Climate change mitigation, development and the role of energy

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Berlin, November 19, 2013

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Outline

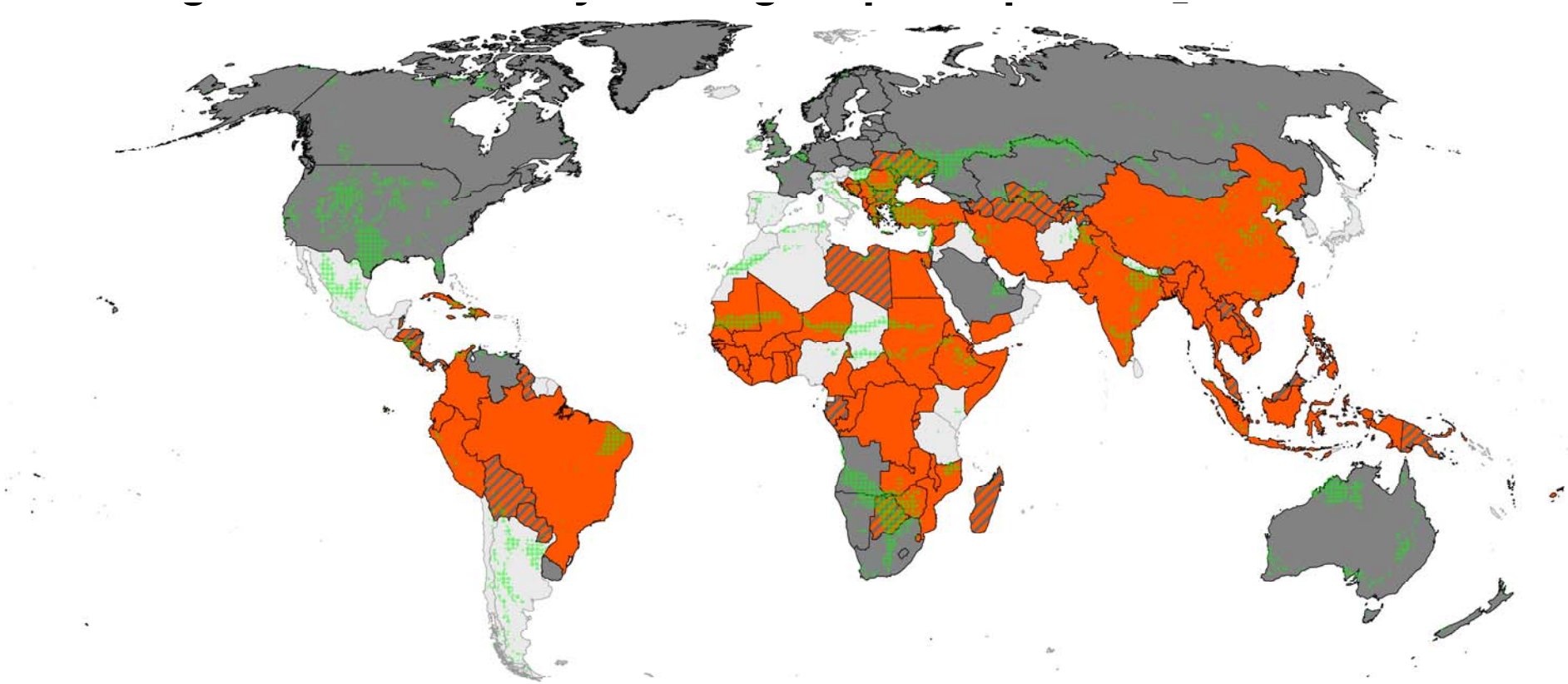
- Some opening statements
- Development, emissions and their drivers
- Energy and development
- Energy system transformations – Opportunities, trade-offs and risks

Climate change and development

Some opening statements:

- Developing countries suffer most from climate changes
  - Not only are impacts more severe; societies are also less prepared to adapt to climate changes

The Moral Dilemma of Climate Change



Highest vulnerability towards climate change vs. largest CO_2 emissions (from fossil fuel combustion and cement production, and including land use change, kg C per person and year from 1950 - 2003)

- Largest per capita CO_2 emitters
- Highest social and / or agro-economic vulnerability
- Largest per capita CO_2 emitters, and highest social and / or agro-economic vulnerability
- Areas with highest ecological vulnerability

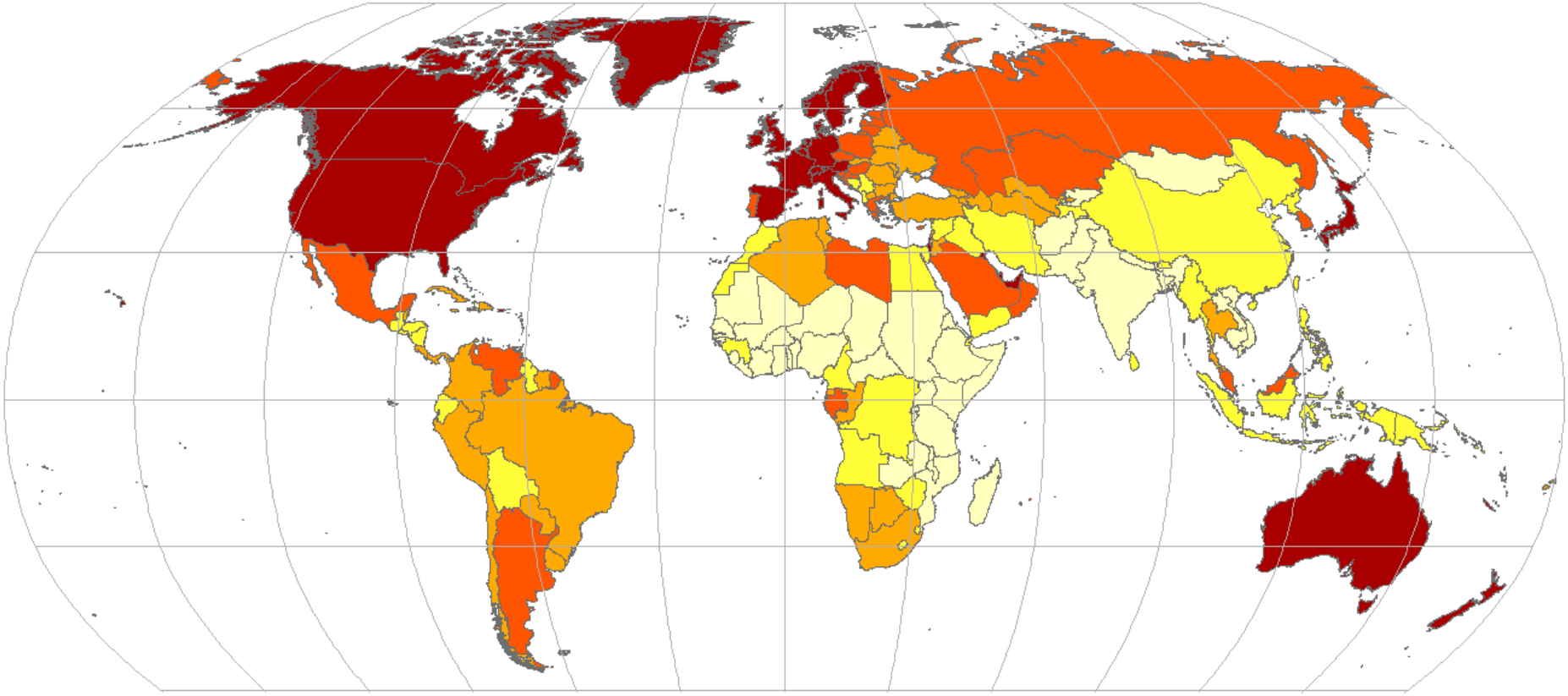
Füssel 2007

Climate change and development

Some opening statements:

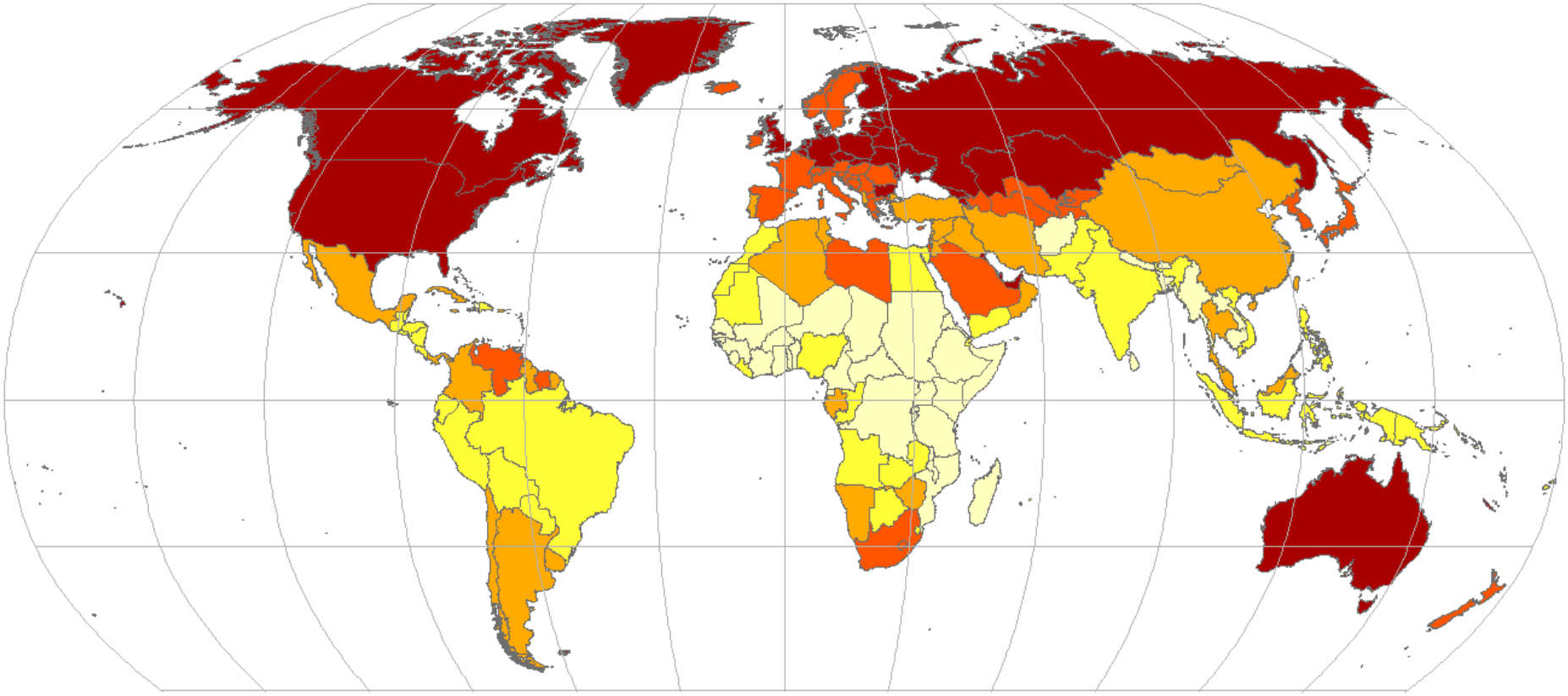
- Developing countries suffer most from climate changes
  - Not only are impacts more severe; societies are also less prepared to adapt to climate changes
- Historically developing countries have not been responsible for carbon emissions, i.e. climate change

World map of wealth
Weltkarte des Vermögens



Füssel 2007

World map of carbon debt

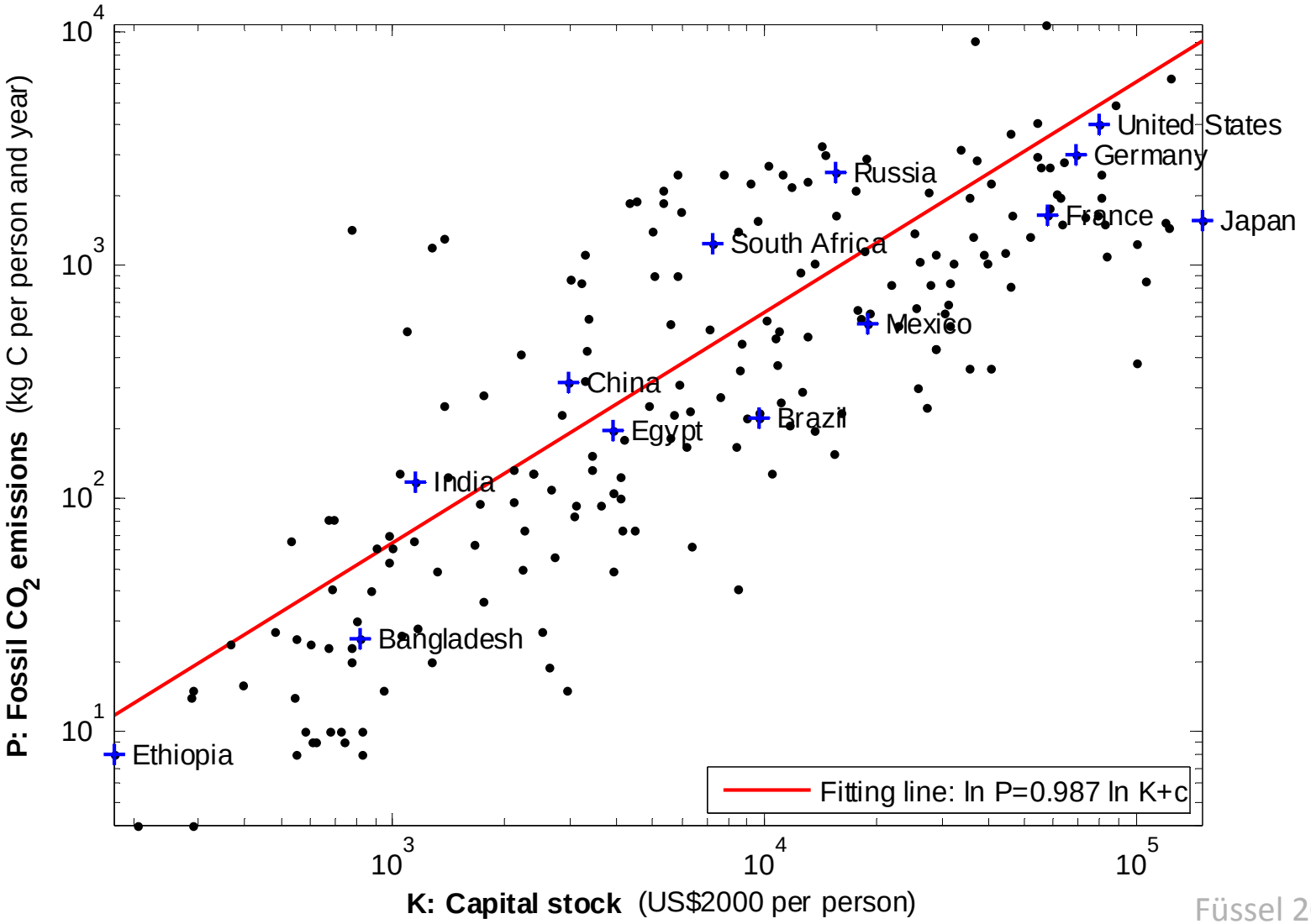


Carbon emissions per person from fossil fuel burning (1950-2003)

very low
low
medium
high
very high

Füssel 2007

Wealth and carbon debt



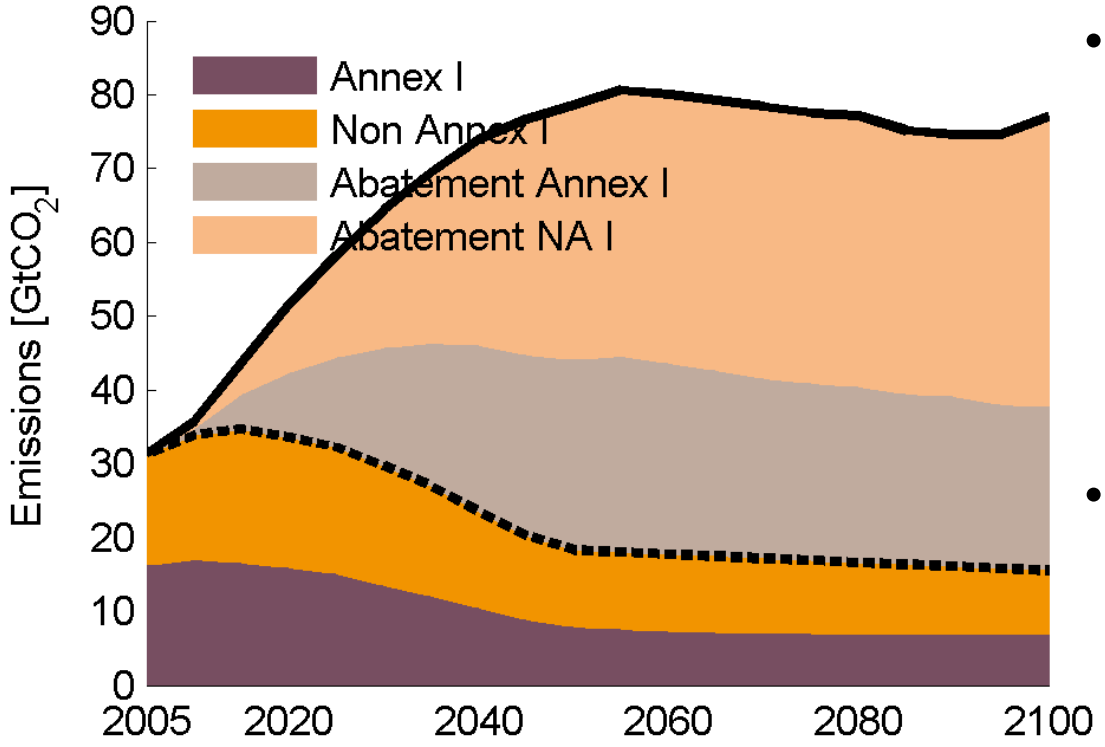
Füssel 2007

Climate change and development

Some opening statements:

- Developing countries suffer most from climate changes
  - Not only are impacts more severe; societies are also less prepared to adapt to climate changes
- Historically developing countries have not been responsible for carbon emissions, i.e. climate change
- Developing countries however play a key role also with respect to mitigation of emissions

Developing countries and mitigation



450ppm CO2-only scenario

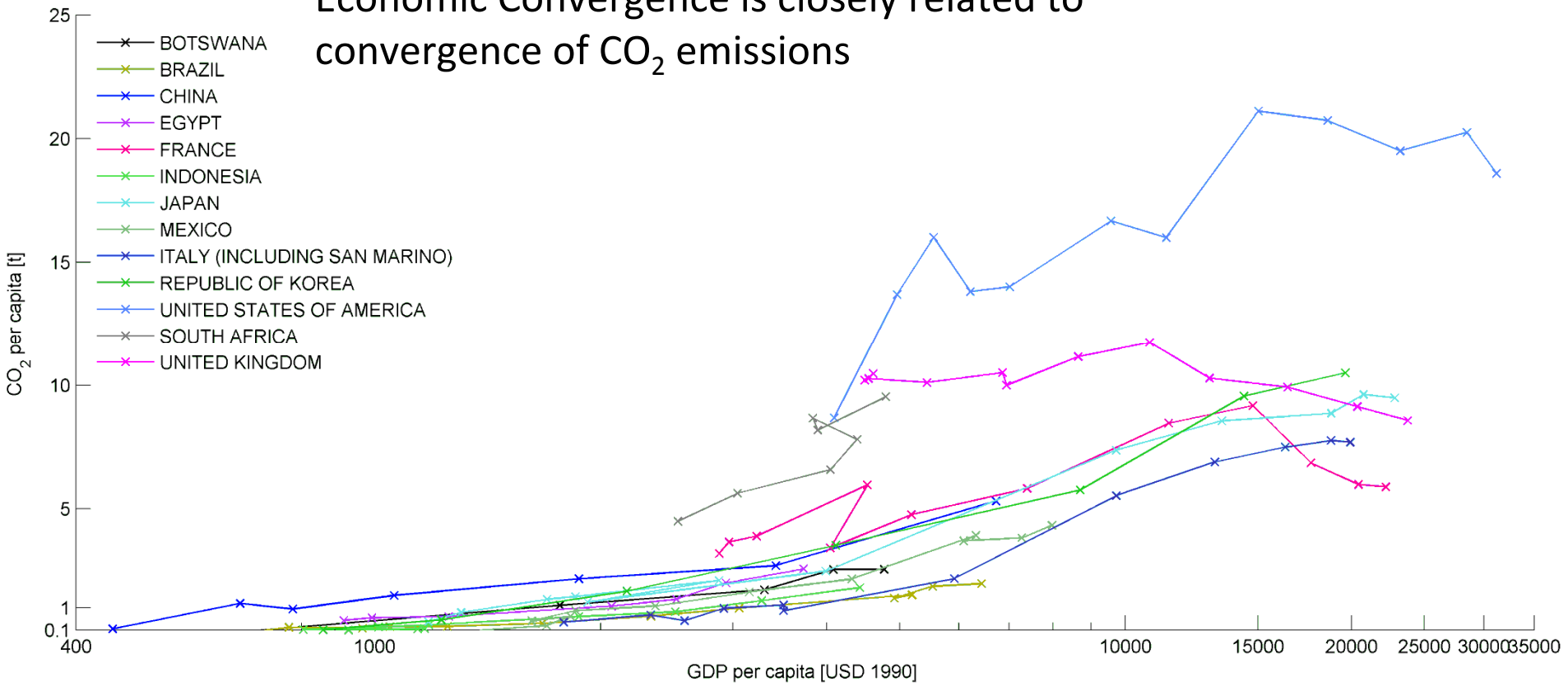
- Ambitious mitigation targets only feasible with emission reductions in developing and transition countries
- Scenarios for globally cost-efficient mitigation: largest share of mitigation in non-Annex-I countries

Jakob and Steckel 2013

Development, emissions and their drivers

Convergence of Emissions

Economic Convergence is closely related to convergence of CO_2 emissions

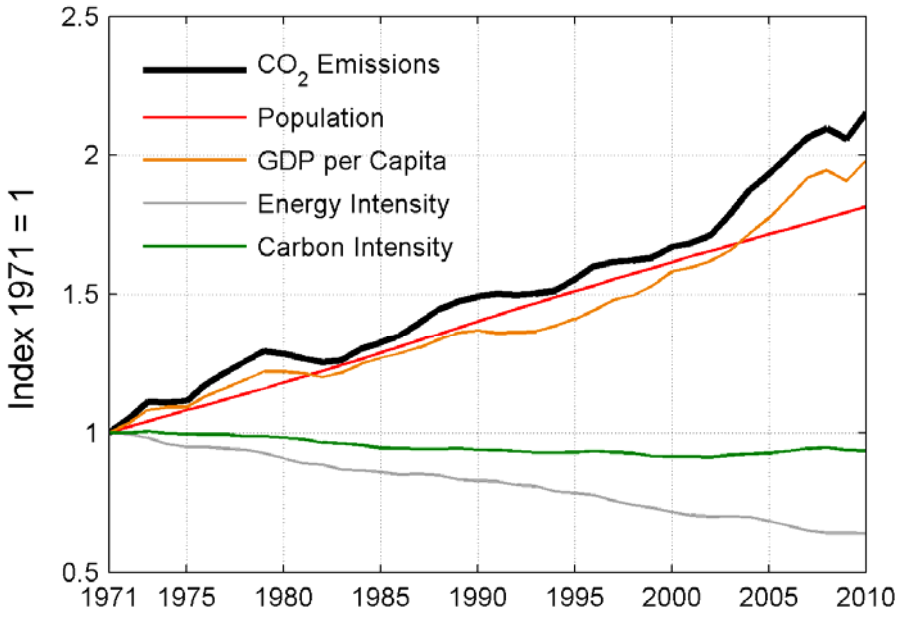


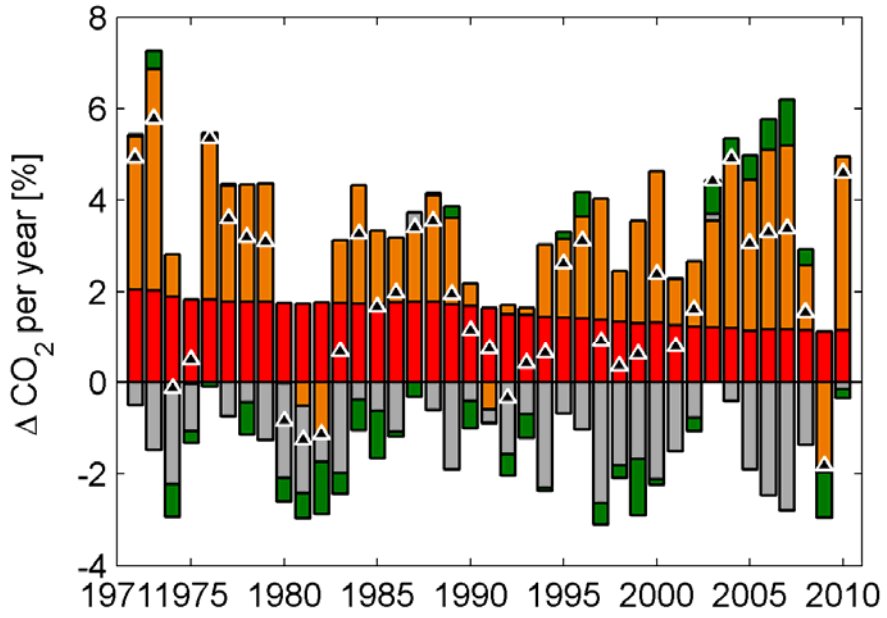
Jakob et al., in preparation

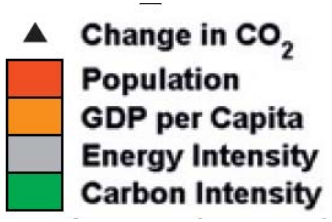
Drivers of GHG emissions

$$CO_2 = \frac{CO_2}{PE} \times \frac{PE}{GDP} \times \frac{GDP}{POP} \times POP$$

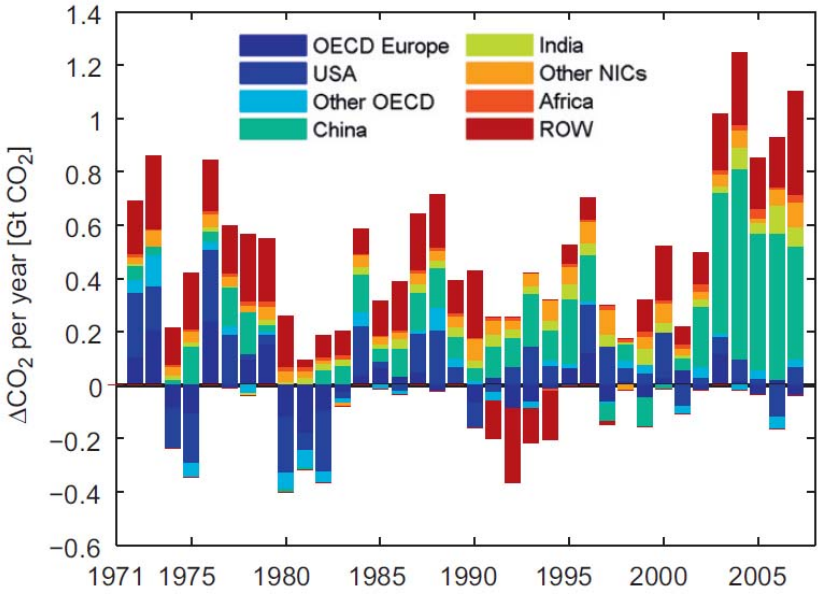
Emissions = Carbon Intensity of primary energy x Energy Intensity of production x Income per capita x Population







Who's driving emissions ?



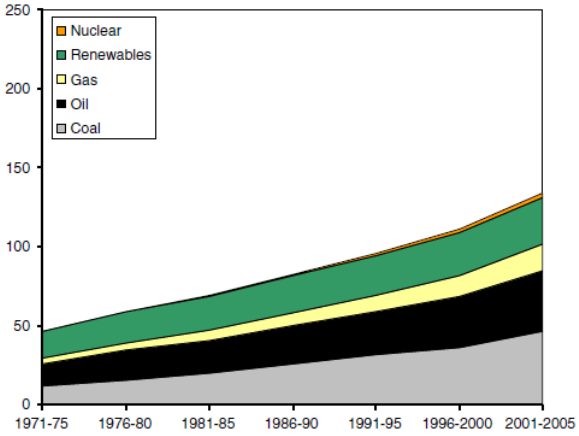
1971-2007 Annual effect on CO_2 growth	World	OECD	NIC	China	China 2000–2007
Population	1.59	0.71	1.93	1.29	0.67
GDP per capita	1.96	2.07	2.84	7.51	9.27
Energy intensity	−1.36	−1.55	−0.66	−4.13	−2.34
Carbon intensity	−0.16	−0.47	0.59	1.2	1.37
CI attributed to					
Coal	0.36	0.1	0.86	1.61	1.9
Gas	−0.04	−0.06	0.04	−0.02	−0.07
Oil	0.02	−0.01	0.52	0.004	−0.19
Nuclear	−0.24	−0.37	−0.15	−0.04	−0.11
Biomass and Waste	−0.18	−0.09	−0.49	−0.24	0.08
Renewables (incl. Hydro)	−0.08	−0.05	−0.18	−0.11	−0.24
Net annual CO_2 growth	2.02	0.76	4.71	5.88	8.97

- Global emissions growth in recent years mainly by newly industrializing and developing countries
- China's role outstanding
    i. High GDP-growth
    ii. Slower improvement of energy intensity
    iii. Scaling effects of traditional coal use in China

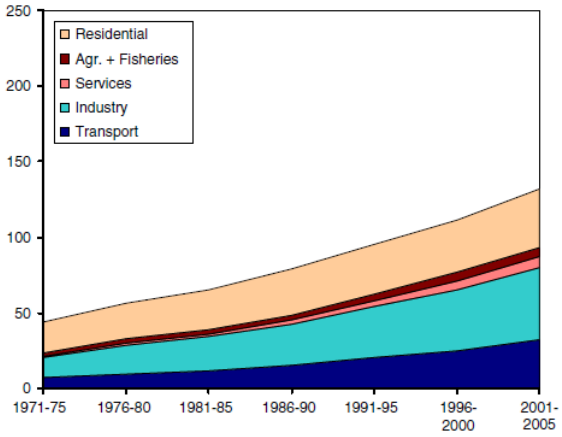
Steckel et al. 2011

Energy use patterns

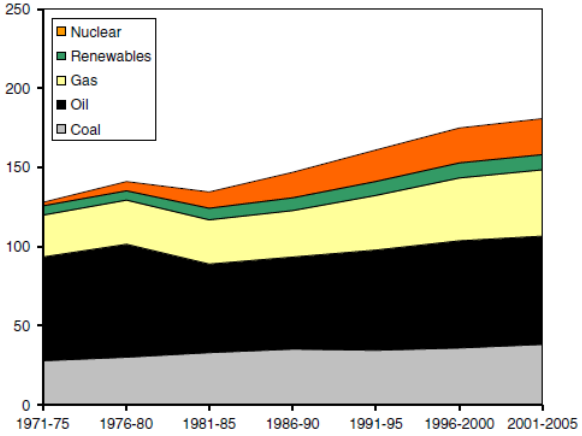
a) Energy mix, developing countries



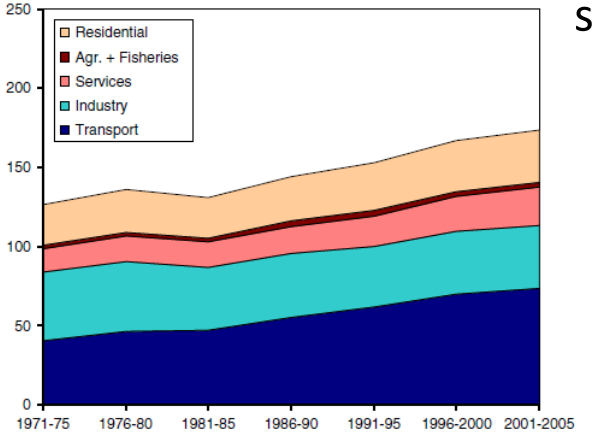
b) Energy use by sector, developing countries



c) Energy mix, OECD countries



d) Energy use by sector, OECD countries

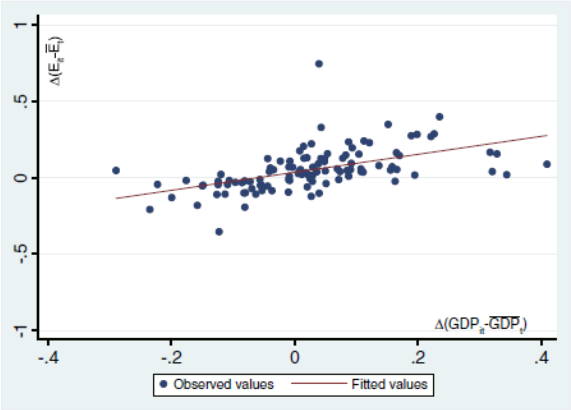


Pronounced differences between OECD and non-OECD countries w.r.t. energy use patterns on the level of primary energy carriers and economic sectors…

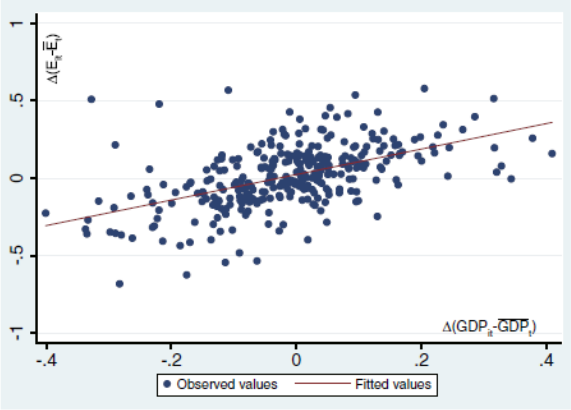
Jakob et al. 2012

Economic and energy use convergence

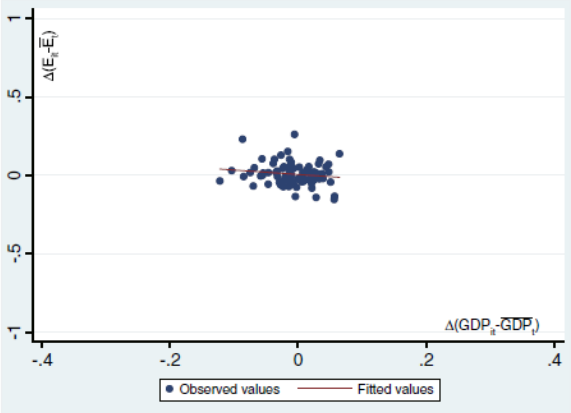
a) Total primary energy use, developing countries



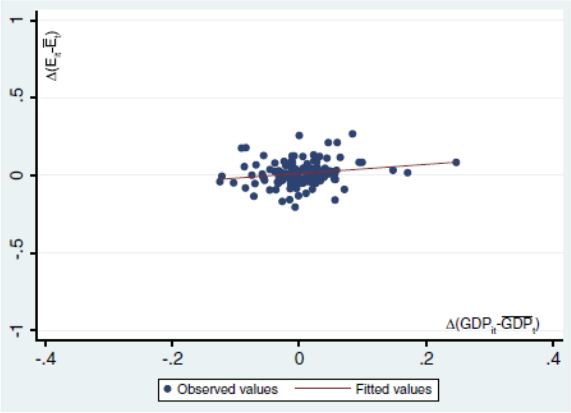
b) Total carbon emissions, developing countries



c) Total primary energy use, OECD



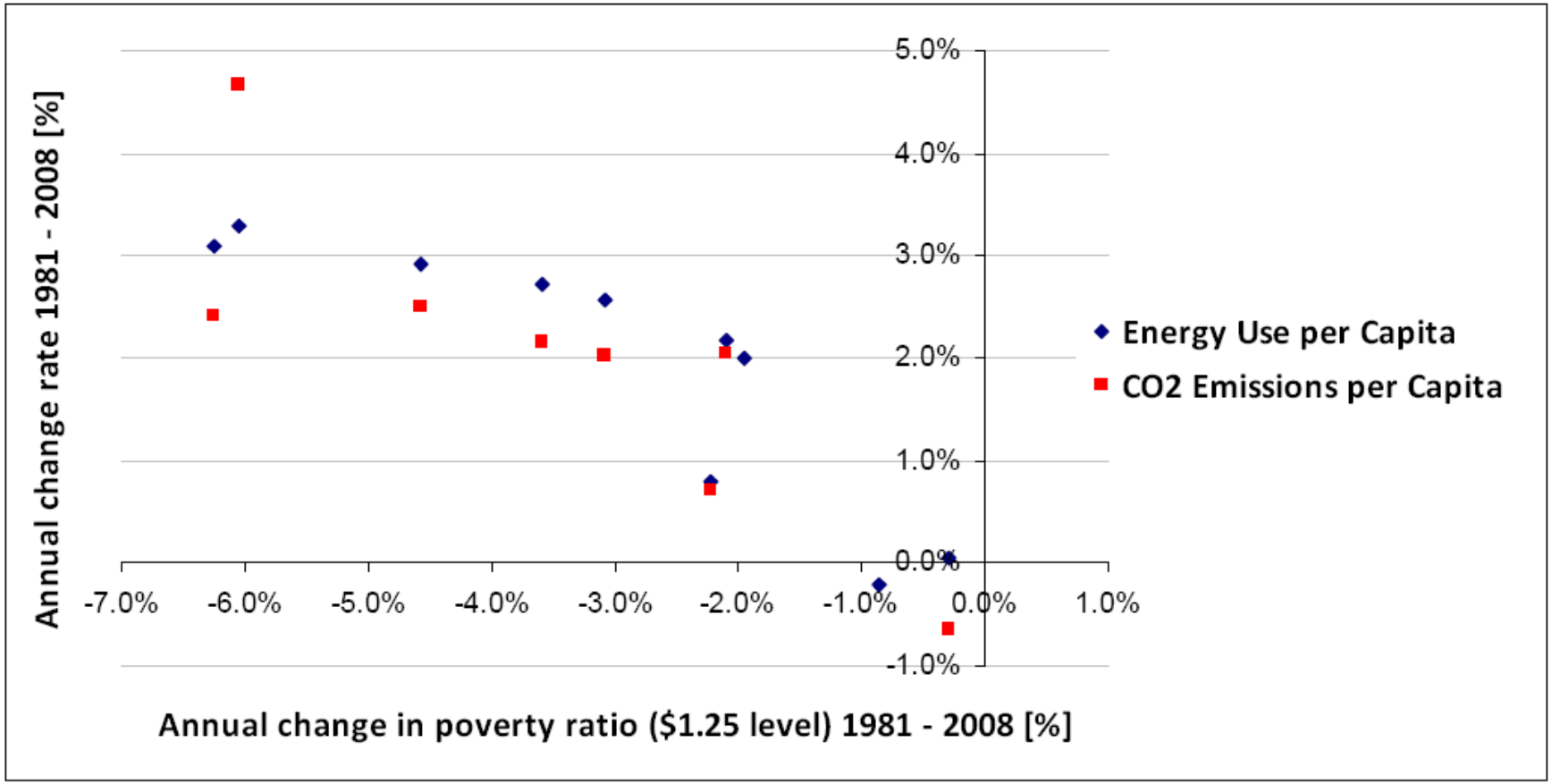
d) Total carbon emissions, OECD



… and economic convergence is closely related to convergence of energy use patterns.

Jakob et al. 2012

Another view point on emissions growth

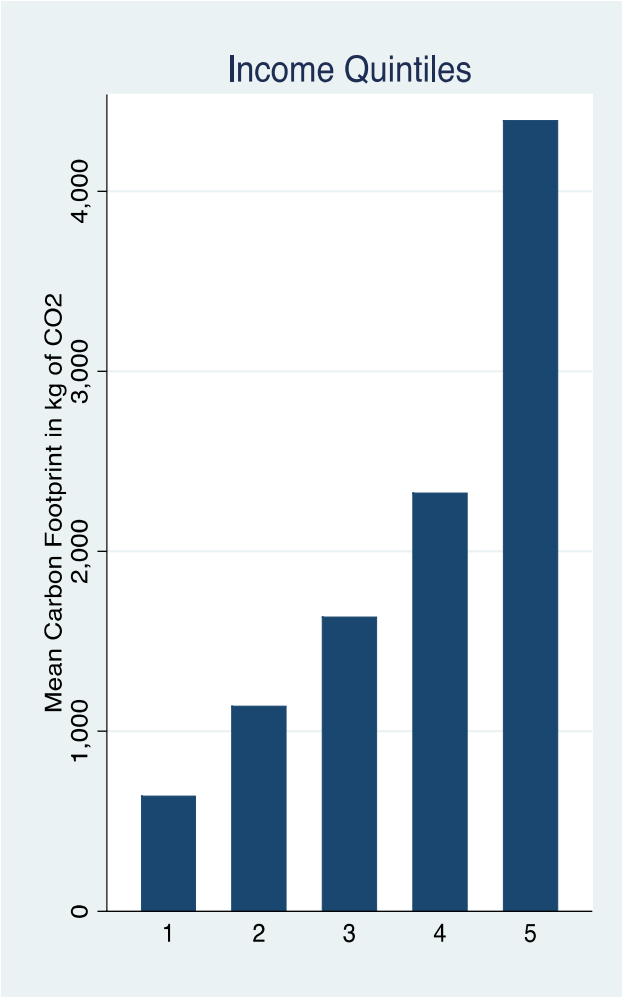


With rising energy use and CO2 emissions per capita, poverty ration have fallen significantly!

Jakob and Steckel 2013

Drivers on the micro level

- Energy use and consumption patterns (lifestyles) differ considerably within countries between income groups
- Last 20 years have seen high growth and rising inequality in many developing countries (including India), alongside rising emissions
- Are the rich responsible for rising carbon emissions?
- Footprint analyses for India, Indonesia, Philippines reveal comparable results:
  - Income largest driver of carbon footprint
  - Rising middle class will strongly increase emissions (move to carbon-intensive lifestyles)
  - Higher emission due to urbanization and education (over and above income effect)

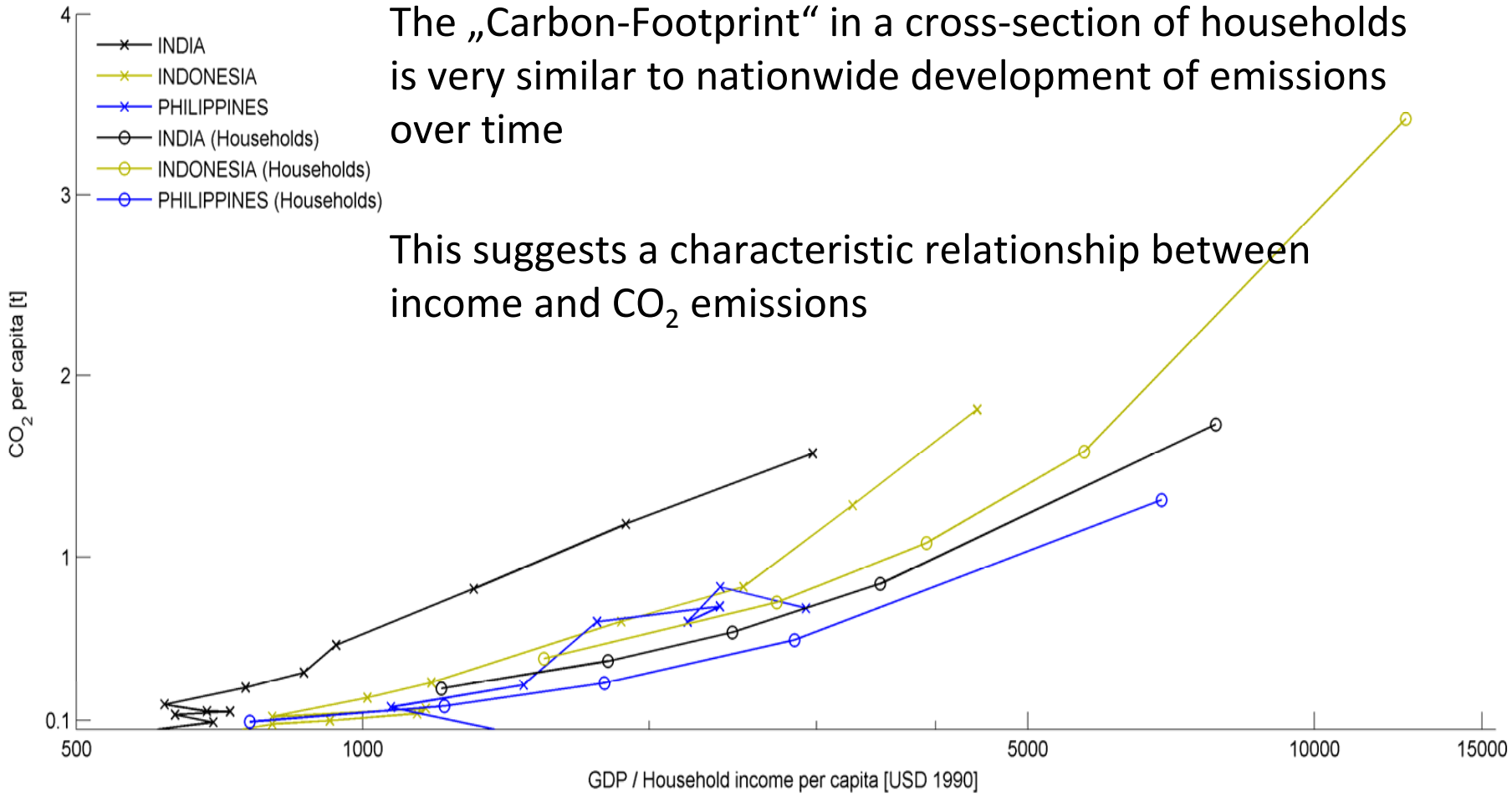


Grunewald et al. 2012

Carbon Footprints and Macro-Economic Developments

The „Carbon-Footprint“ in a cross-section of households is very similar to nationwide development of emissions over time

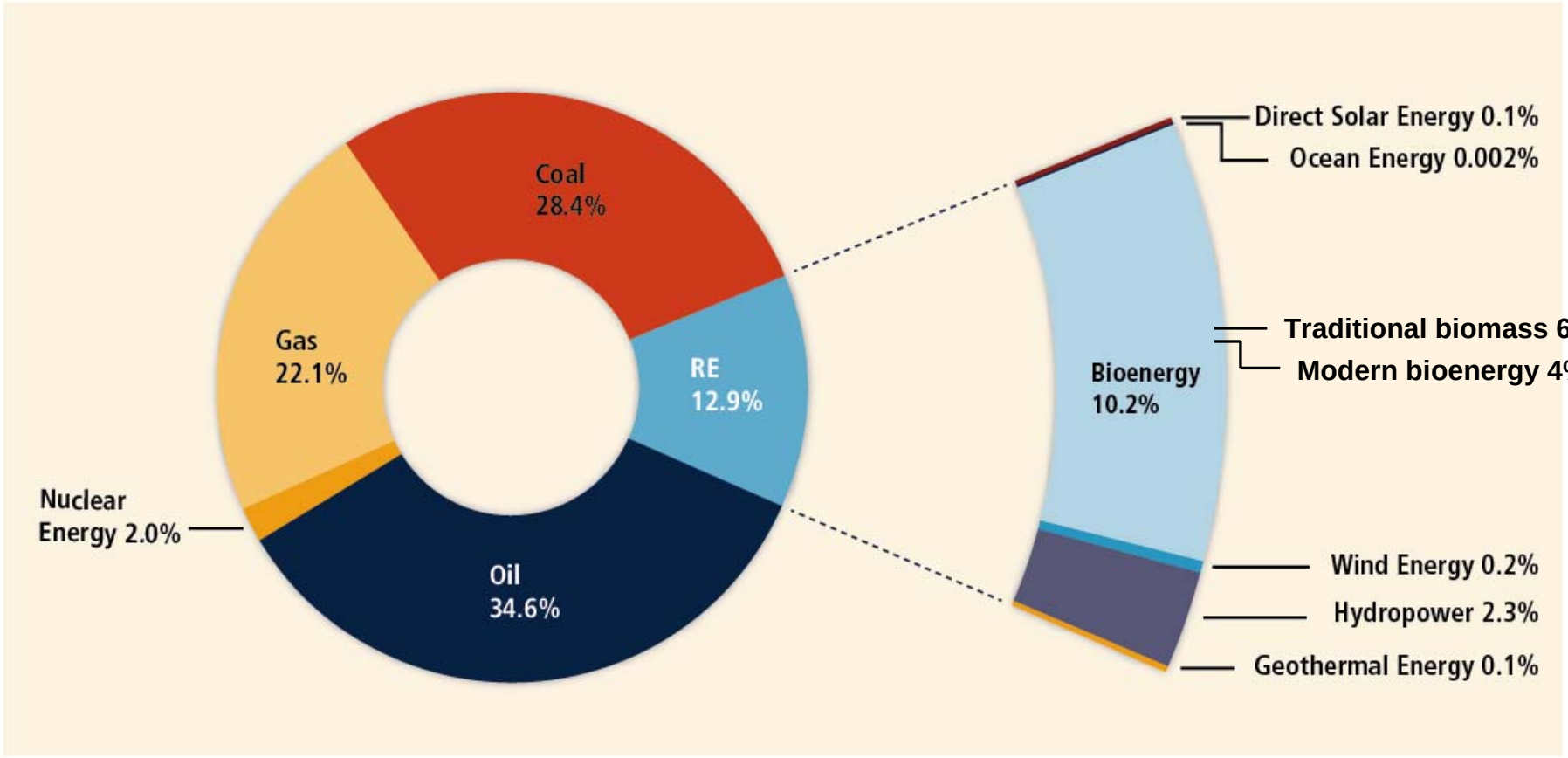
This suggests a characteristic relationship between income and CO_2 emissions



Jakob et al., in preparation

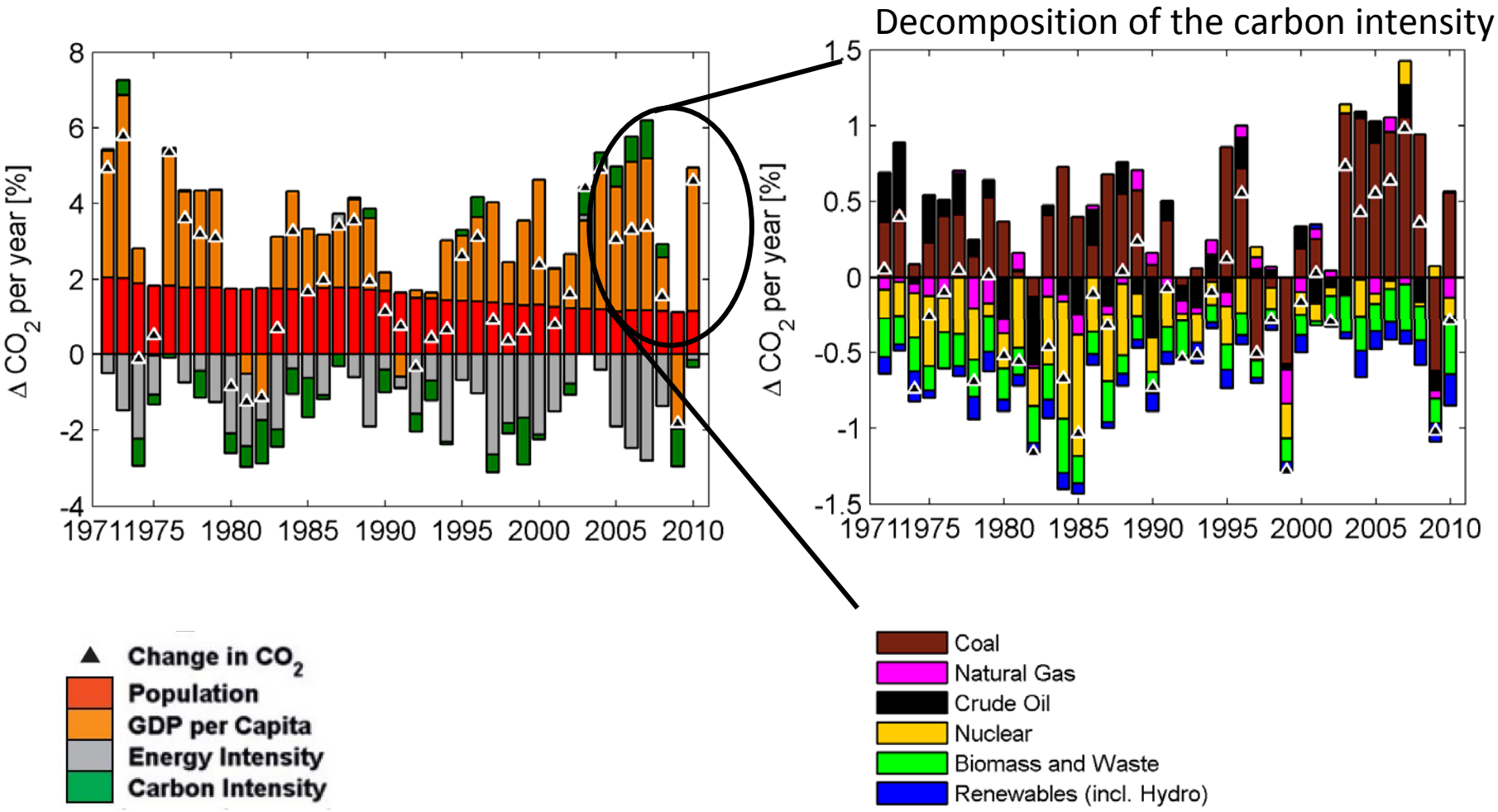
The world energy system today

Shares of Primary Energy Supply 2008



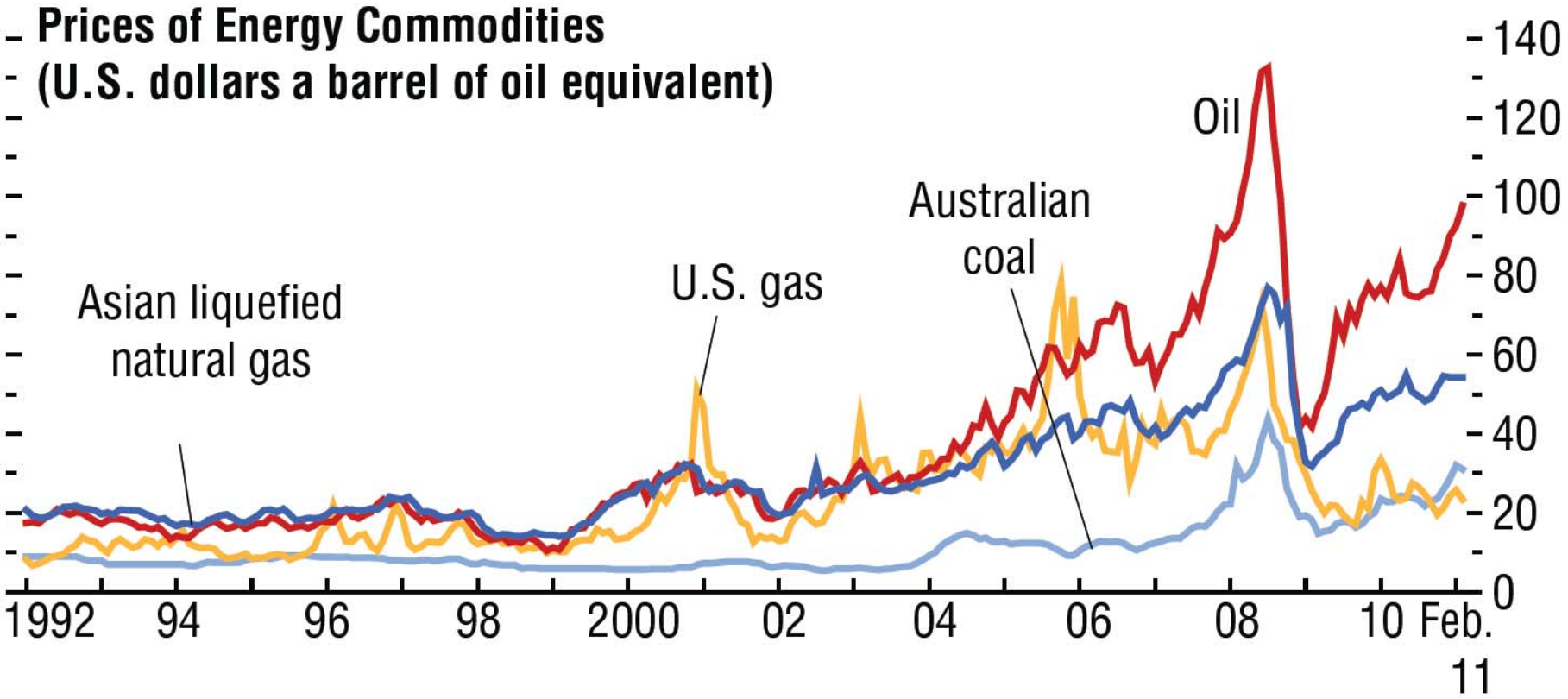
Edenhofer et al. 2011

No decarbonization on the horizon !



Steckel et al. 2011

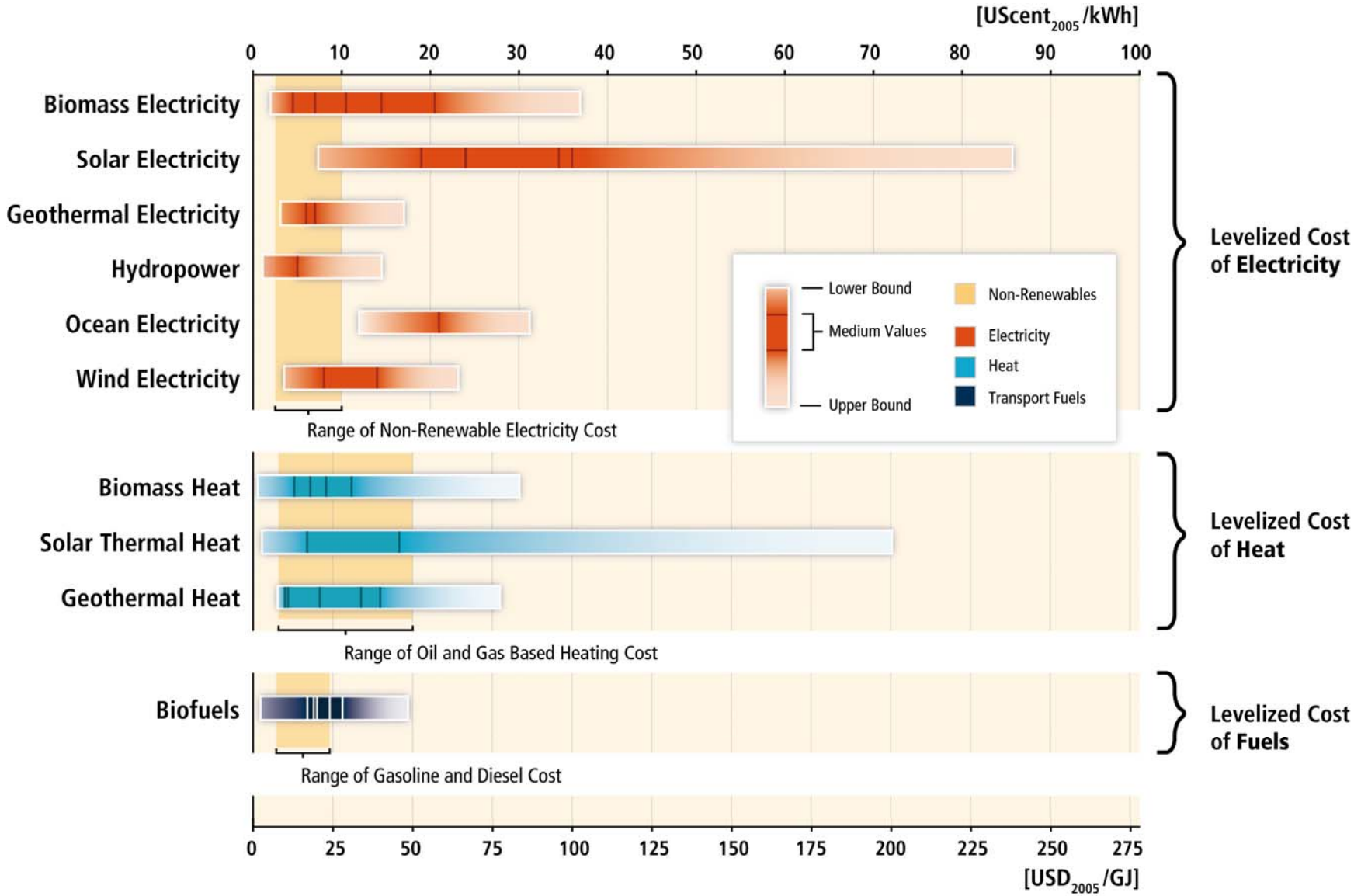
Fossil fuel price development



- Coal gets increasingly attractive
- Renaissance of coal rather than decarbonization

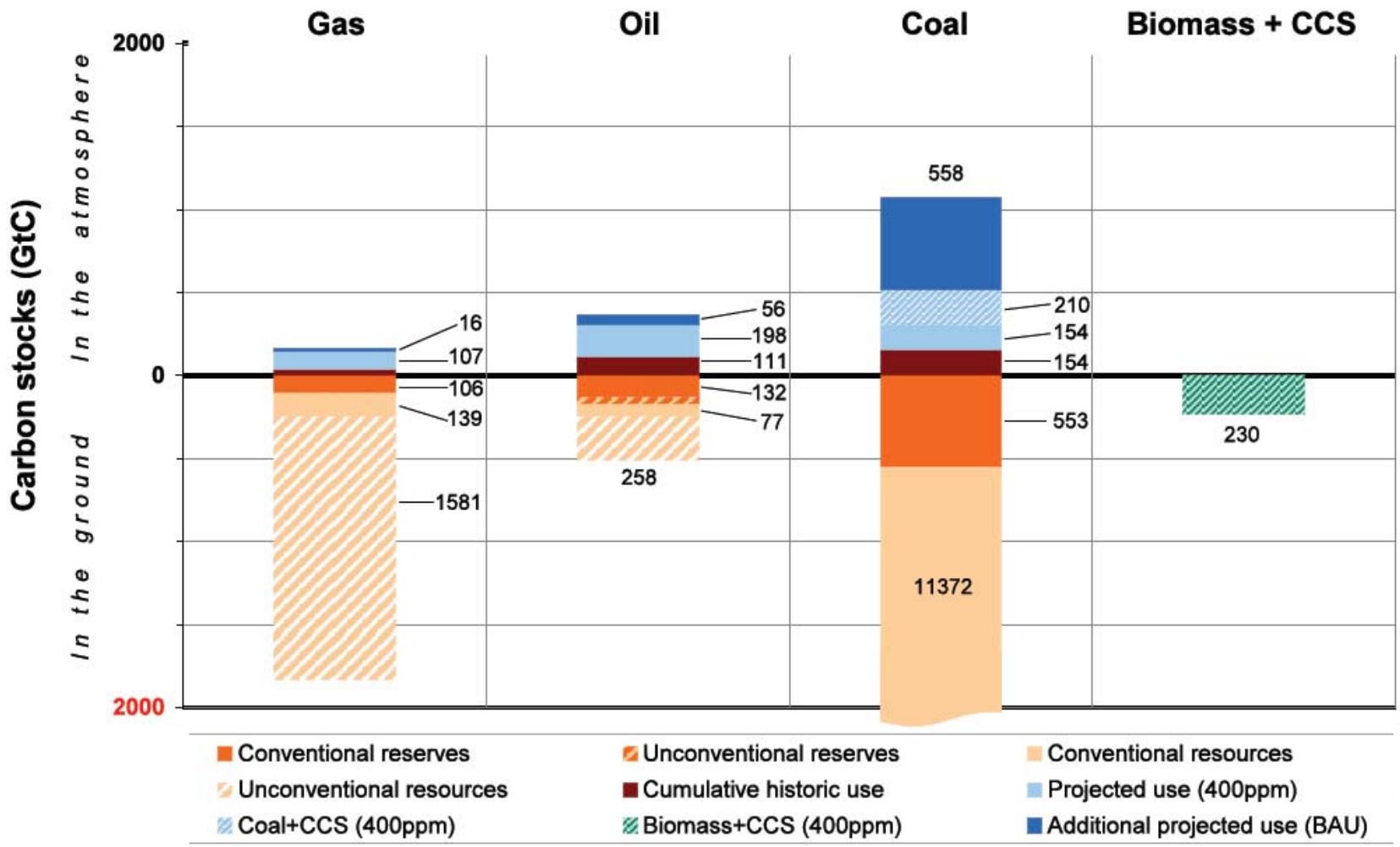
IMF 2011

Costs of Renewable Energy



Edenhofer et al. 2011

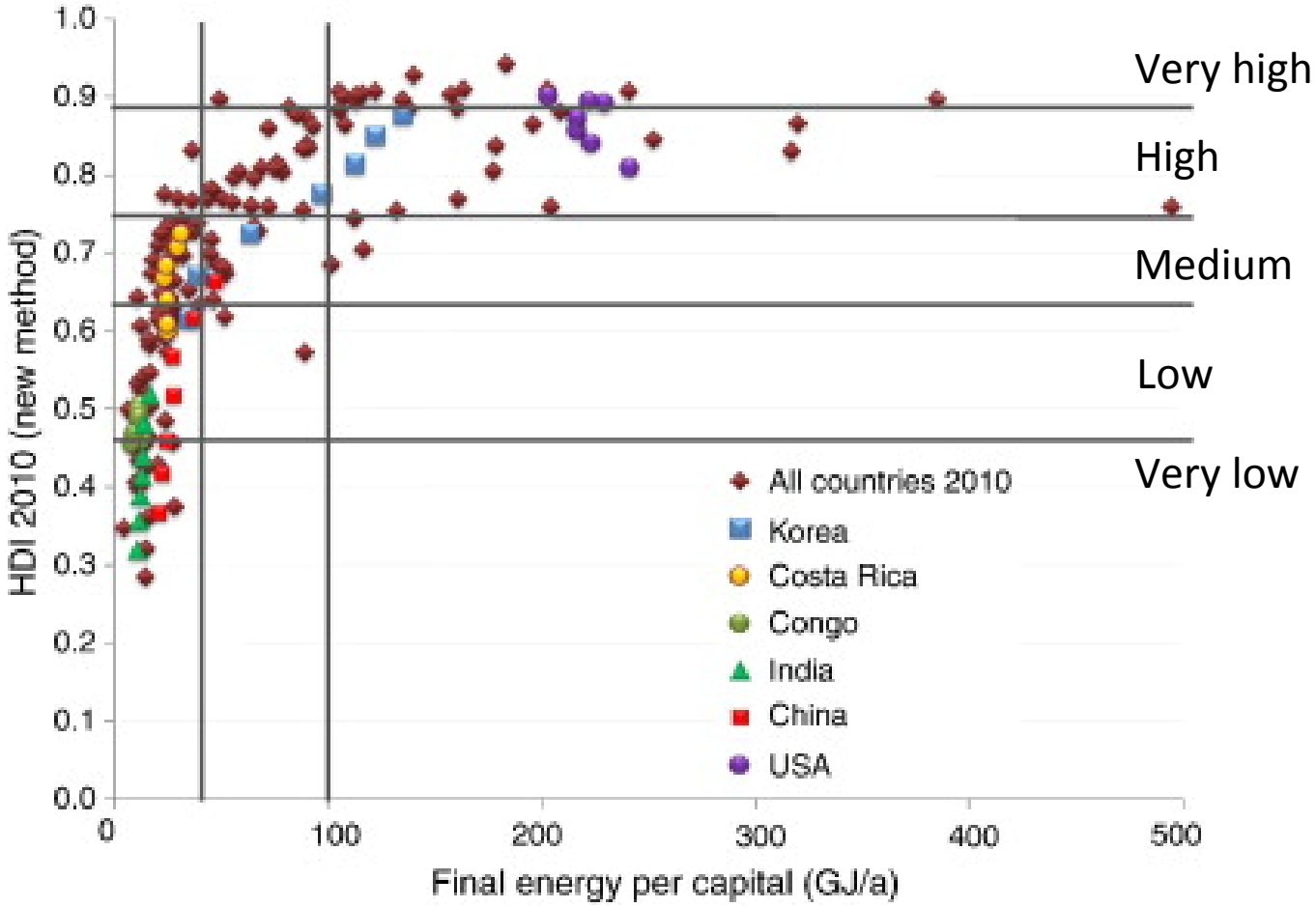
Fossil Fuel Scarcity vs. Limited Atmospheric Space



Kalkuhl, Edenhofer and Lessmann 2009

Energy and development

The role of energy in development processes



Steckel et al. 2013

The energetic metabolism of societies

Socio-ecological regime transitions (Haberl):

Hunter-gatherer society: Unmanaged solar metabolism

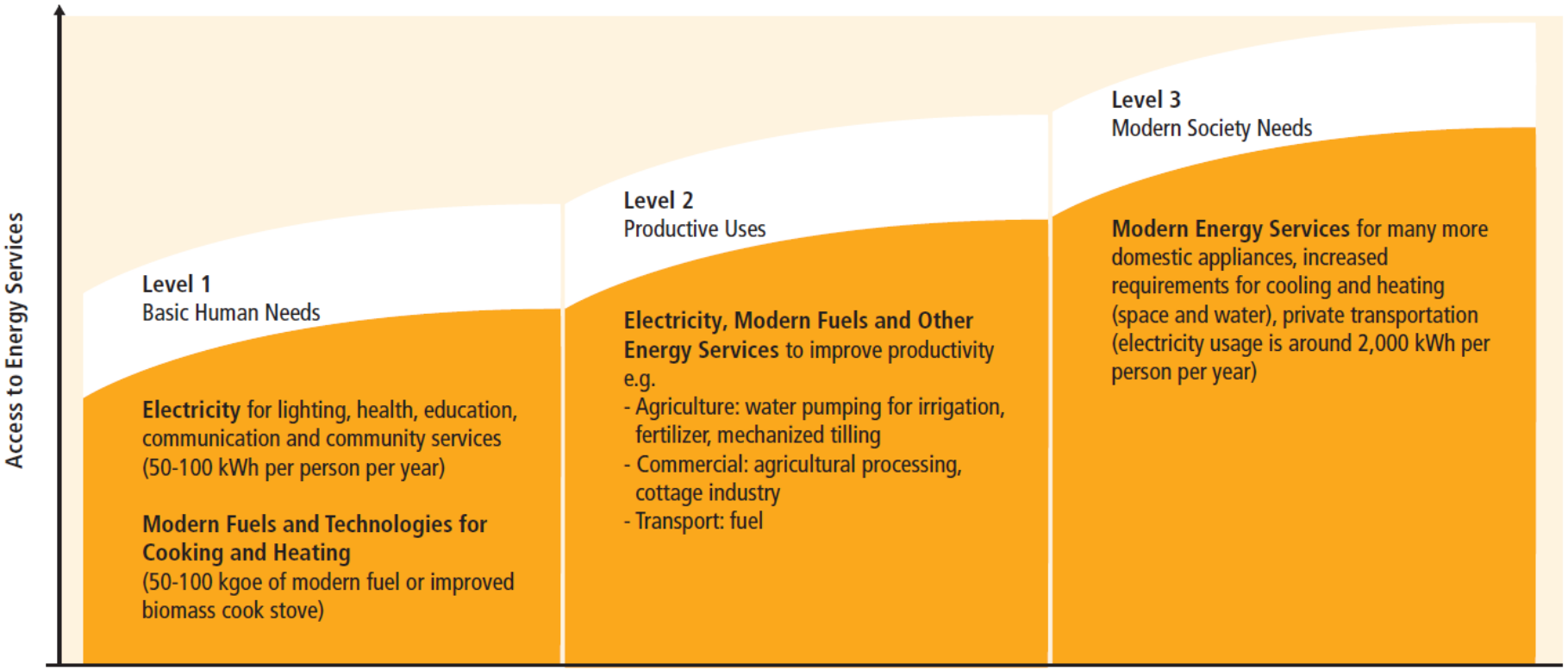
Traditional agricultural society: Managed solar metabolism

Industrial society: Tapping energy stored in fossil fuel resources allows decoupling from solar metabolism (and restricitions on population size due to limited land area)

Energy-development nexus I
Energy mix

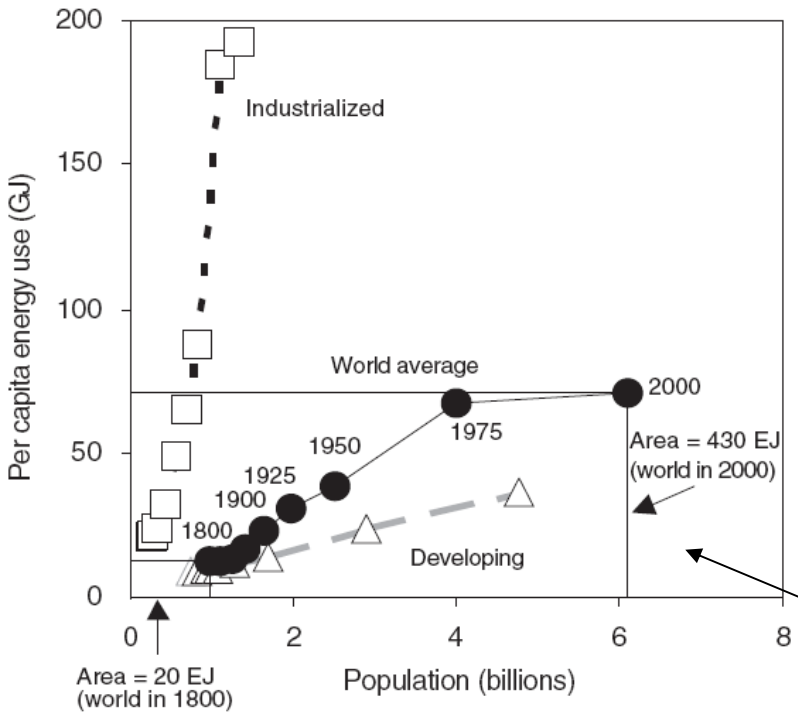
Production + availability → Energy mix

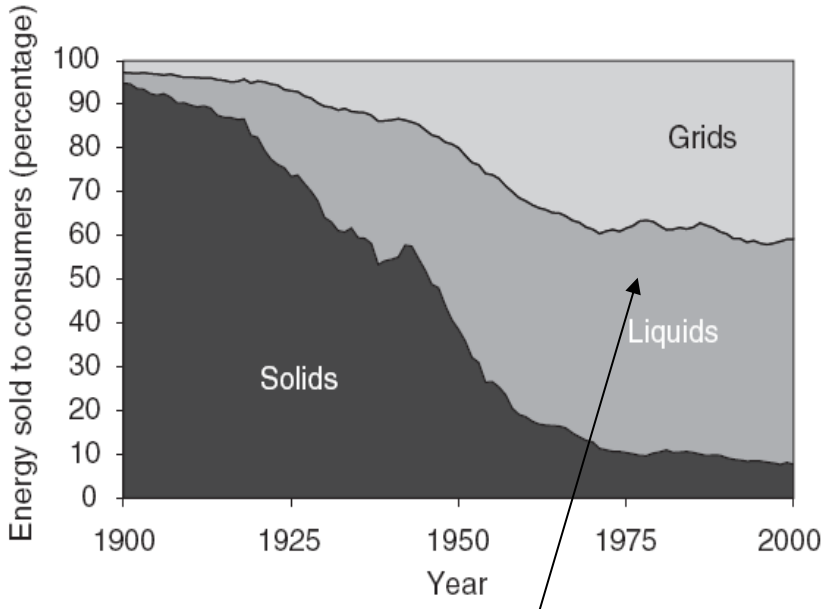
Fuel mix moves up the energy ladder over the course of economic development



Edenhofer et al. 2011

The energy transition(s)





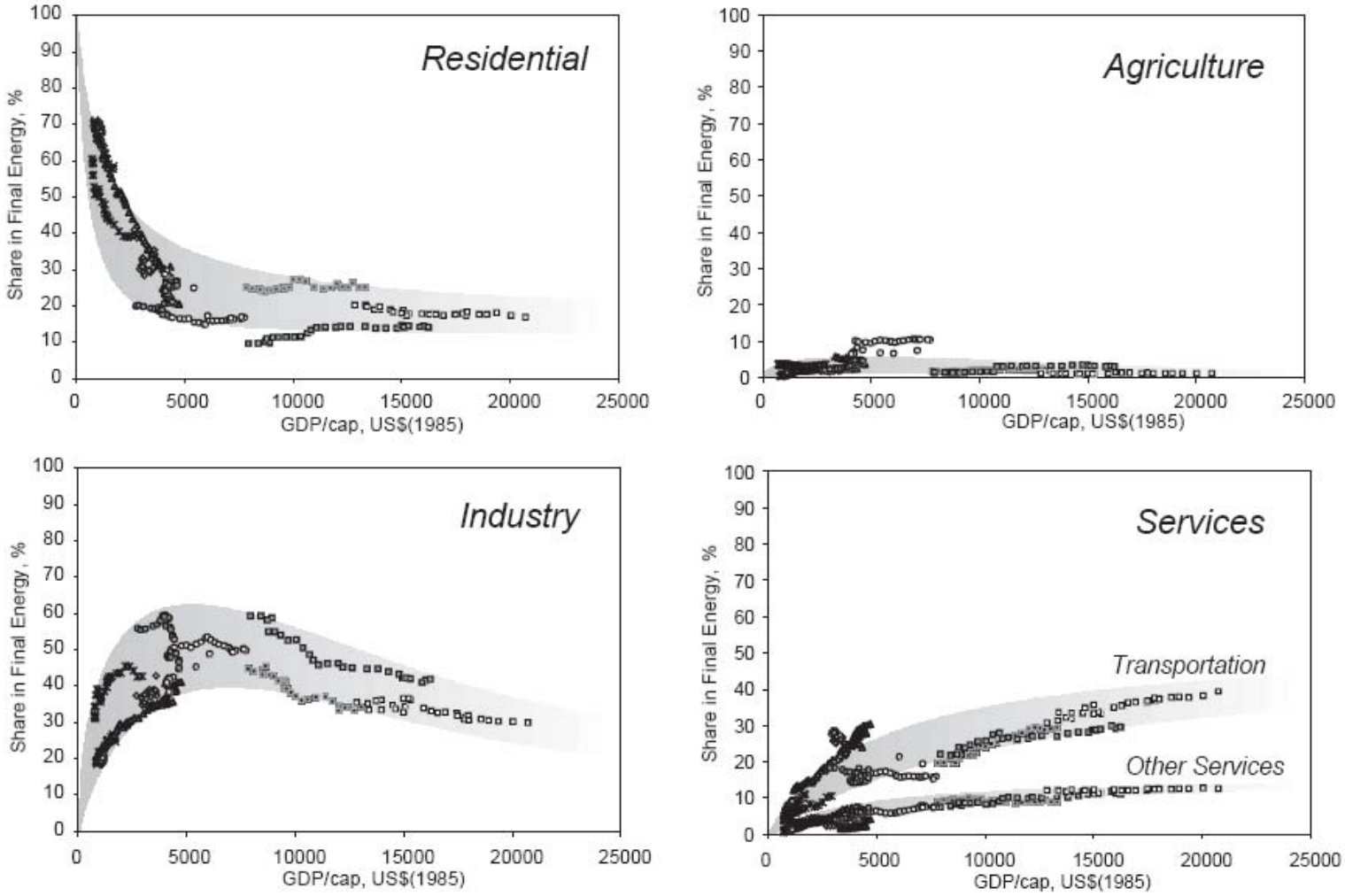
Quantity

Qualtity

Three aspects of energy transitions (Grübler, 2004):

- Changing energy quantities
- Changing energy qualities
- Changing energy structures

The energy transition(s)



Structure

Schäfer 2005

Energy-development nexus II
Access to (modern) energy

Availability of electricity and (modern) energy carriers + improved end-use devices such as cook stoves at affordable prices for all (GEA 2012)

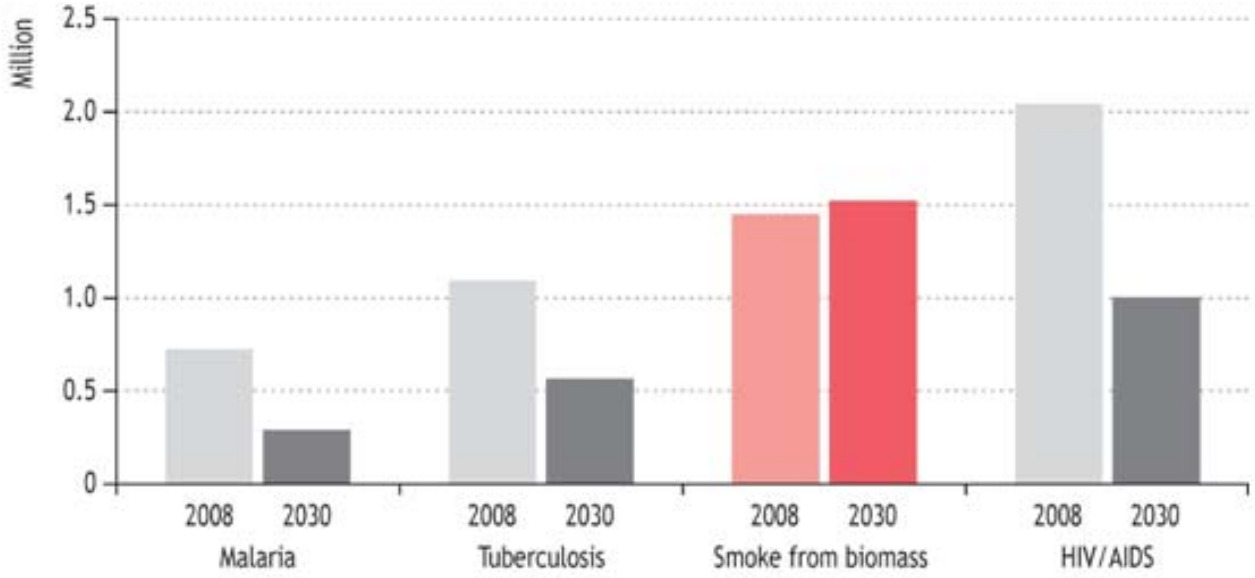
•Energy availability affects economic development through different channels (Toman/Jemelkova 2003, GEA 2012)

- Technological challenges (e.g. grid integration)
- Reallocation of hosehold time (women and children) → education, income generation, gender equality
- Access to transportation and information infrastructure
- Medical services, reduced smoke exposure, refrigeration, clean water
- Electric driven machinery → agricultural productivity, business development, employment

→ *Electricity plays a fundamental role for health care, education and production*

Health impacts of household air pollution

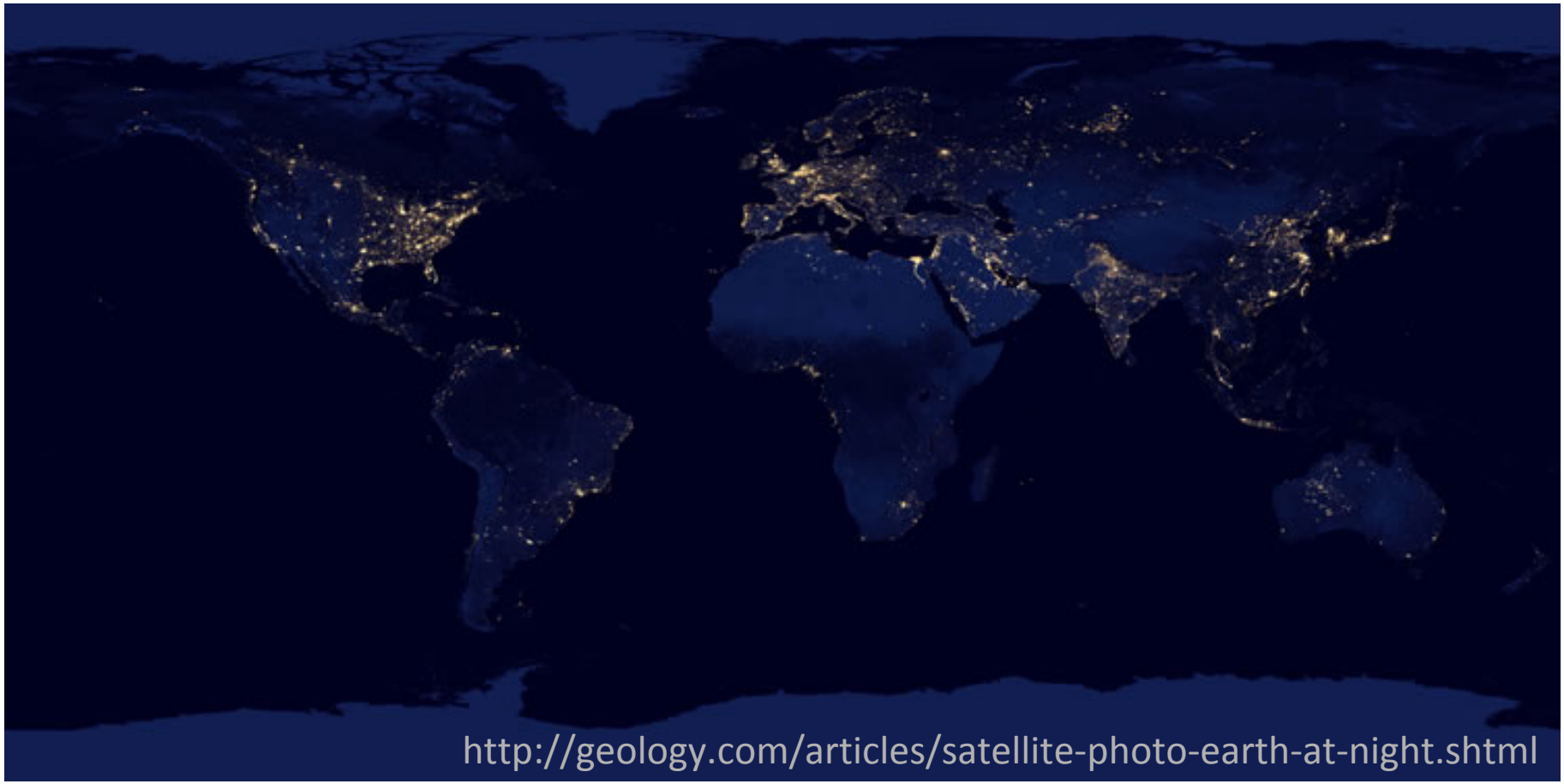
Premature annual deaths per household air pollution and other diseases



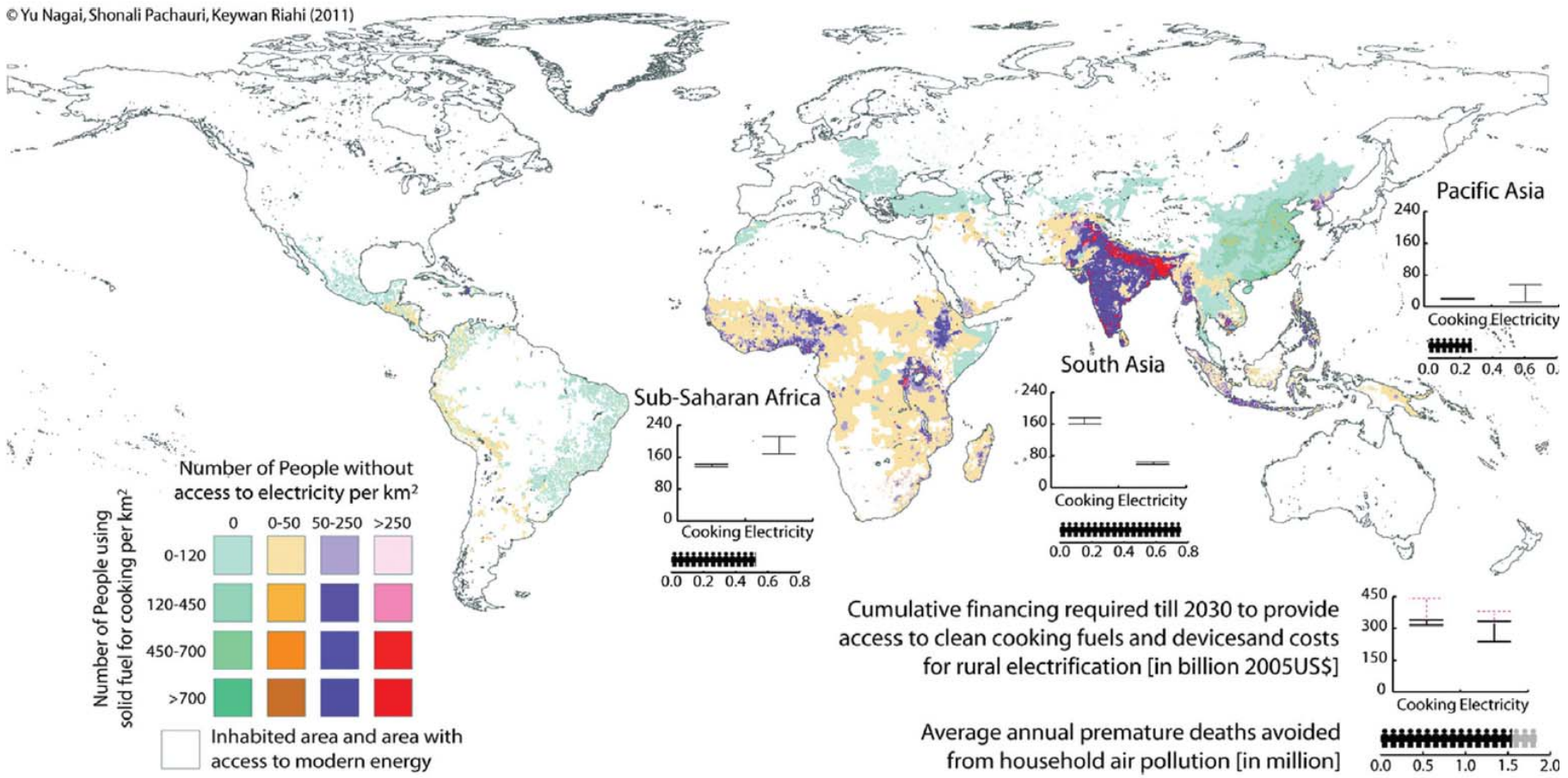
IEA 2010

Global access to electricity …

From satellite data to …

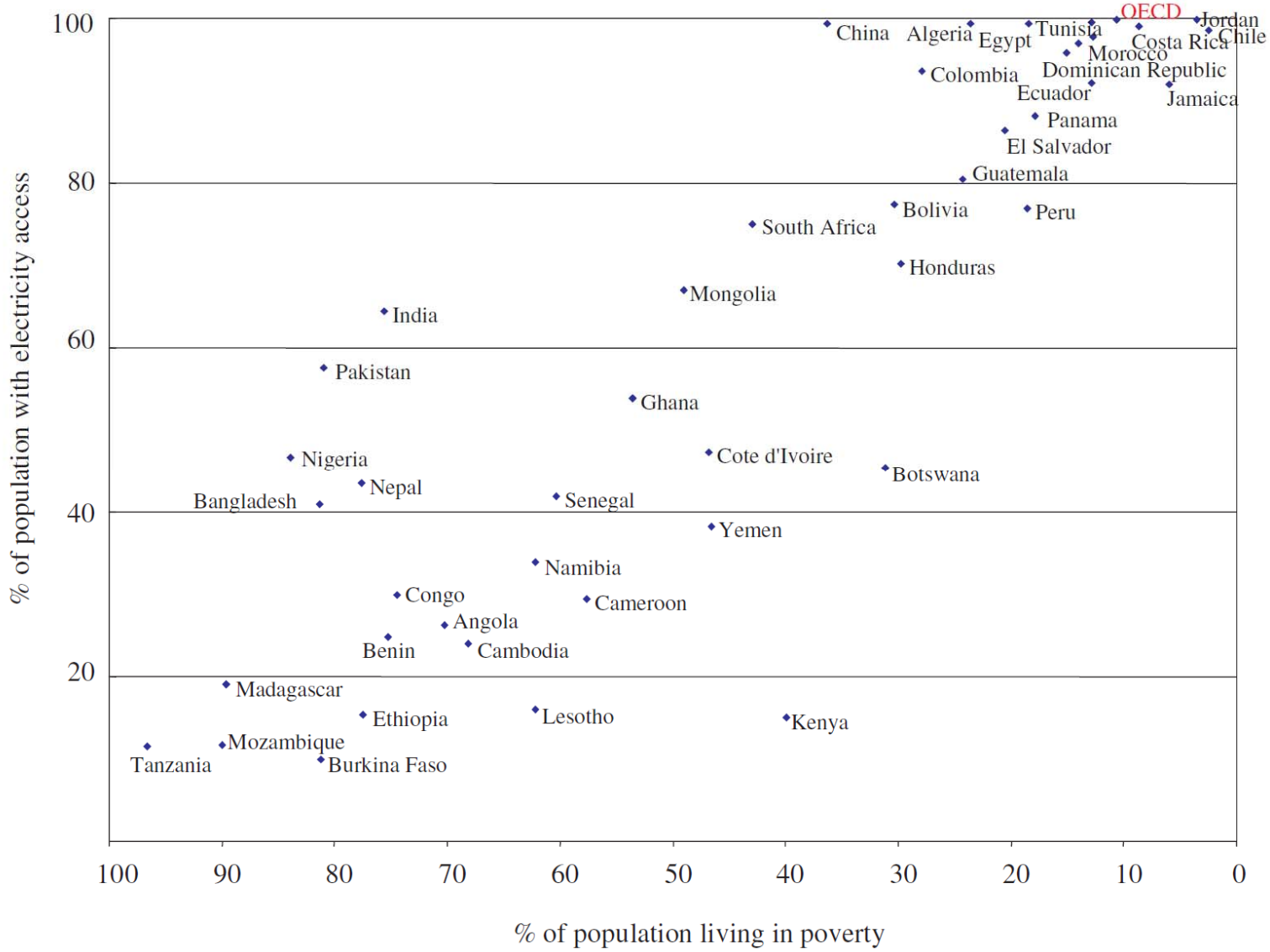


Access to electricity: a global overview



Doll and Pachauri 2010, GEA 2012

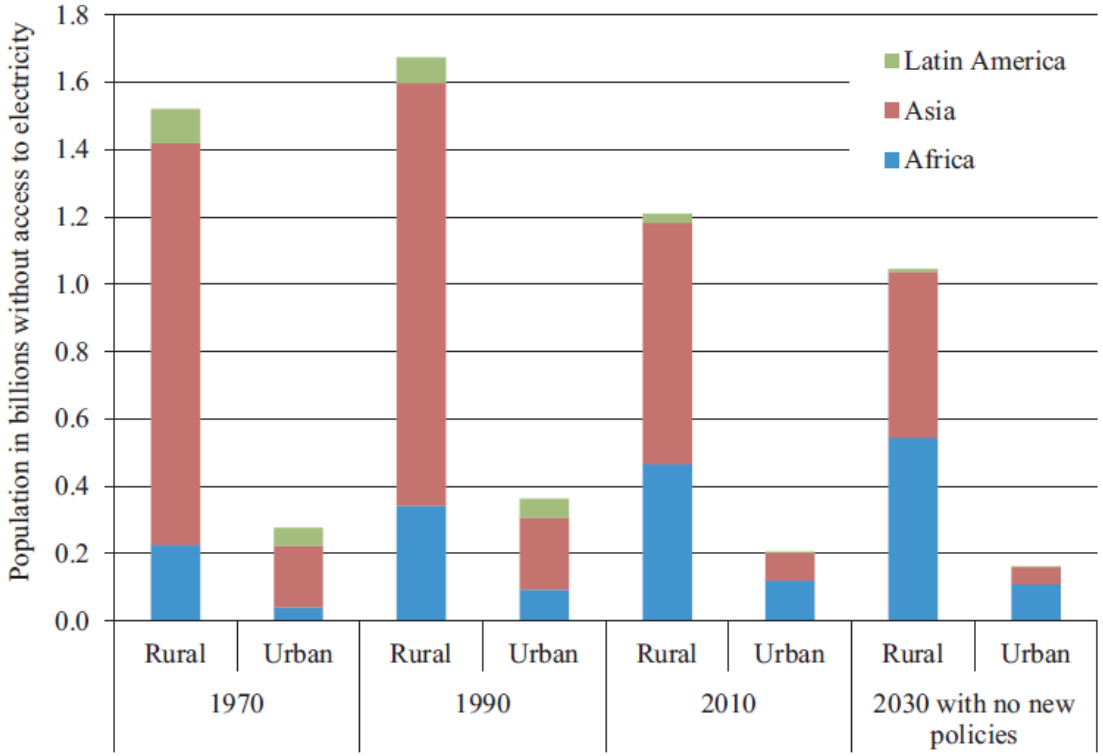
Electricity access vs. poverty



GEA 2012

Electricity access: urban-rural divide

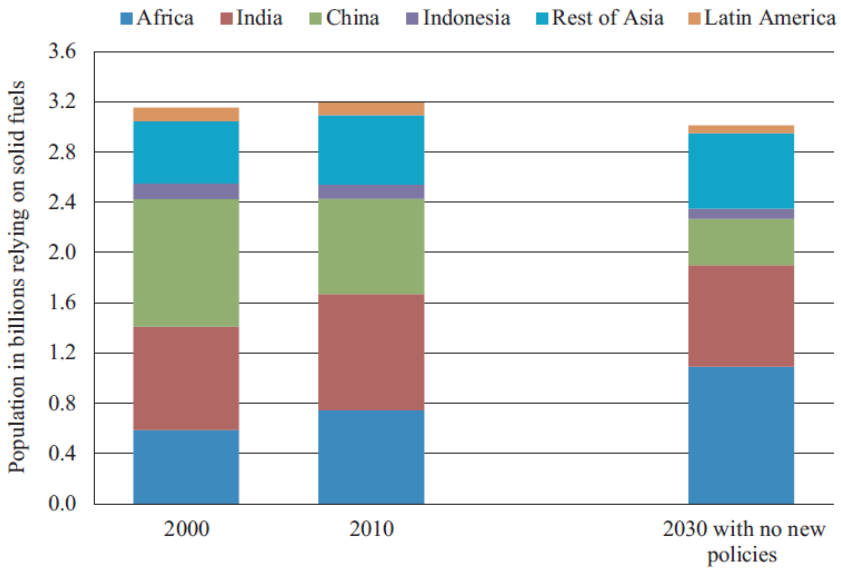
- 1/3 of the global rural population has no access to electricity
- Lowest electrification level in Sub-Saharan Africa (11 %)
- Electrification speed: 2 bln. people gained access to electricity between 1990 and 2008

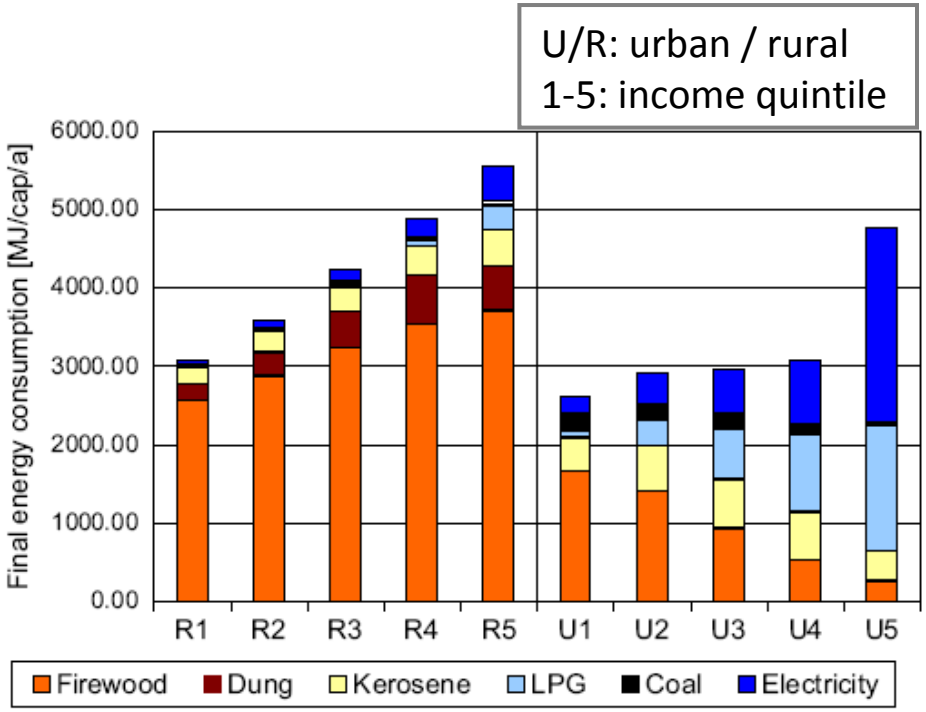


GEA 2012

… at the bottom of the energy ladder

- 75 % of people living in rural areas in developing countries use traditional biomass for cooking (vs. 35 % in urban areas)
- Only ¼ uses improved cooking stoves





GEA 2012, Pachauri et al. 2010

Energy-development nexus III
Energy for production

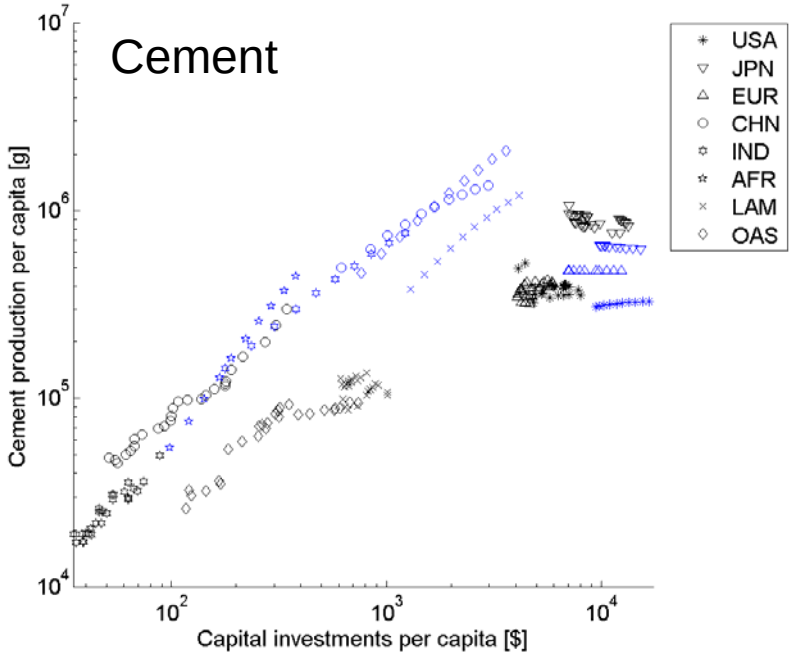
- **Energy availability → Production:** Capital, labor and energy are the primary factors of production
  - Low substitutability between energy and capital (depletion of energy resources)
  - Energy necessary for capital (energy-intensive service) and labor (households, food)

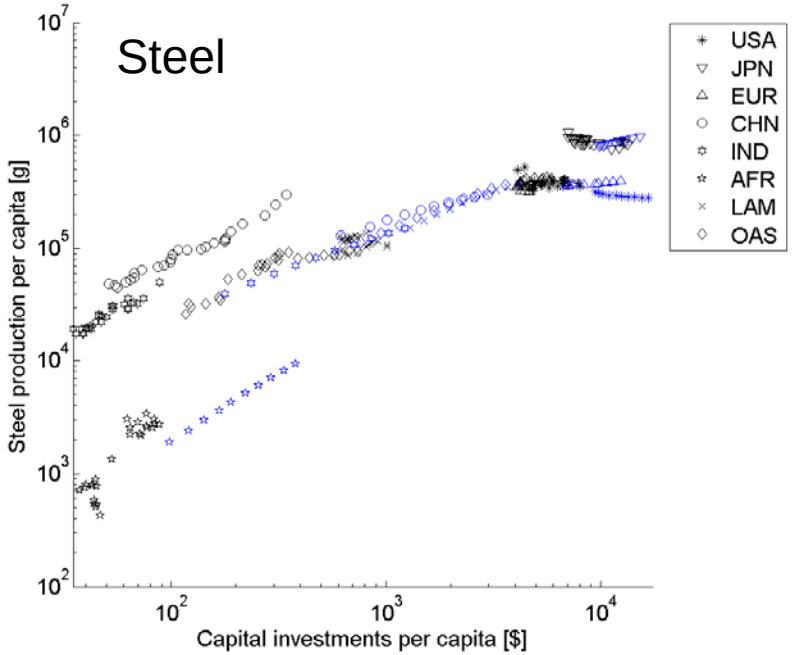
  → energy availability can constrain economic growth, abundance of energy sources alleviates this constraint

- **Production → Energy intensity:** Shifts in energy intensity of output
  - Decreasing energy intensity in manufacturing sector (technical development)
  - Increasing energy intensity for households and service sector

Stern 2011

Production patterns of cement and steel over development





Developing Countries will catch up
(Scenario data in blue)

Steckel et al. 2013

Pathways to a low carbon energy transition

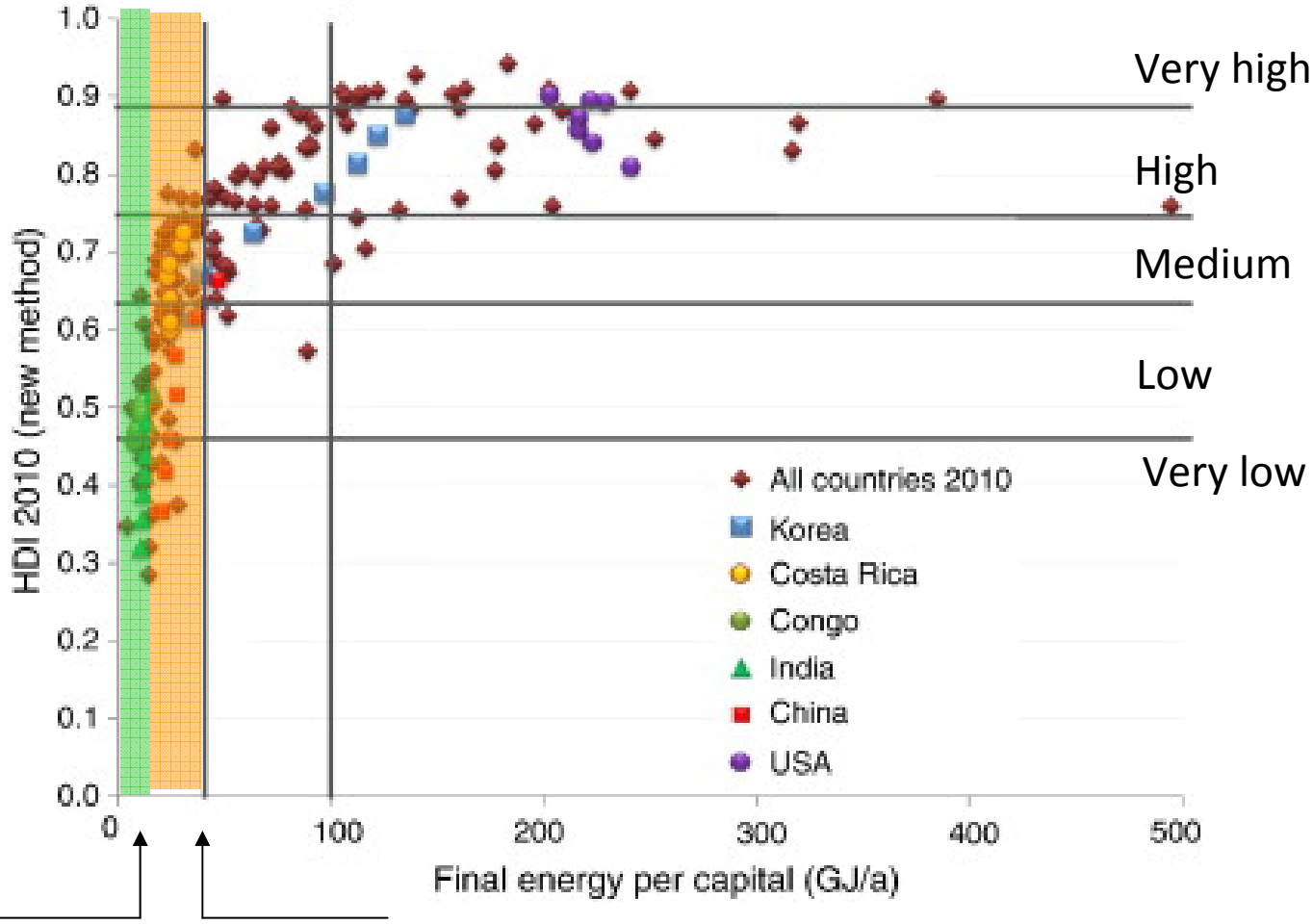
How to grow without increasing emissions?

- Breaking the convergence between economic development and energy use patterns

- Trade-offs
  - Often more expensive than fossil fuels
  - Higher energy prices
    - With adverse distributional implications
    - With negative externalities for economic development (industrialization!)
  - Technological challenges (e.g. grid integration)

- Covering the additional costs of RE would require large financial transfers from industrialized countries

The role of energy in development processes

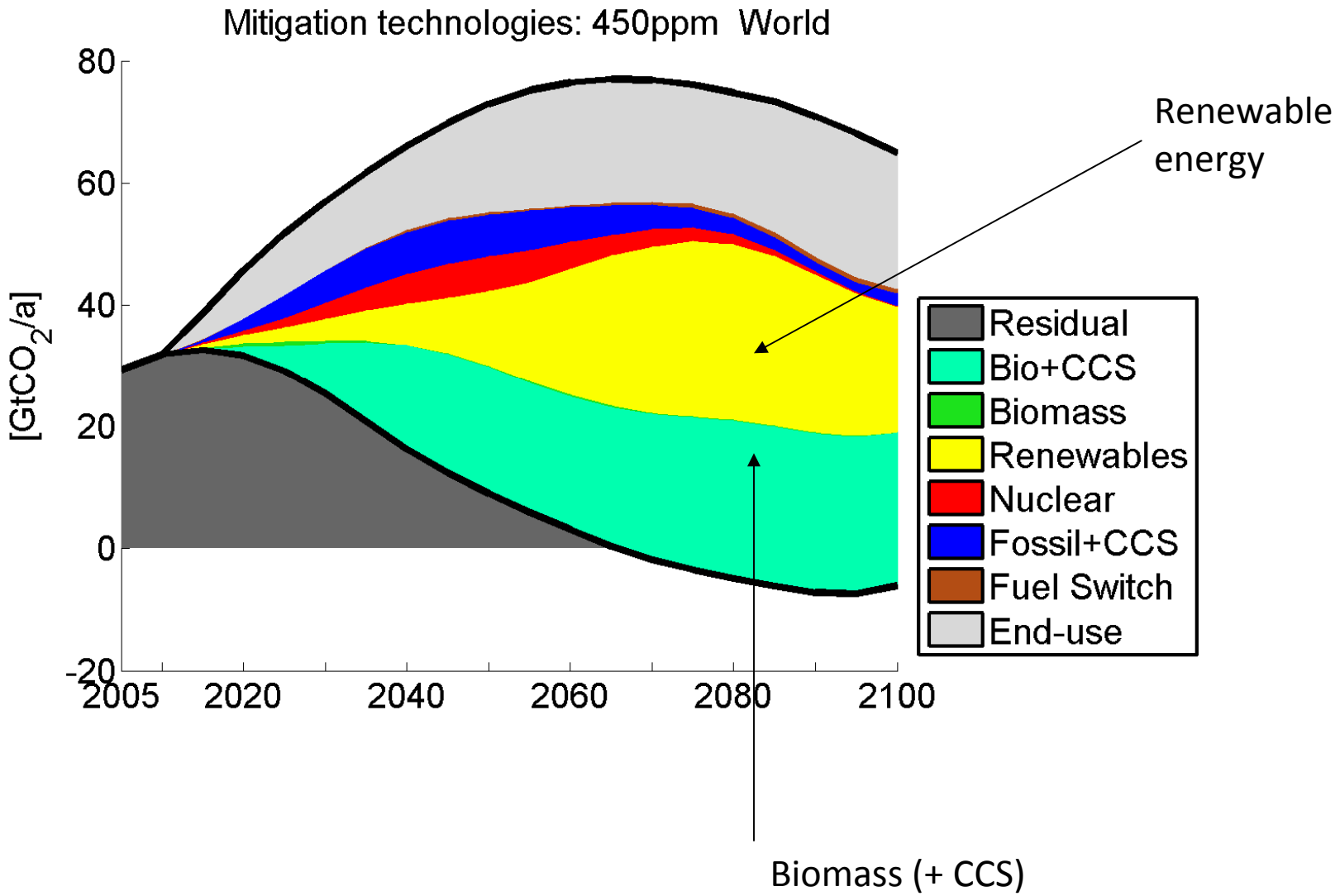


Basic needs

Threshold on the society level at approximately 40 GJ / capita

Steckel et al 2013

Transformation of the Energy System

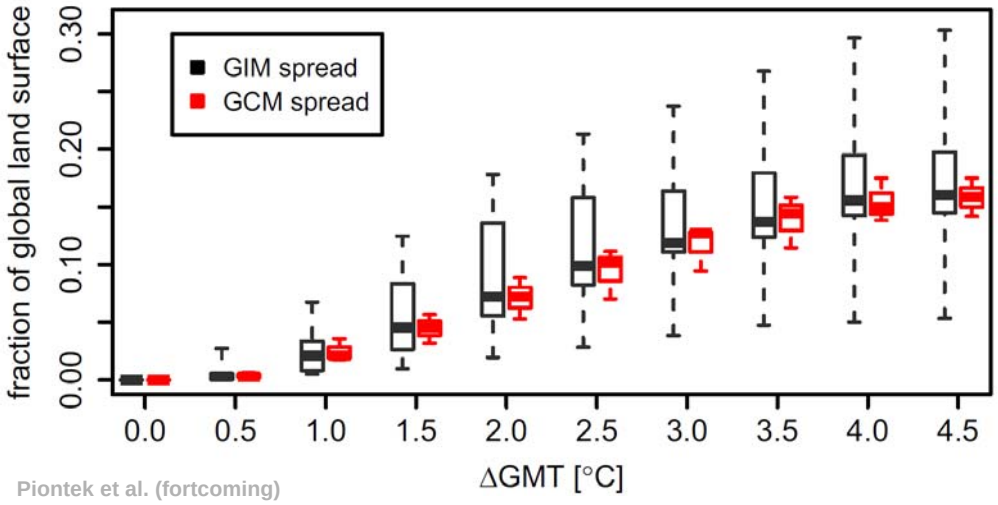


Luderer et al. 2011

Climate Change and the role of land

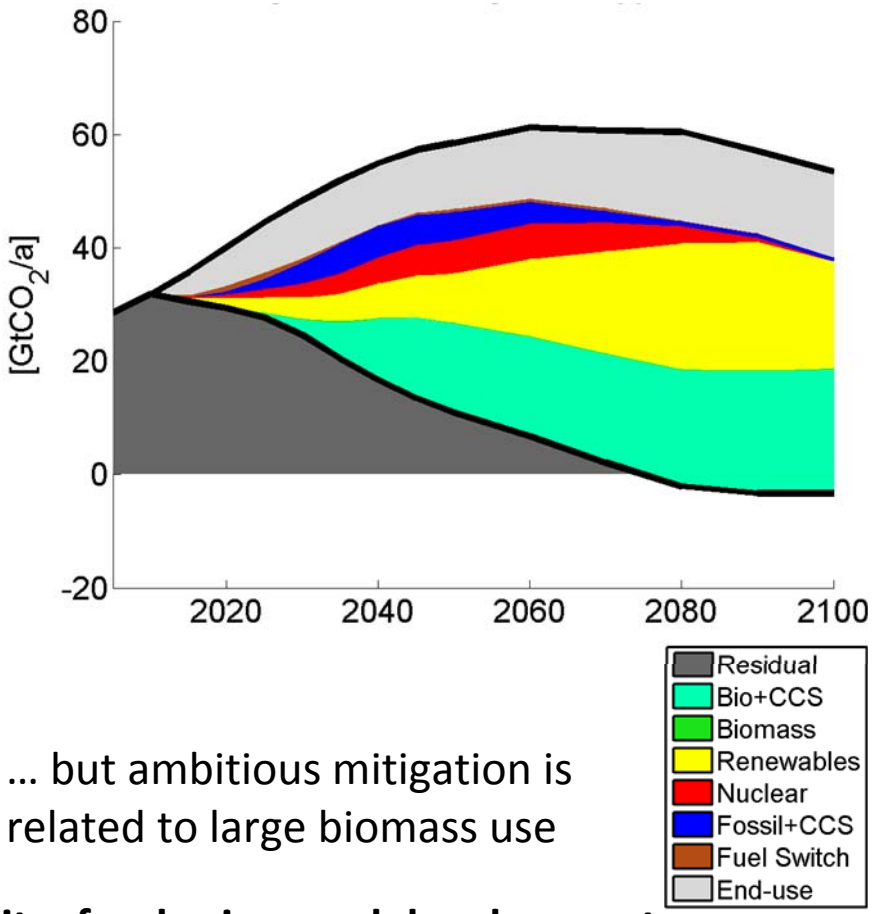
Land is central for human well-being: food production, water, ecosystem services, etc.

Land will become scarcer: population growth, economic growth, urbanisation, climate change…



Cumulative fraction of global land area crossing "affection threshold" for crop production (10th percentile of the reference period distribution 1980–2010)

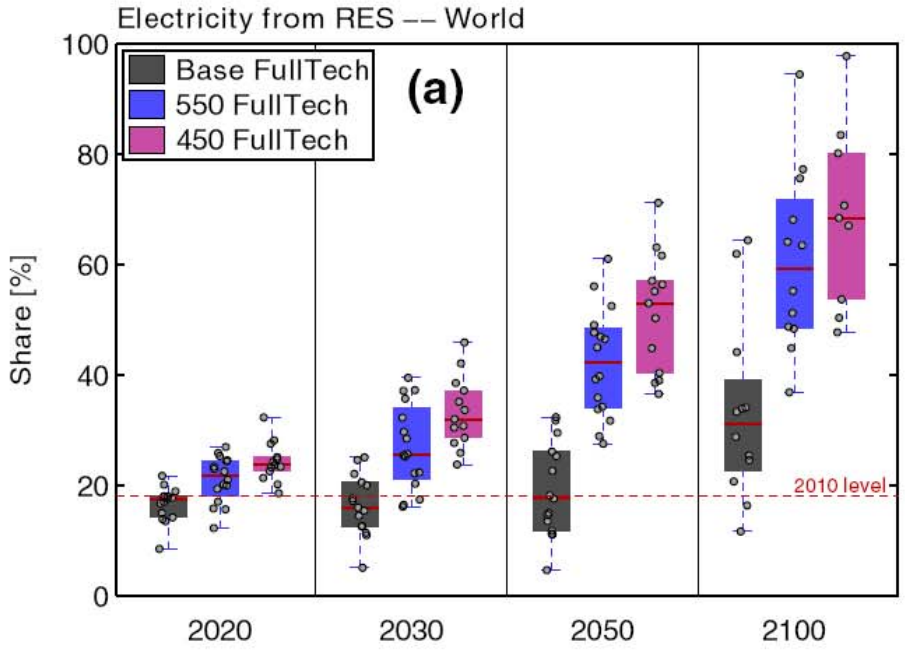
Climate impacts will depress yields…

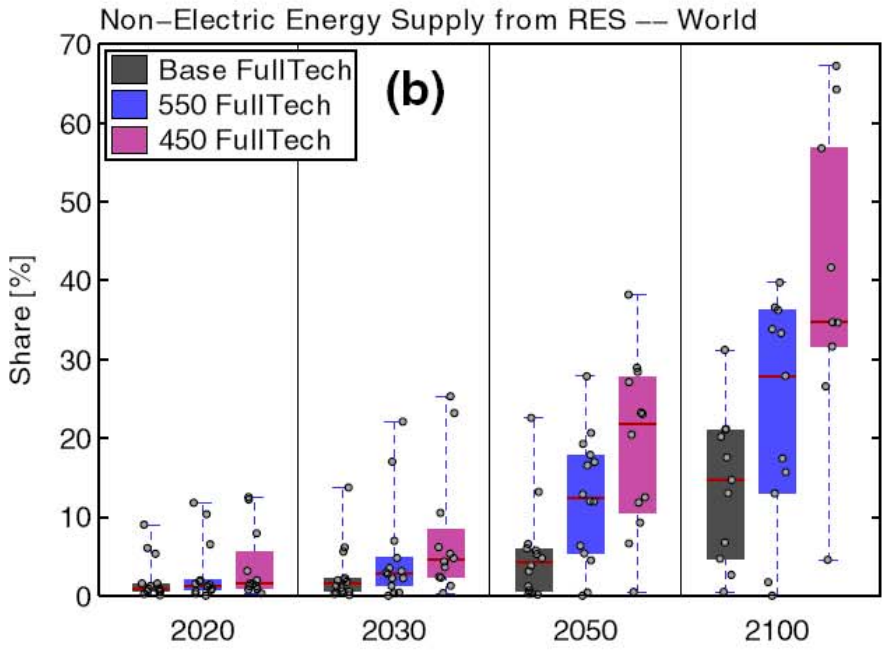


… but ambitious mitigation is related to large biomass use

Opens up new concerns regarding food security, food prices and development …

Role of renewable in future scenarios





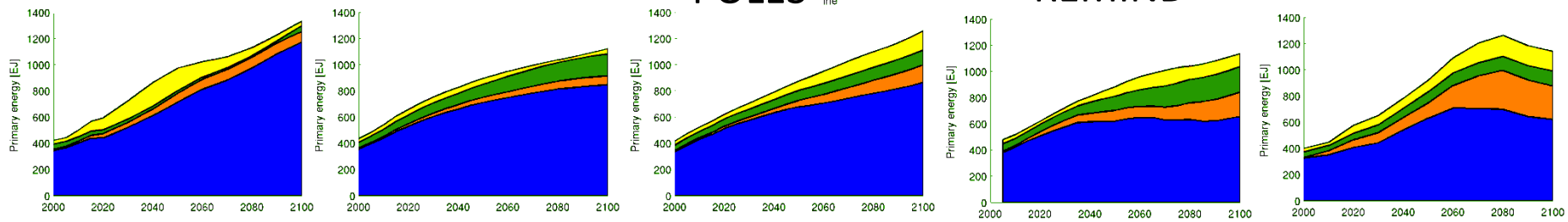
Luderer et al., in press

Transformation of the Energy System

models →

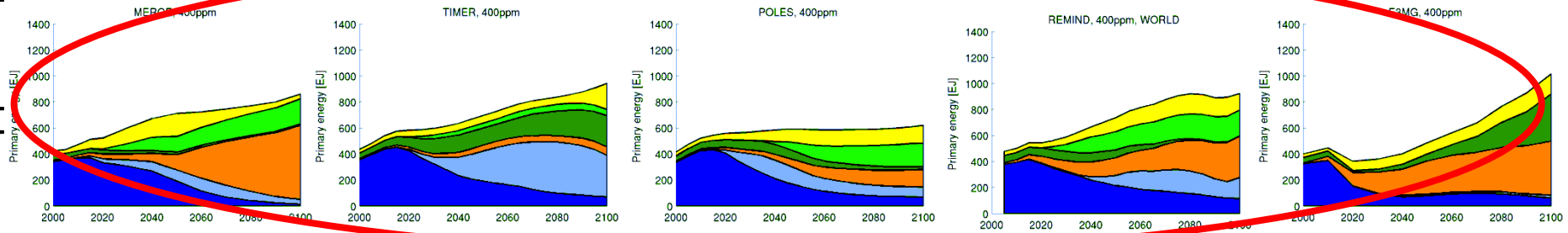
Baseline

MERGE | TIMER | POLES | REMIND | E3MG



Many different pathways to transform the energy system

400 ppm-eq

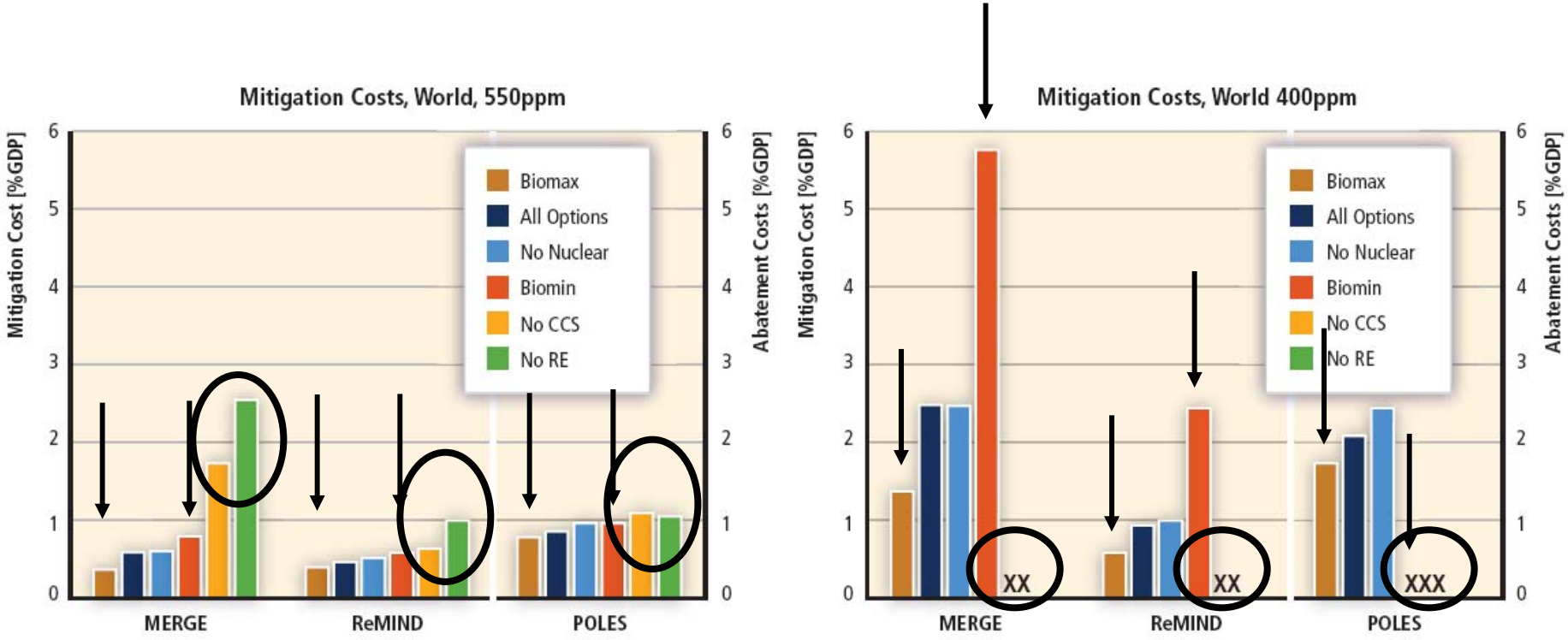


→ Different possibilities to reach low stabilisation

→ 400ppm can be achieved by all models

Knopf et al. 2009

Costs of mitigation



Costs hinge critically on:

- The stabilization target
- The biomass potential
- The availability of technologies, RE and CCS in particular

Edenhofer et al. 2011

How to grow without increasing emissions?

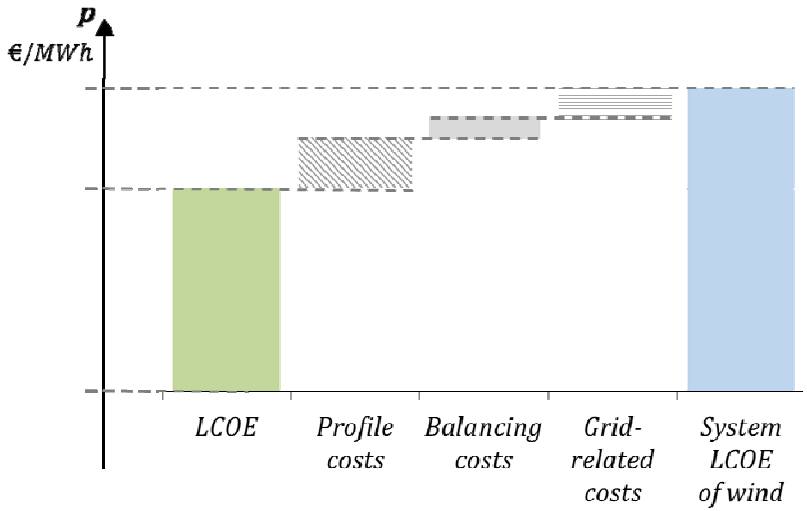
- Breaking the convergence between economic development and energy use patterns

- Trade-offs
  - Technological challenges (e.g. grid integration)
  - Currently often more expensive than fossil fuels
  - Higher energy prices
    - With adverse distributional implications
    - With negative externalities for economic development (industrialization!)

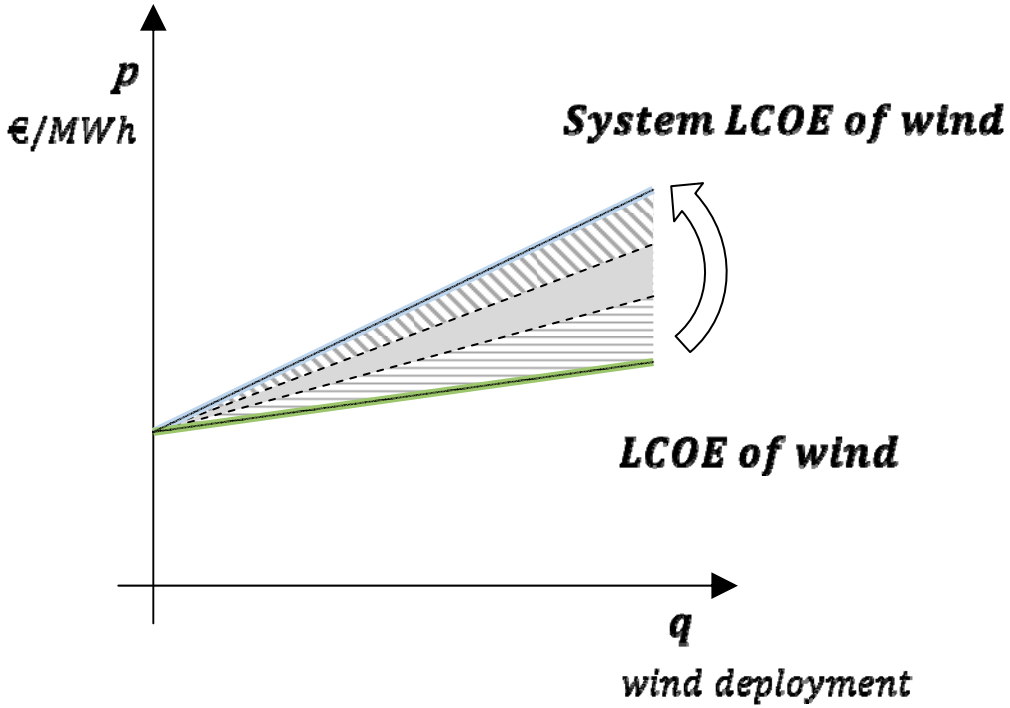
- Covering the additional costs of RE would require large financial transfers from industrialized countries

System LCOE are defined as the sum of generation and integration costs

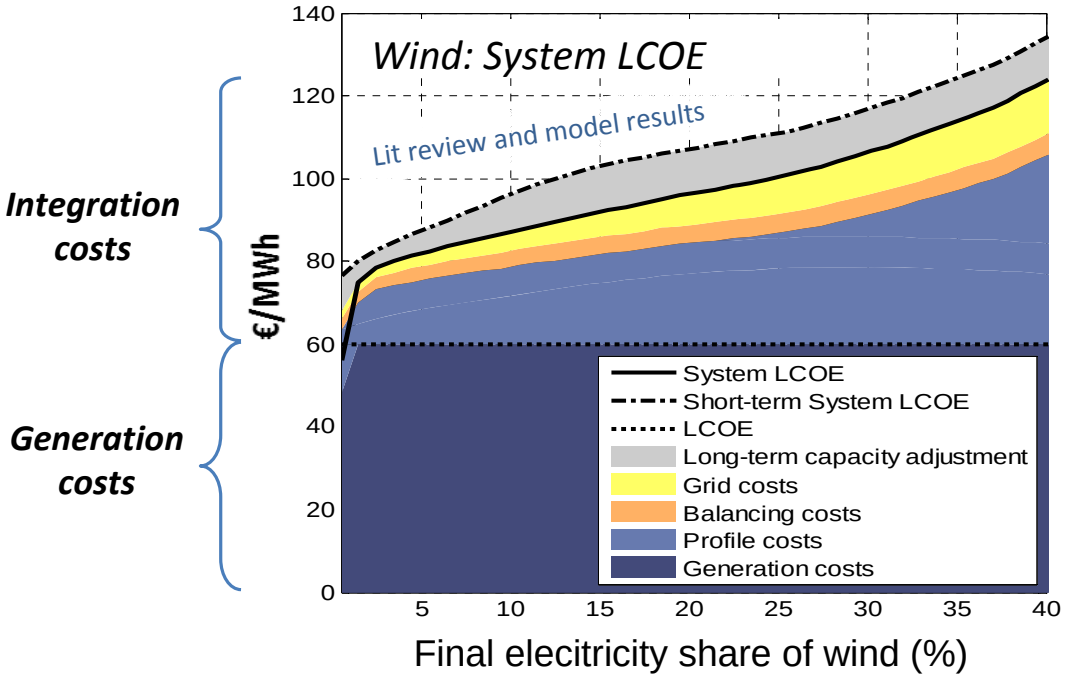
Static



Dynamic



System LCOE – magnitude and shape



- From literature: Grid and balancing costs (Holttinen et al. 2011; Gross et al. 2006; Hirth 2012a, dena 2010)
- From a simple model: profile costs.
- Parameterized from German data, representative for thermal systems in Europe
- Caveats that increase integration costs
  - No import/export
  - No demand elasticity
  - No storage
  - Power sector only

- Integration costs of wind power can be in the same range as generation costs at moderate shares (~20%)
- A significant driver of integration costs are profile costs, especially the reduced utilization of capital-intensive thermal plants.

→ Integration costs can become an economic barrier to deploying VRE at high shares.

→ An economic evaluation of wind and solar power must not neglect integration costs.

Ueckerdt et al., in press

Renewable Energy in Developing Countries (DCs)

- Hydropower
  - Wide-spread adoption: generated by 83% of all DCs
  - Average share of total electricity: 38 percent (11 percent weighted with total country electricity consumption)
  - Top 3 DC producers (billion kWh in 2009): China (549), Brazil (387), Russia (162), also have top technically exploitable capability

- Non-hydropower (biomass, geothermal, solar, and wind)
  - Generated by about 45% of DCs
  - Average share of total electricity: 1.4 percent
  - Most important: biomass, geothermal
  - Very uncommon: solar and wind
  - But: High growth rates from low basis

Pohl et al. 2012

Macro analysis of RET adoption

- Study of diffusion of non-hydro renewable energy technologies for electricity generation (NHRE) across 108 developing countries (between 1980 and 2010)

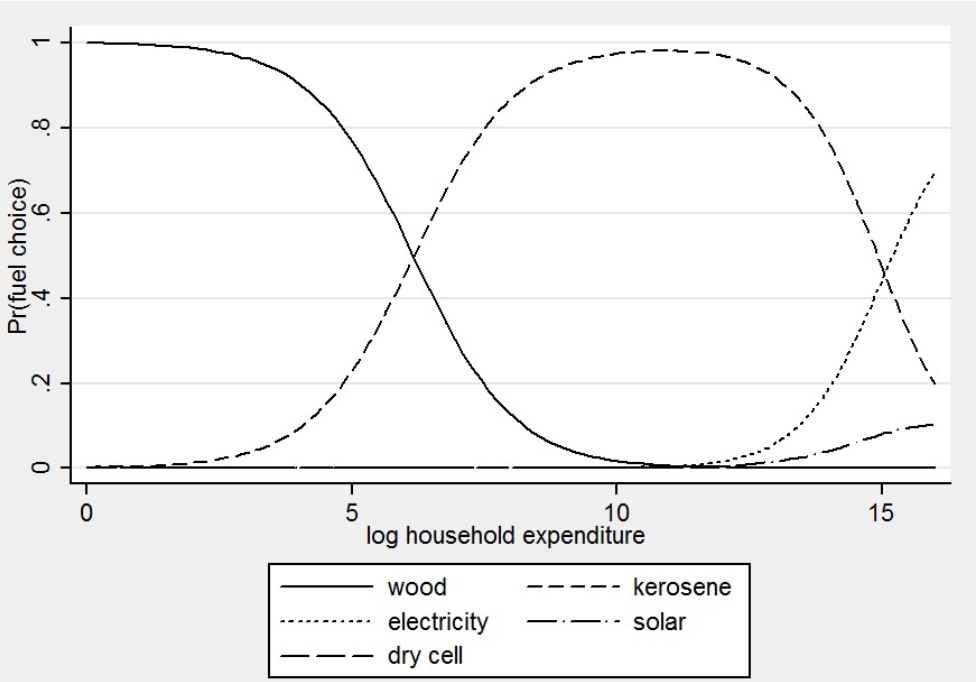
- Main findings: NHRE diffusion accelerates with
  - Implementation of economic and regulatory instruments
  - Higher per capita income and schooling levels
  - Stable, democratic regimes

- NHRE diffusion is slower with
  - Greater openness and aid
  - Institutional and strategic policy support programs
  - Growth of electricity consumption
  - High fossil fuel production

Pfeiffer and Mulder 2013

Micro analysis: Solar home systems in Kenya

- Kenya's SHS market one of the biggest worldwide
- Data on households from the Kenyan Integrated Household Budget Survey (KIHBS) 2005/06, 13 430 households
- With information on SHS use and potential drivers
  - Income, education, residence (rural, urban), housing situation
  - Kerosene price
  - Potential grid access, prevalence of SHS



Evidence for a cross-sectional energy ladder with very **high income threshold** for modern fuel use – including solar energy use – to move beyond traditional and transitional fuel

Lay et al. 2012

Income, education and SHS clustering are key determinants of SHS adoption

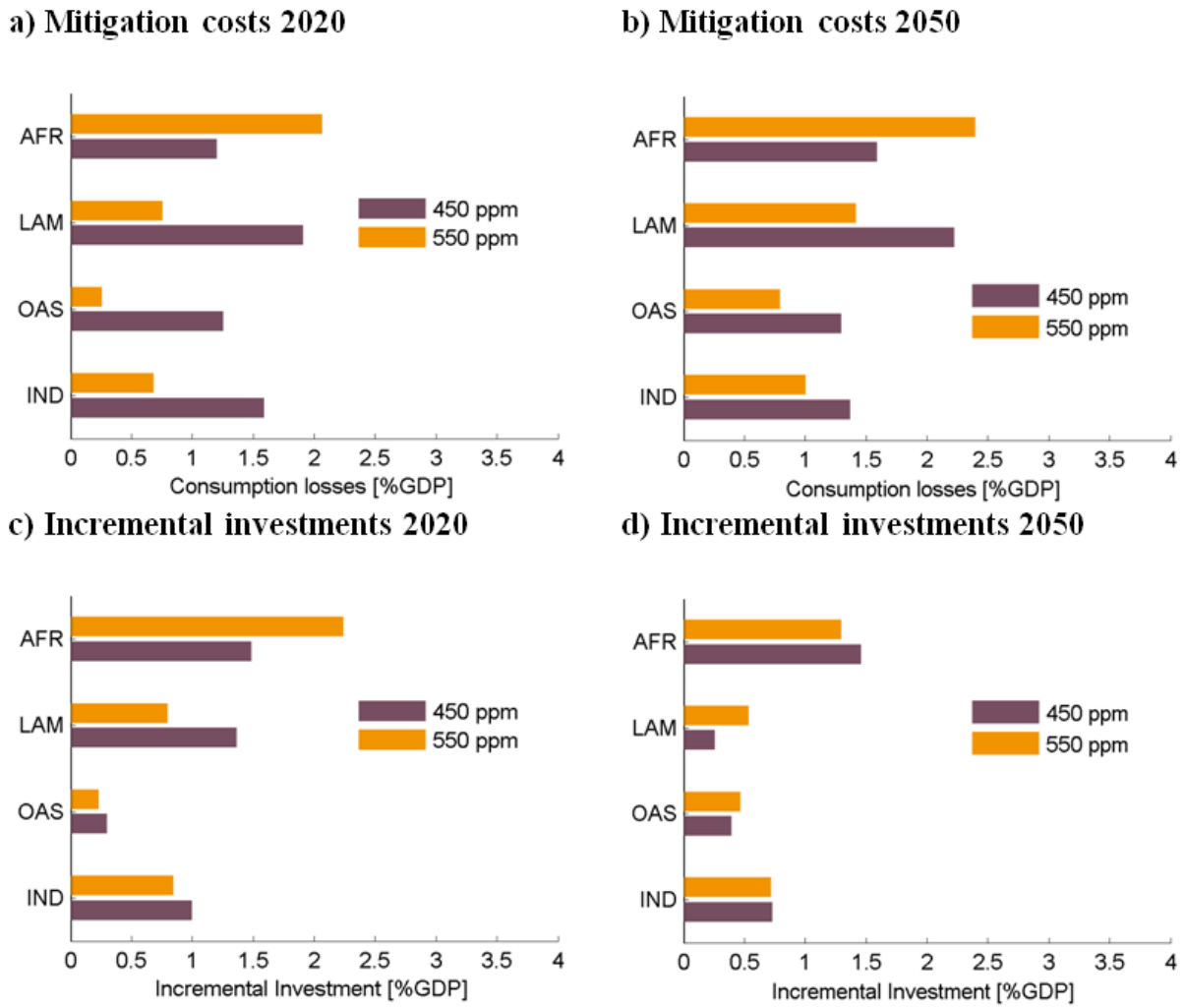
How to grow without increasing emissions?

- Breaking the convergence between economic development and energy use patterns: Renewables as one pathway

- Trade-offs
  - Often more expensive than fossil fuels
  - Higher energy prices
    - With adverse distributional implications
    - With negative externalities for economic development (industrialization!)
  - Technological challenges (e.g. grid integration)

- Covering the additional costs of RE would require large financial transfers from industrialized countries

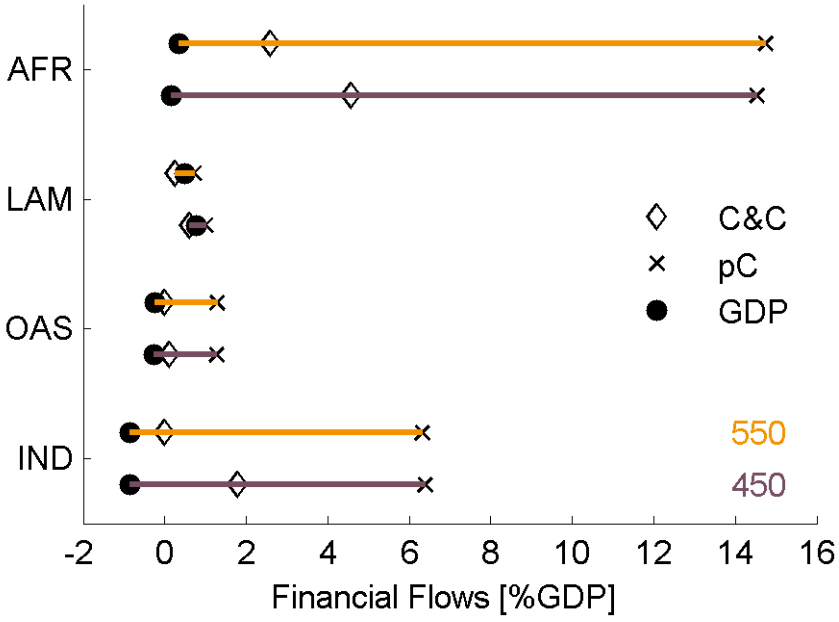
Climate Finance – Non-Market Transfers

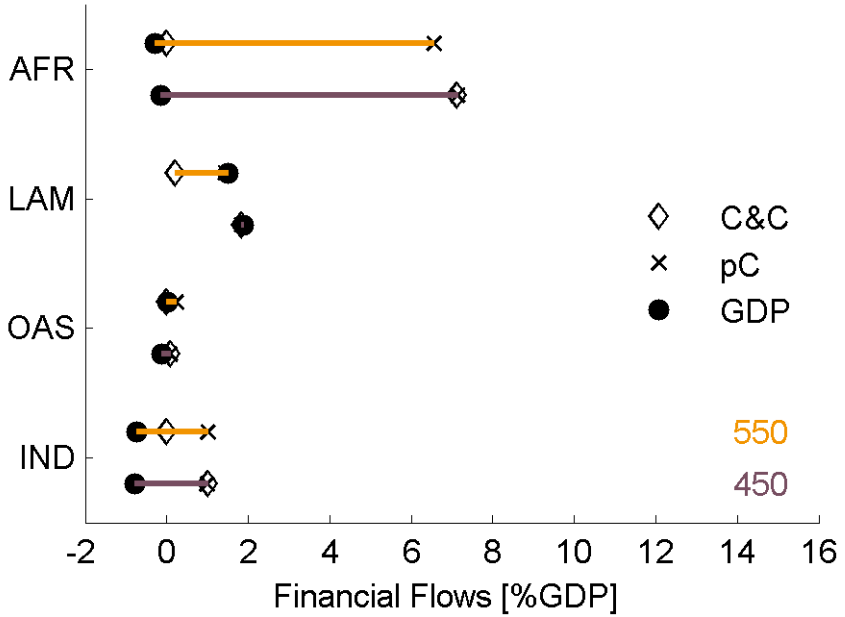


Jakob et al., submitted

Climate Finance – Market-Based

Different allocation schemes: Contraction and Convergence, equal per capita, and based on current GDP (i.e. grandfathering)

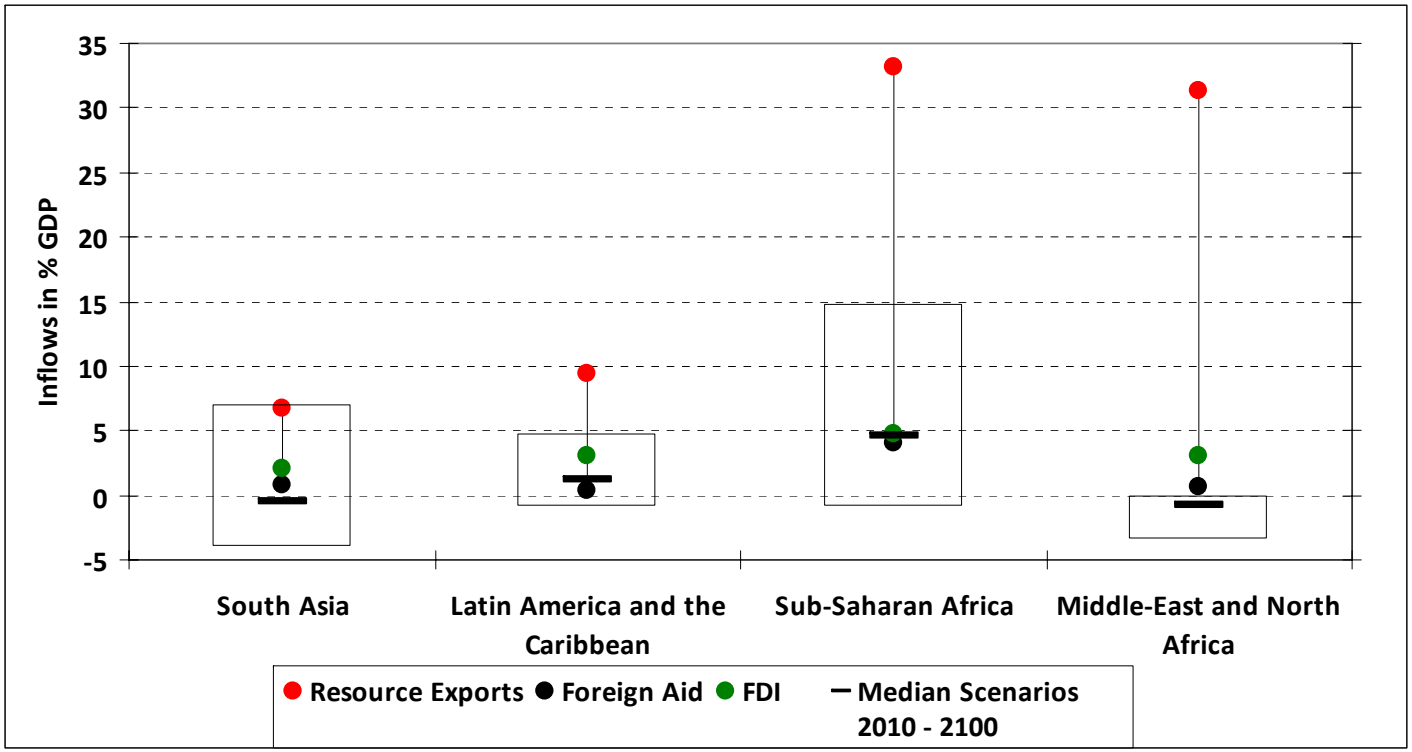




Financial transfers crucially depend on allocation scheme, particularly large for equal per-capita allocation of permits

Jakob et al., submitted

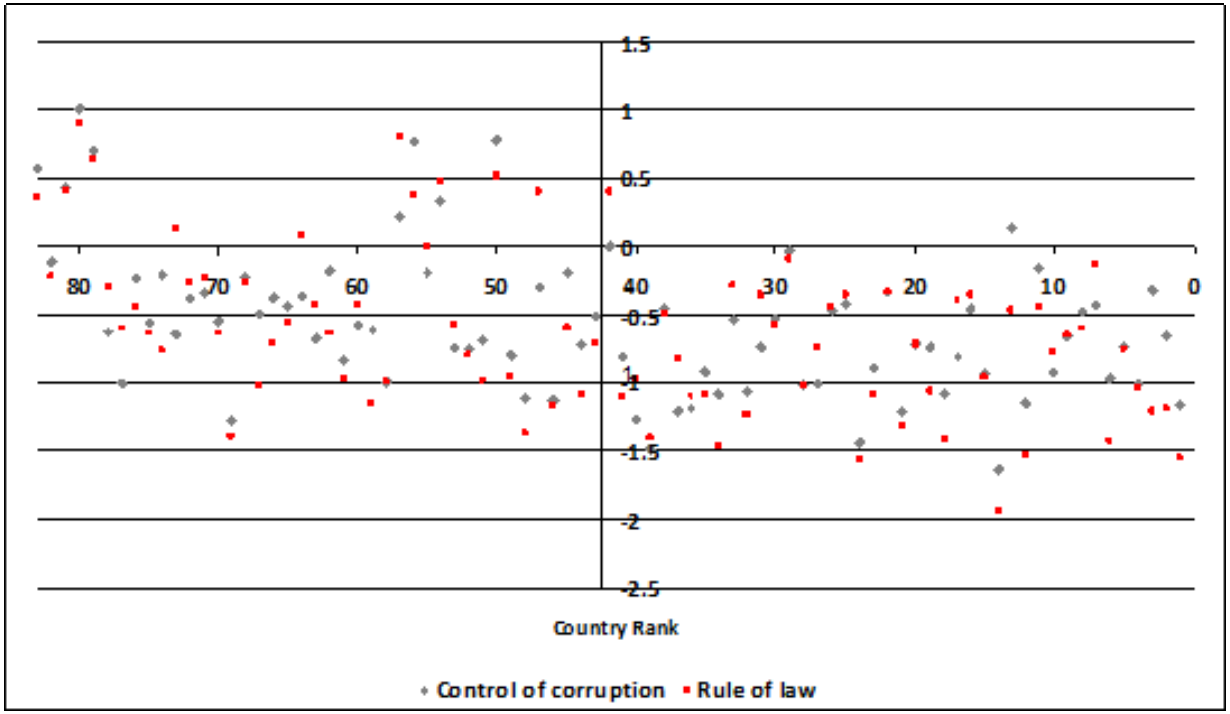
Comparing Financial Inflows



Data Resource Exports, FDI: Year 2009; Aid: Year 2008; ETS: ReMIND scenarios with differently ambitious mitigation targets and different allocation schemes

For some regions and allocation schemes , financial transfers in the order of magnitude as revenues from resource exports

A Climate Finance Curse?



- Largest financial inflows to countries with weak institutions
- This could induce problems similar to revenues from natural resource exports (volatility, „Dutch Disease“, corruption) → ‘Climate Rent Curse‘?

Jakob et al., in preparation

Conclusions

Conculsions

- Development and carbon emissions highly correlated
- At current (relative) prices of fossil fuels it is not realistic to expect a decarbonization of development patters in the short term (w/o policy intervention)
- Low carbon technologies, particularly renewable energy not cost competitive in the short run
- Even on smallest scale, high income threshold
- Strategies to decarbonize energy systems on large scale are necessary and feasible, but might collide with other development goals
- Short term strategy: Improve institutional quality and provide minimum access to basic infrastructures to help the poor

Discussion

Thank you for your attention.

http://www.pik-potsdam.de/members/steckel

Further Reading

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Sectoral use of energy