Global Energy Assessment

Thomas B Johansson

Co-Chair, GEA Executive Committee

Need for an Energy Assessment

- The world is at a critical juncture for energy policy, new challenges have emerged, while old ones remain

- Previous studies do not identify the strategies and solutions needed to ***comprehensively address*** today's major energy and energy-related challenges in an ***integrated*** way

Challenges requiring actions on Energy

a. **equity** in energy services (the 2 billion w/o)
b. **affordable** energy services (@$100/bbl??)
c. **secure** supplies
d. **local and regional environmental challenges**
e. **climate change mitigation**
f. **ancillary risks**

Major Energy System Changes Needed!

These **challenges** must be addressed

jointly

adequately

timely

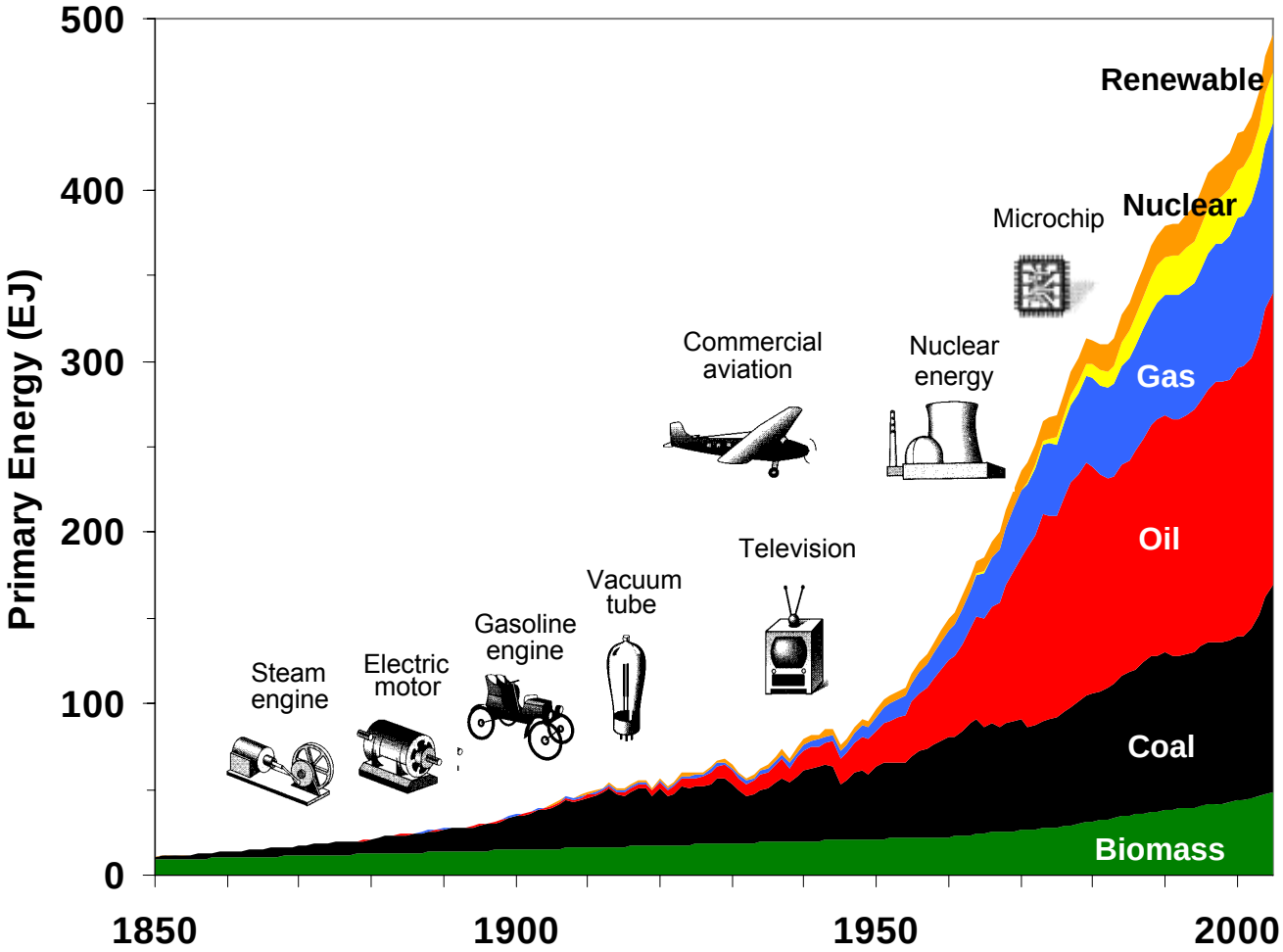
GEA Objectives include:

- ***Science based, comprehensive, integrated, and policy-relevant*** analysis of issues and options related to:
  - Energy and sustainability challenges
  - Resource and technology options, demand and supply
  - System issues, scenarios
  - Policy options
- Local, Regional, and Global dimensions

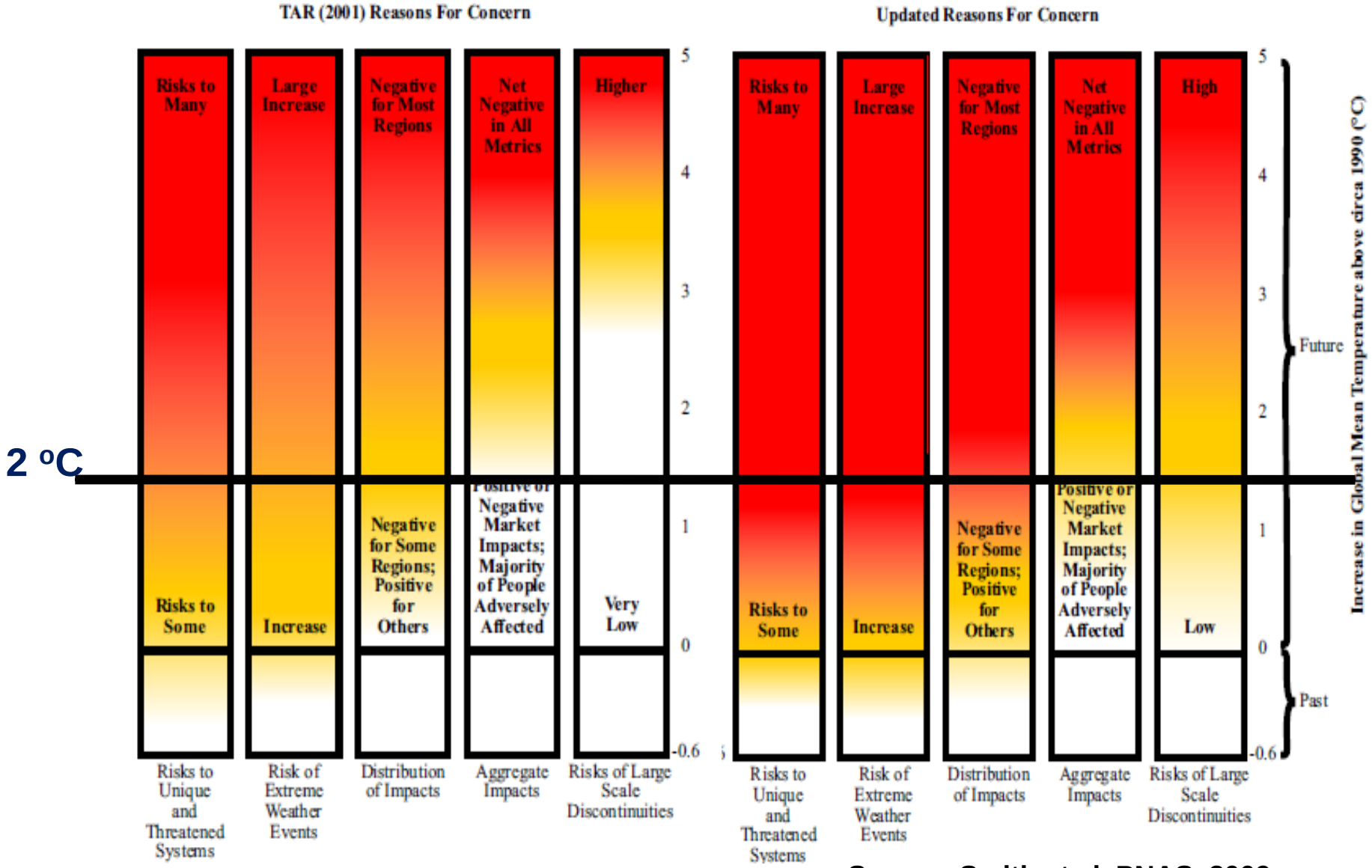
integration of knowledge clusters

- **Cluster I** characterizes nature and **magnitude** of challenges, and express them in selected indicators
- **Cluster II** reviews existing and future resource and technology **options**
- **Cluster III** **integrates** cluster II elements into systems, and links these to indicators from Cluster I
- This will include energising of rural areas, land use, water, urbanisation, life-styles, etc.
- Scenarios, using numerical models and storylines, will be used for the **integration**, in an **iterative** fashion
- **Cluster IV** assesses policy options, and specifically identifies **policy packages** that are linked to scenarios meeting the needs, again in an **iterative** fashion.

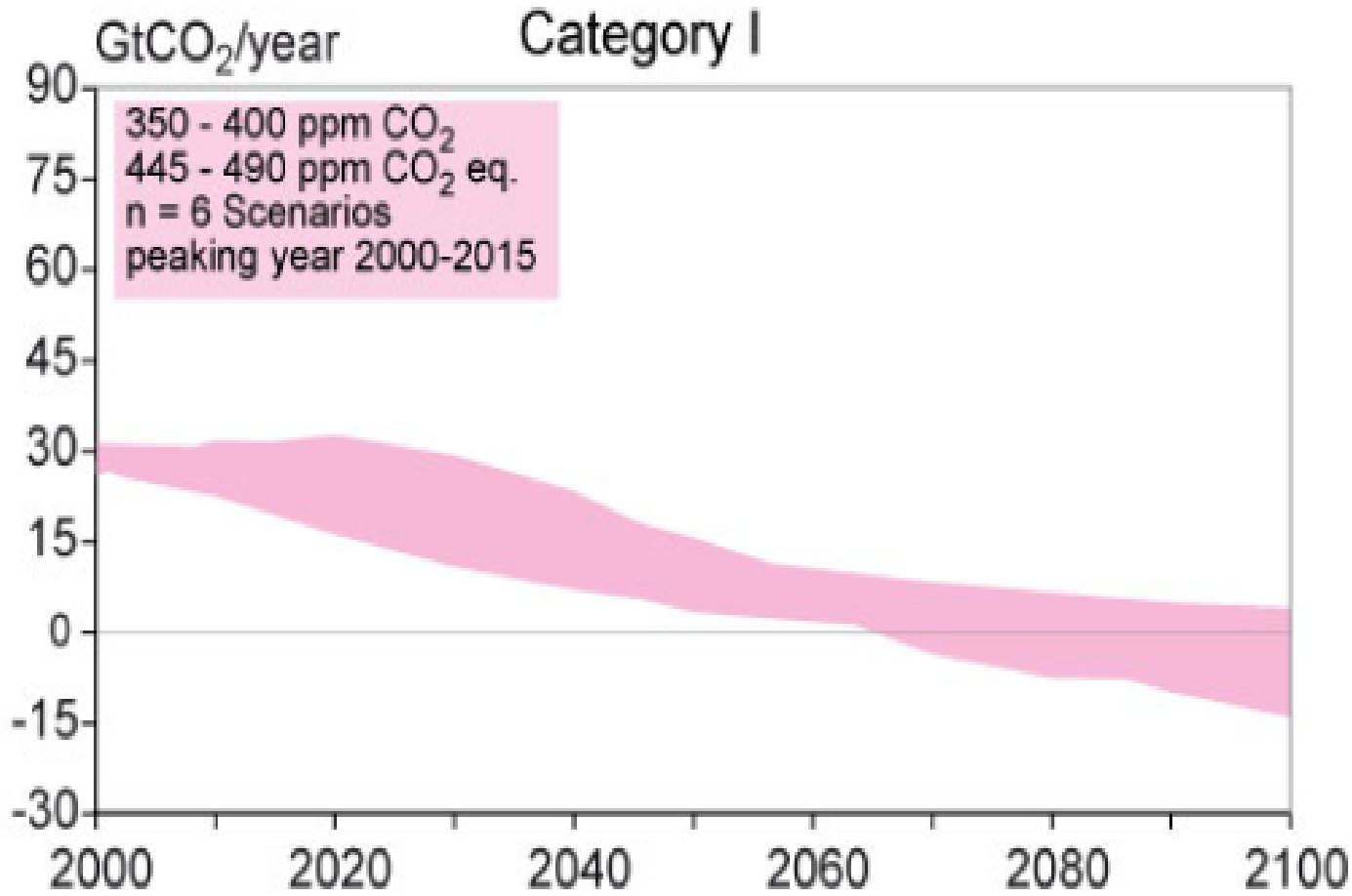
World Primary Energy



Updating reasons for concern



Source: Smith et al. PNAS, 2009


GtCO2/year
Category I
350 - 400 ppm CO2
445 - 490 ppm CO2 eq.
n = 6 Scenarios
peaking year 2000-2015
90
75
60
45
30
15
0
-15
-30
2000
2020
2040
2060
2080
2100

Russian-Roulette Chance (p = 5/6) of Holding 2°C-Line:

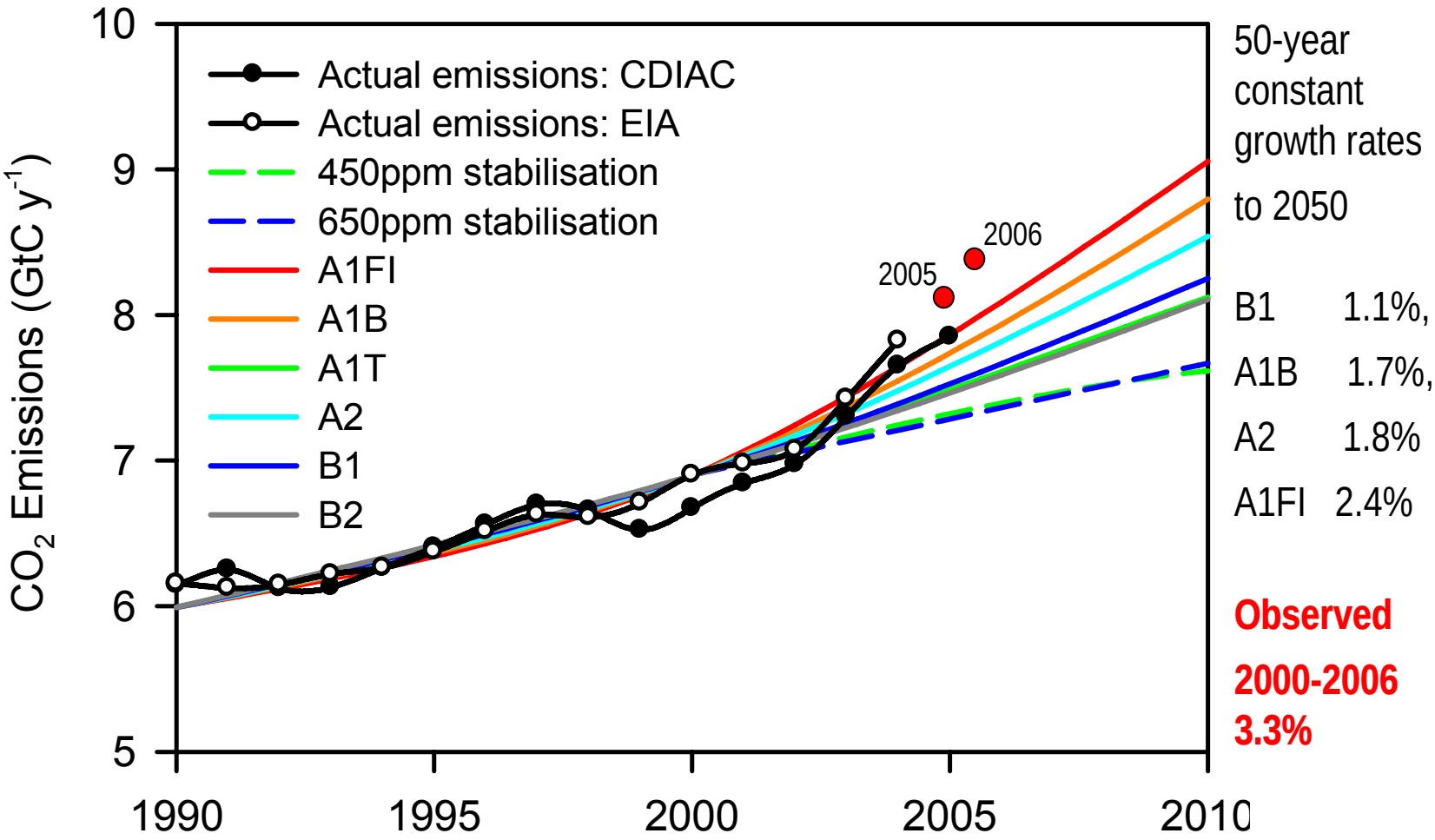
80% Reduction of Global GHG Emissions by 2050, Relative to 1990 Levels

(According to GCM-Ensembles Calculations)

Negative Emissions after 2070 !

Source: Schellnhuber, Copenhagen 2009

Trajectory of Global Fossil Fuel Emissions



Raupach et al. 2007, PNAS

this translates into a need for a major energy system transformation

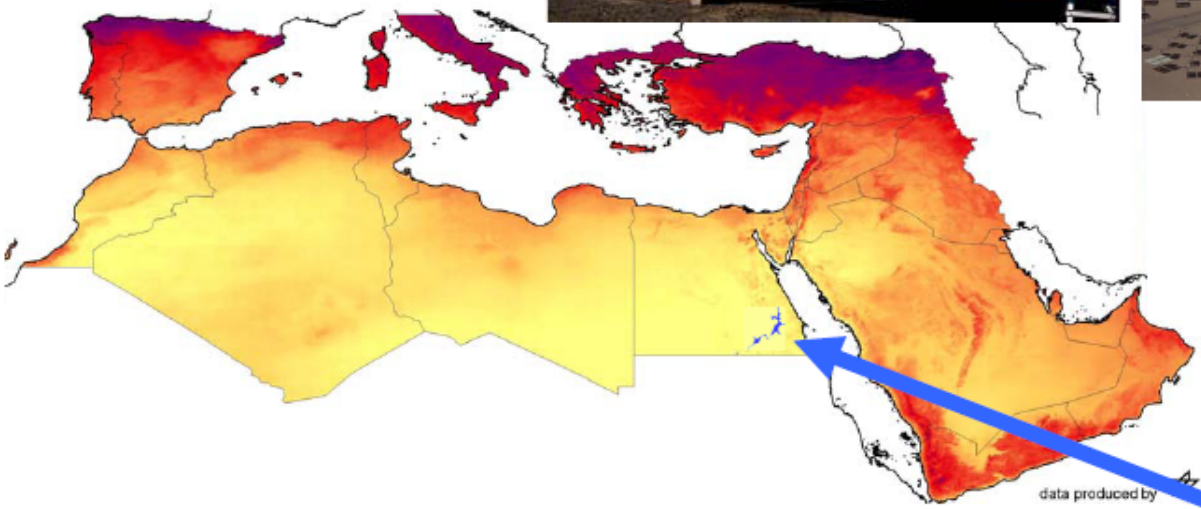
Main elements:

- Energy end-use efficiency
- Renewable energies
- Carbon Capture and Storage

- **Efficiency** and **Renewables** are **INSTRUMENTS** for addressing all the challenges at the same time!

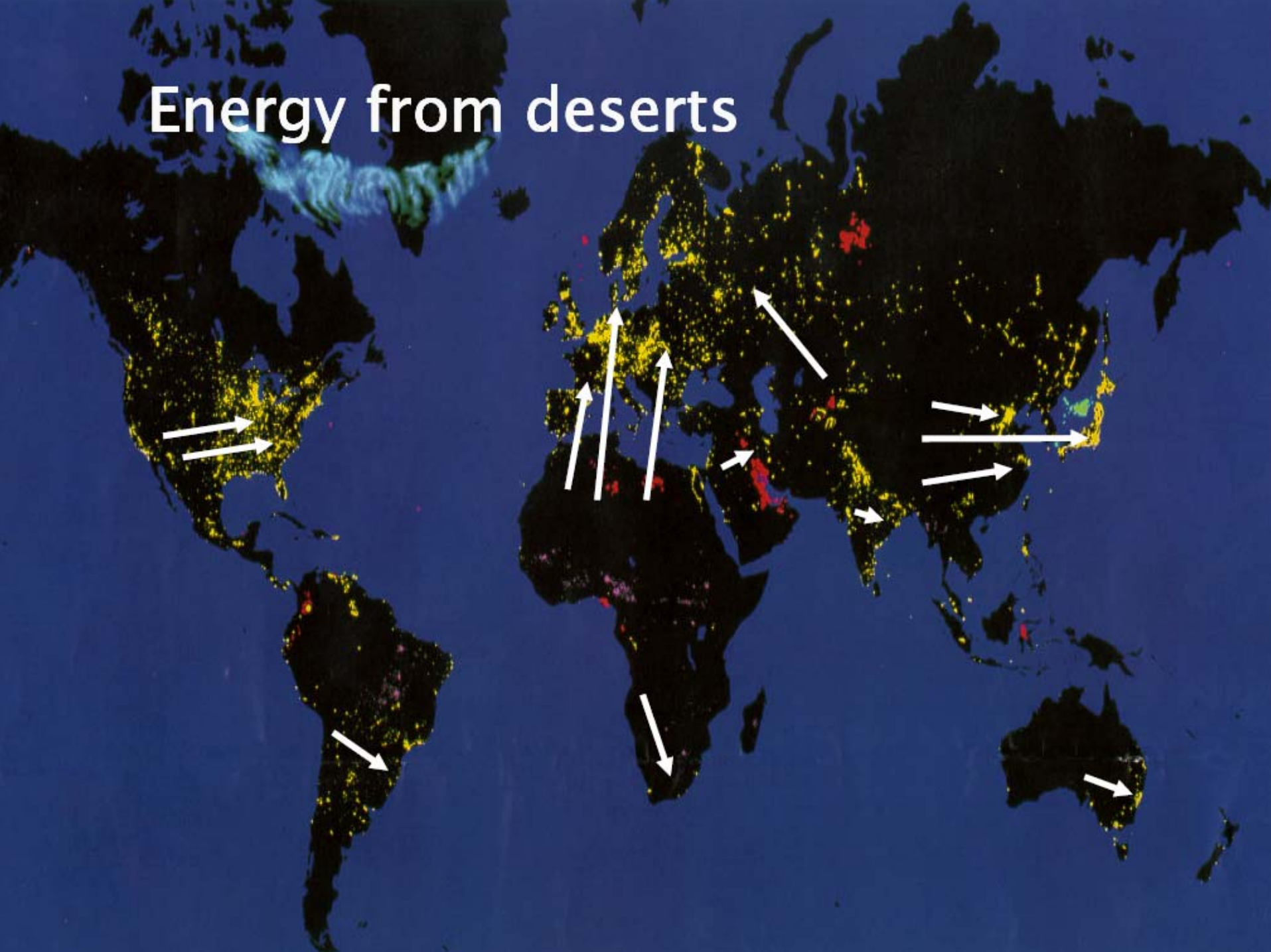
Think

solar resources in the Middle East/North Africa region



a solar thermal power plant of the size of Lake Nasser (Aswan) could harvest energy equivalent to the annual oil production of the Middle East

Energy from deserts



not just energy technology

- Urban planning
- Transportation systems
- Material use
- Land use
- Consumption patterns
- …..

Global Energy Assessment

- **unique** and **timely**
- **comprehensive** and **integrated**
- **process** going beyond a **report**
- **policy** relevant
- **options** and **strategies** for the way forward

www.GlobalEnergyAssessment.org

Nebojsa Nakicenovic

GEA Director

Global Energy Assessment

Global Energy Challenges

- Sustainable access to energy and food (a prerequisite for reaching MDGs)
- Energy **and** ecosystems services
- Security and reliability of systems
- Deep GHG emissions reductions
- Technology R&D **and** deployment
- Integrated policy frameworks

Towards a more Sustainable Future

- The *magnitude of the change* required in the global energy system will be huge
- The challenge is to find a way forward that addresses *simultaneously* climate change, security, equity and economics issues.
- *Paradigm change is needed*: radical improvements in energy end-use efficiency, new renewables, advanced nuclear and carbon capture and storage.
- Needs to be *globally integrated* but with maximum support of countries and local levels.
- In the best spirit of science: *fact-based and peer-reviewed*

GEA Knowledge Clusters

- **Cluster I: Major Global Issues and Energy**
  1. An Introduction to Energy (Goals, Visions, Why?)
  2. Social Issues, MDGs and Energy
  3. Environment and Energy
  4. Health and Energy
  5. Security, Interdependence, Markets and Energy
  6. Energy, Economy and Investment
- **Cluster II: Energy Resources and Technological Options**
  7. Energy Resources (Fossil, Nuclear and Renewable)
  8. Energy End-Use (Efficiency): Industrial Sector
  9. Energy End-Use (Efficiency): Transport
  10. Energy End-Use (Efficiency): Buildings (commercial and residential)
  11. Renewable Energy
  12. Fossil Energy Systems (Conventional and Advanced)
  13. Carbon Capture and Storage
  14. Nuclear Energy
  15. Energy Supply System Operation
  16. Synthesis module: End-use and Supply Linkages and Synthesis

GEA Knowledge Clusters

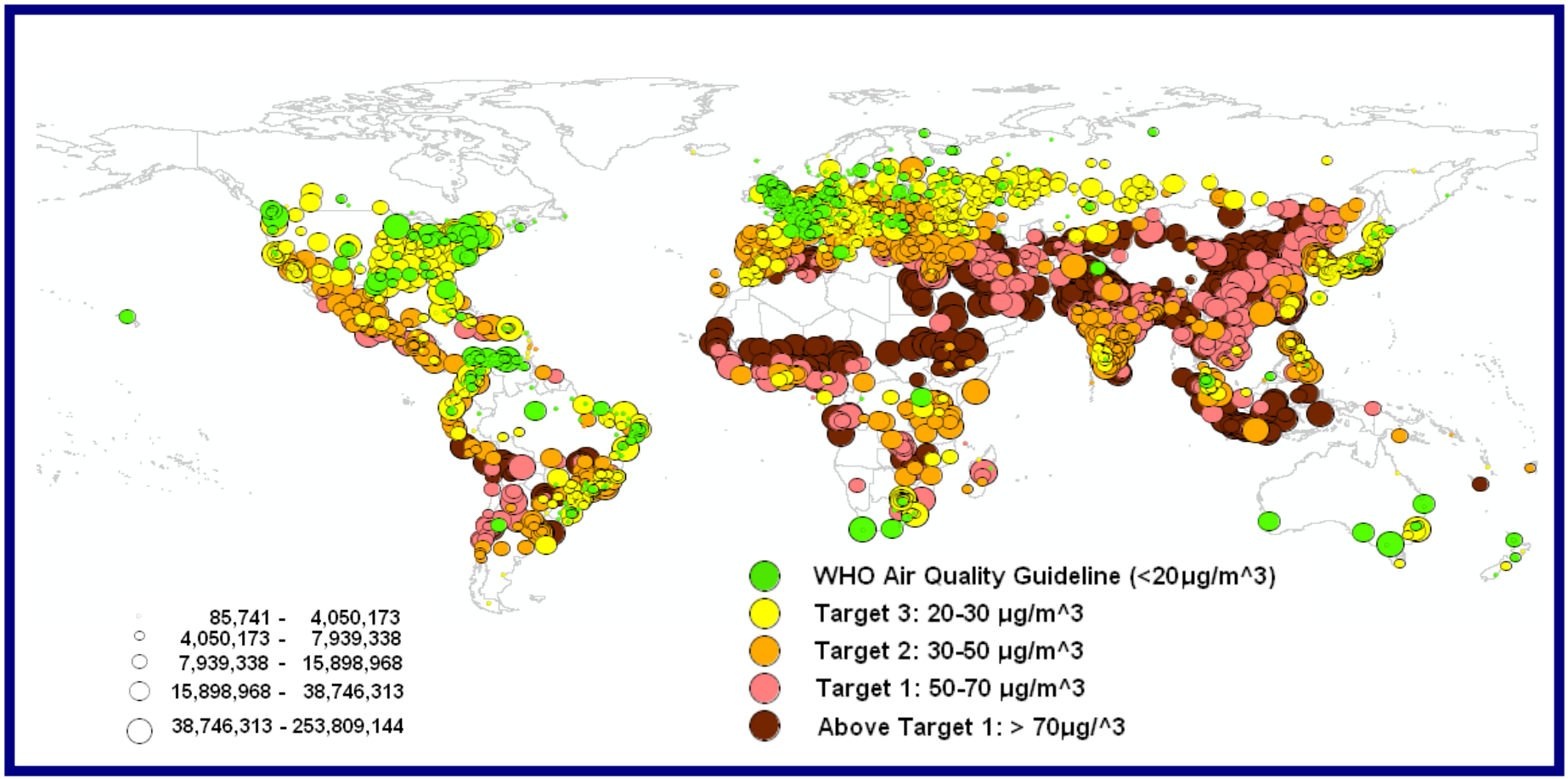
(cont'd)

- **Cluster III: Describing Possible Sustainable Futures**
  17. Global and Regional Scenarios, Normative Futures, and Major Uncertainties
  18. Urbanization
  19. Rural Energy and Increasing Access
  20. Trade-Offs, Land and Water
  21. Energy Services and Human Well Being (Lifestyles, consumption patterns)
- **Cluster IV: Realizing Energy for Sustainable Development**
  22. Energy Policy: Rationales and Mechanisms
  23. Policies for Energy Access
  24. Policies for Innovation
  25. Policies for Capacity Building 'and more'
  26. Sustainable Energy Policy Portfolios
  27. Epilogue

Factors of Growth: The Last 200 Years

	1800	2000	Factor
Population (billion)	1	6	x6
GDP PPP (trillion 1990 $)	0.5	36	~x70
Primary Energy (EJ)	12	440	~x35
CO_2 Emissions (GtC)	0.3	6.4	~x20

PM10 Exposures in 3200 Cities

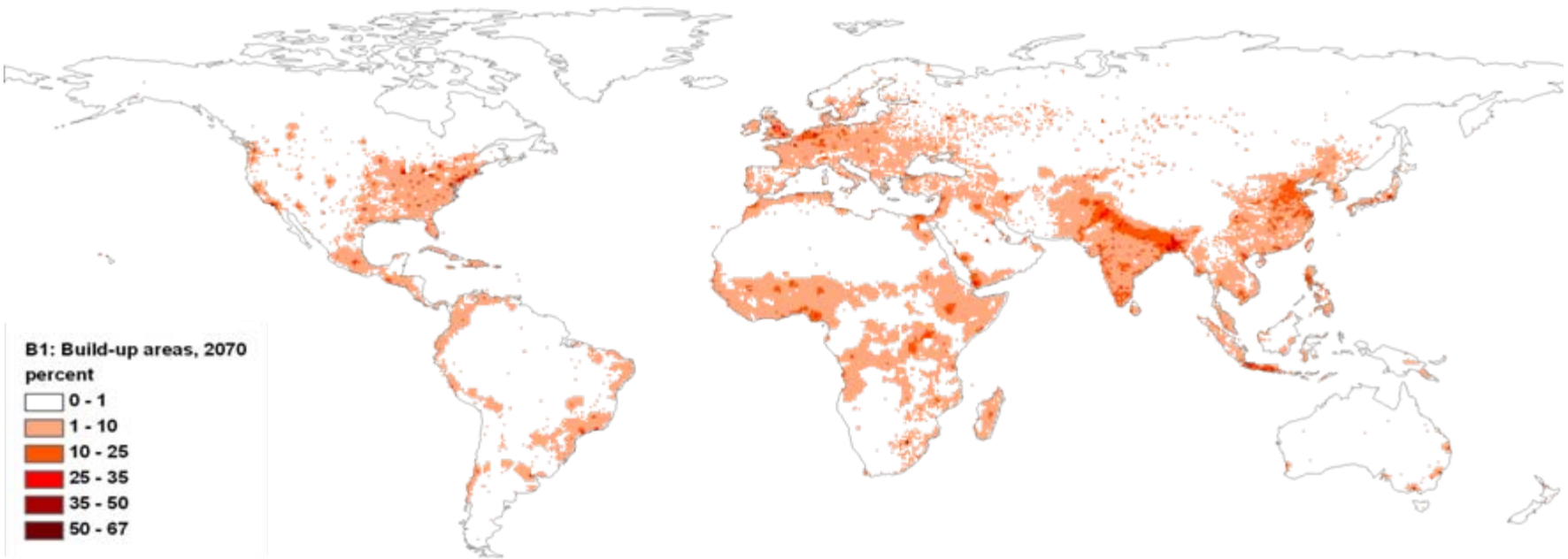


Exposure: PM_{10} concentration*City population (capita.µg/m^3)
Size of circle indicates exposure (Quintiles)
Color of circle indicates underlying PM_{10} Concentration (µg/m^3) range:
7-358 µg/m^3

Source: C. Doll, 2009, based on World Bank data

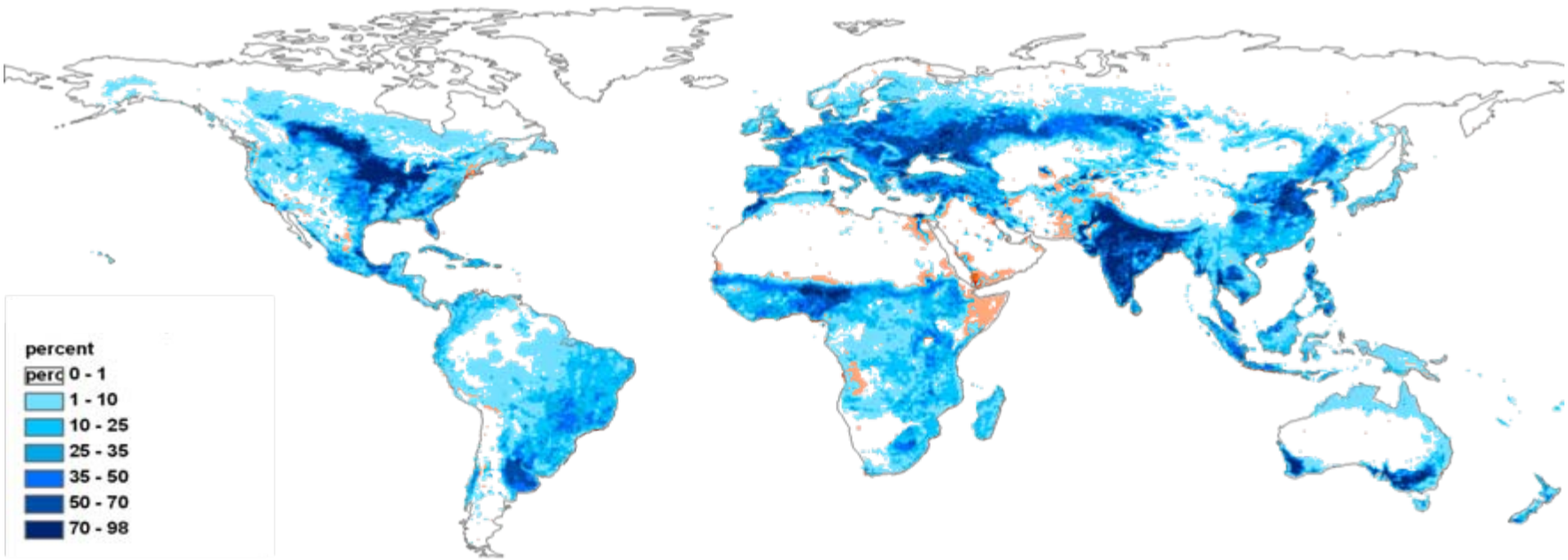
Global Build-Up Area

2070



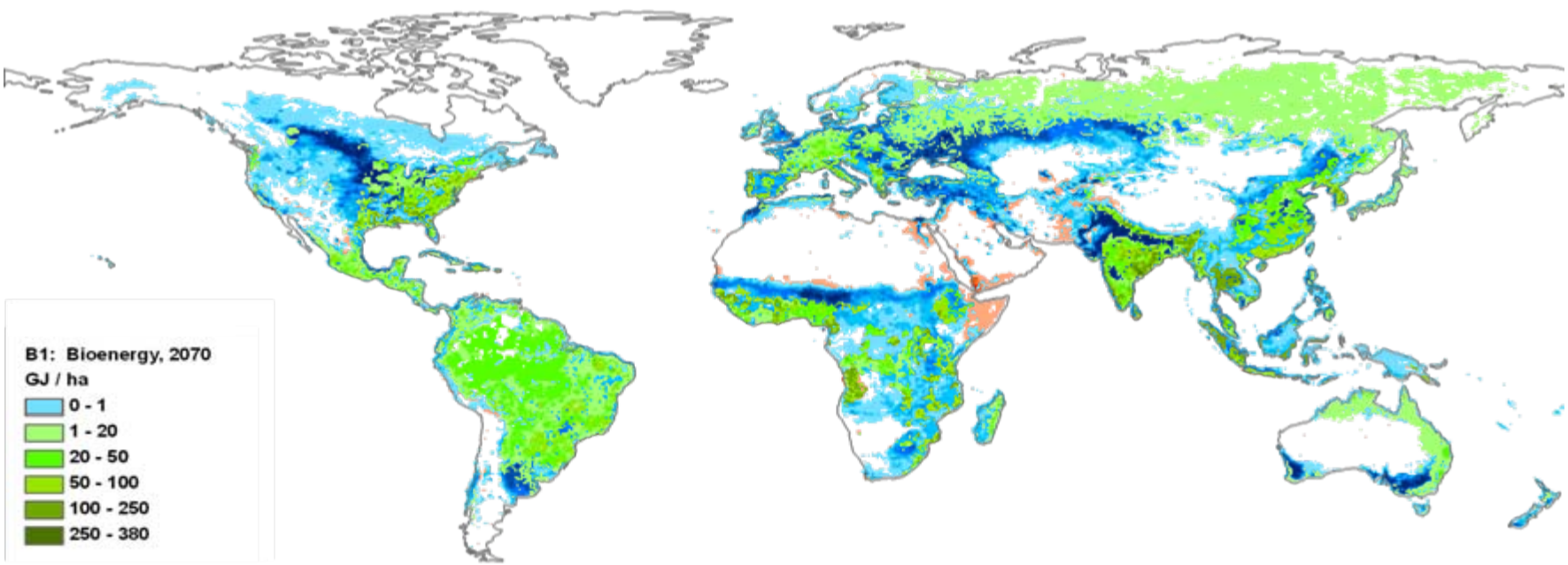
Global Arable Land

2070



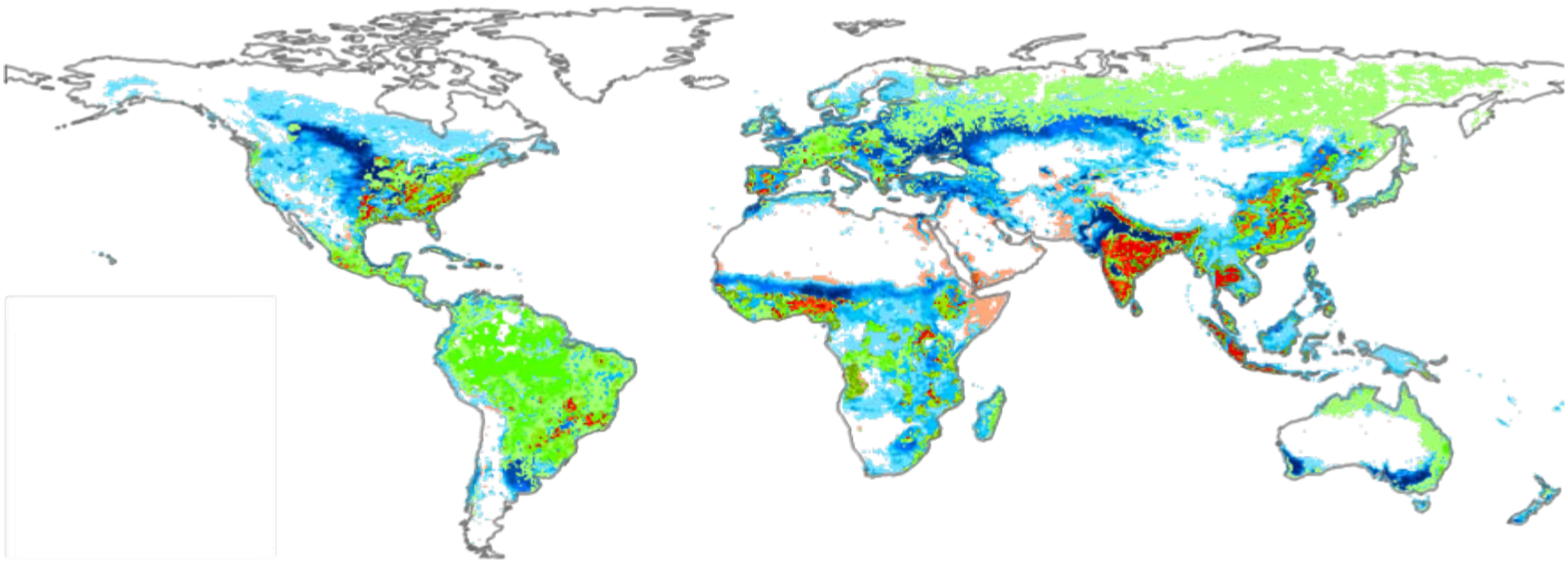
Global Bioenergy Land

2070

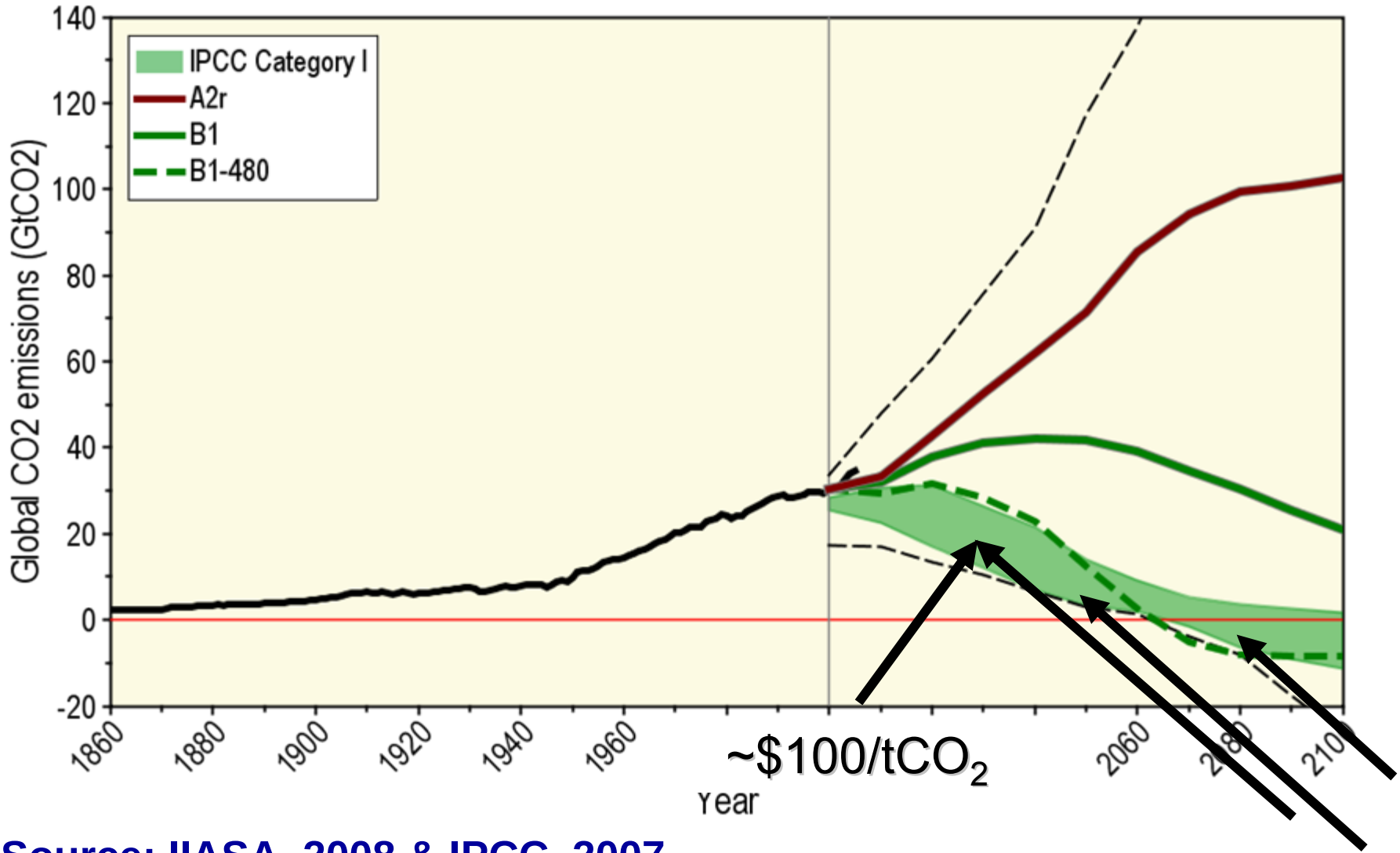


Energy and Food Land Conflicts

2070

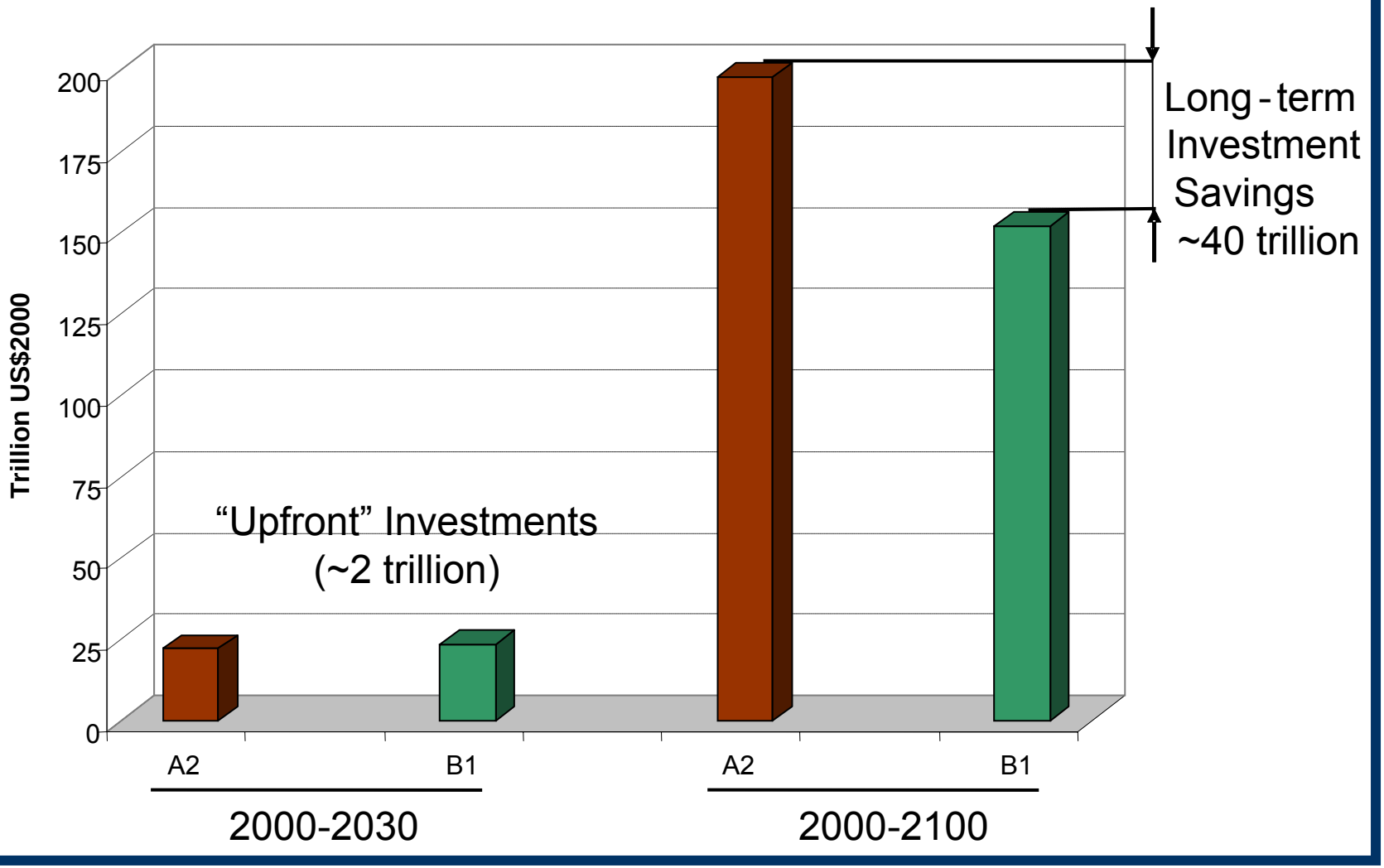


Global CO_2 Emissions

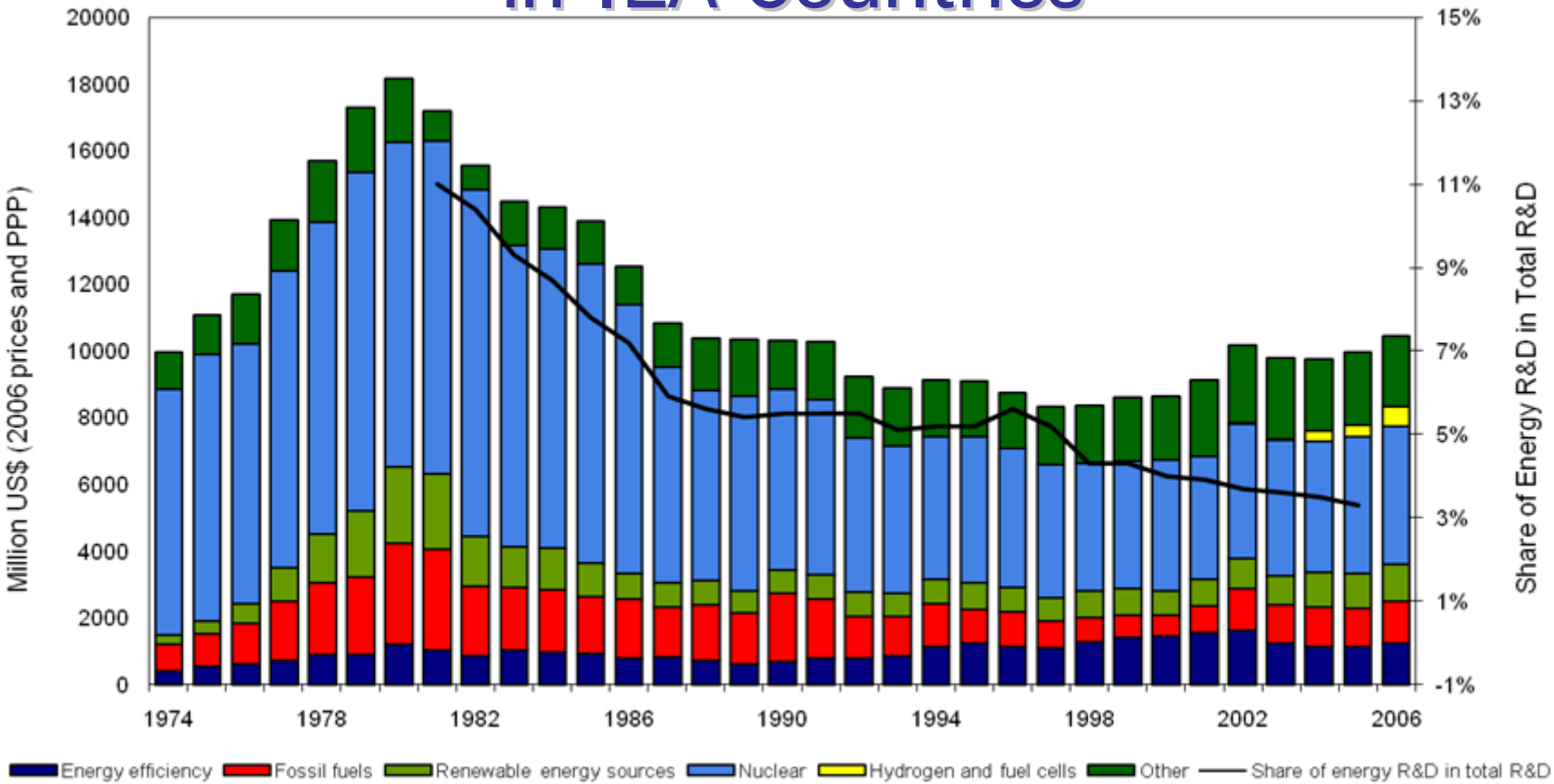


Source: IIASA, 2008 & IPCC, 2007

Total Energy-related Investments (World, short & long-term)



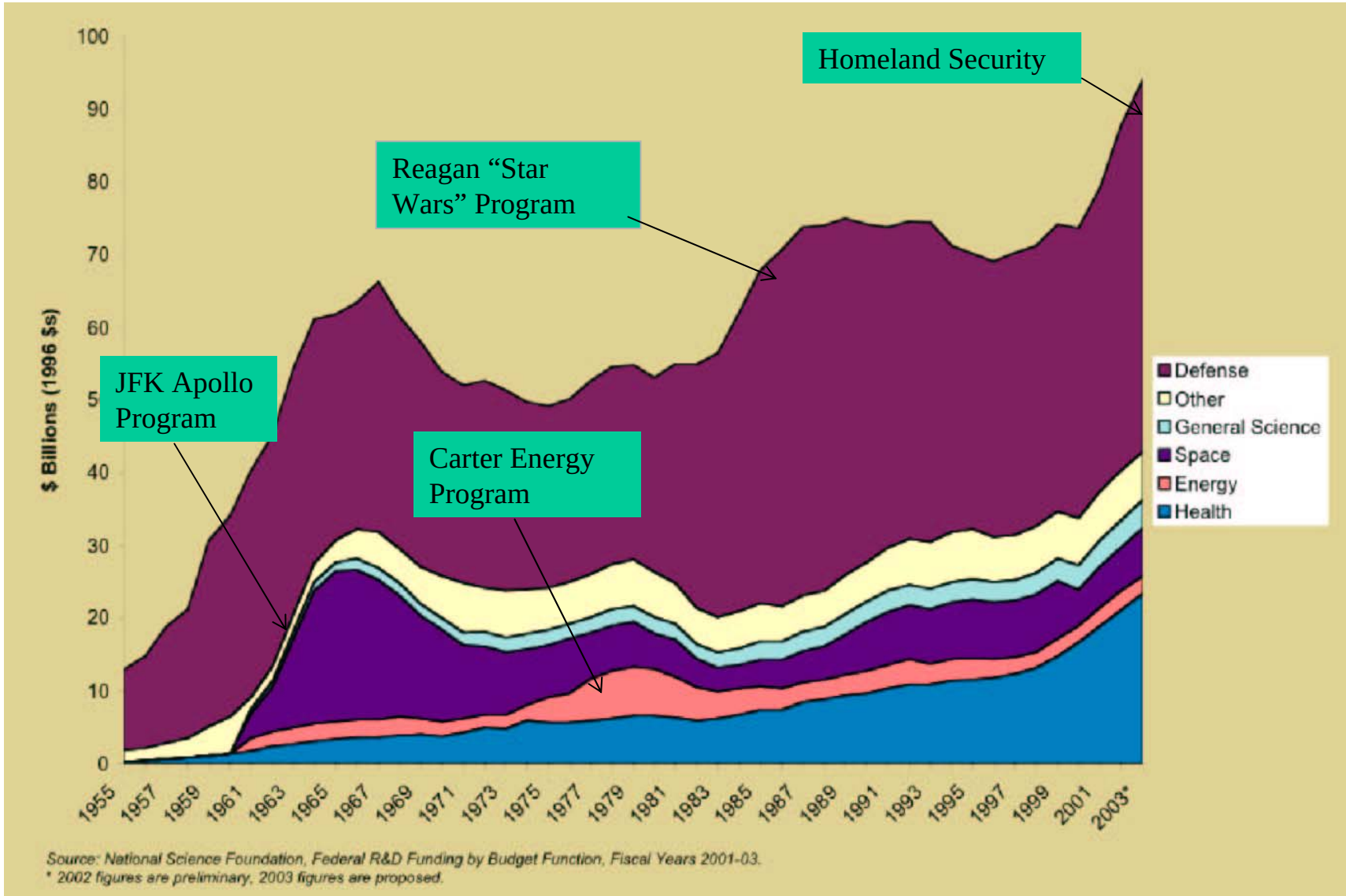
Public Sector Energy R&D in IEA Countries



Share of public budgets for energy R&D in total R&D significantly fell over the last two decades. Private-sector R&D is increasingly focused on projects with short-term payoffs

Source: IEA Databases, Doornbosch, et al., 2008

History of US Federal Government R&D



Source: after Margolis and Kammen, 1999

"Energy RD&D programs are not commensurate in scope and scale with the energy challenges & opportunities the 21st century will present."

Source: PCAST, 1997

Investments Themes in Stimulus Packages

Green New Deals? Climate Change Investment Themes in 2008 Stimulus Packages (USD bn)

Country	Stimulus Package	Total Package	Low Carbon Power (Renewables, CCS)	Energy Efficiency, R&D, Modal Shift	Waste, Water Treatment & Pollution Control	Green Investments (%)	Other Infra	Period	Status
Chile	Anti-crisis stimulus package	4.0	-	-	-	-	0.7	2009	Pending
China	NDRC Stimulus Package	581.2	-	147.6	50.9	34%	239.9	2009-2010	Passed
EU	Recovery Plan	253.6	19.0	15.5	-	14%	8.0	2009-2010	Passed
France	Revival Plan	32.9	0.8	2.0		8%	18.7	2009-2010	Pending
Germany	Stimulus Plan	63.4	-	11.9	-	19%	-	2009-2010	Pending
India	Stimulus Package	6.8	-	-	-		2.0	2009	Passed
Israel	Stimulus Plan	5.0	-	0.1	-	2%	2.3	2010 onwards	Passed
Italy	Emergency Package	101.4	-	1.2	-	1%	-	2009 onwards	Passed
Japan	Stimulus Package	476.0	-	11.0	-	2%	2.2	2009 onwards	Pending
Poland	Stimulus Package	30.0	-	-	-	-	-	2009 onwards	Pending
South Korea	Green New Deal	38.1	-	8.5	17.8	69%	-	2009-2012	Passed
Spain	Stimulus Package	13.9	0.8	0.6	-	10%	11.2	2009	Passed
Thailand	Stimulus Package	8.7	-	-	-	-	-	2009	Pending
United Kingdom	Pre-budget report 2008	29.7	0.6	1.4	-	7%	26.5	2009	Pending
United States	Emergency Economic Stabilization Act	700.0	12.0	1.7	-	2%	0.9	Next 10 years	Passed
	Economic Stimulus Package	825.0	10.4	85.9	32.3	16%	9.2	2009-2010	Pending
Total Funds Unveiled		**3170**	**43.5**	**287.4**	**101.0**	**14%**	**321.5**	**Available from 2 to 10 yrs**	

Source: HSBC

Source: HSBC 2009

Implications for Policy and Capacity Building

- Develop new ways to stimulate investment in risky processes of disruptive technological change and build the capacity to do so
  - at the level of the firm –through the promotion of business models such as open innovation and the research and development capacities required to participate in them,
  - at the international level – by using existing mechanisms, the CDM, for example, to promote technology transfer, strengthen local innovation capacity and finance the energy future in Developing Countries
- Build capacity at local and national levels to create new institutional and regulatory frameworks that involve greater actor participation in collaborative projects and more consensual bottom-up processes to complement traditional top down policy approaches.

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Shonali Pachauri
Rural Energy

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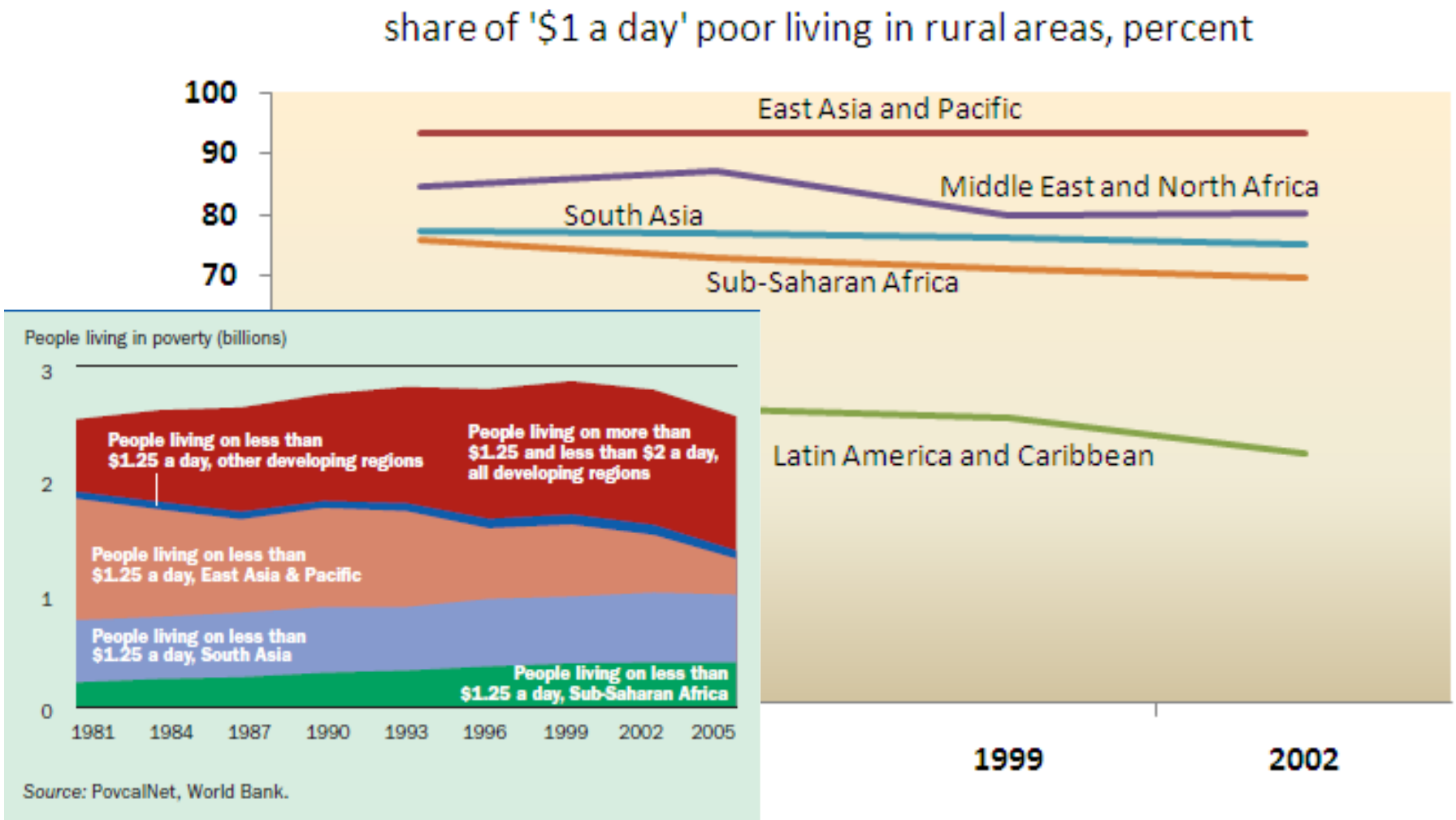
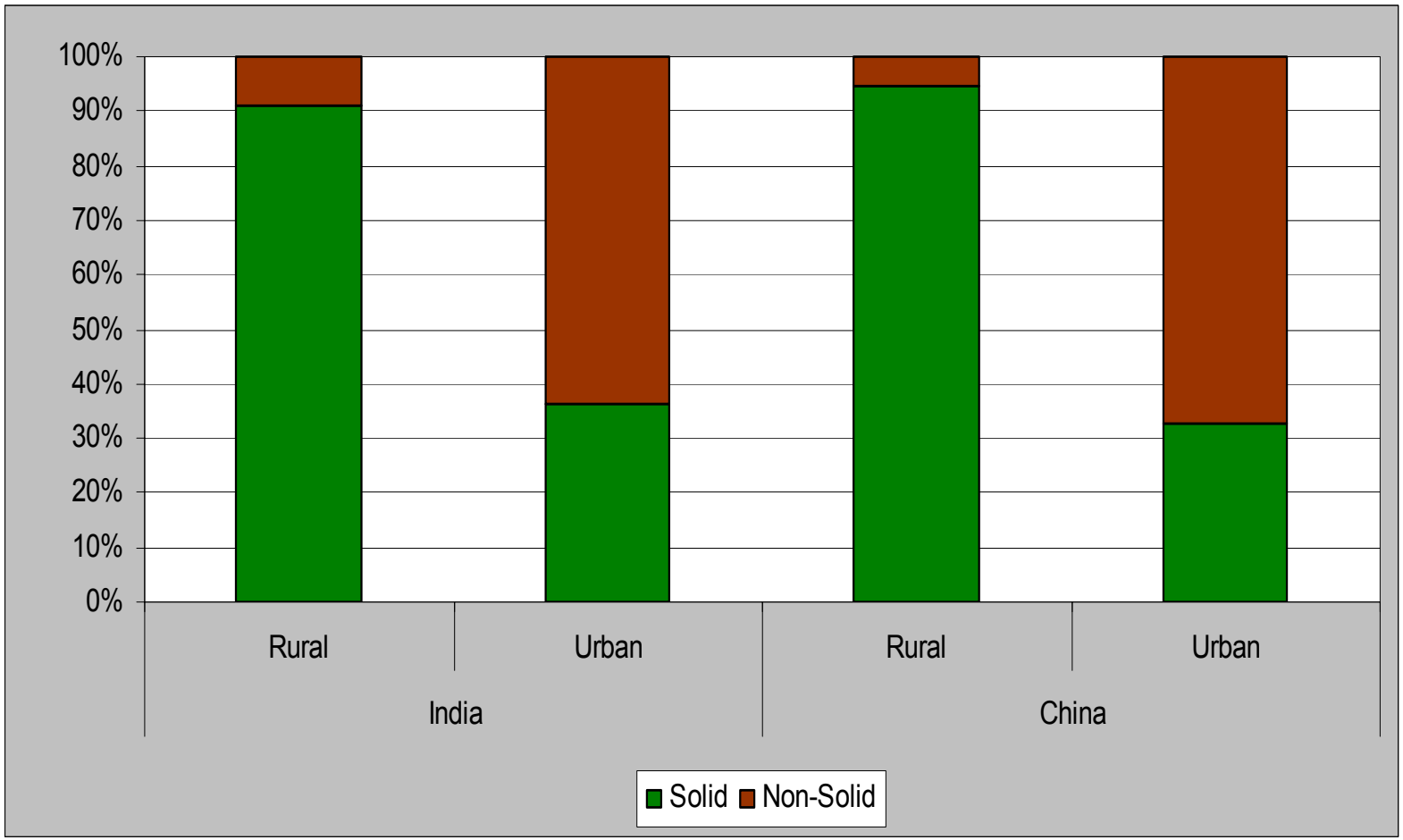
Rural Poverty in Decline (Good News … ?!)



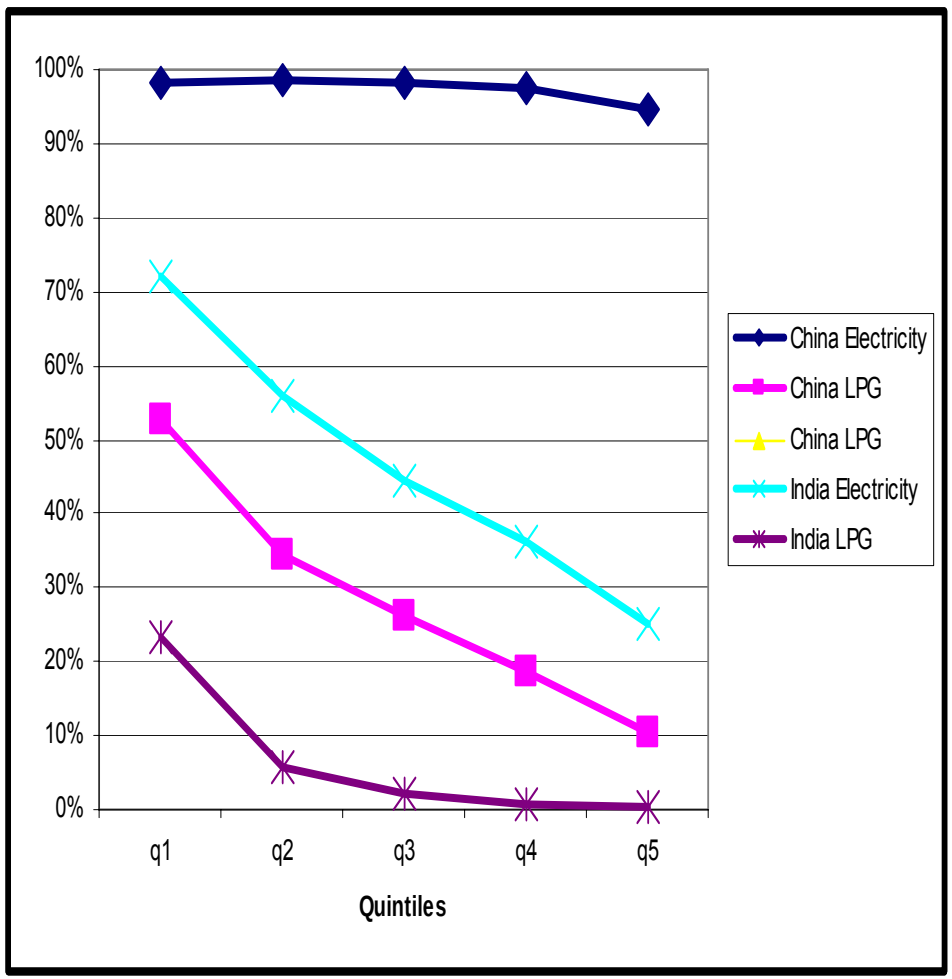
Data Source: Ravallion et al. (2007), Adapted

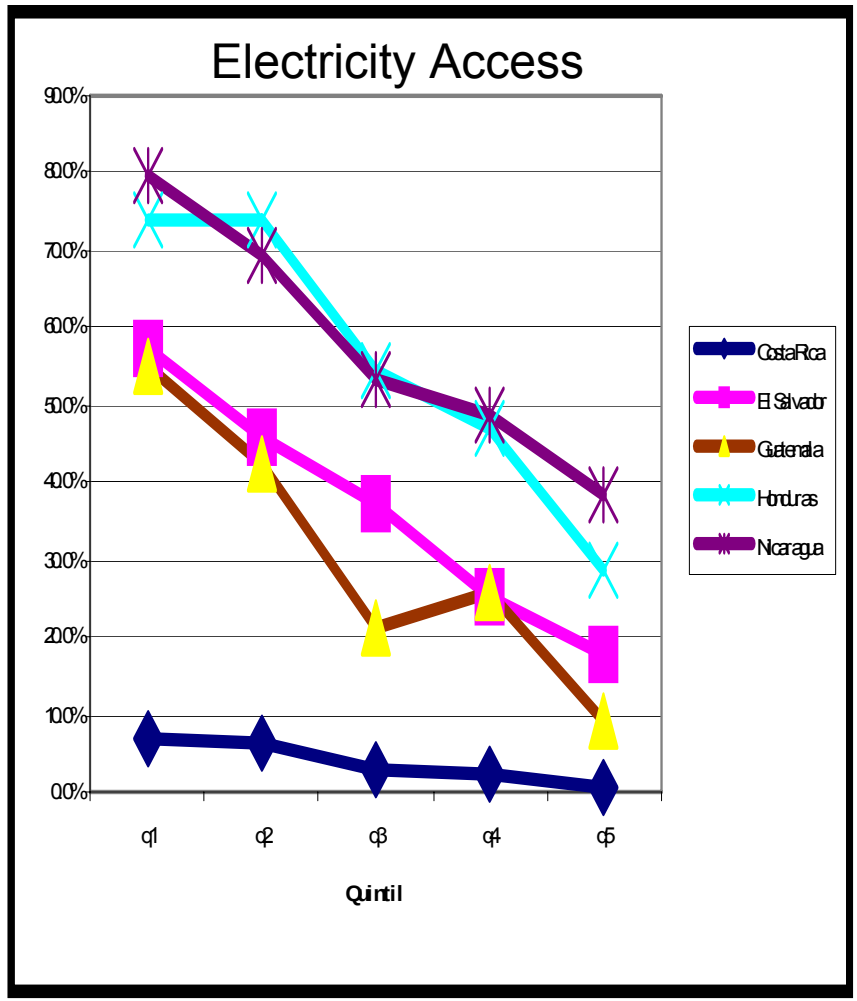
Final Energy Split In Households



Data Source: Pachauri & Jiang 2008

Learning from China, India and Latin America
- energy access across rural household groups

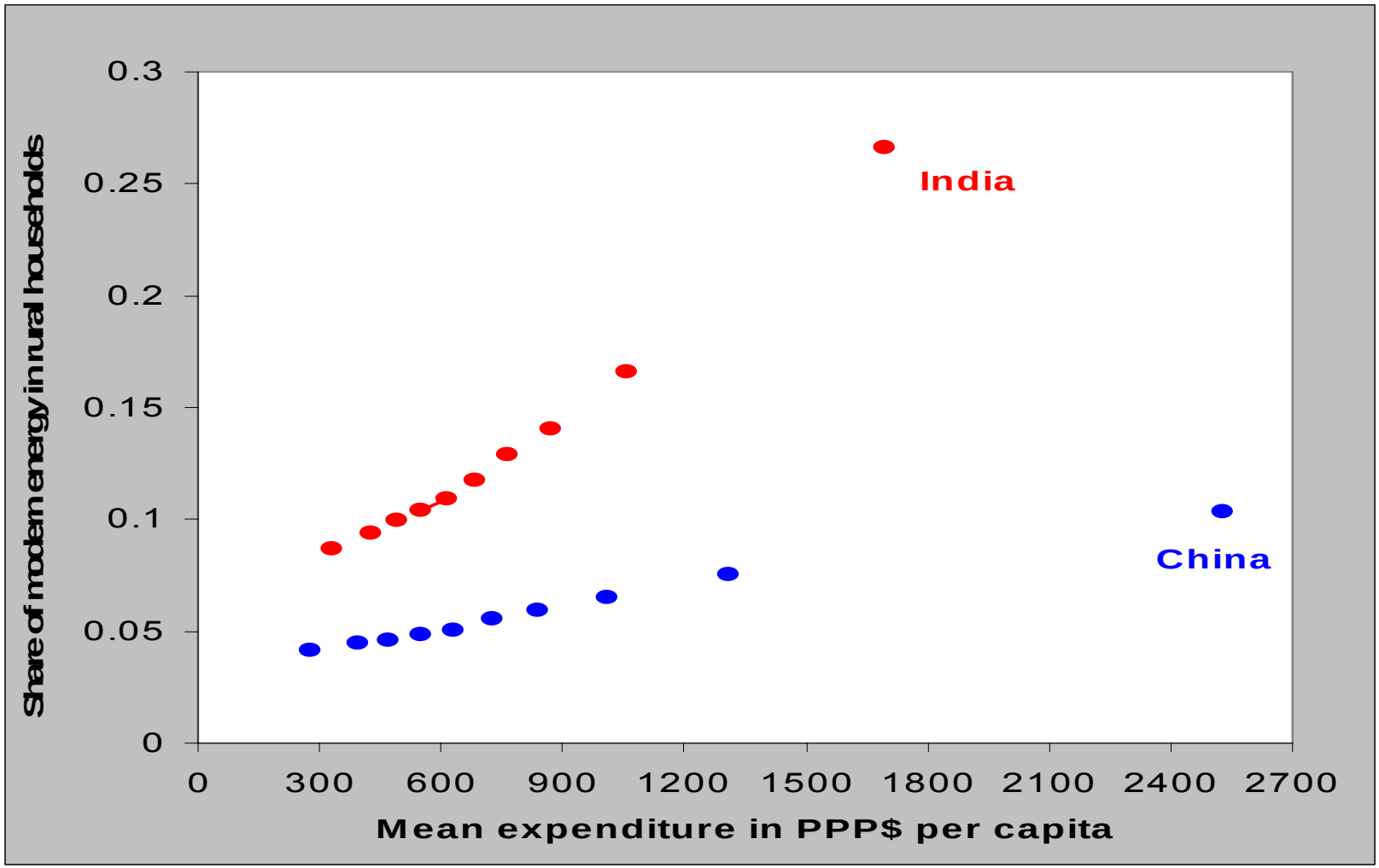




Data Source: Pachauri & Jiang 2008.

Data Source: CEPAL, Chile.

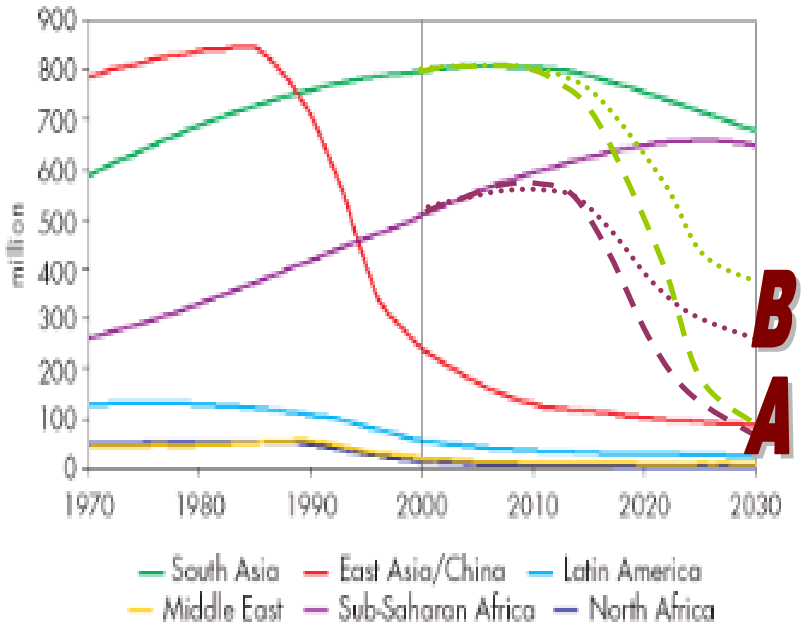
Share of Non-Solid Fuels by Income in Rural Households



Data Source: Pachauri & Jiang 2008

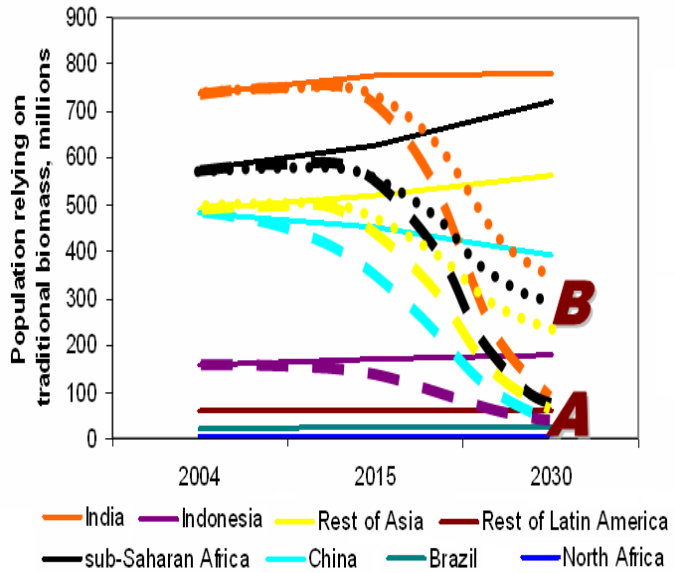
Electricity

- Electricity for All in the Medium Term (may be achievable)
  - Use of both grid-extension and decentralized systems + conventional and renewable energy technologies
  - Strong national (and local) + public (and private) delivery models
  - Smart use of subsidies and other innovative financing mechanisms (global effort would be required)



Traditional Biomass

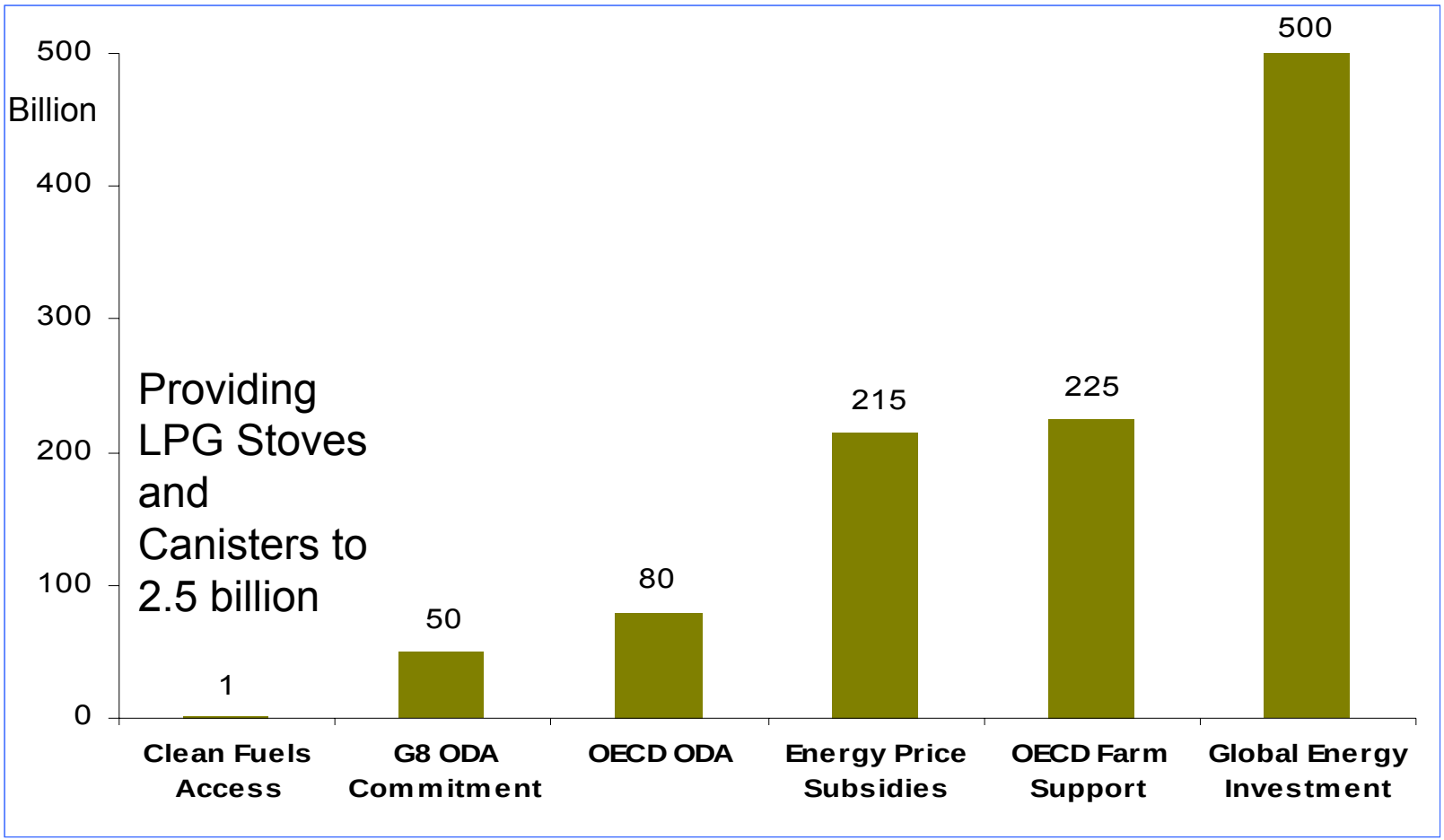
- Limits to “modern fuels”
- Cleaner/more efficient use of biomass may be the key MT option
- Key challenge remains how to scale-up best practice/technologies



Mechanical Power

- Single-focus / single-objective programs predisposed to fail – multi-tracked approaches may be required
- Emphasis on productive uses may hold key to accelerating access in rural areas
- Rural development is key

Some Annual Cost Comparisons to 2015



Data Source: Various

Key Messages

- Integrating energy into rural development and recognizing diversity of approaches in service delivery
- Demanding more institutional leadership and critical roles for the public sector also in public-private partnerships
- Widening the policy “spectrum” and putting more emphasis on learning-by-doing capacity development

Arnulf Grubler
Urbanization

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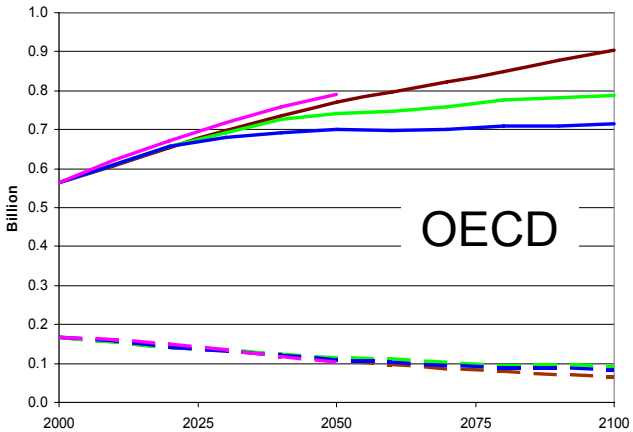
GEA KM18 Urbanization

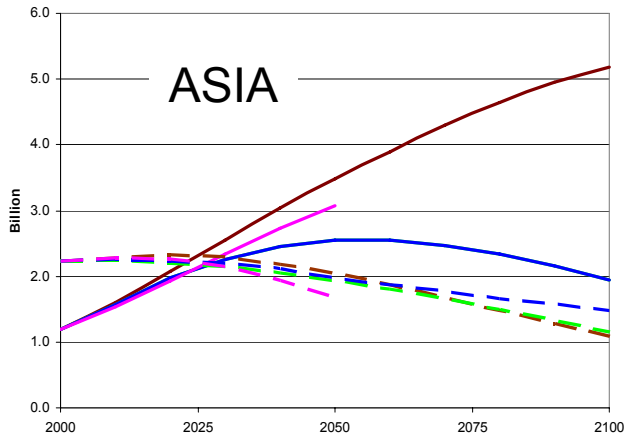
- Why urbanization focus?
  -- rapid urbanization (6-8 billion urbanites by 2050)
  -- ~2/3 of current final energy use is urban
  -- cities as policy and innovation centers

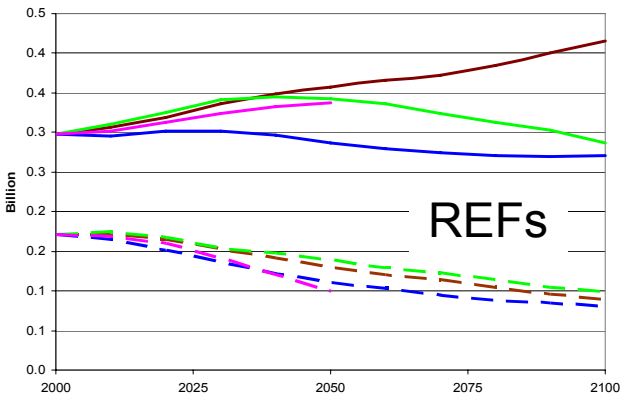
- Assessment:
  -- current urban energy use (GIS and city energy DB)
  -- energy/carbon accounting:
  methodology & uncertainty
  -- explaining differences in urban energy use
  (→policies)
  -- efficiency and emission improvement potentials
  (→policies)
  -- systemic view (urban form, systems integration)

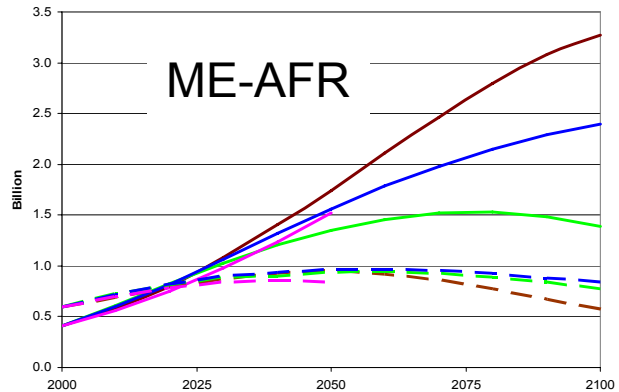
Urban vs. Rural Population Scenarios in 4 Macro-Regions

(IIASA GGI, 2007, and UN WUP, 2007, in Billion)









Data source: Riahi et al., 2007; UN, 2007

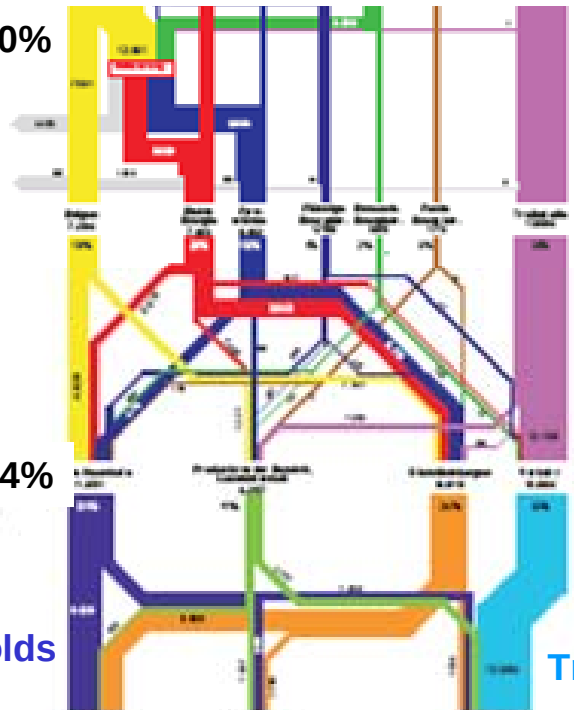
Vienna - 1st and 2nd Law Efficiencies

Gas Heat, Liquids Renewables

Electricity Motor fuels

Secondary Energy: 45 TWh 100%

Secondary Exergy: 171 TJ 100%



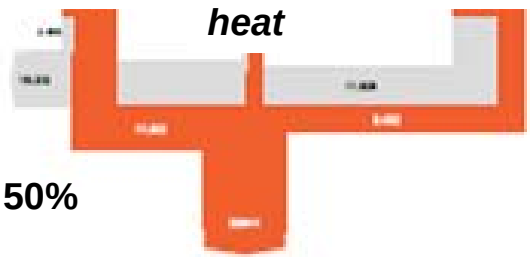
Final Energy: 38 TWh 84%

Final Exergy: 140 TJ 82%

Households

Traffic

L.T. heat *Process heat* *Light, motion*



Useful Energy: 23 TWh 50%

Useful Exergy: 31 TJ 18%

GEA KM18 Draft Key Messages

1. The world is already today predominantly urban (~2/3 of final energy) and will become even more so
2. Rural populations are likely to peak at 3.5 billion and decline after 2020
3. **Urban population projected to continue to grow to 6-8 billion by 2050 with largest growth in settlements <0.5M**
4. Shrinking cities new phenomenon of demographic decline
5. Cities have specific sustainability challenges (high density calls for ~zero-impact systems)
6. Many still do not have access to basic energy services, which need to be supplied based on economic, social, and environmental sustainability
7. **Vast improvement potentials, but most require demand-supply integration and systemic changes (recycling, cascading, transport systems integration,..)**
8. **"Upstream" energy and CO_2 emission accounts fraught by uncertainty and system boundary ambiguity**
9. New sustainability criteria needed, considering the functional interdependence among different systems that are geographically separated
10. **Governance Paradox:**
    - largest leverage from systemic change, but
    - most difficult to implement in view of policy fragmentation and dispersed, decentralized decision taking

Arnulf Grubler
Innovation

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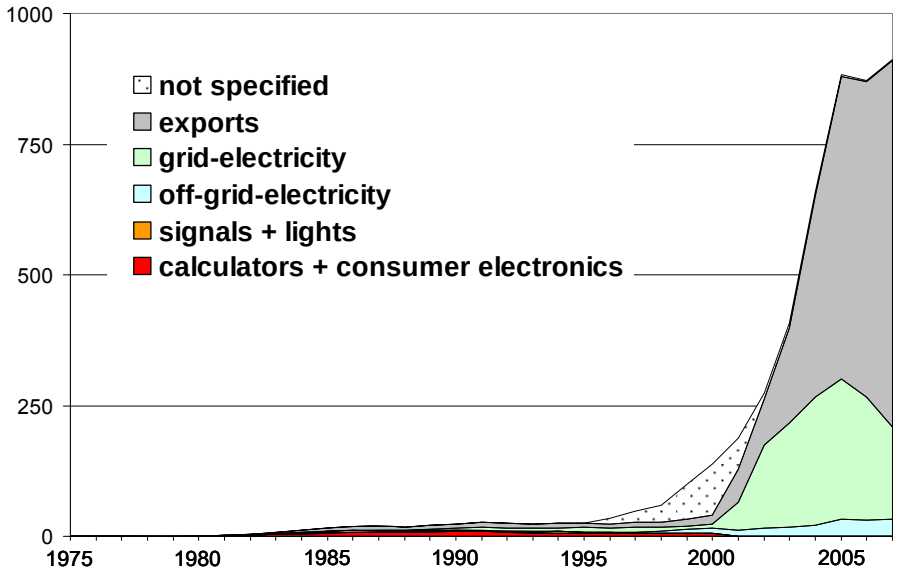
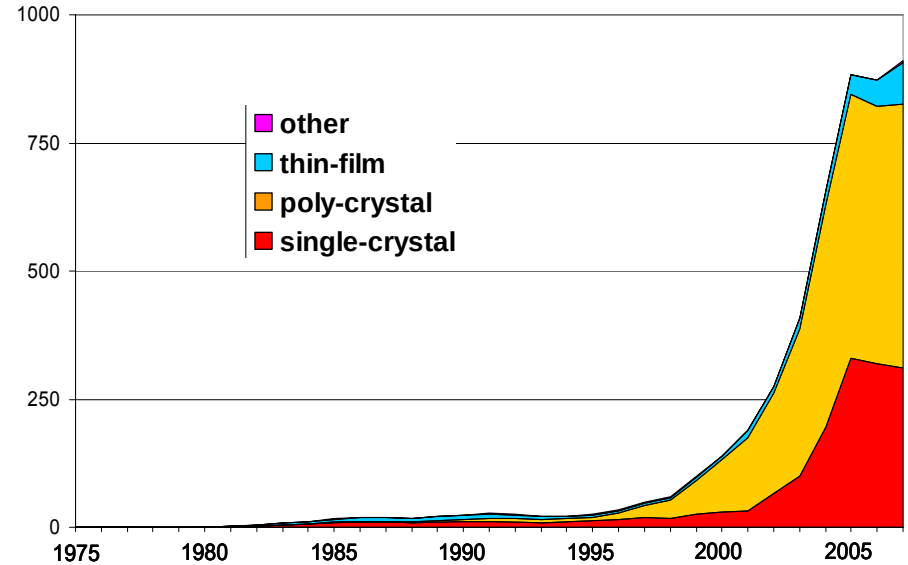
GEA KM24 Policies for Energy Technology Innovation Systems

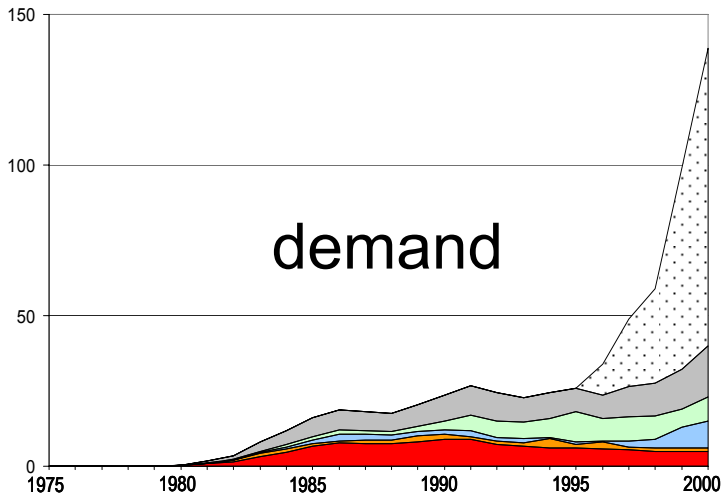
- Why? Innovation as main leverage for sustainability transition
- Broad concept of technology and innovation (hardware, software, institutions)
- Systemic view of innovation (emphasizing feedbacks and interaction between supply **and** demand factors)
- Literature synthesis plus case studies (successes and failures)
- Policy myths and lessons for policy design

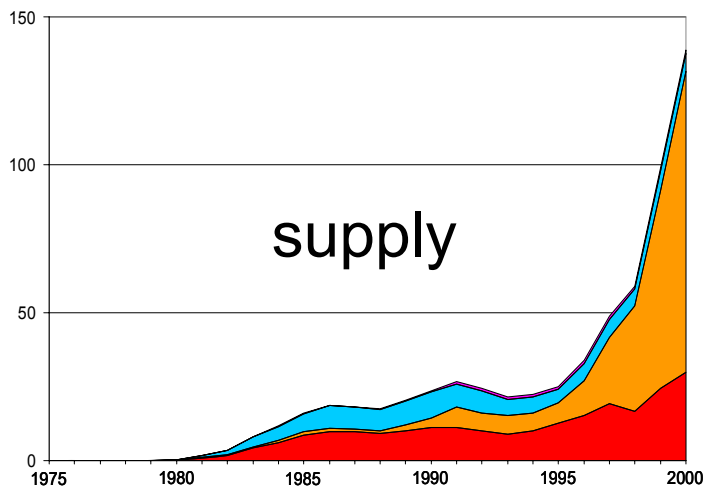
Japan PVs 1975-2007 (in MW)

Importance of demand pull AND supply push factors









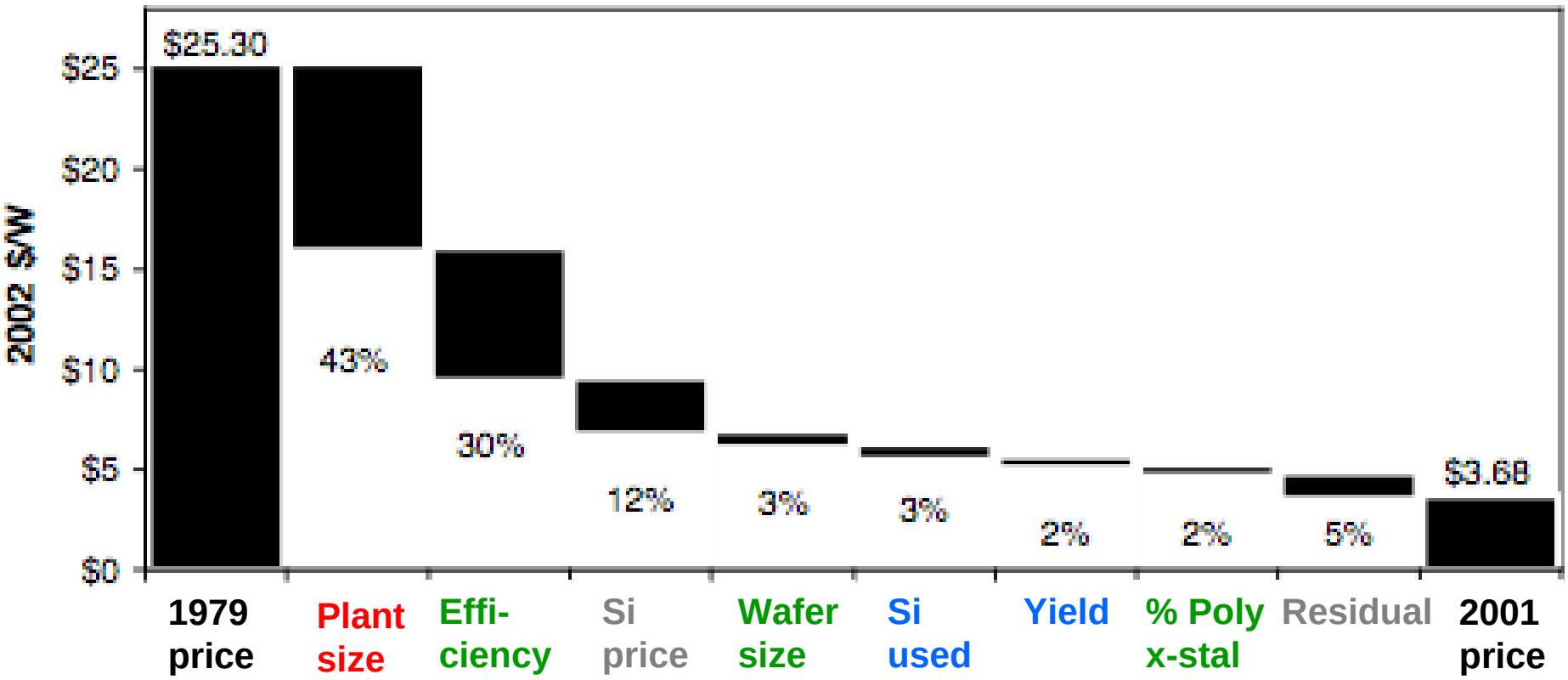
Data: Watanabe, 2003, and JPEA, 2009

KM24 Case Studies to Analyze Drivers of TC

- Wind turbines (comparative assessment US-Europe-Mexico-India-China)
- PVs (comparative assessment EU-US-Japan)
- Solar thermal electricity
- US synfuels programs
- Coal gasification & upscaling in China
- Hybrid cars
- Solar heaters
- Solar cooling
- Ethanol in Brazil
- Negative C-emissions technologies (e.g. BECS)
- Weyburn project
- Role of standards: ex. Building efficiency
- Methods for innovation risk hedging and technology portfolio design

Factors in US PV Cost Declines 1979-2001:

Economies of Scale (43%), R&D (35%), Learning by Doing (5%), Others (17%)



Source: Nemet, 2008

GEA KM24 Draft Key Messages

- Substantial and accelerated innovation needed
- Drivers of innovation as well as the policies that support it are complementary rather than substitutable
- Innovation systems change needed rather than (more) individual innovations
- Innovation policies need to be:
  -- *aligned*
  -- *consistent*
  -- *patient*
- Key importance of “granularity”: Success from many small scale (end-use) innovations (efficiency) rather than few, big supply side innovations (fusion) minimizes risks and allows for necessary failures

www.GlobalEnergyAssessment.org

Energy End-Use in Buildings

www.GlobalEnergyAssessment.org

Sustainable energy in the buildings sector: global significance

- Buildings are responsible for app 1/3 of energy-related CO_2 emissions and 2/3 of halocarbon emissions
- In most countries they consume 35 – 45% of TPES (~50% in developing countries)
- Largest GHG mitigation potential in short- to mid-term at low costs

Example of savings by reconstruction

Before reconstruction

Reconstruction according to the passive house principle

over 150 kWh/(m²a)

-90%

15 kWh/(m²a)

Source: Jan Barta, Center for Passive Buildings, www.pasivnidomy.cz, EEBW2006

If so attractive, why is it not happening?

- The market barriers to energy-efficiency are perhaps the most numerous and strongest in the buildings sector
- These include:
  - imperfect information
  - Limitations of the traditional building design process
  - Energy subsidies, non-payment and energy theft
  - Misplaced incentives (agent/principal barrier)
  - Small project size, high transaction costs
  - others

Co-benefits of GHG mitigation in buildings (selection)

- Co-benefits are often not quantified, monetized, or identified
- Overall value of co-benefits may be higher than value of energy savings
- A wide range of co-benefits, including:
  - **Improved social welfare**
    - Fuel poverty: In the UK, about 20% of all households live in fuel poverty. The number of annual excess winter deaths is estimated at around 30 thousand annually in the UK alone.
    - Energy-efficient household equipment and low-energy building design helps households cope with increasing energy tariffs

Pushing the frontiers: provisional highlights from the KM

- Low- and zero-energy buildings are dynamically growing
- Often at no extra cost; typically at little extra cost
- Low-energy retrofits are also becoming possible -> paradigm shift
- Ambitious policies and targets are spreading; showing the way for other policy fields
- The industry is playing a leadership role - visionary presence also in GEA