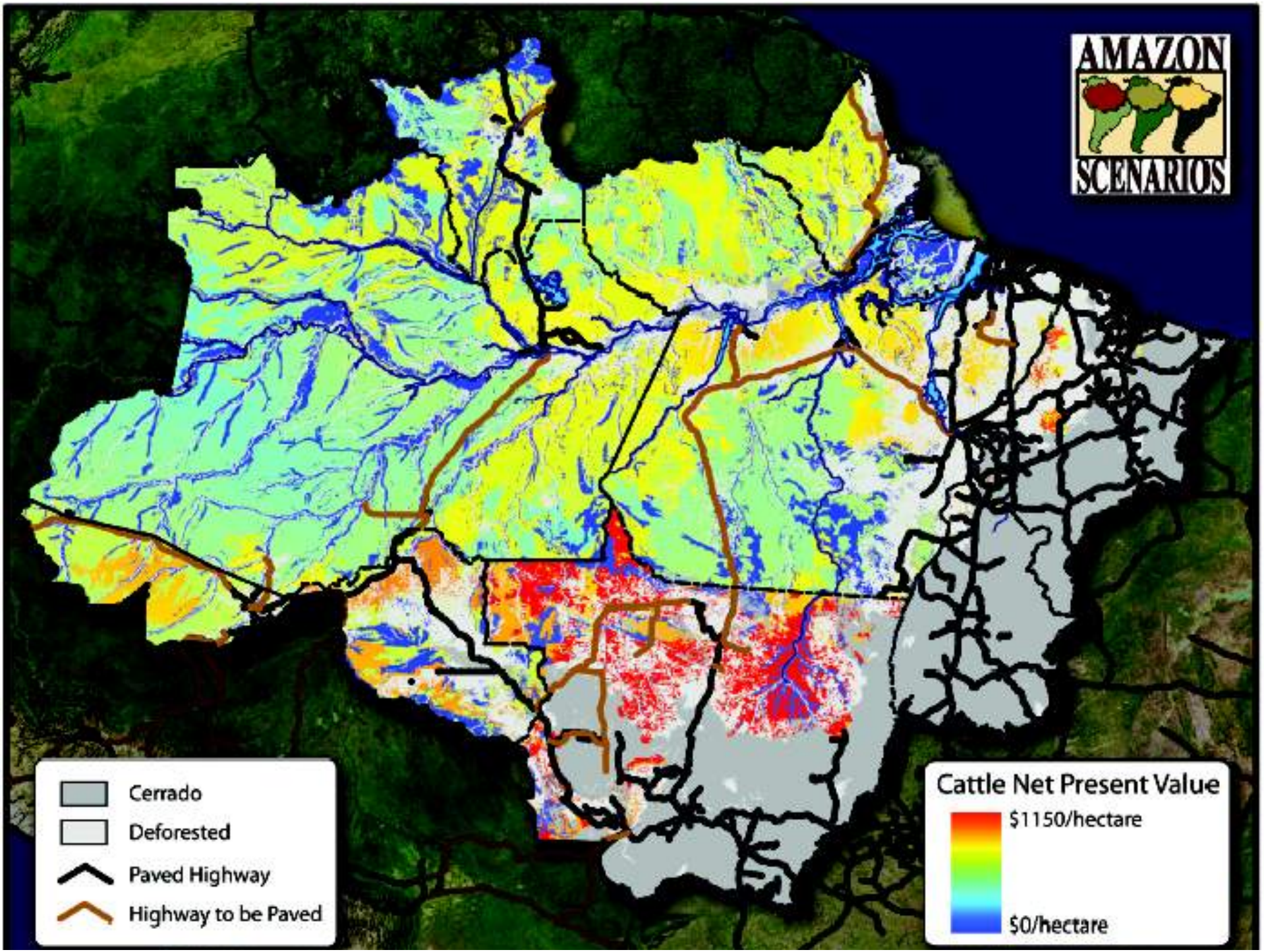
Opportunity costs of foregone profits from cattle production

*70-80% of deforestation today is driven by cattle pasture formation*

# The cattle rent model




Merry et al. In prep.

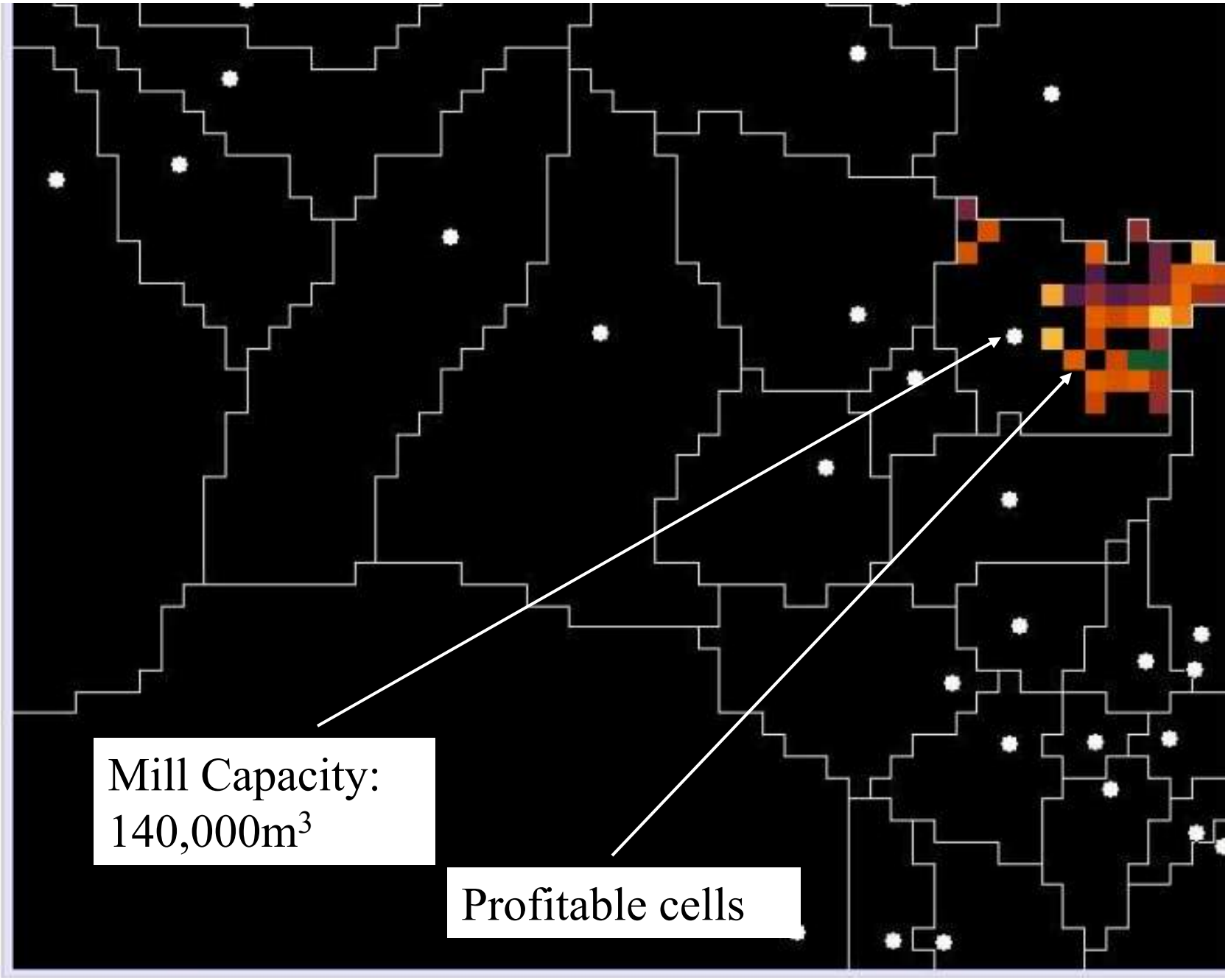

AMAZON
SCENARIOS
Cerrado
Deforested
Paved Highway
Highway to be Paved
Cattle Net Present Value
$1150/hectare
$0/hectare

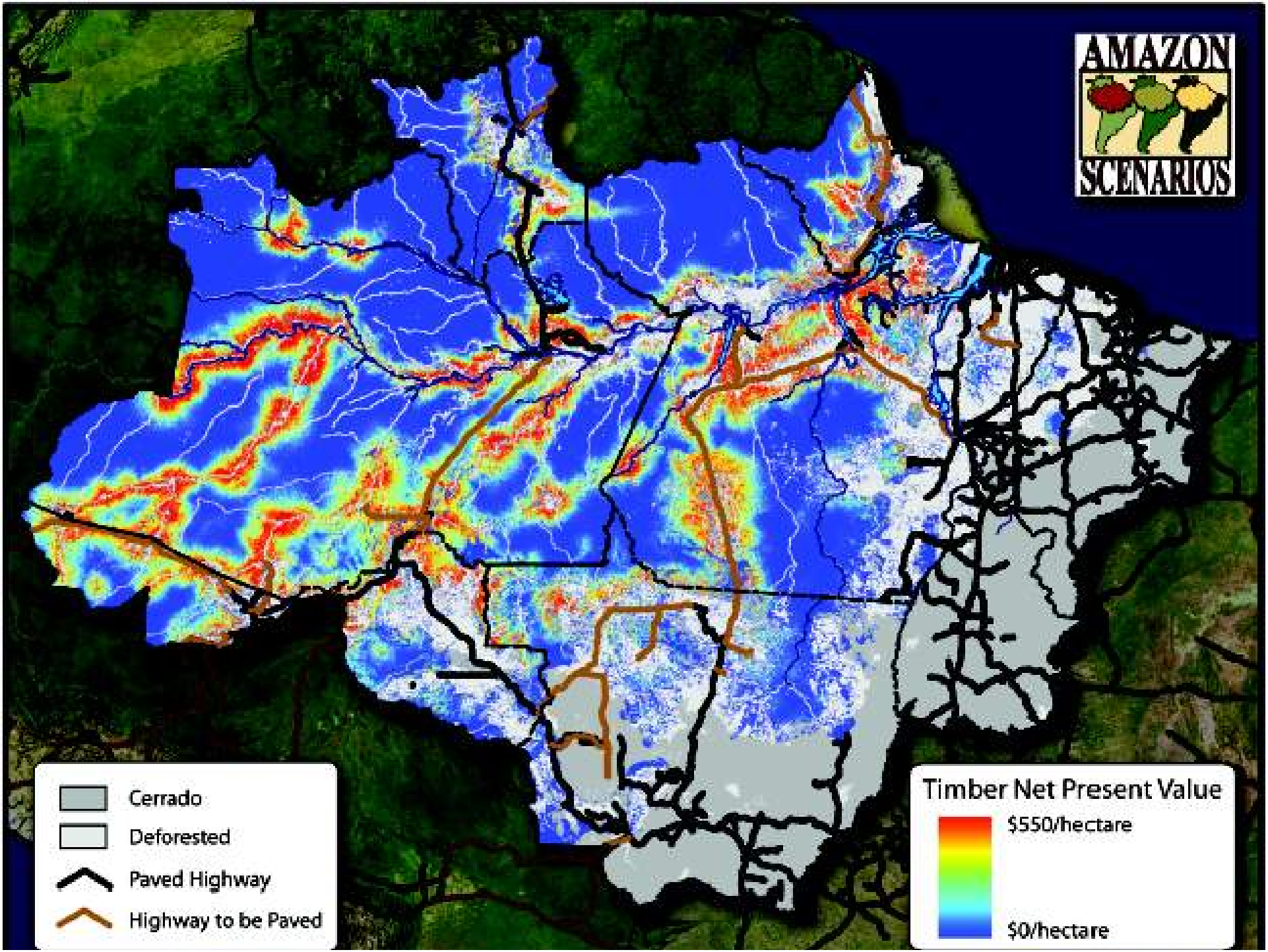
Opportunity costs of foregone profits from sustainable timber production

*Restricts processing centers to 1/30$^{th}$ of commercial volume per year*

*Estimates commercial volumes, processing capacity, harvesting costs, birth and extinction of processing centers*

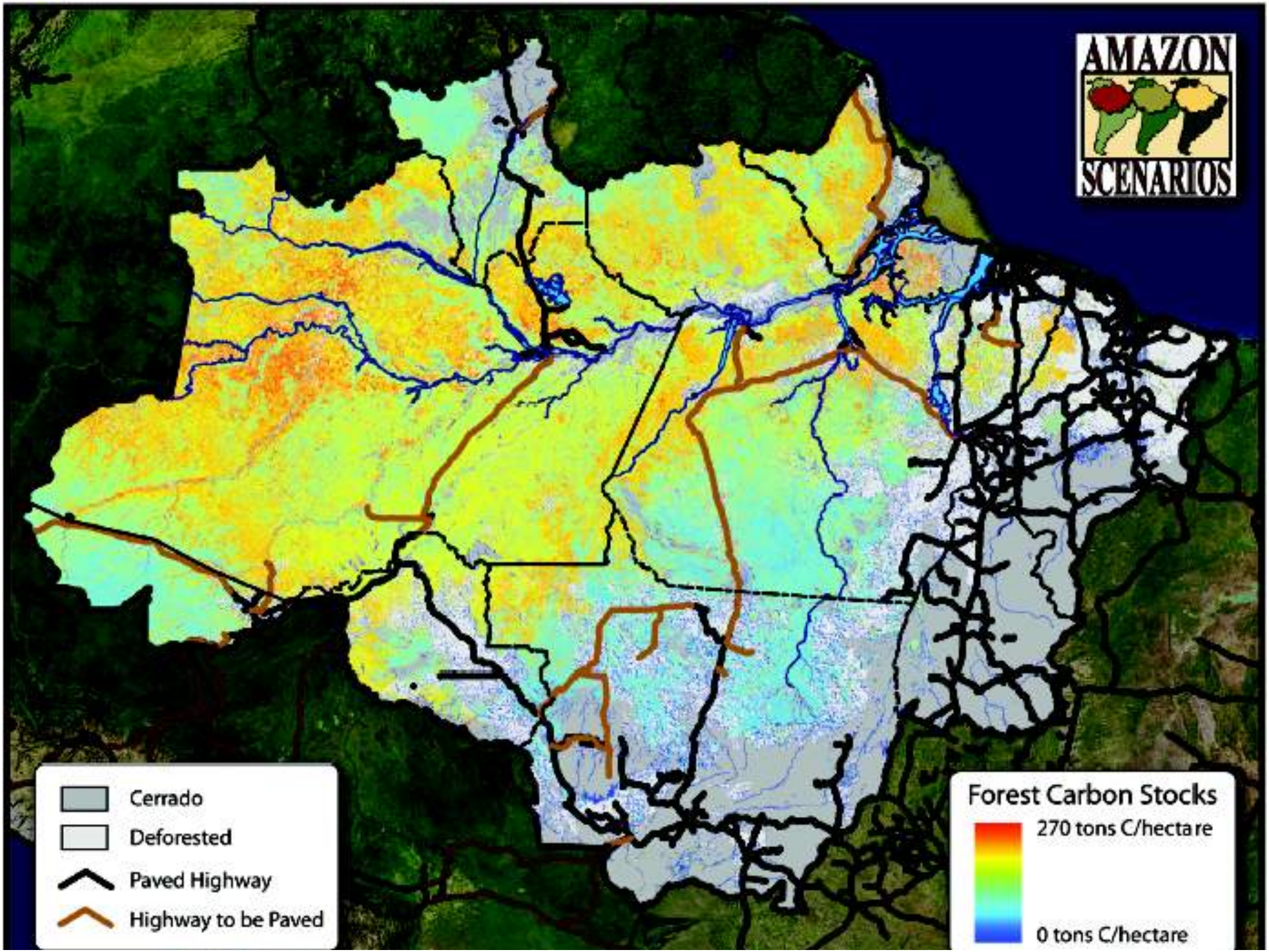
*Merry et al. In review. Proc. Nat. Acad. Sci.*

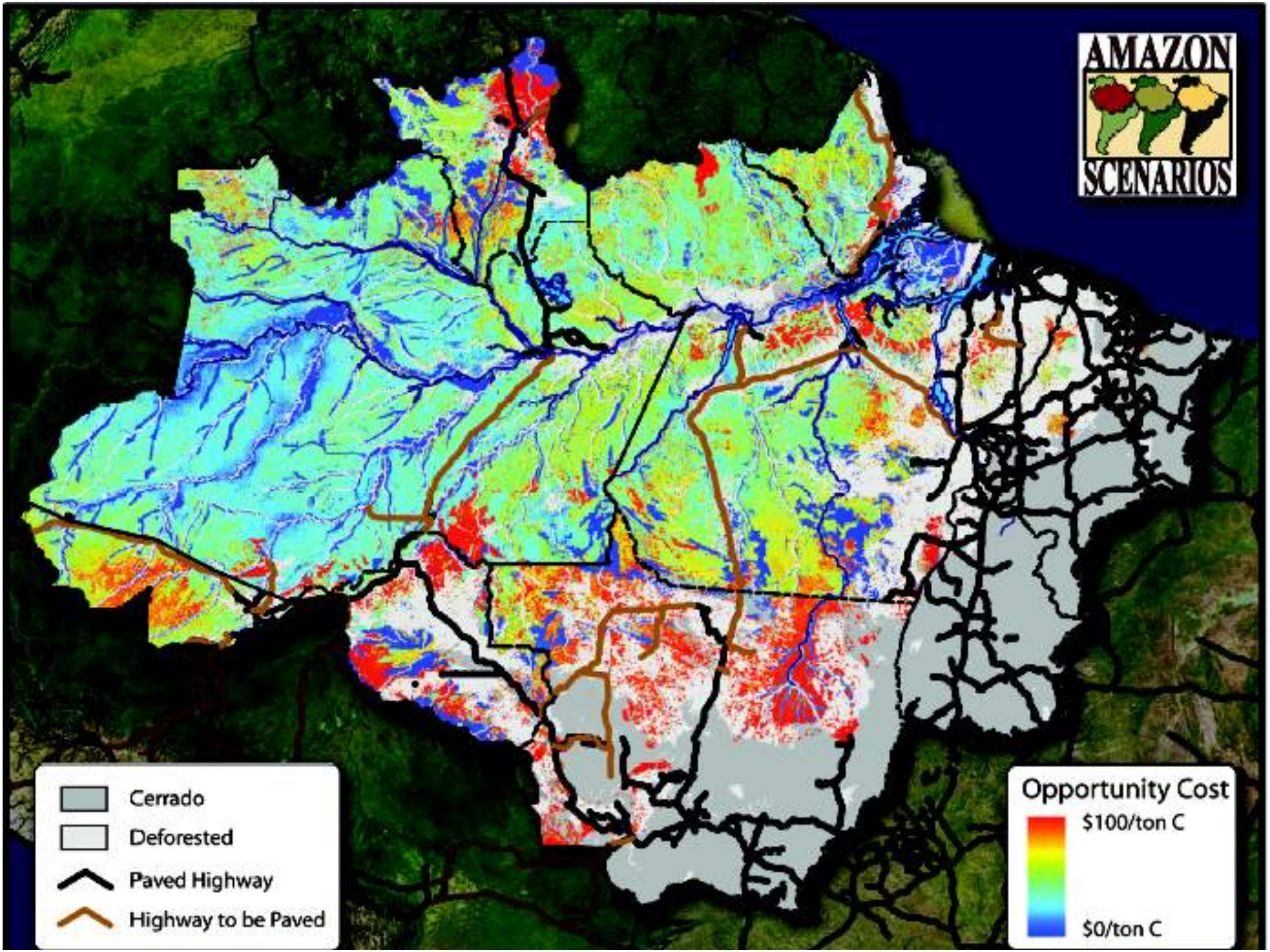

Mill Capacity:
140,000m3
Profitable cells


AMAZON
SCENARIOS
Cerrado
Deforested
Paved Highway
Highway to be Paved
Timber Net Present Value
$550/hectare
$0/hectare

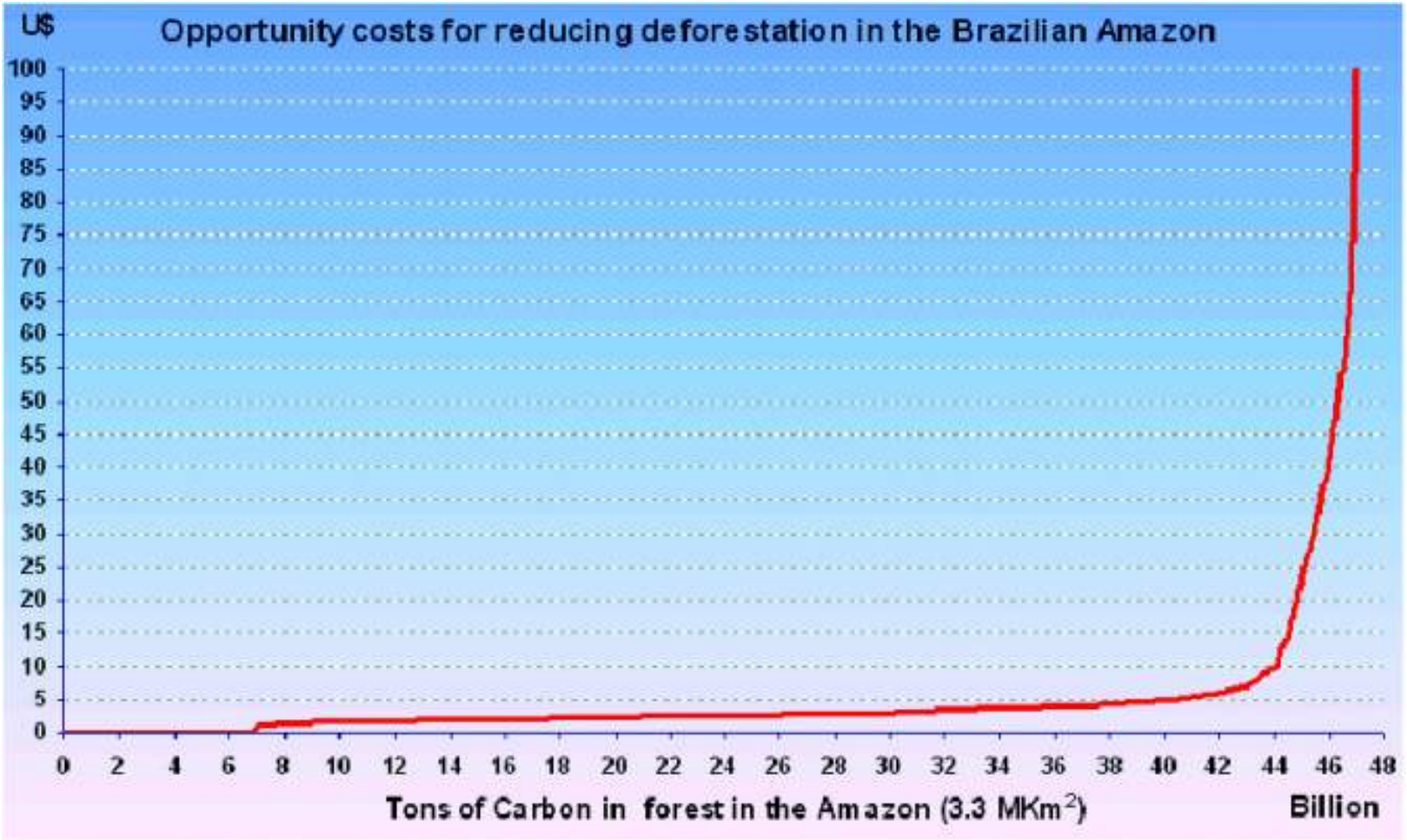
# Forest carbon stocks (including roots)

Saatchi et al. 2007


AMAZON
SCENARIOS
Cerrado
Deforested
Paved Highway
Highway to be Paved
Forest Carbon Stocks
270 tons C/hectare
0 tons C/hectare


AMAZON
SCENARIOS
Cerrado
Deforested
Paved Highway
Highway to be Paved
Opportunity Cost
$100/ton C
$0/ton C

Forest carbon stock: 48 B tons
Total opportunity costs of remaining forests: $257B
Cost per ton C: 90% <$5 94% <$10
Impact of including timber management: 4%



*How much will it cost in practice?*

Forest People Fund ("Public Forest Stewardship Fund")

- Forest family subsidy ($1,200/yr)
- Forest protection/management ($10/km2)

## *How much will it cost?*

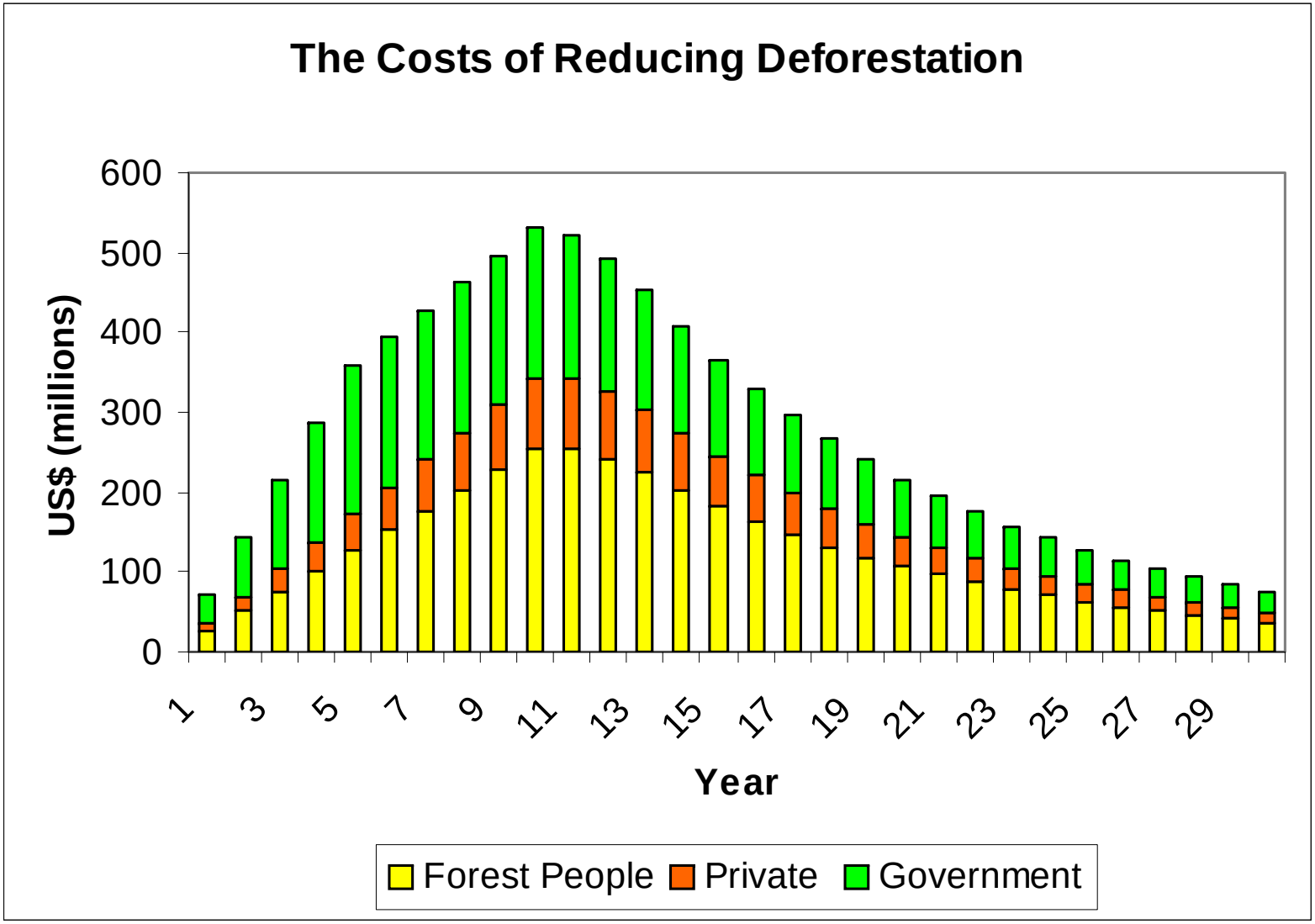
### Private Forest Stewardship Fund

- 100% compensation of opportunity costs for forests beyond legal requirement
- 20% compensation for forests required by law

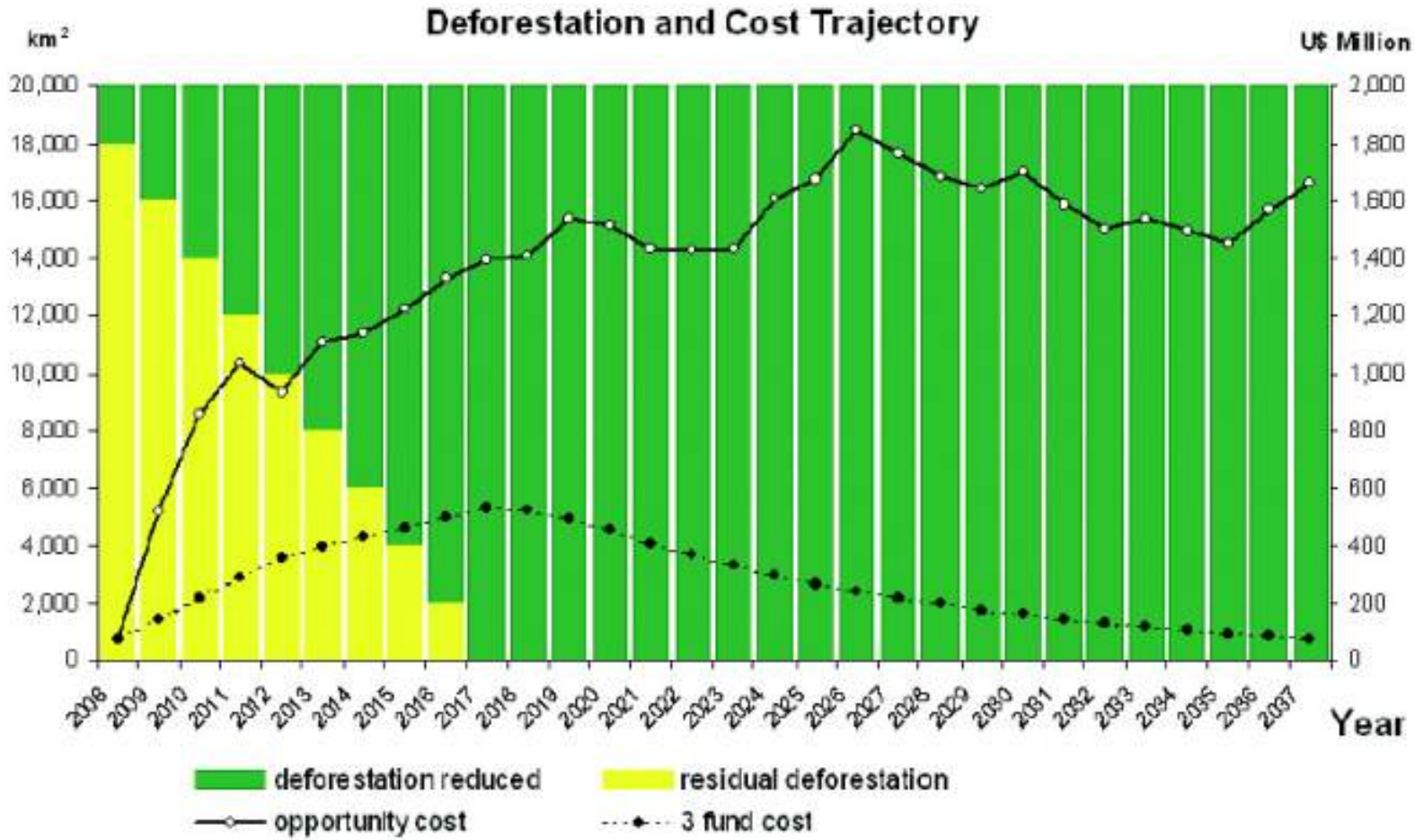
## *How much will it cost?*

### Government Fund

- Public land protection/management ($20/km2/yr)
- Protected area creation ($50/km2)
- Private land licensing/monitoring $10M/yr)
- Services (heatlh, education, credit) ($700/family/yr)


The Costs of Reducing Deforestation
US$ (millions)
600
500
400
300
200
100
0
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
Year
Forest People
Private
Government

30 years of REDD:
Carbon emission reduction below baseline (6.3 B tons)
Carbon emission reduction below projected (~20 B tons)




The price of carbon:
Full compensation of $41B in opportunity costs=$6.5/ton C
Adjusted costs = $1.2/ton C

# Co-Benefits of REDD

- Doubled income for 200,000 rural families
- Improved health, education, justice
- Biodiversity conservation
- Regional climate protection—rainfall
  - Within Amazon
  - South-Central Brazil: hydroelectric, agriculture
- Fire-related: $11 to 80 million per year
  - Respiratory illness
  - Agricultural damages
  - Forestry damages

Conclusions:

*1. REDD may be much cheaper than previous analyses suggest*

*2. Opportunity cost as a ceiling on the cost of REDD*

*3. Long-term revenue for tropical forest countries*

*4. Slow rates of reductions = low impact on carbon market*

*5. Substantial benefits for indigenous people, biodiversity, regional climate`*

# Linking Climate Policy With Development Strategy: The China Case Study

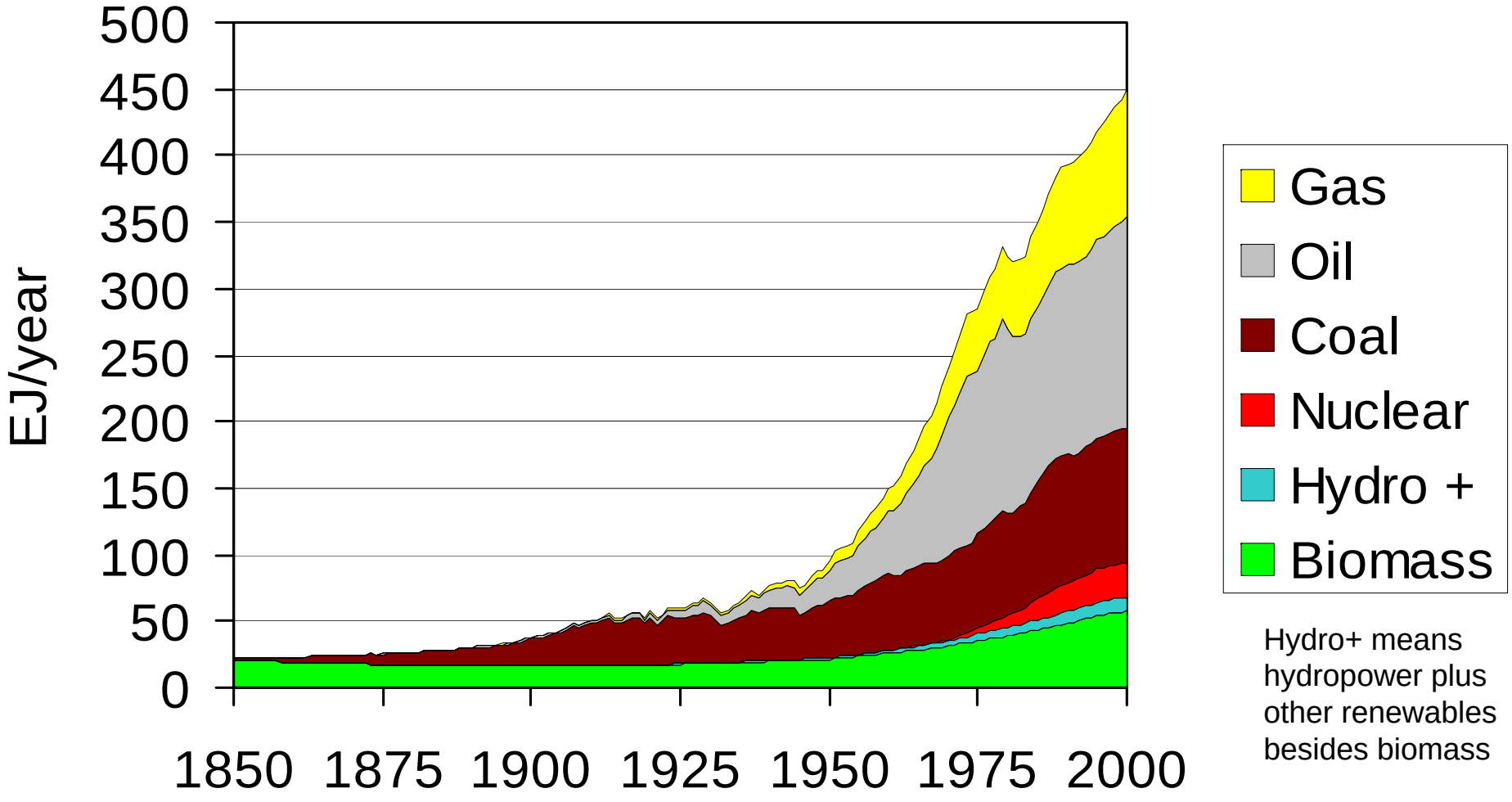
**John P. Holdren**
Director, Woods Hole Research Center

*substituting for*

**ZOU Ji**
Director, Institute of Environmental Economics
Renmin University

# Motivation

# Coal, oil, & gas have fueled world energy growth for 150 years




Hydro+ means hydropower plus other renewables besides biomass

**Energy supply grew 20-fold between 1850 and 2000.**

# Fossil fuels continued to dominate in 2005

| | | World | USA | China |
|---|---|---|---|---|
| **Primary Energy (exajoules)** | | **514** | **106** | **80** |
| of which… | Oil | 34% | 40% | 18% |
| | Natural Gas | 21% | 24% | 2% |
| | Coal | 26% | 25% | 62% |
| | Nuclear Energy | 6% | 8% | 0.6% |
| | Hydropower | 2% | 1% | 2% |
| | Biomass and Other | 11% | 3% | 15% |

**Fossil-fuel dependence was 81% for the world, 82% for China, 88% for the United States**

## **Energy Supply, 2005** (continued)

About 1/3 of primary energy is used to generate electricity

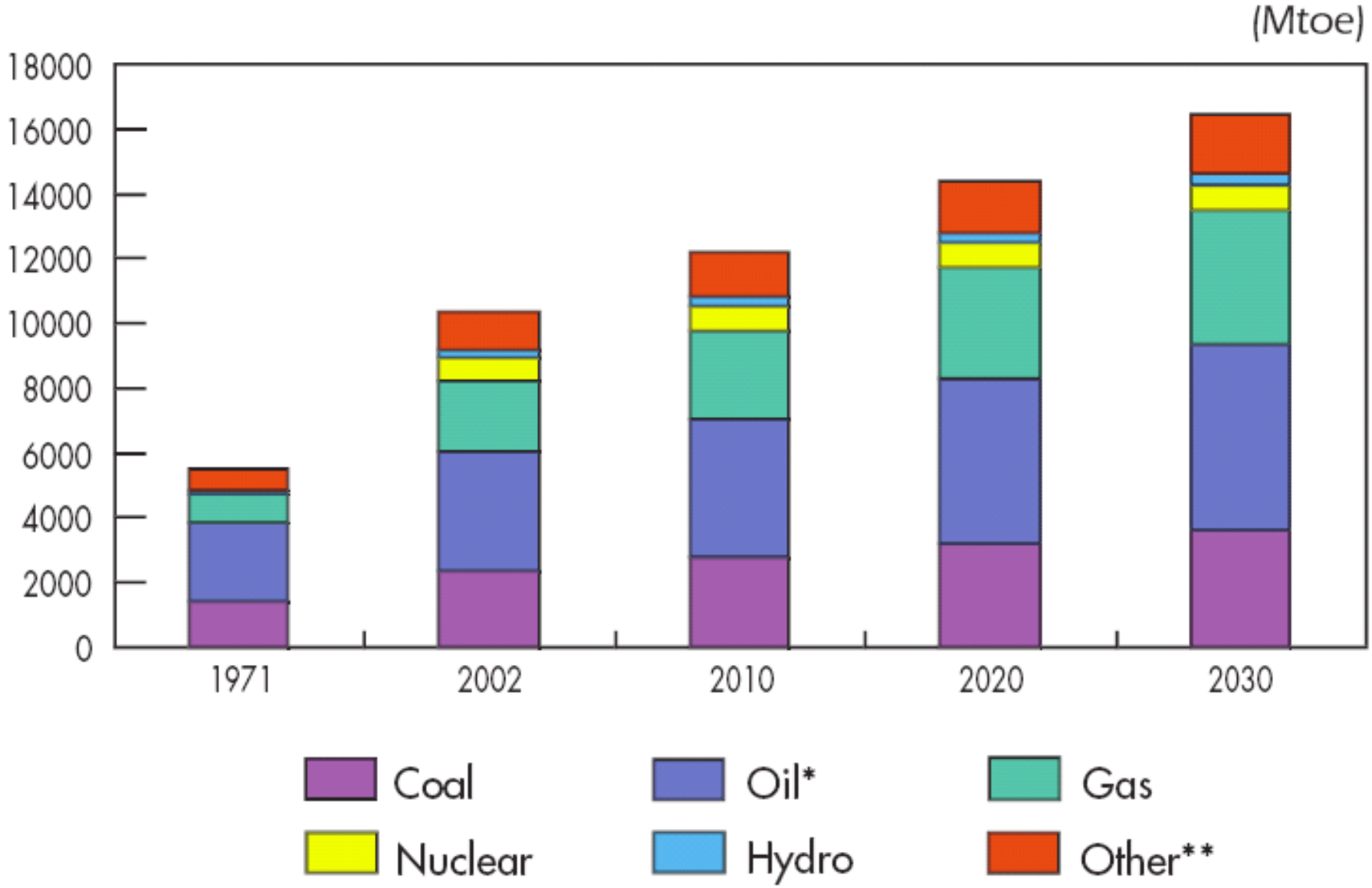
| | **World** | **USA** | **China** |
|---|---|---|---|
| **Net Electricity** (billion kWh) | **17300** | **4000** | **2400** |
| of which... | | | |
| coal | *40%* | *50%* | *80%* |
| oil & gas | *26%* | *21%* | *3%* |
| nuclear | *16%* | *20%* | *2%* |
| hydropower | *16%* | *7%* | *15%* |
| wind, geo, solar | *2%* | *2%* | *0.1%* |

**Nuclear energy supplies ~1/6 of the world's electricity.**

## “Reference” growth through the 21st century leads to huge energy & electricity increases

- World use of primary energy reaches 2.5 times the 2000 level by 2050, 4 times by 2100.
- World electricity generation reaches 5 times the 2000 level by 2100.
- World $CO_2$ emissions reach 3 times the 2000 level by 2100.
- China passes USA in $CO_2$ emissions in 2007 or 2008 and becomes increasingly dominant thereafter (but much smaller per capita).

# Fossil fuels continue dominance for decades




**This is the "reference" (BAU) primary-energy projection of the International Energy Agency (IEA).**

# Growth of coal-fired electricity is extremely high

Actual and projected coal-fired capacity, GWe

| | *USA* | *China* | *India* | *World* |
|---|---|---|---|---|
| *2003* | 310 | 239 | 67 | 1120 |
| *2010* | 319 | 348 | 95 | 1300 |
| *2020* | 345 | 531 | 140 | 1600 |
| *2030* | 457 | 785 | 161 | 2000 |

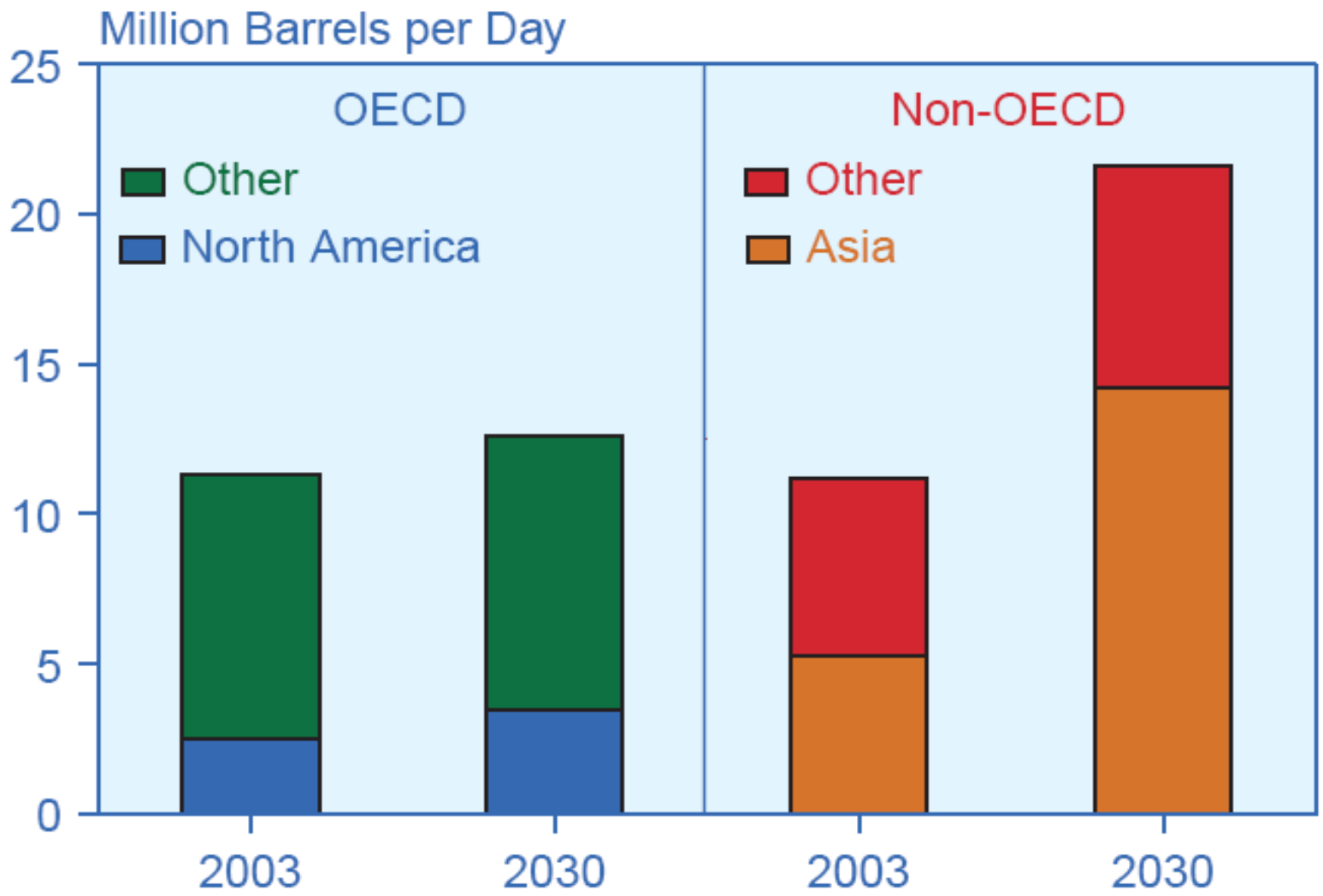
**Source: US EIA, International Energy Outlook 2006**

# The biggest dangers with this "business as usual" scenario are…

- Oil and natural gas supply: Economic damage from sudden price increases. International tensions and conflict over access and terms.
- Air pollution: Health damage from SOx, NOx, and soot. Acid rain from SOx and NOx.
- Global climate change: Increased floods, droughts, heat waves, powerful typhoons & hurricanes, sea-level rise, damage to agriculture & fisheries (and more) from climate disruption by $CO_2$, other greenhouse gases, soot.

Each of these problems has the potential to undermine development goals. And each has global dimensions. Every country is affected by what other countries do.

# Imports of Persian Gulf oil by region, 2003 & 2030




Source: EIA International Energy Outlook 2006

**Developing Asia's dependence on the Persian Gulf is already bigger than North America's and is expected to grow much faster.**

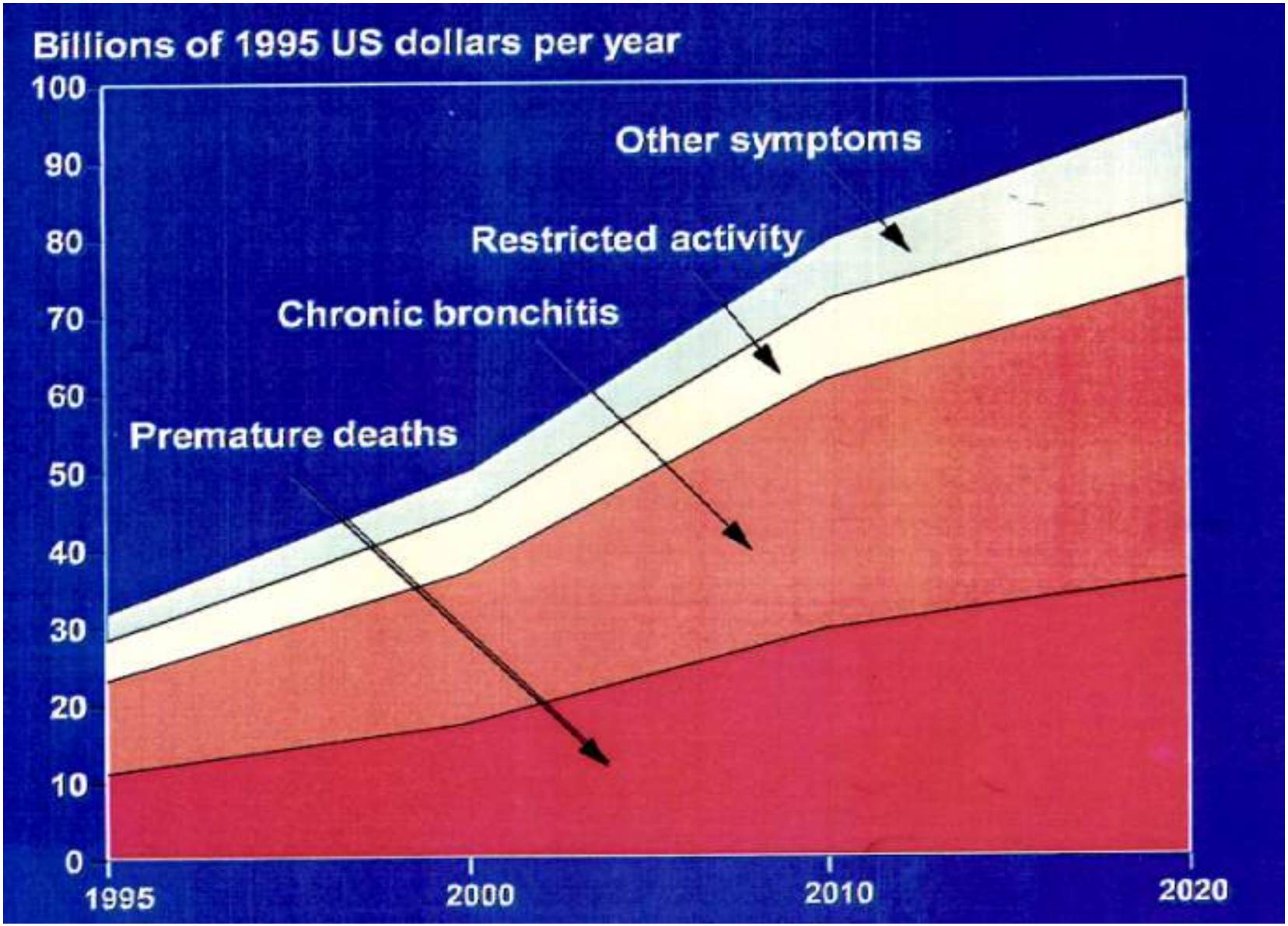
# 二氧化硫和氮氧化物产生量预测
# Forecasts of S02 and NO2 Emissions

| | 情景 Scenario | 2000 | 2010 | 2020 |
|---|---|---|---|---|
| 二氧化硫（万吨） $SO_2$ (10,000 tons) | A 情景 Scenario A | 2719 | 4072 | 5738 |
| | B 情景 Scenario B | 2719 | 3900 | 4947 |
| | C 情景 Scenario C | 2719 | 3443 | 4056 |
| 氮氧化物（万吨） $NO_X$ (10,000 tons) | A 情景 Scenario A | 1988 | 3417 | 4982 |
| | B 情景 Scenario B | 1988 | 3273 | 4295 |
| | C 情景 Scenario C | 1988 | 2889 | 3521 |

**Under the preferred (green) scenario, Chinese NOx emissions still increase 75% by 2020, SOx emissions by 50%.**

Liu Shijin, The State Council, 2004

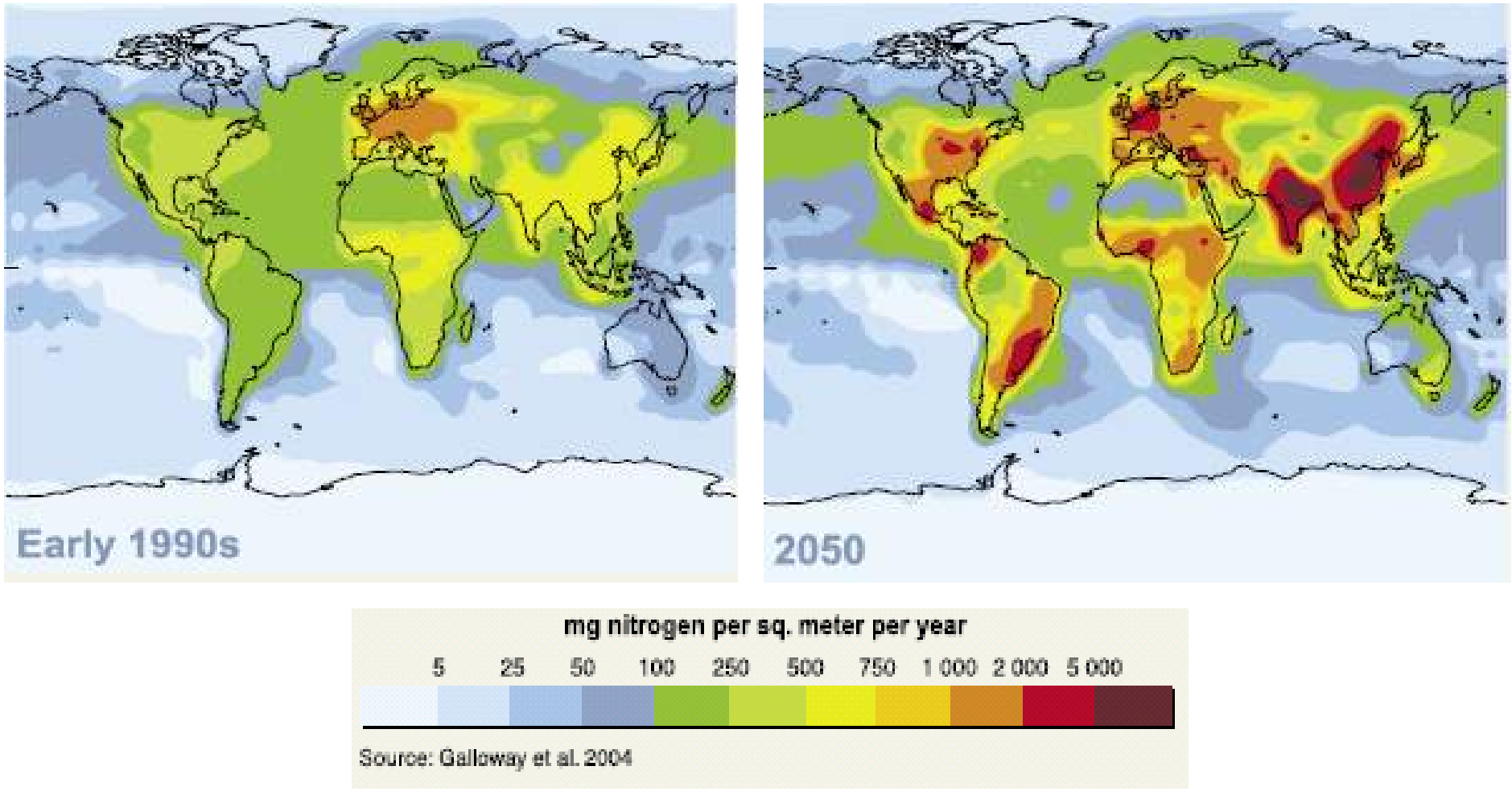
# Health Costs from Particulate Pollution in China




*Source*: Clear Water, Blue Skies; *China's Environment in the New Century*, World Bank, 1997.

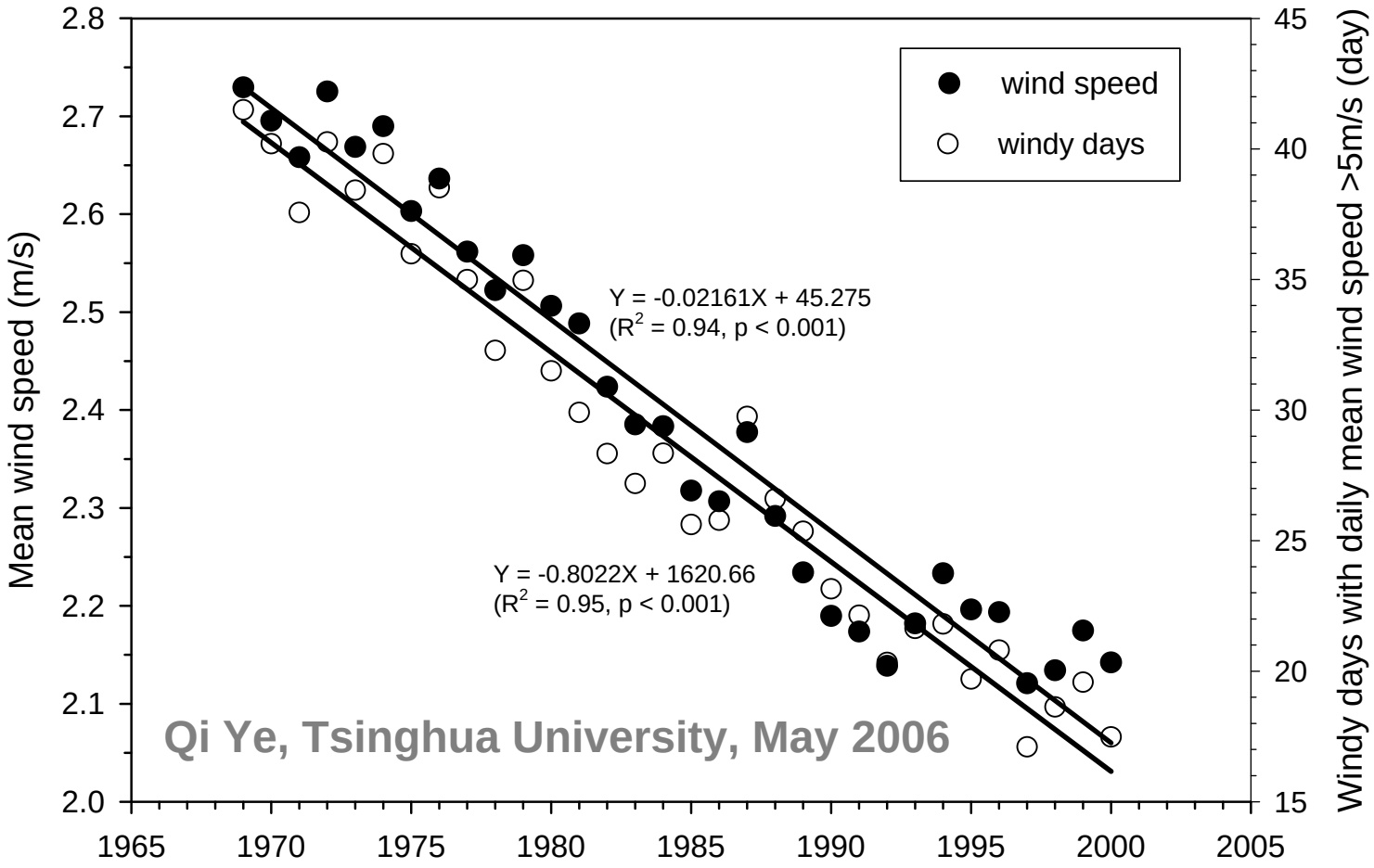
# Acid precipitation under BAU growth

**Wet and dry reactive nitrogen deposition from the atmosphere, early 1990s and projected for 2050**



# Climate change is harming China already

## The East Asia monsoon has been weakening




**The change is as predicted by Chinese climate modelers. It has produced increased flooding in the South of China and increased drought in the North.**

# Glaciers feeding China's rivers are shrinking

*Qinghai - Xizhan (Tibet) plateau*

*the roof-of-the-world, 2.5 million km$^2$*

*important role in climate of China*

*hot-spot of climate change*

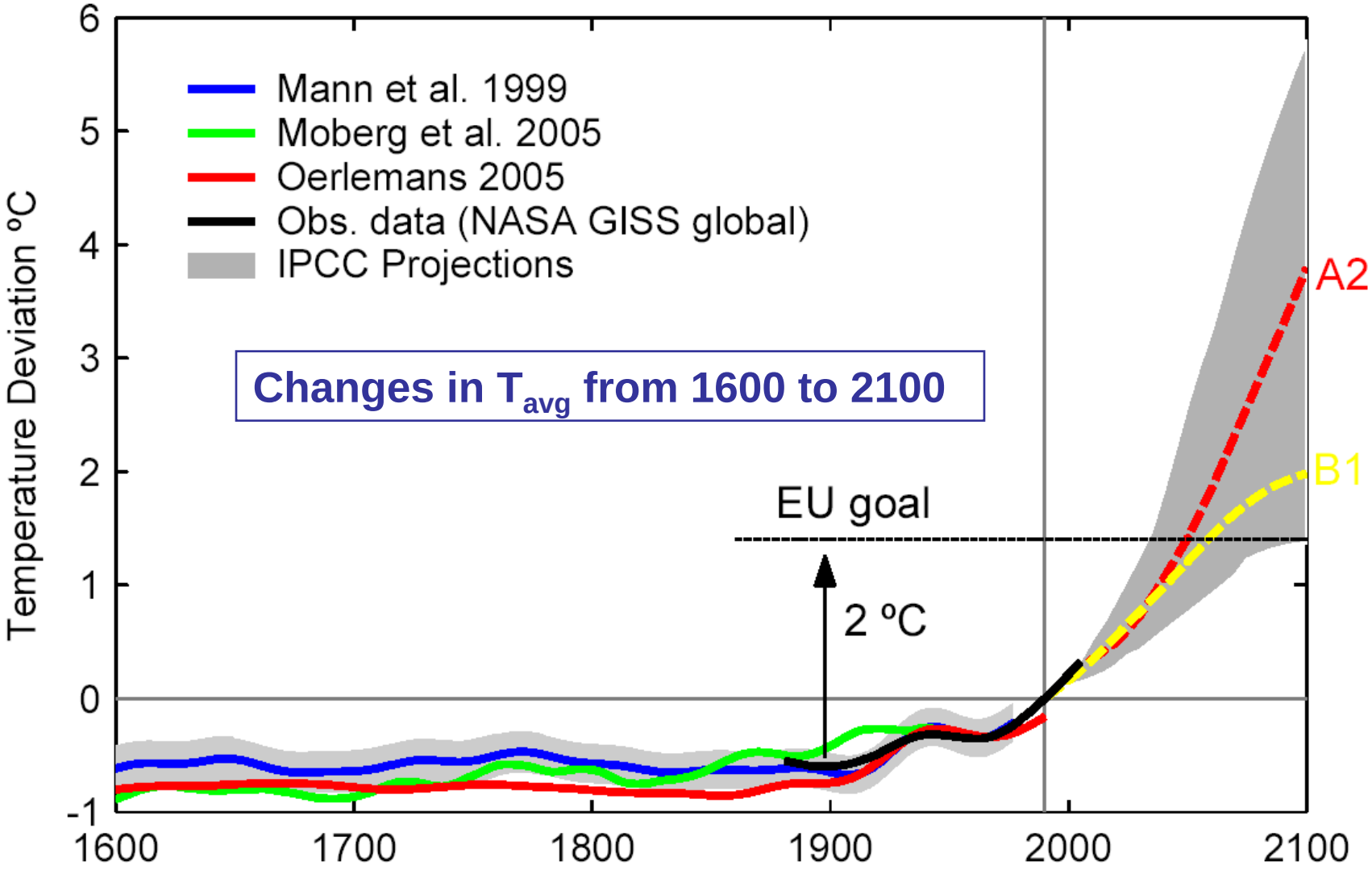
temperature rise by ~0.9°C since 1980s

Increase in thawing of permafrost

Decrease in glacier area by 7% per year

Xiangming Xiao, U of New Hampshire, May 2005

# Far bigger climate change occurs in BAU future




**Last time T was 2ºC above 1900 level was 130,000 years ago, and sea level was 4-6 m higher. Last time it was 3ºC above 1900 level was ~25 million years ago, and sea level was 20-30 m higher.**

We have concluded that the largest leverage for China against the problems of oil dependence, air pollution, and contributions to global climate change is to be found in two domains:

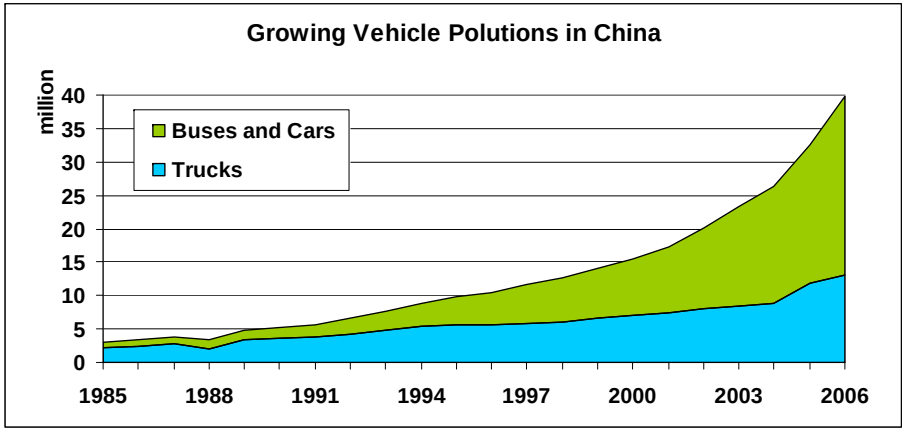
- cleaner and more efficient passenger vehicles
- cleaner coal technologies, ultimately with electricity & liquid-fuel or $H_2$ co-production and carbon capture & sequestration

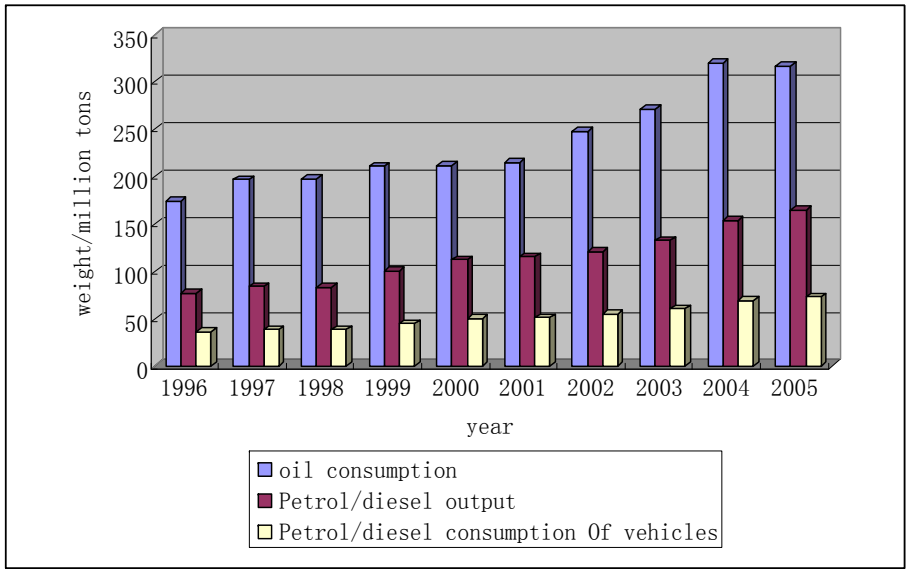
# Key findings on vehicles

- China's passenger vehicle sector presents enormous challenges in relation to reducing GHG emissions. Scenarios explored in our study show that full implementation of the passenger-vehicle fuel-economy standards currently projected for China will lead to some reduction in CO2 emissions compared to "business as usual", but the absolute increase would still more than a doubling by 2020.
- Larger reductions in the vehicle sector would require much stronger measures. These would have a variety of co-benefits (e.g., in reduced conventional pollution and reduced oil imports, compared to business as usual), but many barriers experienced and perceived by a variety of stakeholders will need to be overcome for such measures to be realized.

# Vehicle fuel economy in China: background

- Vehicle population has grown very rapidly in China
- Fuel consumption by vehicles has also risen significantly
- There are great concerns for oil security, local air pollution, and GHG emissions associated with vehicle population growth



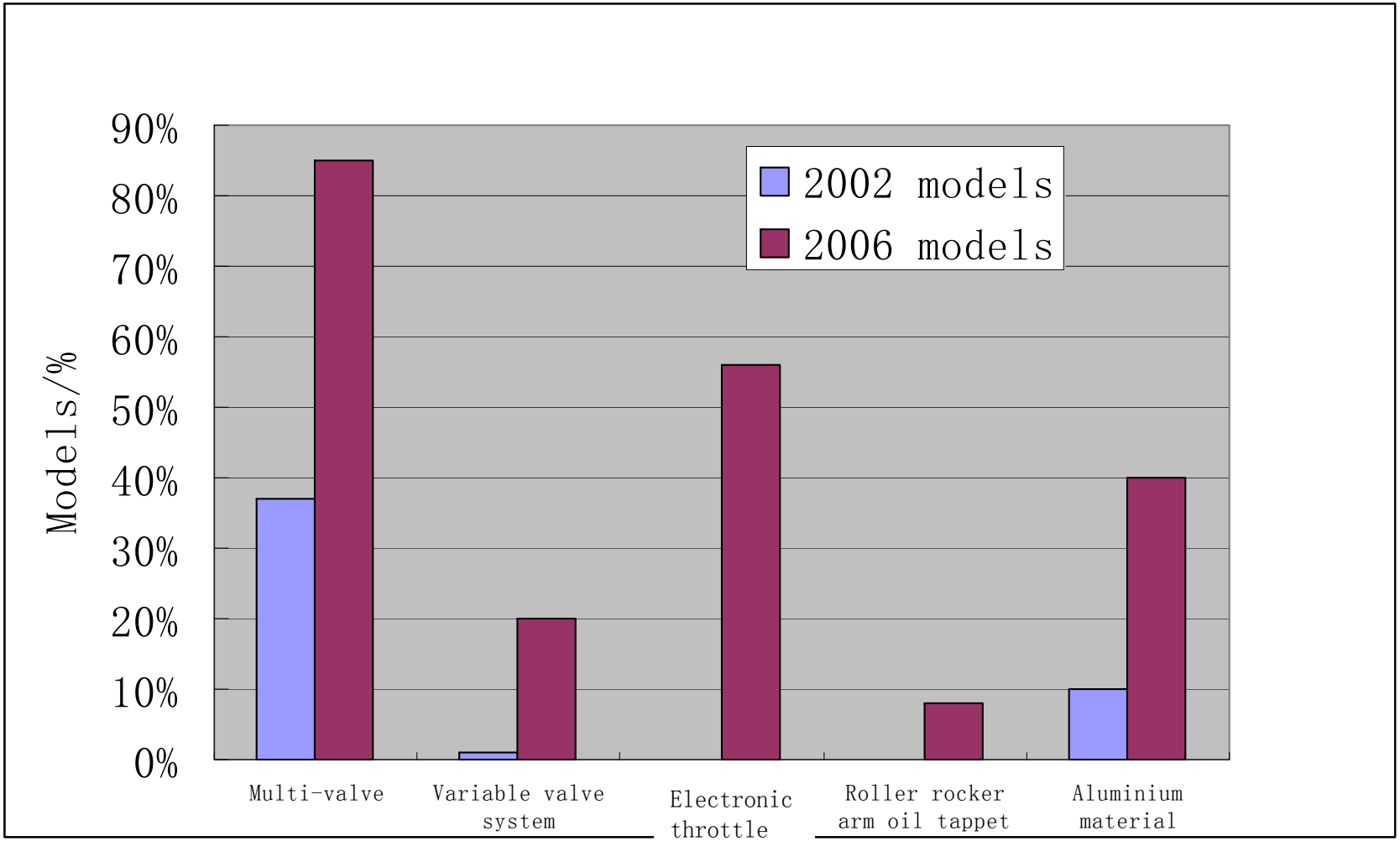

Source: China Automobile Yearbook 2006, China Energy Statistics Yearbook 2006.

# Deployment of advanced vehicle technologies for fuel economy

Comparing passenger vehicle models in 2006 with those in 2002, we saw deployment of

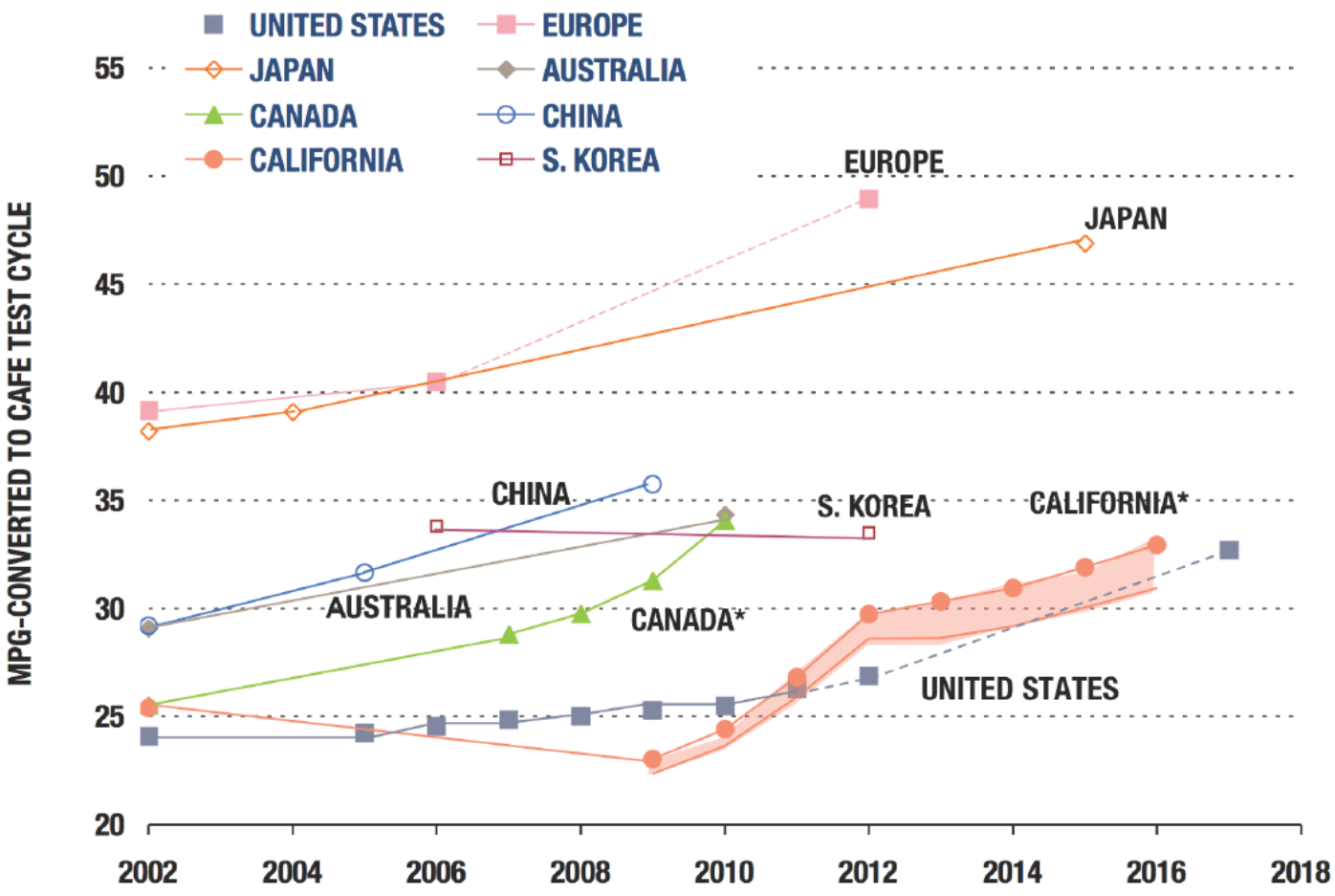
- Better engine technology (increased air/fuel ratio)
- Better lubricant (reduced engine friction)
- Improved body design (lower drag coefficient)
- Improved tyre (lower rolling resistance)
- Better transmission technologies (application of variable valve timing technology, 6-speed automotive transmission technology, continuous valve transmission)
- Lighter yet better performance materials (reduce weight )

# Deployment of better technologies for fuel economy (continued)




Source: CATARC 2007.

# Vehicle fuel-economy standards compared




Source: International Council on Clean Transportation, 2007.

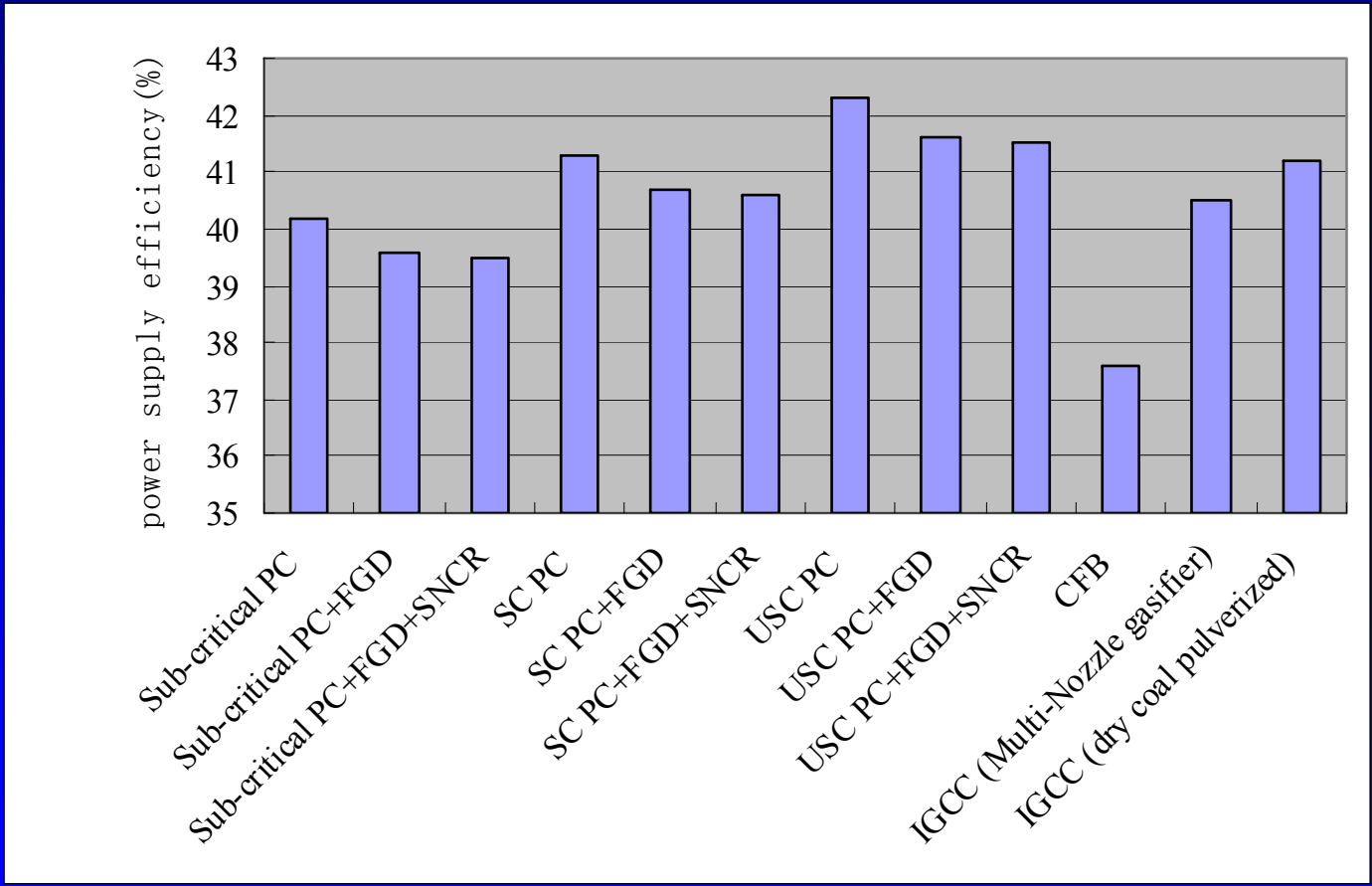
# Key findings on clean coal

- Analysis of three scenarios for future coal-fired electricity generation in China -- Business as Usual, Advanced Technology (emphasizing ultra-super-critical power-plant technology), and Very Advanced Technology (emphasizing carbon capture and sequestration) -- shows that the Very Advanced Technology scenario offers by far the largest GHG emissions reductions but is too costly under current circumstances and will not materialize absent drastic changes in economics and/or policy.
- A more likely early path, modeled by the Advanced Technology scenario, entails accelerating the diffusion of ultra-super-critical coal technology, promoting commercialization of fluidized bed and integrated gasification combined cycle technologies, and increasing R&D on carbon capture and sequestration. Achieving even this much will require significant strengthening of relevant policies and still will be not enough to reduce absolute GHG emissions under expected electricity growth.

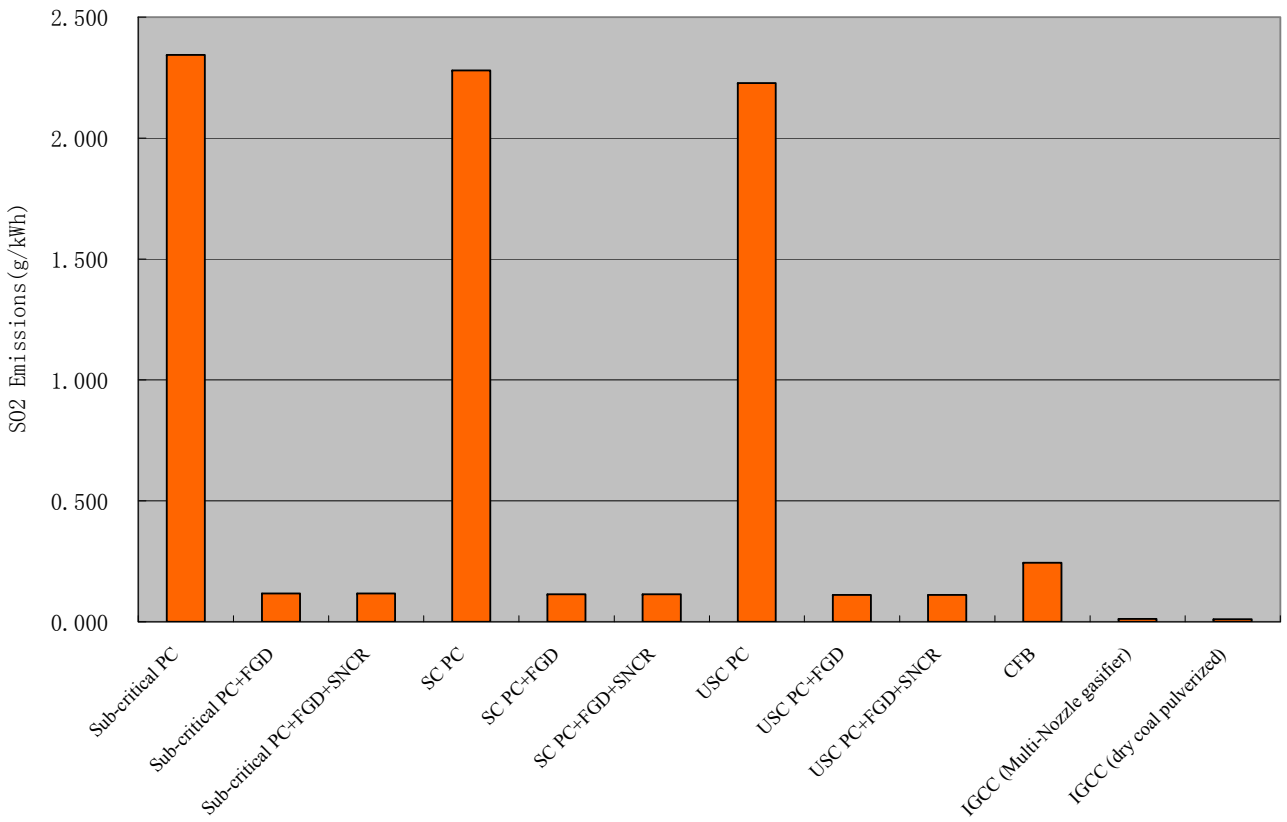
# Brief Introduction

- **Cost differences among different technology options**
  - **Sub-critical PC, 600MW**
  - **Sub-critical PC, 600MW+FGD**
  - **Sub-critical PC, 600MW+FGD+ Flue gas denitrification**
  - **Super Critical PC 600MW**
  - **Super Critical PC 600MW+FGD**
  - **Super Critical PC 600MW+FGD+ Flue gas denitrification**
  - **USC PC, 600MW**
  - **USC PC, 600MW+FGD**
  - **USC PC, 600MW+FGD+ Flue gas denitrification**
  - **CFB，300MW**
  - **IGCC，200MW**
- **What should we do**

# Thermodynamic Performance



# Environmental Performance



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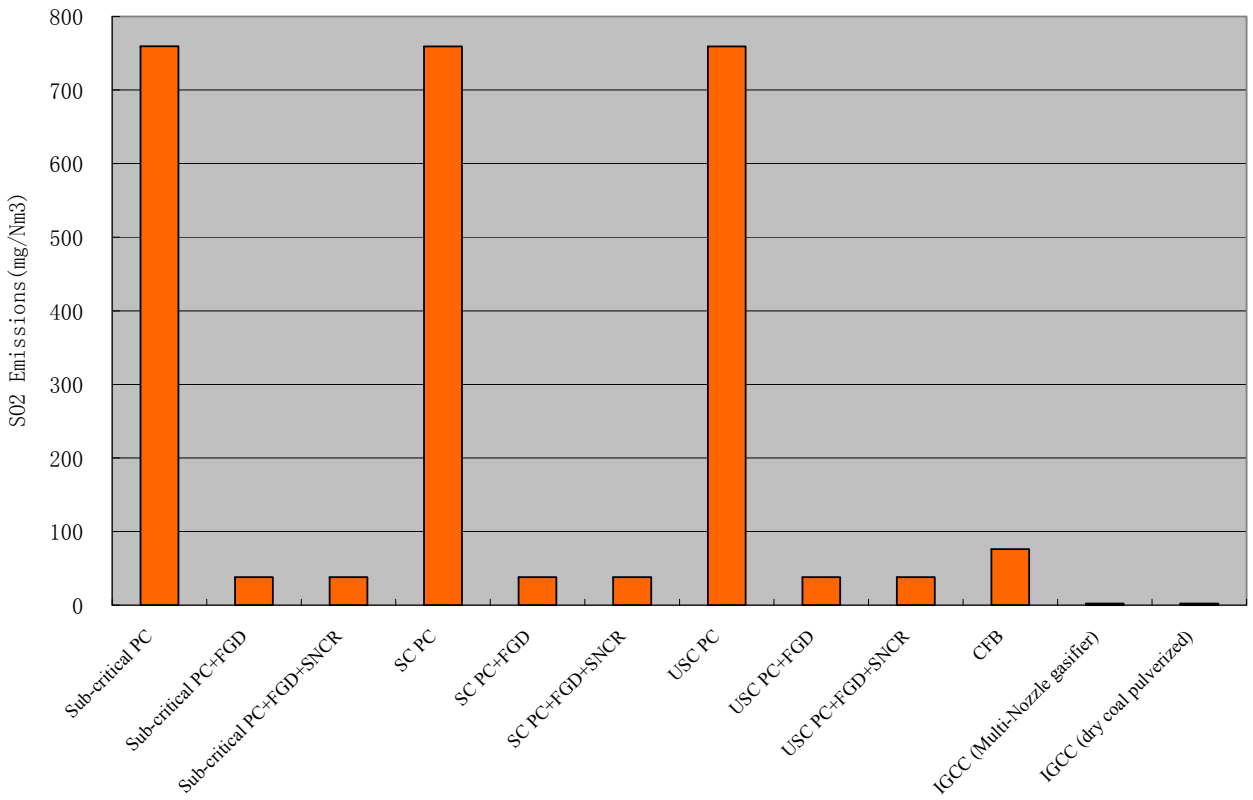

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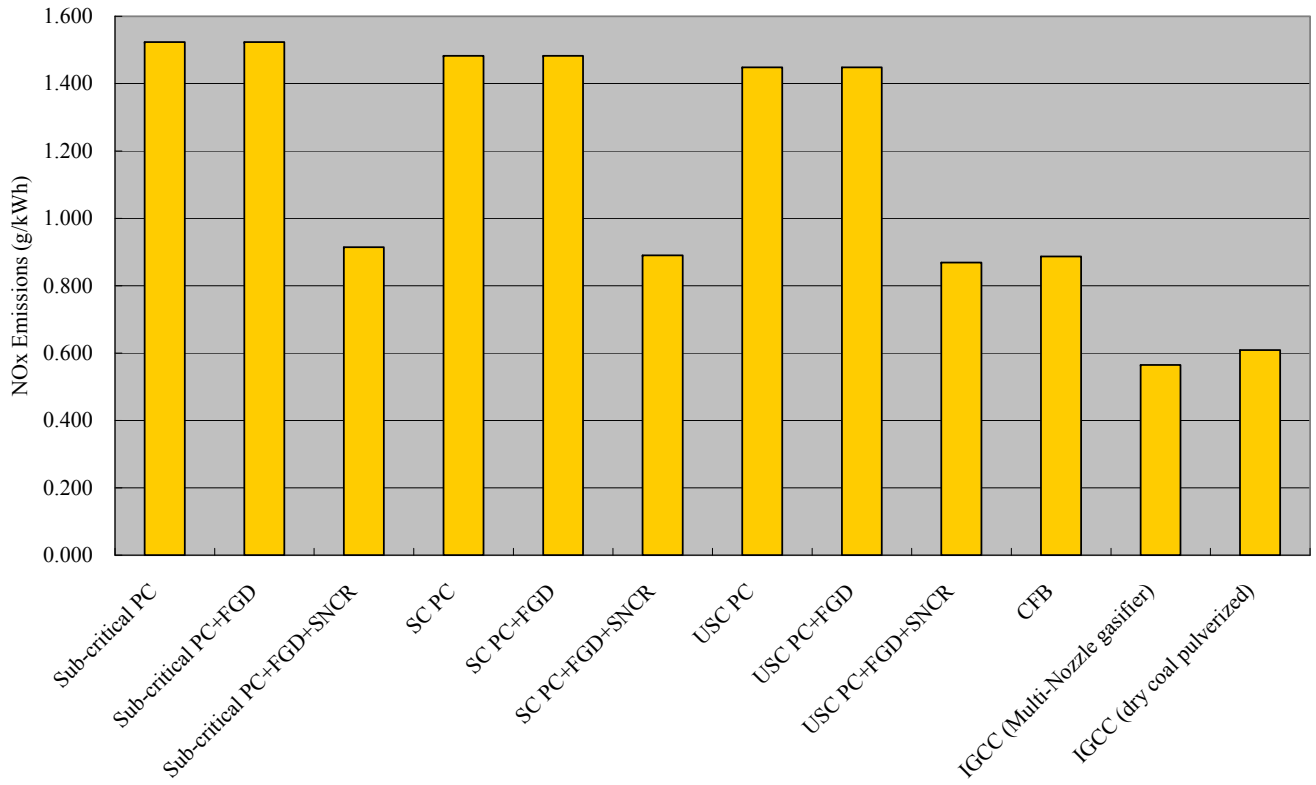
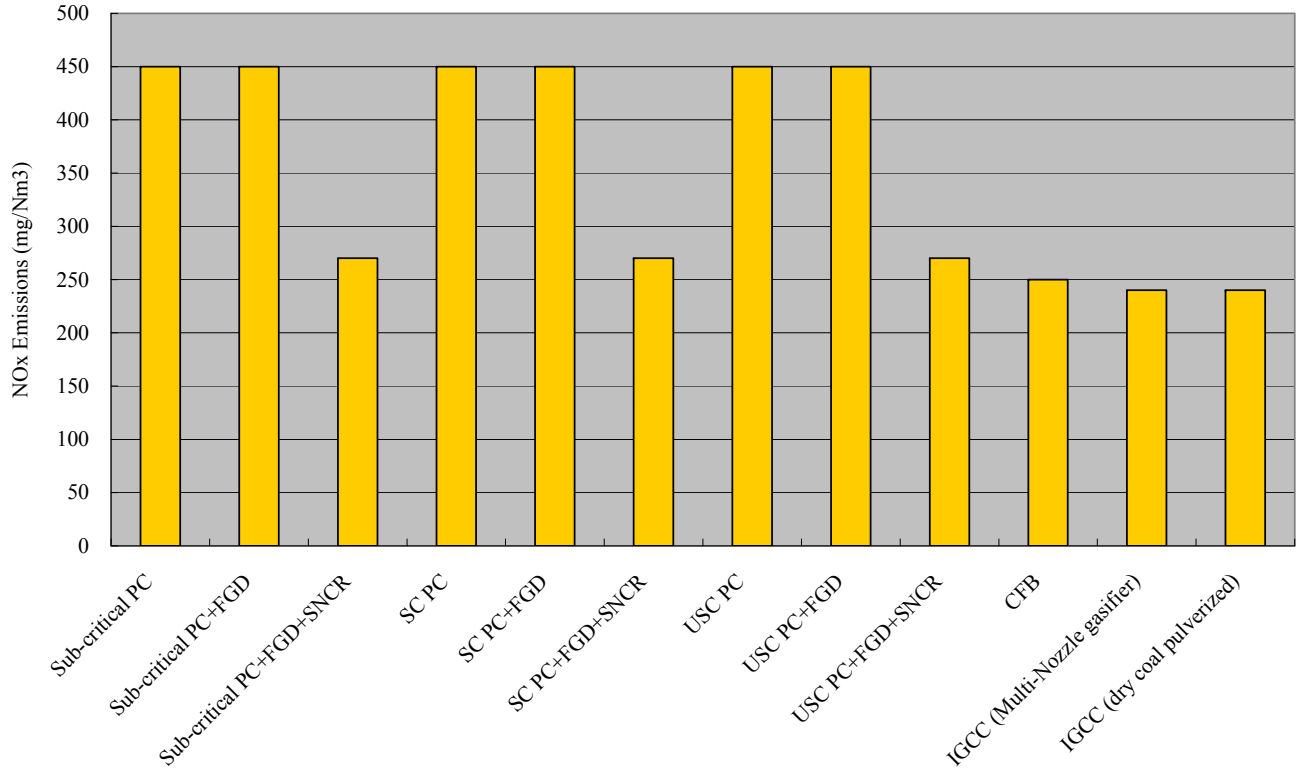


# Environmental Performance



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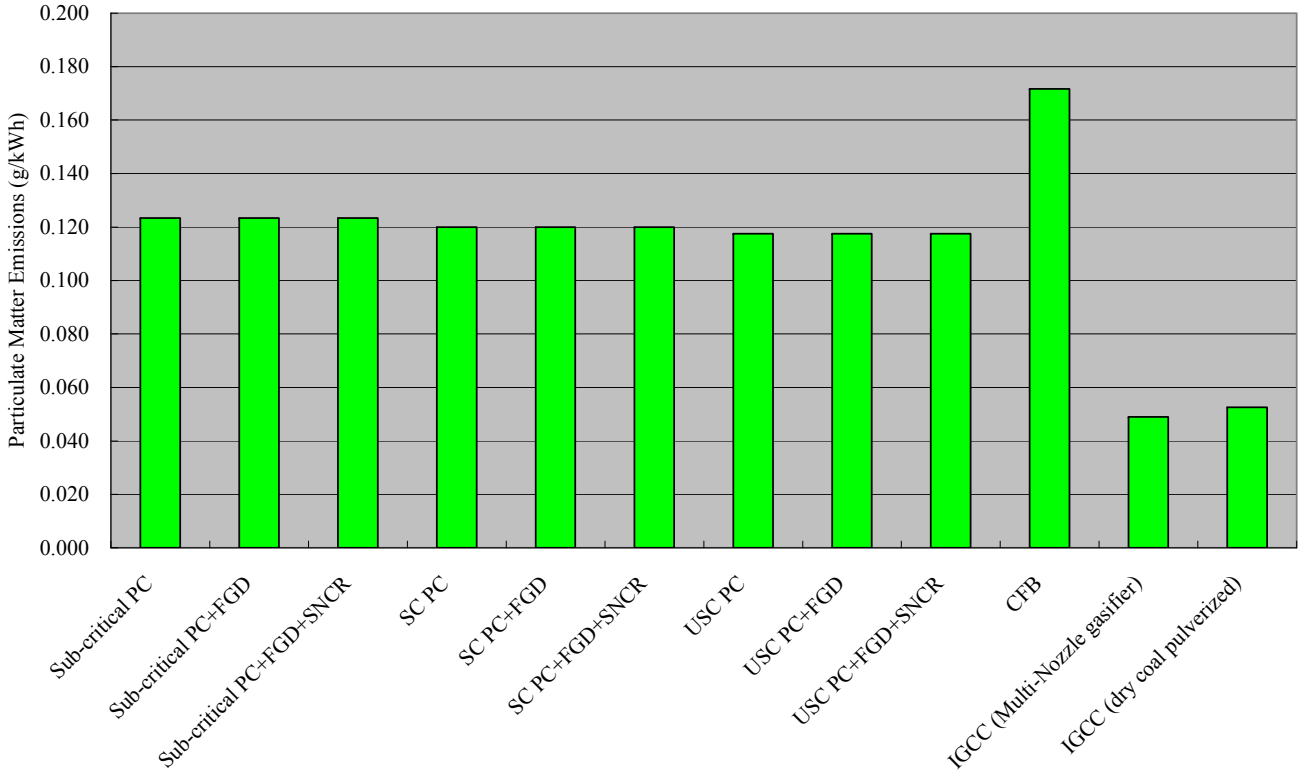
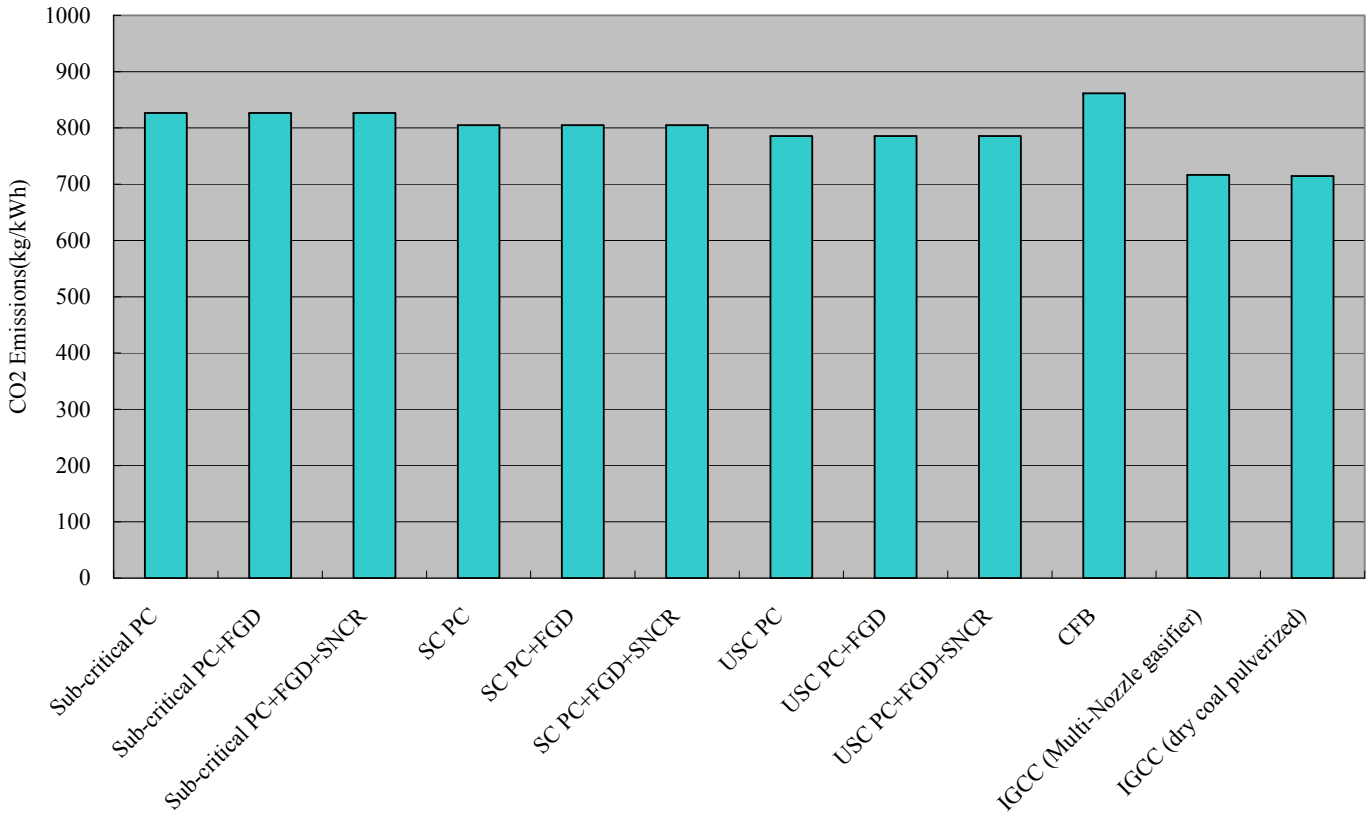
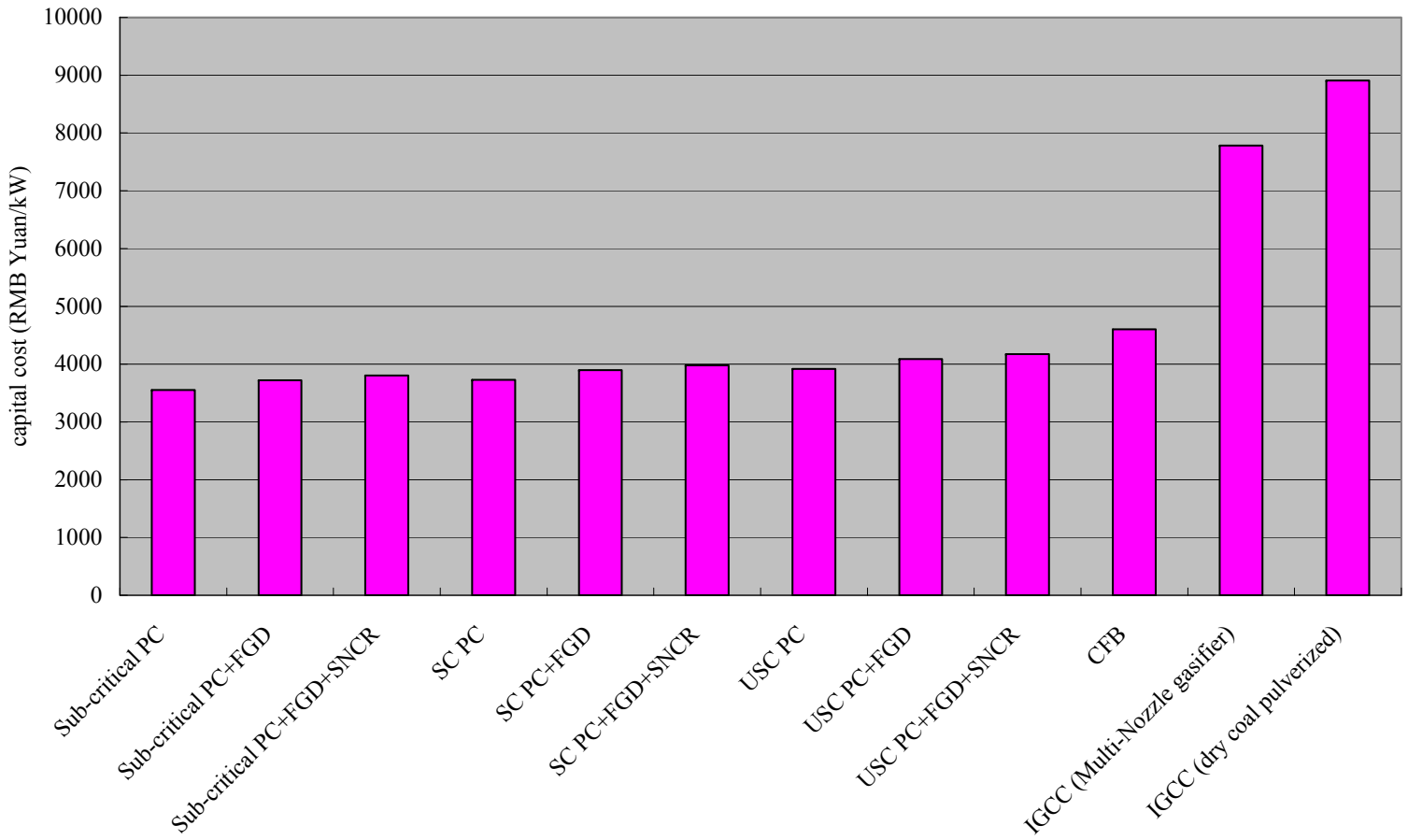


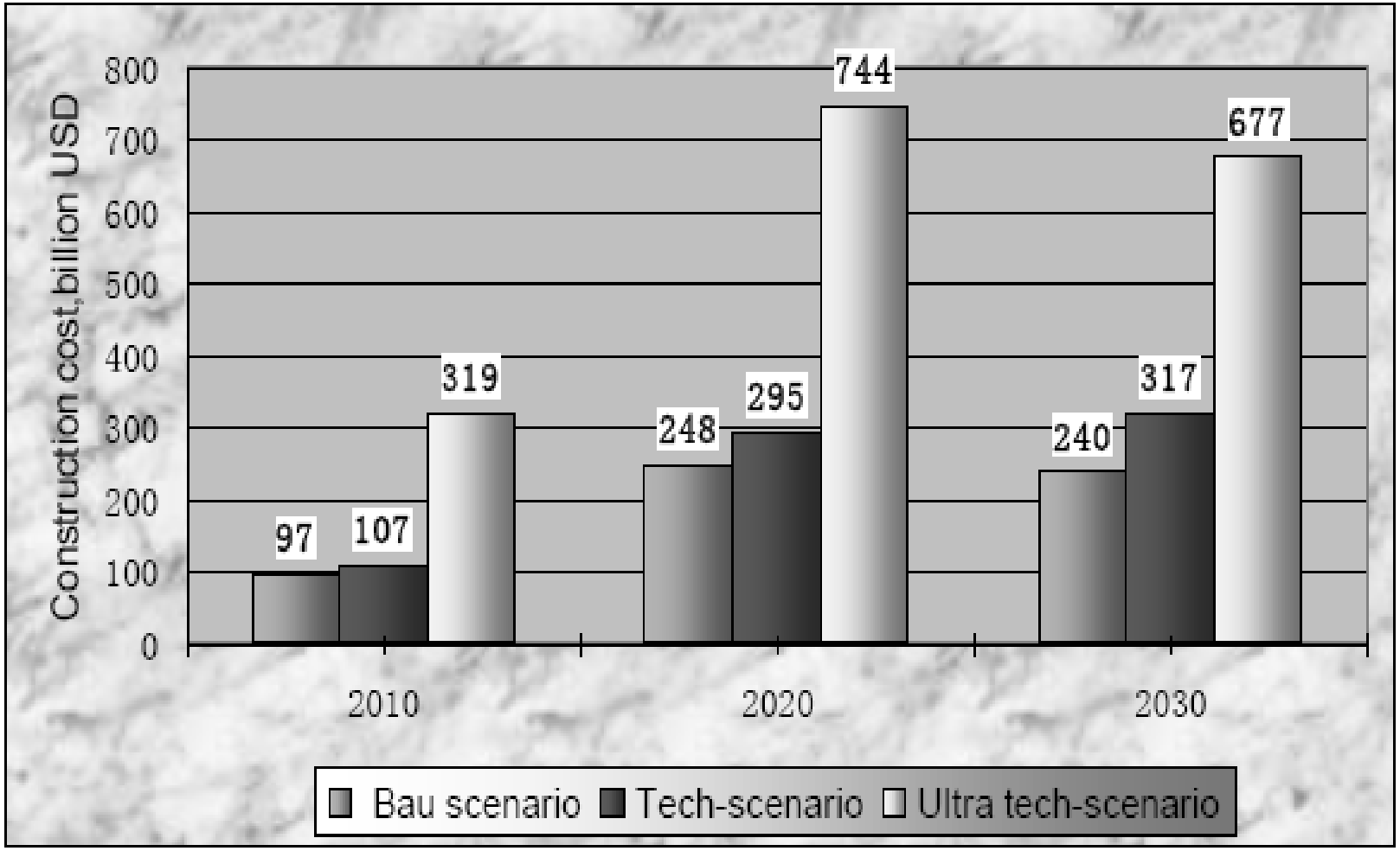
# Environmental Performance



# Economic Assessment



# Construction costs for the 3 scenarios



## Elaboration on advanced-coal prospects

- Interest has grown very rapidly in China and the USA (and in the UK and Australia) in advanced coal technologies that can reduce conventional pollutants & Hg from coal-electric power plants, can co-produce electricity & $H_2$, can produce liquid fuels from coal, and can capture & sequester $CO_2$.
- Research, development, & demonstrations on these technologies have been multiplying in all of our countries, but much more work will be needed to clarify the full potentials.
- Irrespective of technology, CCS will not occur on the needed scale until strong policies make it attractive or require it.
- There are very large benefits to be obtained from public-private partnerships and from increased international cooperation on both the technical and the policy aspects of this challenge.

## Elaboration on advanced-coal prospects

- Options for C capture in coal-burning power plants are (a) pre-combustion capture of the $CO_2$ in IGCC plants with shift reaction to $H_2$ and $CO_2$; and (b) post-combustion capture in PC power plants.
- With current technology, cost of electricity from IGCC with carbon capture appears to be less than from PC with carbon capture (comparing new plants built from outset to do this). Cost per ton of avoided $CO_2$ emission is likewise lower for IGCC with CCS.
- Further development of PC/post-combustion options conceivably could close the cost gap, and more R&D should be done to pursue this. Promising options include oxy-firing, chilled-ammonia absorption.
- Until $CO_2$ price or policy dictates $CO_2$ capture, most new plants will be PC. It's important that these be built in a way that allows later retrofit for $CO_2$ capture when price or regulation makes this attractive.
- Regulations specifying fraction of coal-electric-generation $CO_2$ to be sequestered could be considered to get started.
- Fischer-Tropsch coal-to-liquids technology lends itself to low-cost C capture (~\$10/t$CO_2$) and should not be deployed without this.

## Status and prospects of IGCC and Co-Production

- Six IGCC demo plants are operating worldwide, 2 in the USA.
- IGCC offers similar efficiency to Ultra-Super-Critical Pulverized Coal (USCPC) plants. USCPC is cheaper, but IGCC offers better control of conventional pollutants, lower water demand, reduced solid waste, possibility of $H_2$ co-production, and lower cost to add $CO_2$ capture (to a new plant). USCPC can be made amenable to retrofit for CCS (IGCC cannot), but cost of retrofit itself would be high.
- Deployment of IGCC has been slow because of high cost, complexity similar to chemical plant, lack of $CO_2$ policy, and (until recently) cheap natural gas.
- China's goal is to have commercialized IGCC capacity by 2020 to convert coal to electricity & $H_2$ with near-zero emissions, plus synthetic oil and gas capacity to replace 50 million t/a of oil.
- A variety of pilot and demo projects around China with both corporate & gov't support are underway or planned pursuant to that goal. Chinese alliance for IGCC and co-production is intended to coordinate RD&D and provide platform for international cooperation.

## $CO_2$ storage and utilization technology

- Storage options are oceanic (large capacity but least understood), terrestrial (moderate capacity), and geologic (medium to large capacity).
- Best geologic options on current understanding are enhanced coal bed methane recovery (ECBM), enhanced oil recovery (EOR), depleted oil & gas fields, unmineable coal seams, and saline reservoirs. Largest capacity worldwide is in saline reservoirs.
- Enhanced recovery of oil & gas and enhanced coal-bed methane production bring economic benefits that offset sequestration costs, thus are particularly attractive for early implementation.
- More research is needed on all technical aspects of sequestration -- fundamental processes (e.g., pore behavior), leak rates & safety, storage capacities, and measurement-monitoring-verification -- as well as on policy aspects including permitting and liability.
- Unlike technology, geology can't be transferred; thus geologic assessments of sequestration potential must be done for every region with large $CO_2$ sources. These assessments are large tasks and for most regions have barely begun.

# Chinese government energy RD&D investments

- During the Eleventh Five-Year Plan (starting Sept. 2006) the Ministry of Science and Technology's (MOST) budget authority for energy research, development, & demonstration is about 3.5 billion RMB (approx. $425 million).
- Budget authority for advanced coal technology is about 0.7 billion RMB (approx. $85 million). This accounts for 21 percent of the total energy budget.
- Five coal co-production and gasification demonstration projects are planned for the next 5 years, in collaboration with Chinese industry.

## Gov’t-industry alliances for IGCC and co-prod’n

- Gov’t-industry alliances are working well in the USA (FutureGen) and Europe (and starting to work in China), bringing together the complementary skills and resources of the private & public sectors.
- International participation in such alliances is increasing and is very promising as a way to share insights, costs, & risks and to accelerate progress in all of the partner countries.

# Cross-cutting points

# Classes of policy options

- Standards and sectoral targets
- Government activities in research, development, demonstration
- Economic incentives
- Capacity building for implementation, monitoring, and enforcement

Applicability and attractiveness differ across technologies and sectors.

# Obstacles to achieving technology goals for addressing climate & development

- Weakness of plans and strategies
- Division of institutional responsibilities (especially for R&D); lack of coordination
- Market structure: competitiveness and monopoly issues
- Inadequacies in human resources
- Inadequacies in financing and efficiency, especially for weaker companies & provinces
- Lack of coordination between IPR protection and promotion of technology diffusion

# Development and Climate Change Benefits of Clean Energy: India case study

COP-13 Side Event

*Linking Climate Policy With Development Strategy: Options for Brazil, China, and India*

December 10, 2007

# India Research Team:

a. *GHG mitigation options:*

-- Review of studies: P.R. Shukla, D. Menon-Choudhary (IIM-A)

b. *Biomass*

-- Resource assessment: N.H. Ravindranath, P. Deepak, S. Najeem (IISc)

-- Advanced cooking technologies: C. Venkataraman (IIT-B), S. Maithel (Greentech Knowledge Solutions)

-- Biomass gasifiers: V.V.N. Kishore, S. Mande (TERI)

*c. Power Sector*

-- Resource Assessment: S.K. Chand (TERI)

-- Clean Coal: R. Anthony, I.R Pillai, R. Banerjee* (IIT-B)

-- T&D and Efficiency: S. Saikia, R. Banerjee* (IIT-B)

Outline of talk:

1. Prospects for new technologies
2. Options for win-win deviations
3. Climate and development benefits
4. Barriers to, and strategies for, deployment

# 1. Prospects for new technologies

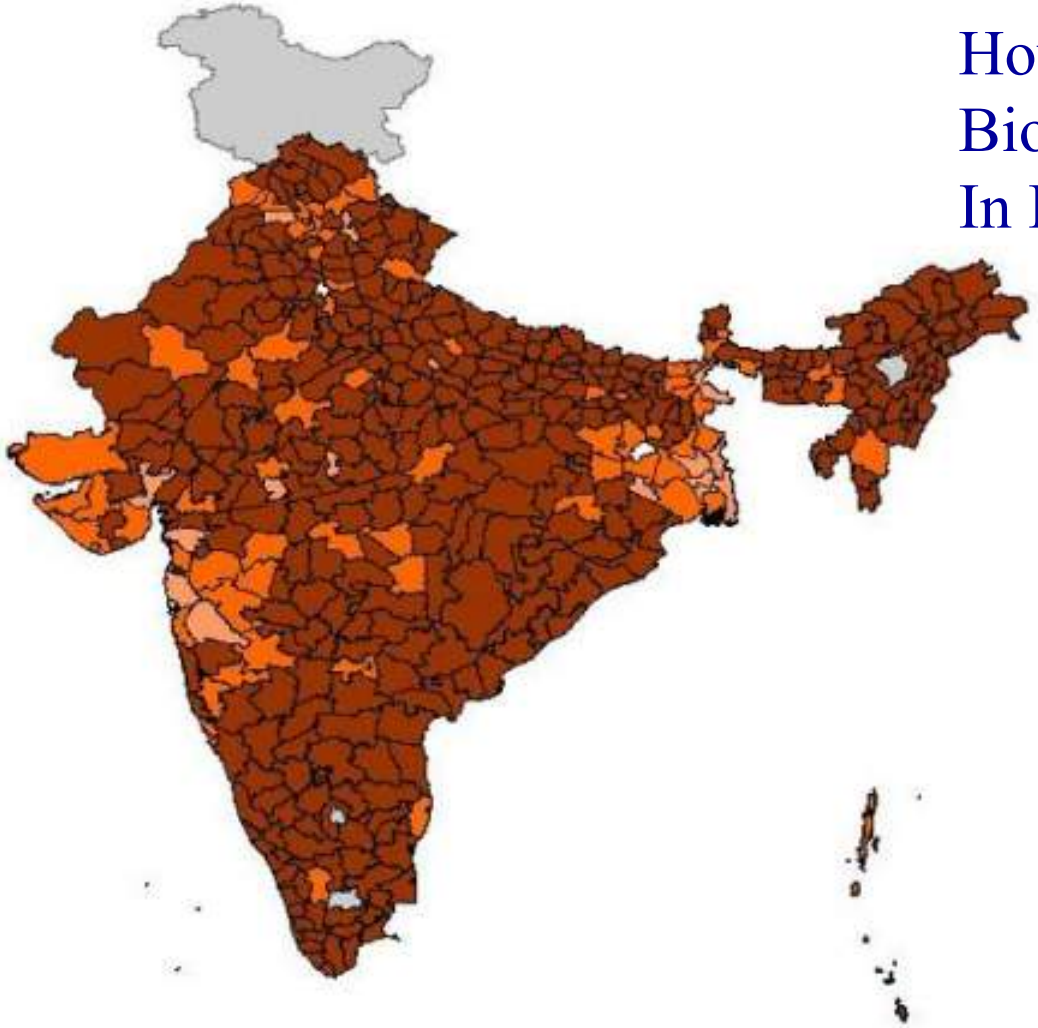
*a. Advanced biomass energy technologies*

Biomass accounts for over 25% of India's TPES and over 70% of its rural energy

-- Household and institutional cooking

- current cooking technologies largely mud stoves and some metal, cement and pottery, or brick stoves
- Low thermal efficiency
- Significant emissions of air pollutants leading to health damages (~400,000 premature deaths annually (Smith et al. 2004))
- Significant emissions of long-lived (CH4 and N20) and short-lived (CO and non-methane HCs) GHGs

# Households Using Biomass Fuels In India



Percentage of Households

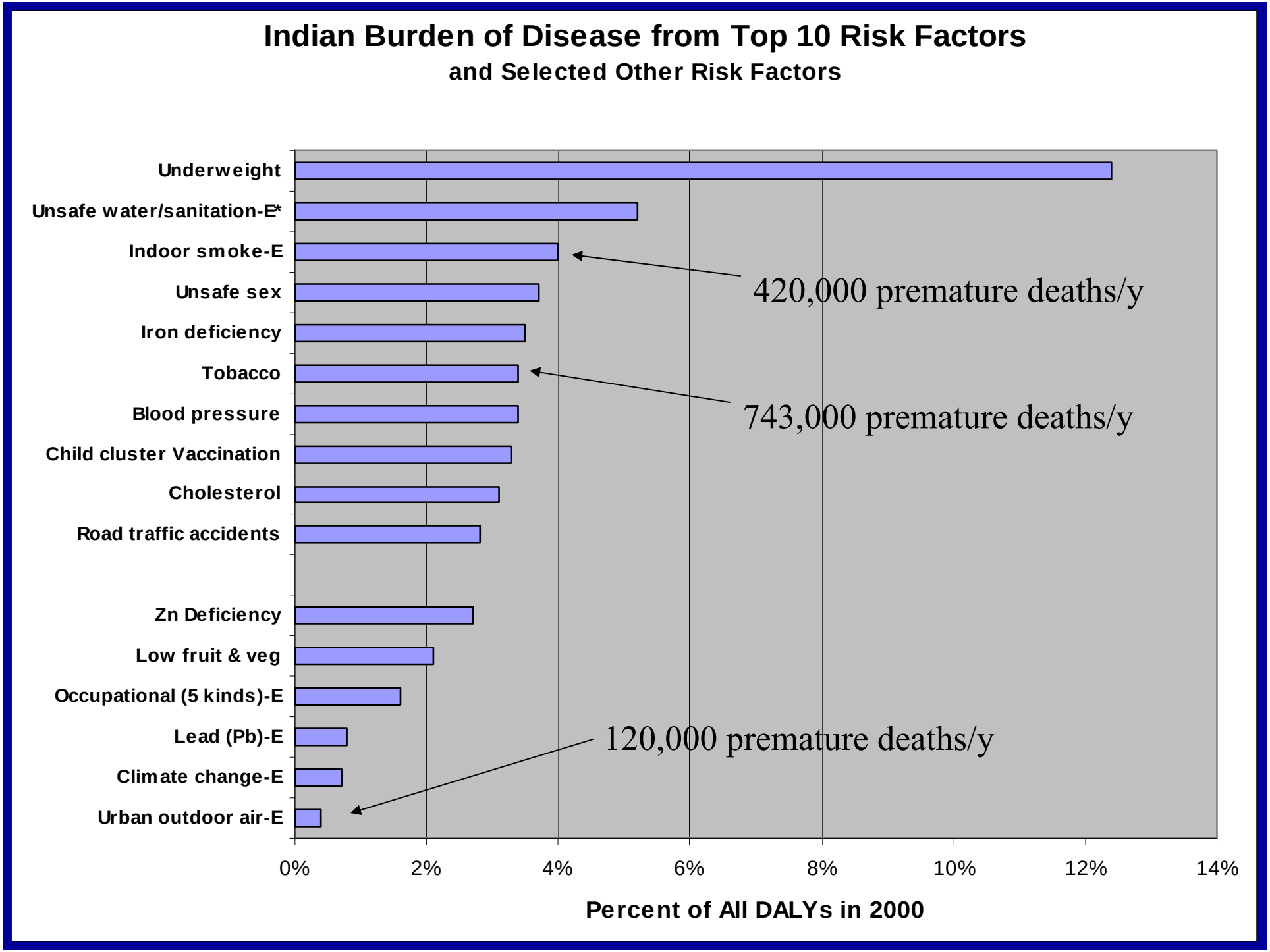
- 0-24
- 25-49
- 50-74
- 75-100
- unknown

*Source: Census of India 1991

# Energy flows in a well-operating traditional wood-fired Indian cooking stove

PIC = products of incomplete combustion = CO, HC, C, etc.

Source: Smith, et al., 2000


Indian Burden of Disease from Top 10 Risk Factors
and Selected Other Risk Factors
Underweight
Unsafe water/sanitation-E*
Indoor smoke-E
Unsafe sex
Iron deficiency
Tobacco
Blood pressure
Child cluster Vaccination
Cholesterol
Road traffic accidents
Zn Deficiency
Low fruit & veg
Occupational (5 kinds)-E
Lead (Pb)-E
Climate change-E
Urban outdoor air-E
420,000 premature deaths/y
743,000 premature deaths/y
120,000 premature deaths/y
0%
2%
4%
6%
8%
10%
12%
14%
Percent of All DALYs in 2000

## Diseases for which we have some epidemiological studies

ALRI/ Pneumonia
(meningitis)

Asthma

Low birth weight

Early infant death

Cognitive Impairment?

Chronic obstructive lung disease

Interstitial lung disease

Cancer
(lung, NP, cervical, aero-digestive)

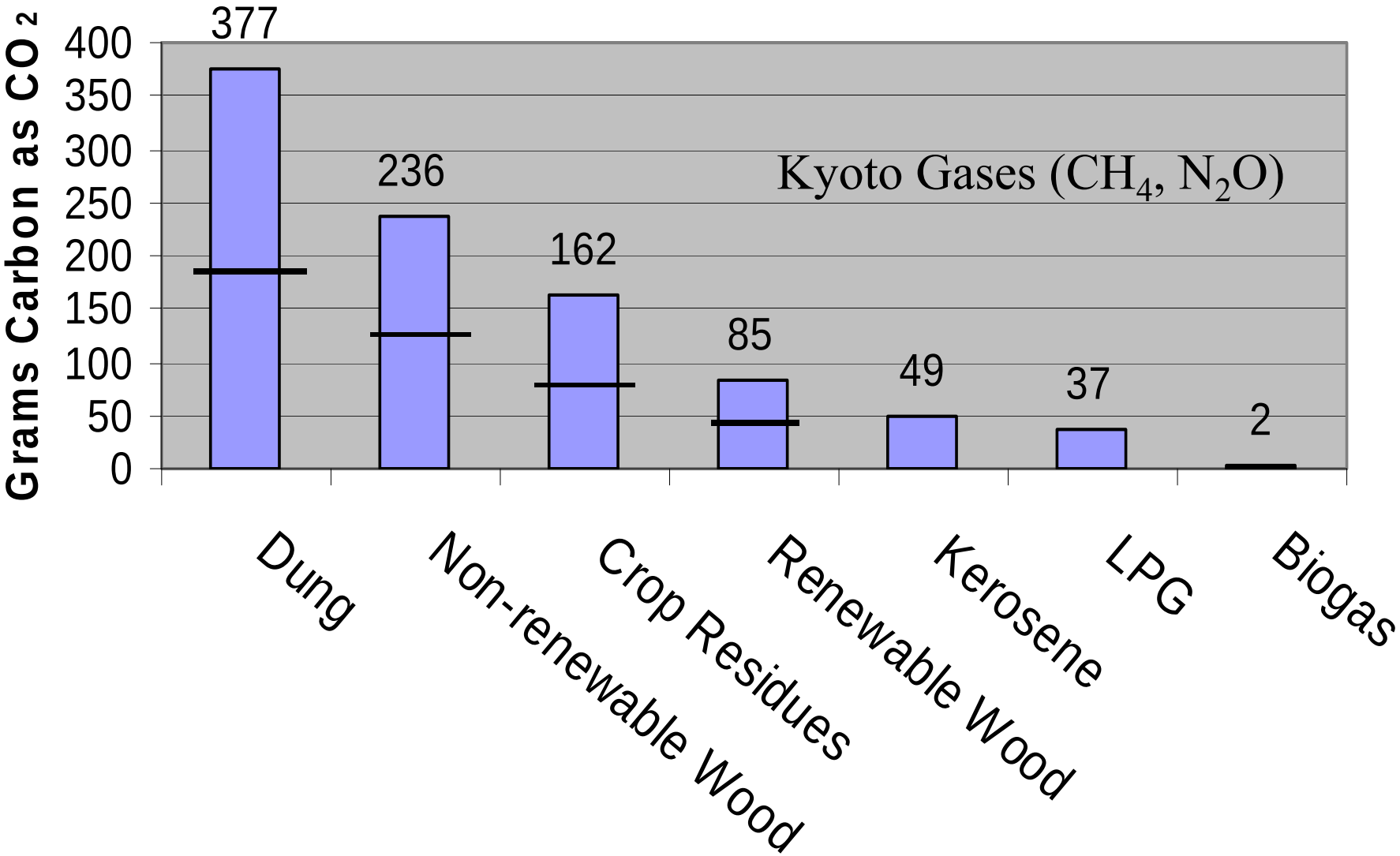
Blindness
(cataracts, trachoma)

Tuberculosis

Heart disease?

# Global Warming Commitment per MJ Energy Delivered to Cooking Pot in India

Full GHG Potentials-$CH_4$, $N_2O$, HC, CO



# 1. Prospects for new technologies

## *a. Advanced biomass energy technologies (contd.)*

-- Small and medium enterprises

- ~ 3 million SMEs in country (accounting for 40% of country's industrial production and 7% of GDP)
- Large numbers of such enterprises are heavily energy consuming
- Dependent on inefficient biomass combustion or diesel for thermal energy; diesel for power generation
- Expenditure on fuels often major share of production costs

Gasifier-based cottage basin-oven

# 1. Prospects for new technologies

## *b. Power-sector technologies*

-- Coal-power generation

- ~70% of national generation based on coal; ~ 75% of coal used in power
- Peak shortage (~12%) and energy shortage (~8%); over 50% of households without access to electricity – urgent need for enhancing power availability and access
- Average efficiency of 27.7% with wide variation (14.6% to 34.6%) – low by global comparison
- Average aggregate technical and commercial losses (ATC) about 35% with wide variation – very high by global comparison

## 2. Options for win-win deviations

### *a. Advanced biomass energy technologies*

-- Household and institutional cooking

- Promising advanced biomass cooking technologies (ABCTs) – advanced combustion stoves; gasifier stoves; biogas technology

- Advanced biomass combustion and gasifier stoves have potential for about 2-fold improvement in efficiency and 4-fold reduction in emissions of pollutants per MJ of useful energy delivered

# 2. Options for win-win deviations

## *a. Advanced biomass energy technologies (contd.)*

-- SMEs

- Biomass gasification for process heat needs – low-temperature applications (water boiling, drying, steam) and high-temperature applications (kilns and furnaces)
- Biomass gasification coupled with internal combustion engine for power generation
- Replace fossil fuel use up to 100% and biomass by 50-60% (approximately 3-4 kg of biomss to replace 1 kg of petroleum-based fuels).

## 2. Options for win-win deviations

### *b. Power-sector technologies*

-- Generation technologies

- Supercritical power plants most appropriate for India in short term – offer significant gain in efficiency (40-46% efficiency)
- Other advanced technologies (CFBC, PFBC, IGCC) may be appropriate in longer term

-- Improved T&D and end-use technologies

- Improved accounting methodology, improved distribution transformers, and optimal network planning could reduce losses by over 25%
- Efficient agricultural pumpsets, efficient lighting, and solar water heating could offer quick end-use reductions

| **All Compared to Business as Usual in 2025** | Direct Fuel/Energy Savings | | | | GHG Savings (MT $CO_2$-eq/y) | Compared to all Indian emissions (%) |
|---|---|---|---|---|---|---|
| | Biomass (MT) | Petroleum Fuels (MT) | Coal (MT) | Electricity (BU) | | |
| **BIOMASS** | | | | | | |
| SMIE(Scenario–II)* | 5 | 14 | 17 | | 81 | 2.2 |
| ABCT (Scenario-I) | 124 | | | | 36 | 1.0 |
| Subtotal | 129 | 14 | 17 | | 117 | 3.2 |
| **COAL POWER** | | | | | | |
| Coal power generation | | | 100 | | 153 | 4.1 |
| Power T&D | | | | 125 BU | 103 | 2.7 |
| Ag pumping | | | | 225 BU | 185 | 4.9 |
| Lighting | | | | 150 BU | 123 | 3.3 |
| Solar water heating | | | | 20 BU | 16 | 0.4 |
| Subtotal** | | | 100 | 520 BU | ~520 | 14.4 |
| **TOTAL** | 129 | 14 | 117 | 520 BU | ~637 | 17.6 |

# 3. Development benefits of clean energy technologies

| Option | Development Benefit | Effects / Impacts | Quantification (in 2025) |
|---|---|---|---|
| Advanced Biomass Cooking Technologies | Health (+++) | Reduction in respiratory and other diseases of women and children | 90 million households (5 member family) |
| | Economic (Household) (-+) | Initial capital expenditure for new stove (-), which can be reduced by smart subsidies More time for women to engage in other economically productive activities | Rs. 1500 per stove of ~ 7 y lifetime (~ the current household subsidy per year for LPG) |
| | Economic (Society) (++) | Reduction in annual amount paid as subsidy for LPG | Per I MT/y of LPG substituted will need 4.3 million ABCTs. Savings of Rs. 6.45 billion /y in LPG subsidy. |
| | Access / Equity (++) | Convenient clean fuels for rural poor; reduction of burden of fuelwood collection for women and children | 90 million households (5 member family) |
| | Energy Security (+) | Reduction of demand for LPG, conservation of biomass resources. | Savings of 124 million tonne of biomass/year. Each MT/y of LPG substitution will need 4.3 MT/y of biomass, available from savings. |
| | Employment (++) | Enterprise development for gasifier stove, processed-fuel industries, biogas construction and maintenance | *Employment for 150,000 persons |

# 3. Development benefits of clean energy technologies

| Option | Development Benefit | Effects / Impacts | Quantification (in 2025) |
|---|---|---|---|
| Biomass Gasifiers | Economic (SMIE) (++) | Reduced energy bill | |
| | Energy Security (+) | Reduction of oil consumption | Scenario-II: Fuel savings<br>Coal: 17 million tons/year<br>Biomass: 5 million tons/year<br>Petroleum fuels:14 million tons/year |
| | Employment (++) | Creation of biomass markets, jobs for equipment manufacture, supply, maintenance, biomass supply, transport, pelletization | *Total: Employment for 900,000 persons (300,000 employment for gasifier manufacturer and operation and 600,000 employment in biomass production, processing, supply chain and after sale service) |
| | Access / Equity (-?) | Possible reduction in access for cooking fuel for poor households due to biomass markets | |
| | Others | Reclamation of degraded lands (+)<br>Land availability for food (-) | |

# 3. Development benefits of clean energy technologies

| Option | Development Benefit | Effects / Impacts | Quantification (in 2025) |
|---|---|---|---|
| Clean Coal | Energy Security (+) | Conservation of existing coal reserves | 100 million tonne of coal annually saved |
| | Economic (--)<br><br>Economic (++) | Additional capital investment, technology development cost<br>Annual savings in fuel cost | |
| | Local Environmental (+) | Reduced NOx, SOx, particulate emissions | |

| Option | Development Benefit | Effects / Impacts | Quantification (in 2025) |
|---|---|---|---|
| T & D and Efficiency | Economic (++) | Improved revenue of utilities<br>Deferred capacity addition | Rs. 500 billion additional<br>110,000 MW |
| | Equity / Access (+) | Reduced power shortages, availability of power for new connections | 520 billion units savings |
| | Employment (+) | Jobs for energy efficiency, pump rectification, transformer audit | |
| | Same benefits as Clean Coal | By reducing demand for coal power, the same kinds of benefits as found under Clean Coal occur | |

# 4. Barriers, to, and strategies for, deployment

## *a (1): Advanced biomass cooking technologies*

-- Barriers

- Sustained biomass supply systems
- Limited technology and product development and standardization
- Lack of supply chains for product deployment and maintenance

-- Strategy

- Targeted technology development
- Support for biomass supply systems
- Subsidy to end-users
- Enterprise development
- Testing, quality control, and certification

# 4. Barriers, to, and strategies for, deployment

*a (2): Biomass gasifiers for SMEs*

-- Barriers

- o Sustained biomass supply systems
- o Technical issues
- o Lack of standards for performance, safety, and quality => limited confidence among potential adopters
- o Limited infrastructure for product dissemination

-- Strategy

- o Mainstreaming technology
- o Better organization of product development systems and deployment channels
- o Support for biomass supply systems
- o Availability of financing

# 4. Barriers, to, and strategies for, deployment

*b (1): Advanced coal-power generation*

-- Barriers

- Sustained coal supply
- Limited exposure to advanced technologies
- Technical issues regarding deployment with Indian coals
- No incentive to invest in more capital-intensive options

-- Strategy

- Better understanding of coal reserves and supply
- Regulatory and other approaches for speeding up deployment of supercritical combustion plants
- Support establishment of prototype plants for other advanced technologies (CFBC, PFBC, IGCC)
- Assessment and review of prototypes and performance

# 4. Barriers, to, and strategies for, deployment

## *b (1): T&D and end-use improvements*

-- Barriers

- Lack of detailed data
- Supply-focused organizations
- Electricity subsidies
- Lack of information for consumers
- High initial capital costs of improved end-us technologies

-- Strategy

- Programmatic focus on T&D improvements
- Institutionalization of DSM programs within utilities
- Metering of pumpsets by consumption rather than by connected load
- Development of efficiency standards for new technologies