Potsdam Institute for Climate Impact Research

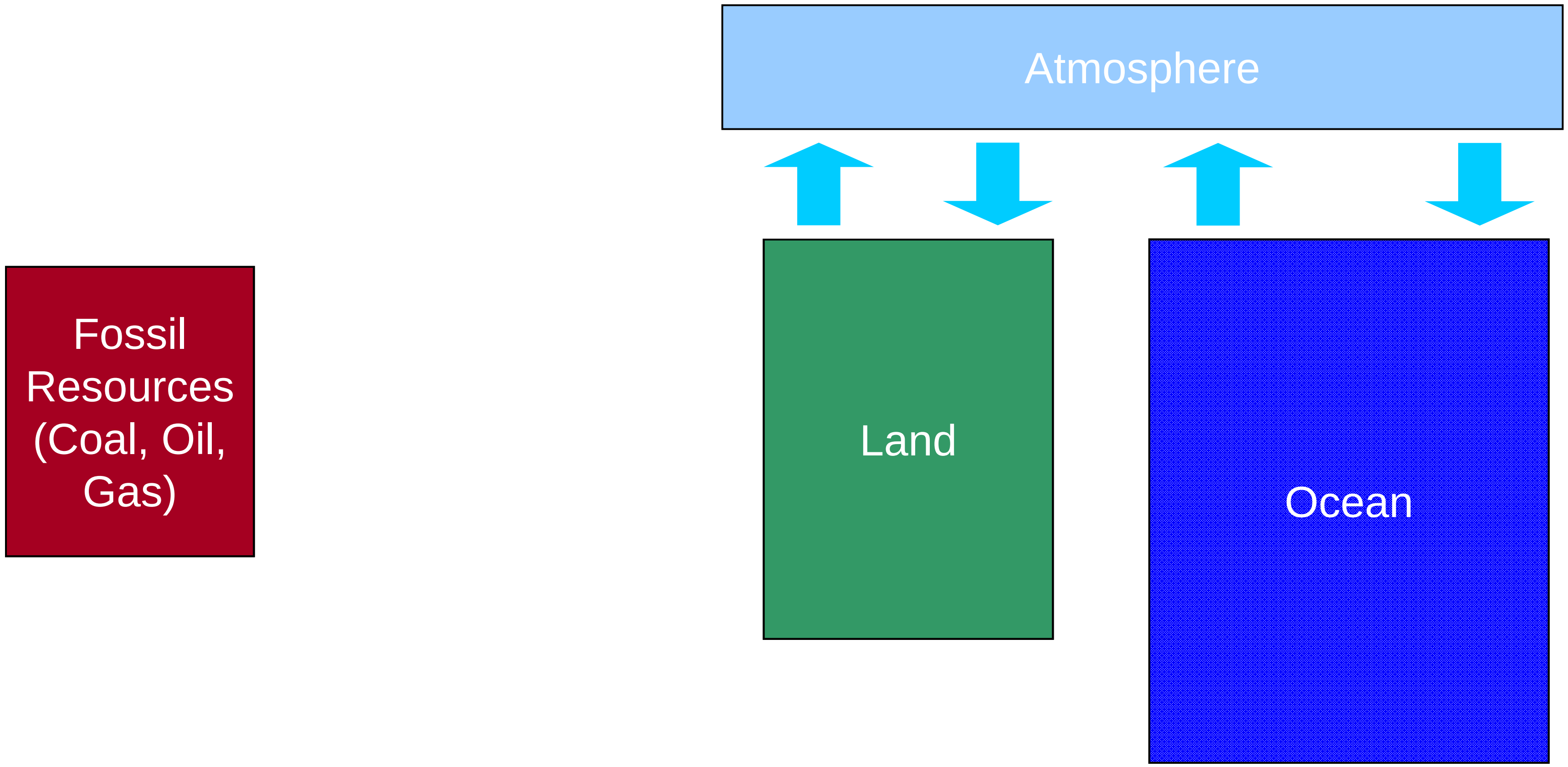
# On the Economics of Climate Change

„Science & Pretzels“

Potsdam, 22 February 2012

Prof. Dr. Ottmar Edenhofer

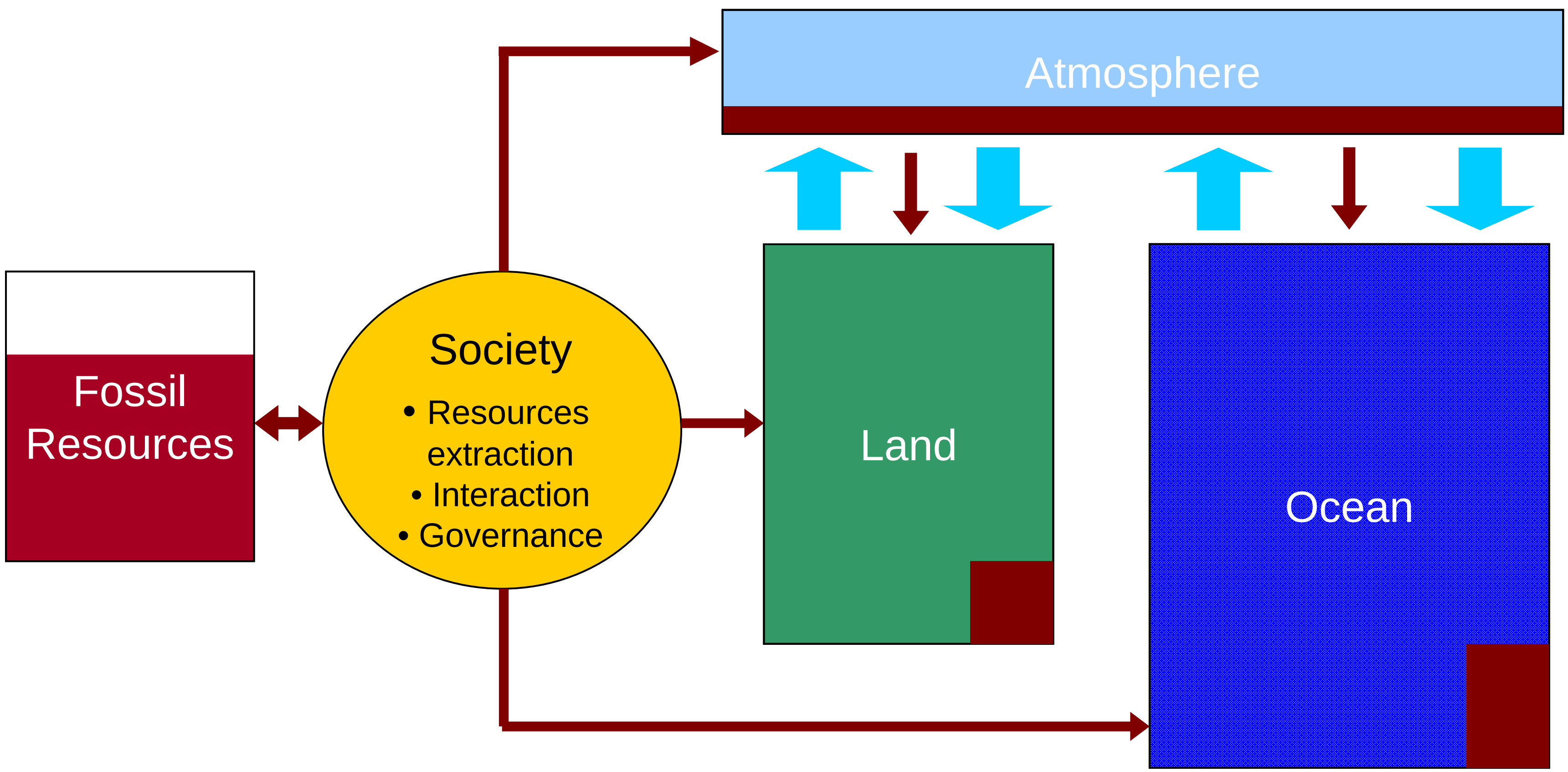
# The Preindustrial Earth System – A Sketch




According to Lenton (2011)

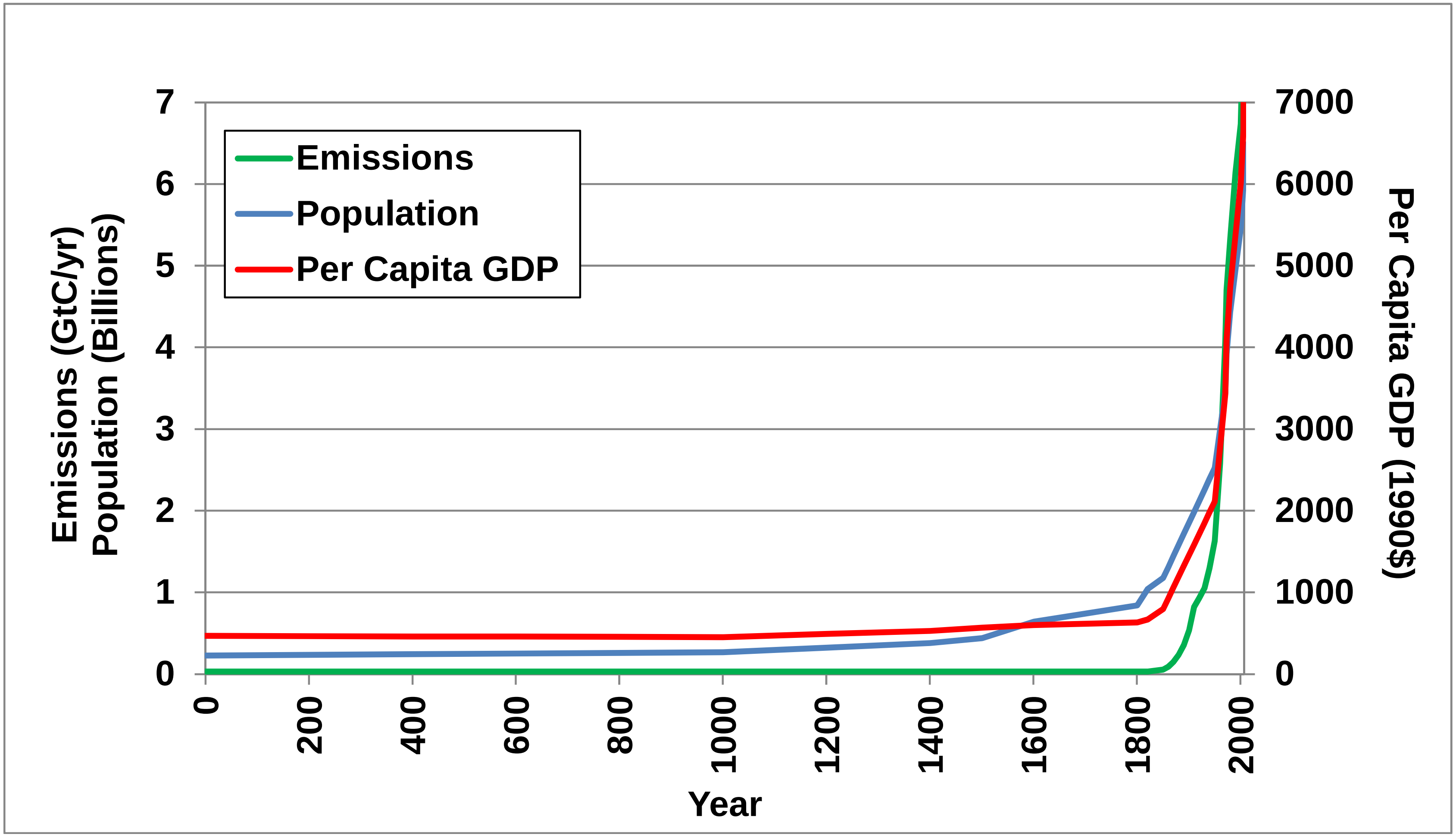
# From a Solar to a Fossil Stock Economy

## The Earth System of the Anthropocene



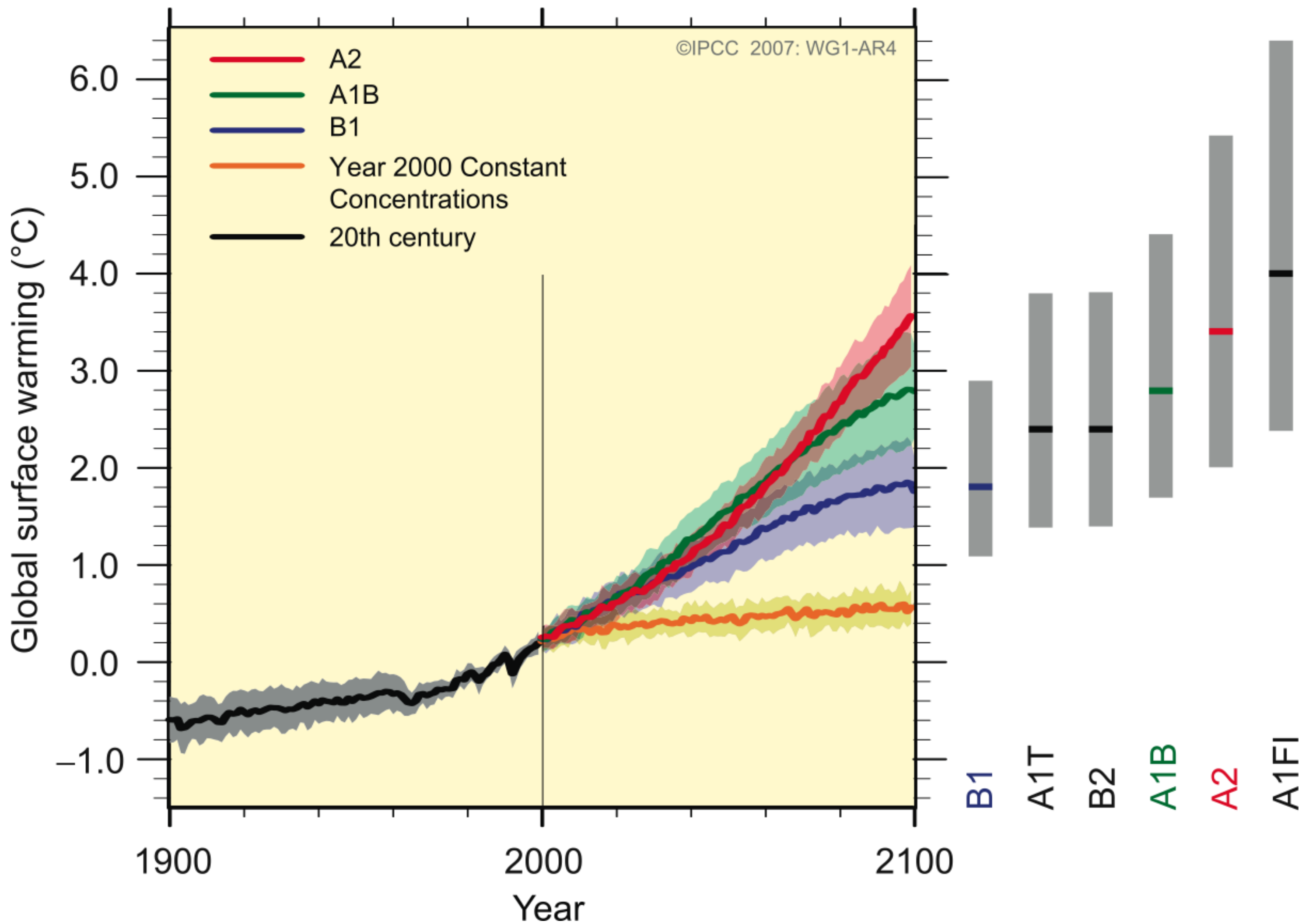

According to Lenton (2011) and Ostrom (2011)

# Fossil Resources Stock – A Lottery Prize!

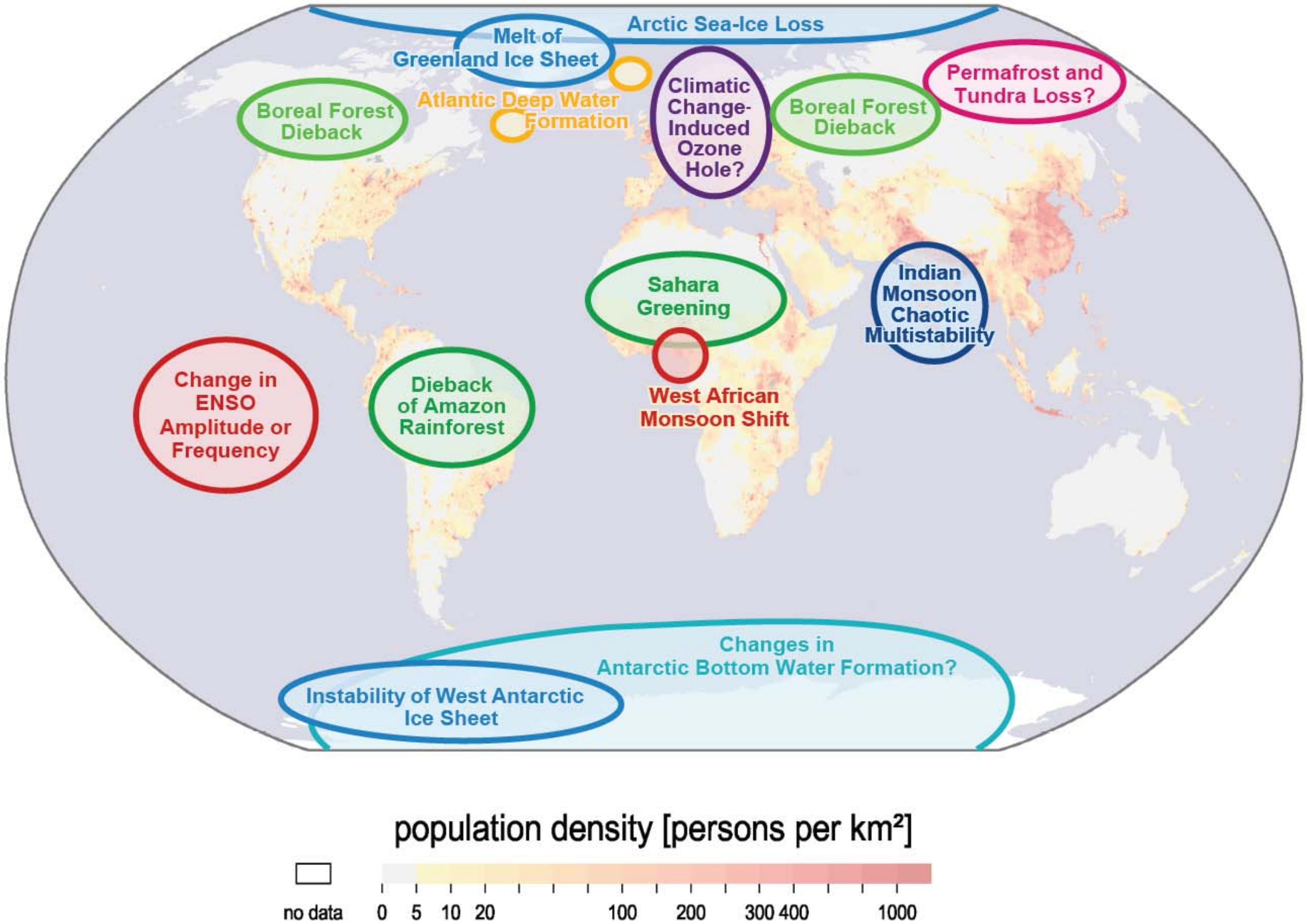



Edenhofer et al. 2012

# What are the Impacts on Climate?



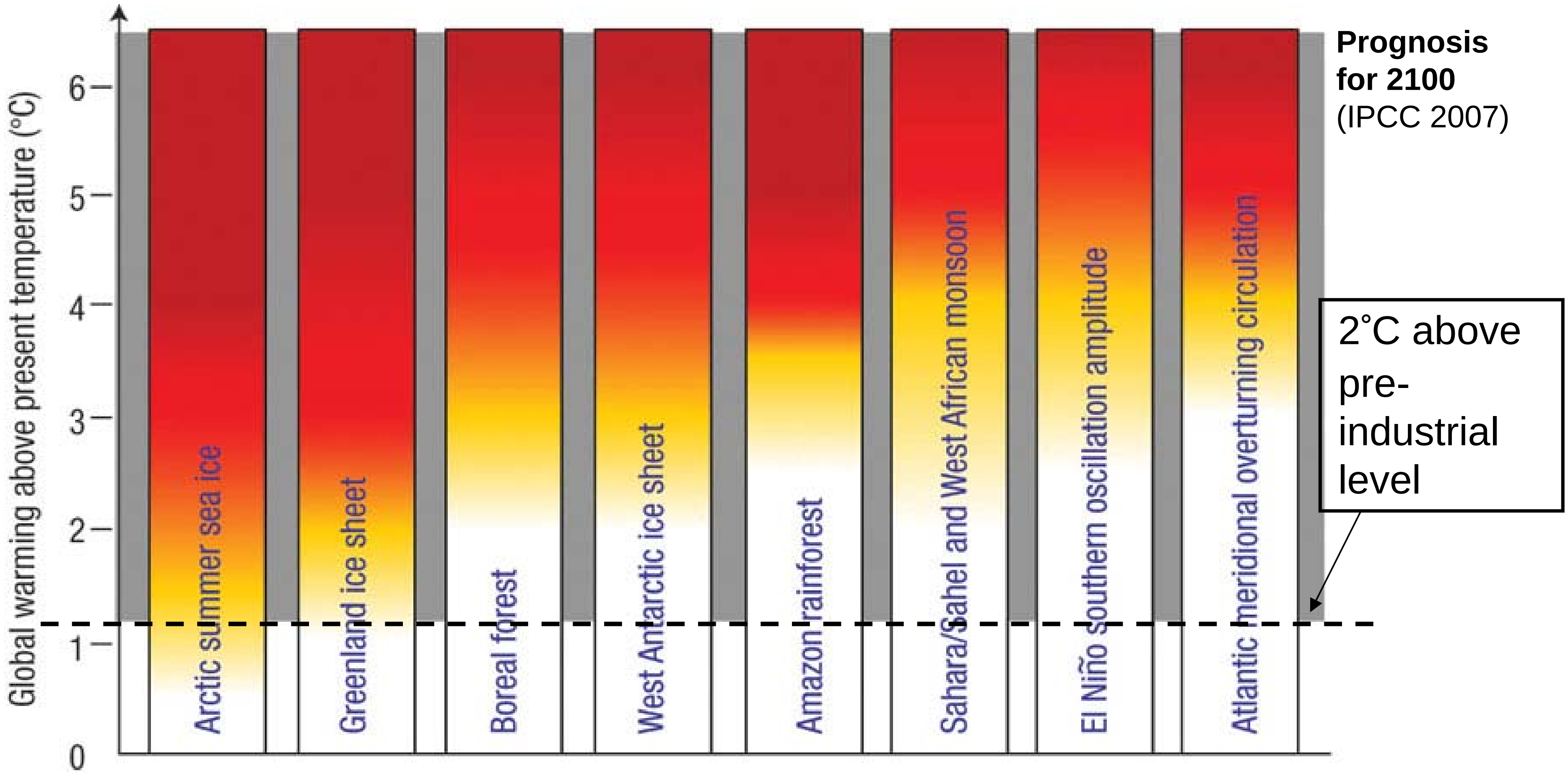
# Tipping Points in the Earth System




**"Tipping processes of the climate system" show a strong reaction already to small climate changes**

Schellnhuber, 1996; Lenton et al., 2008

# Burning Embers Diagram




T. M. Lenton & H. J. Schellnhuber (Nature Reports Climate Change, 2007)

# Climate protection as an insurance

- In this case, the cost-benefit calculation is collapsing since risk aversion would result in practically spending the whole income to eliminate the possibility of disastrous damages

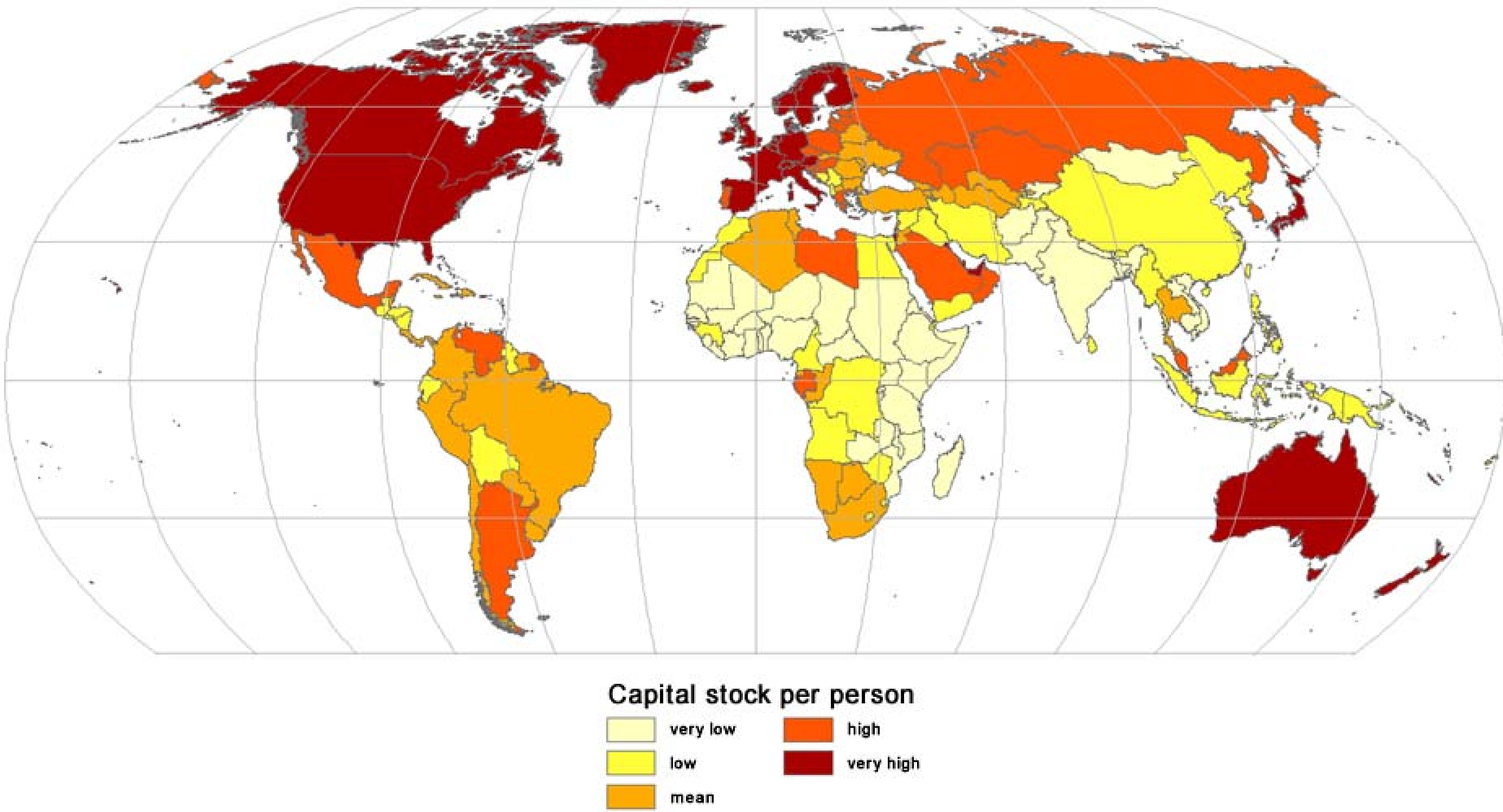
- Climate politics as an **insurance against disastrous climate change!**

TABLE 1—LIKELIHOOD (IN PERCENTAGE) OF EXCEEDING A TEMPERATURE INCREASE AT EQUILIBRIUM

| Stabilization level (in ppm $CO_2e$) | 2°C | 3°C | 4°C | 5°C | 6°C | 7°C |
|---|---|---|---|---|---|---|
| 450 | 78 | 18 | 3 | 1 | 0 | 0 |
| 500 | 96 | 44 | 11 | 3 | 1 | 0 |
| 550 | 99 | 69 | 24 | 7 | 2 | 1 |
| 650 | 100 | 94 | 58 | 24 | 9 | 4 |
| 750 | 100 | 99 | 82 | 47 | 22 | 9 |

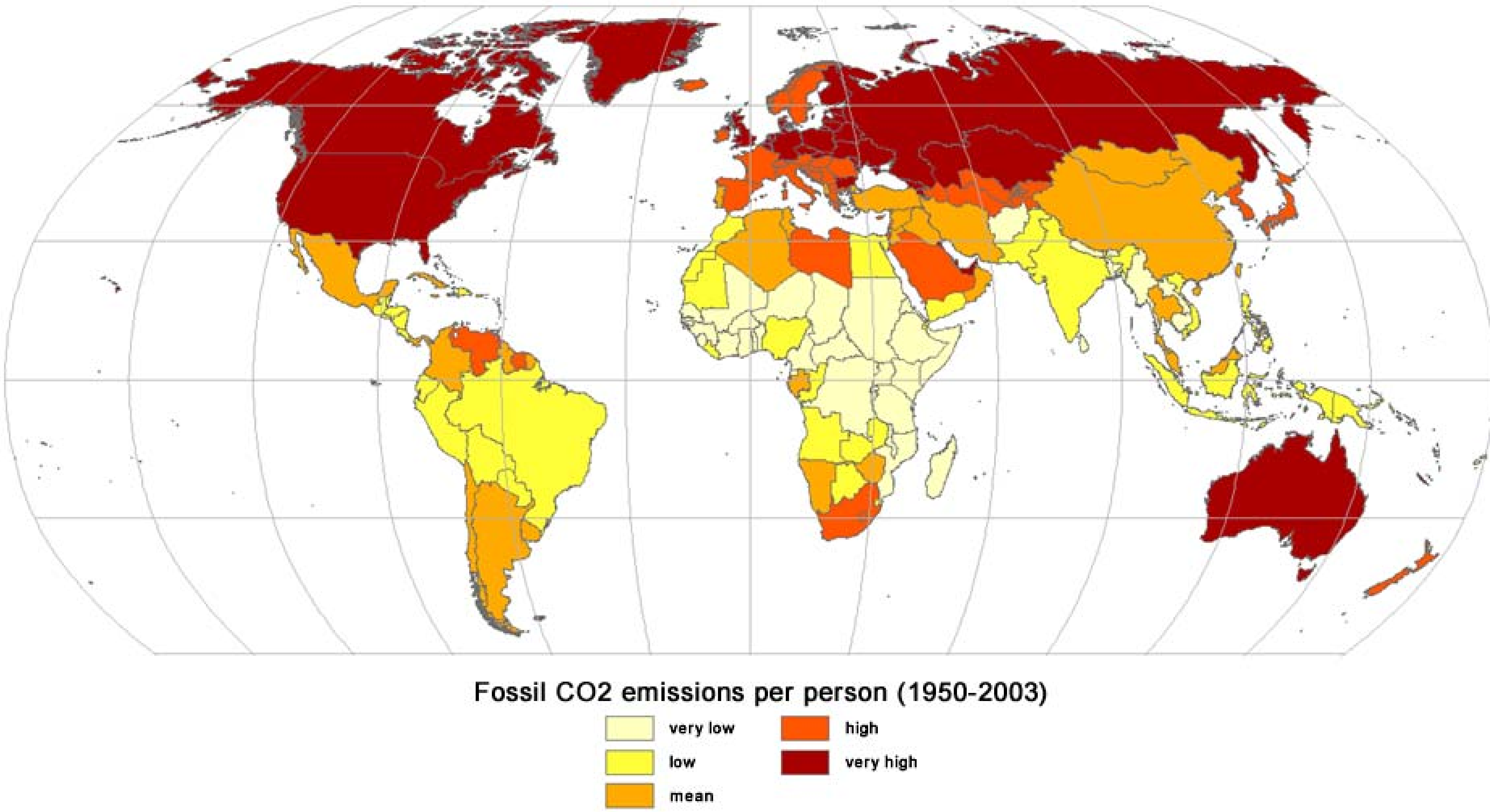
**Stern 2008**

# World Map of wealth



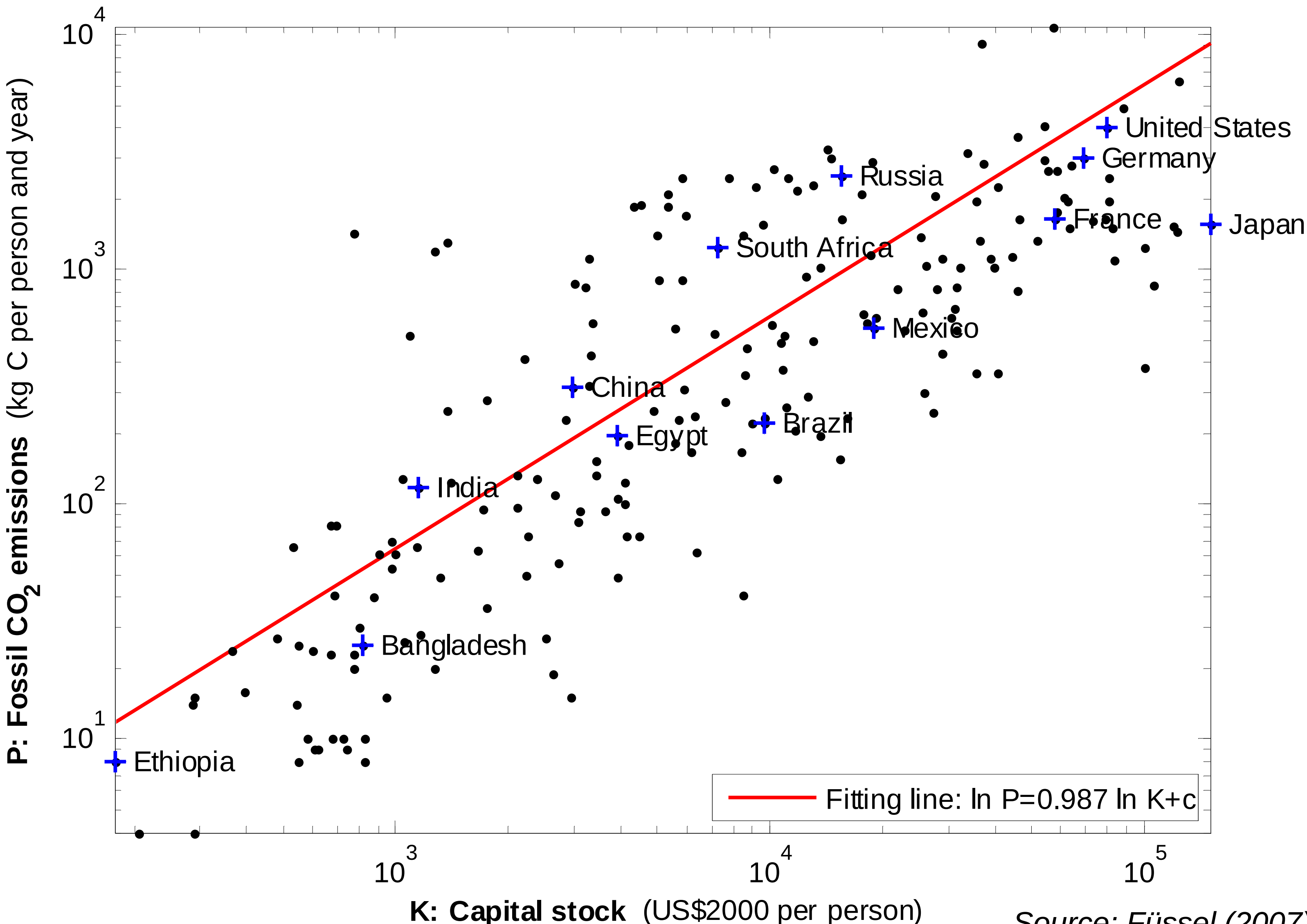

*Source: Füssel (2007)*

# World Map of Carbon Debt



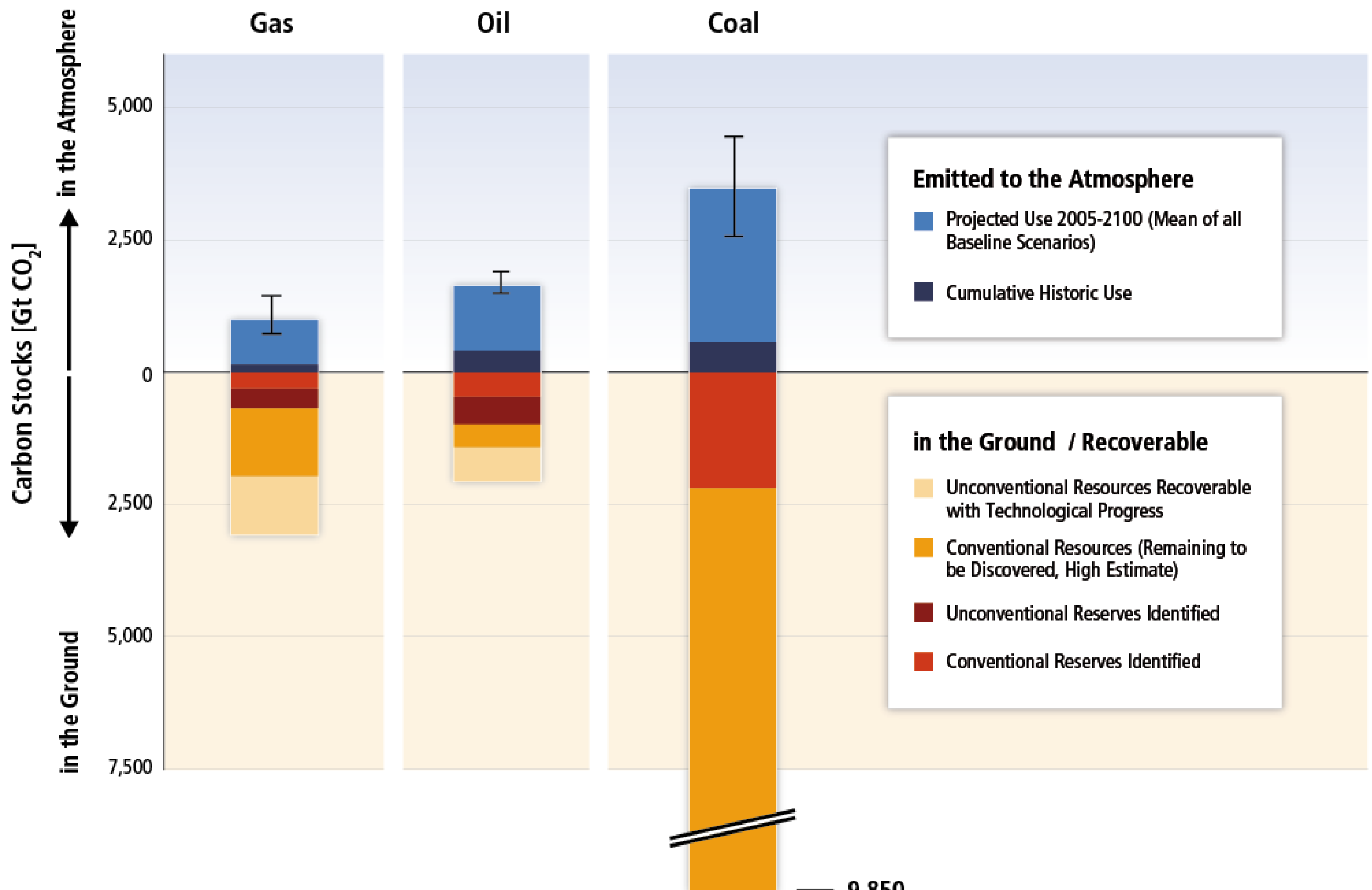

*Source: Füssel (2007)*

# Carbon Debt and Wealth



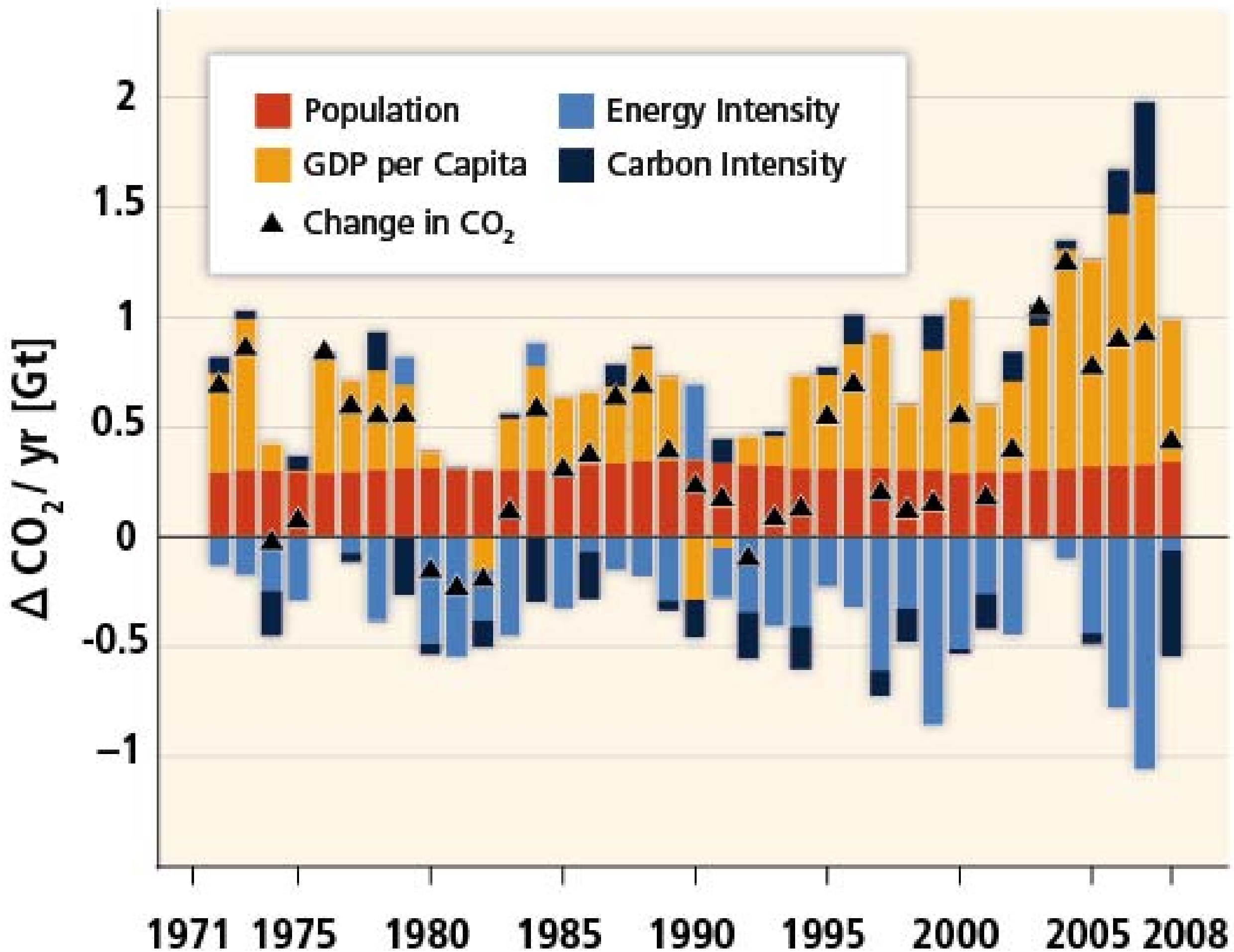

*Source: Füssel (2007)*

# The BAU Scenarios Could Exceed the Level of Greenhouse Gas Concentration of 600ppm (~4° C Temperature Increase)



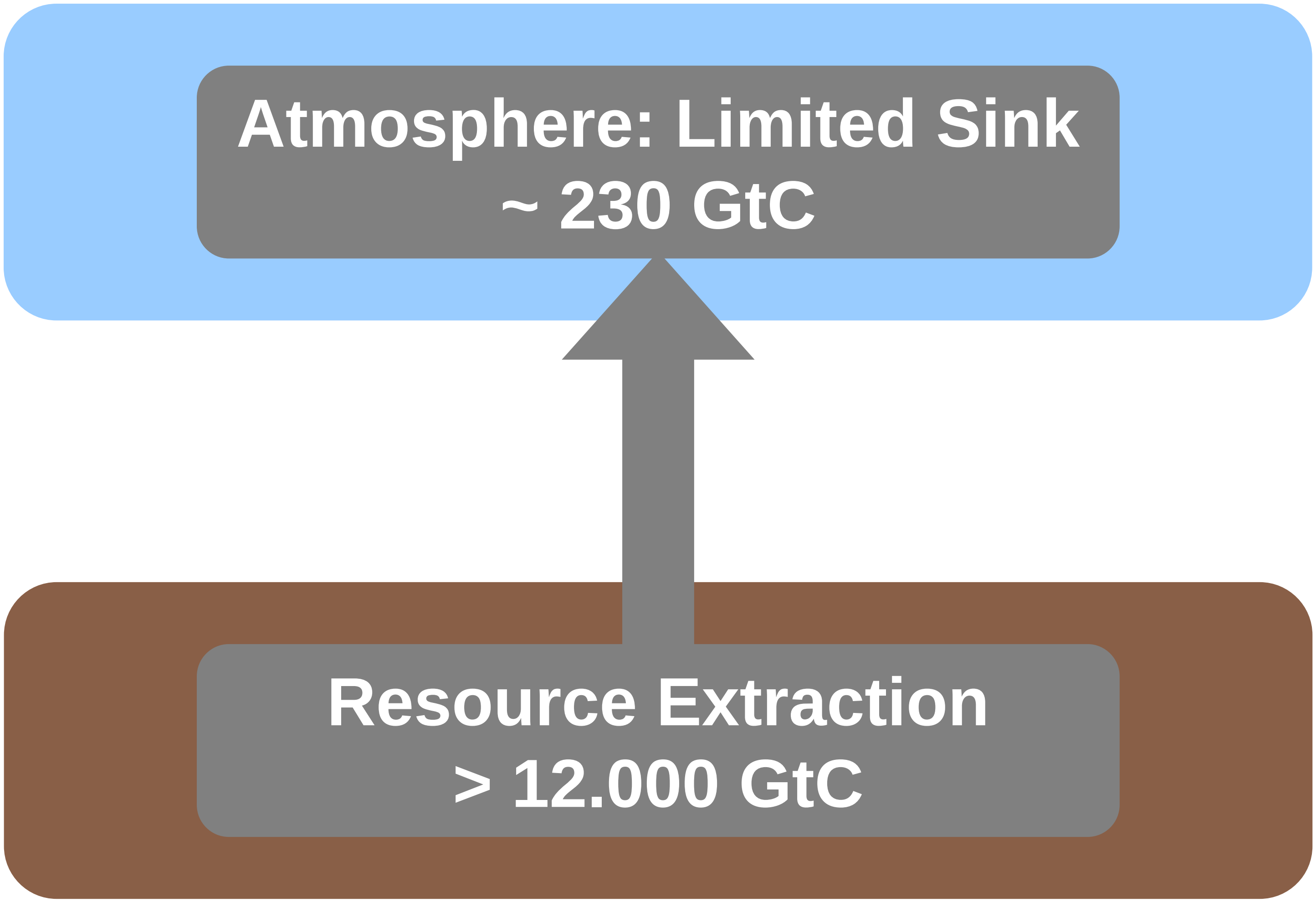

SRREN, Edenhofer et al. (2011)

# We are not on track – Renaissance of Coal!

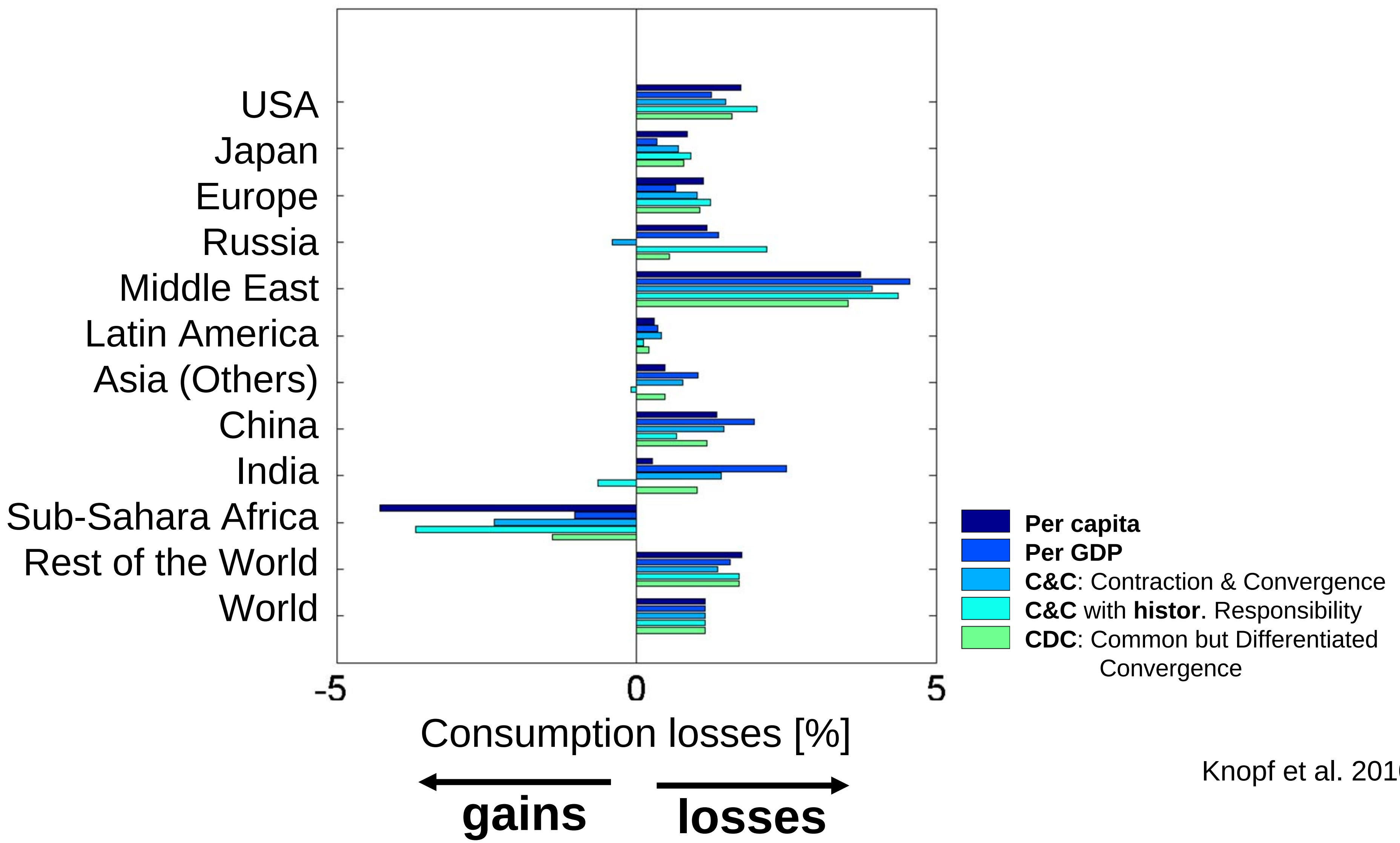



SRREN, Edenhofer et al. (2011)

## The Atmosphere as a Global Common



# Allocation of Emission Rights



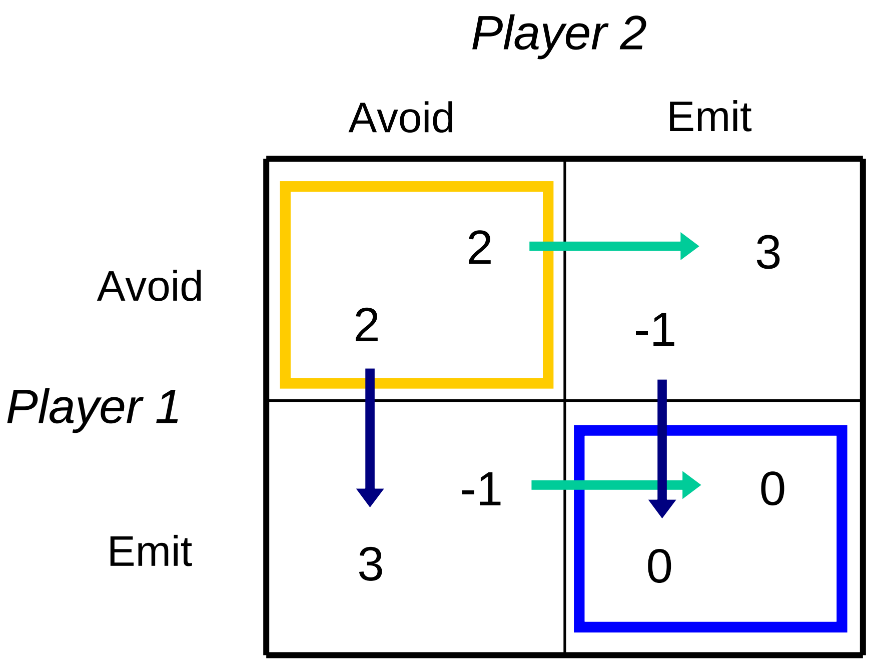

Knopf et al. 2010

# Climate policy as prisoners‘ dilemma

| | | *Player 2* | |
|---|---|---|---|
| | | Avoid | Emit |
| *Player 1* | Avoid | 2<br>2 | 3<br>-1 |
| | Emit | -1<br>3 | 0<br>0 |

- The socially optimal result would be for everybody to avoid…

# Climate policy as prisoners‘ dilemma




- but every individual prefers to profit as free rider
  - Saving of abatement costs
  - Carbon Leakage benefit

→ Cooperation is not accomplished

# IPCC and the UN System

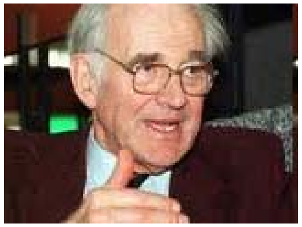
Nobel peace prize 1961, posthumous

Dag Hammarsjköld (1905 – 1961)

Second Secretary General of UN

Nobel peace prize 2007 – IPCC

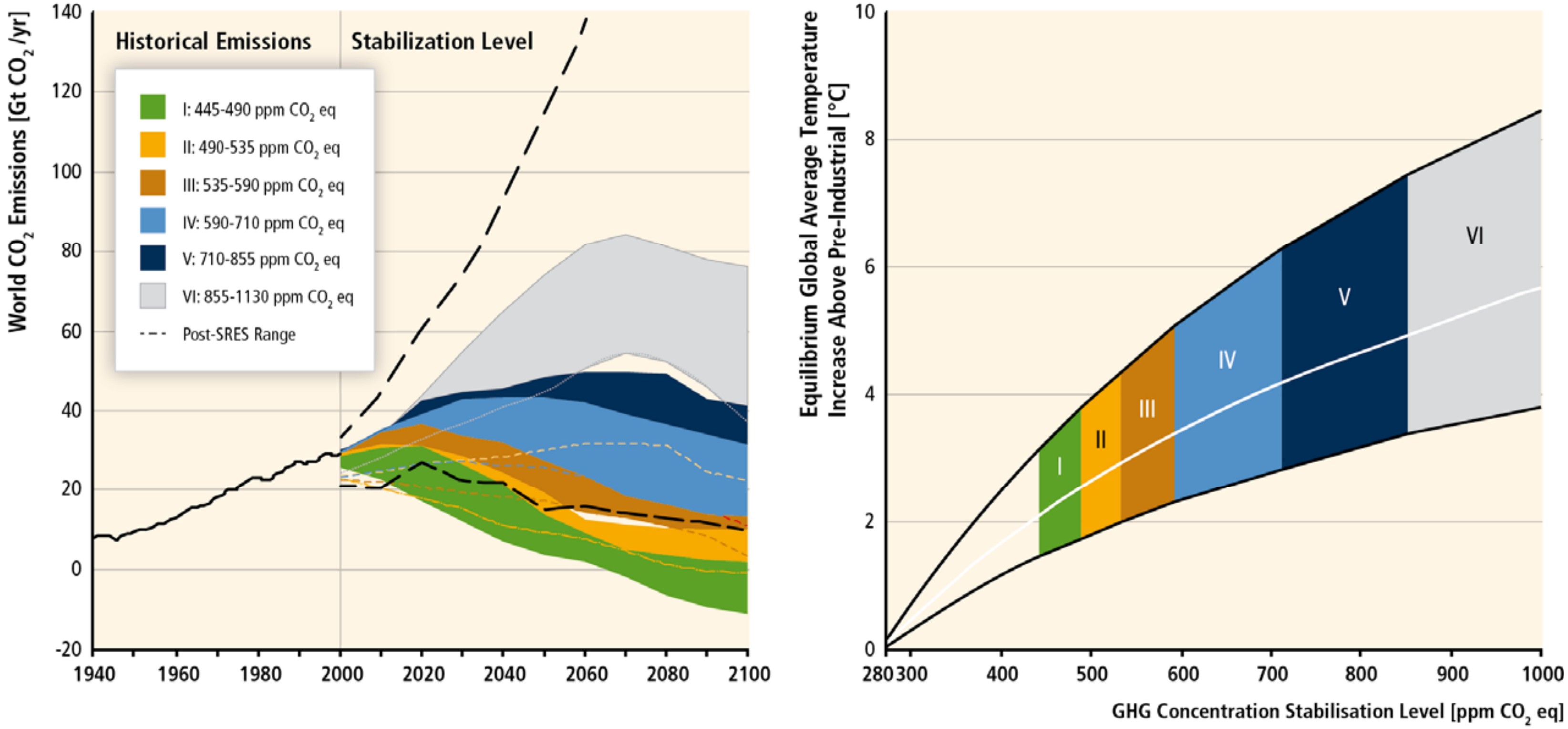
Bert Bolin  (1925-2007), First IPCC chair



Nobel prize in economics 2009

Elinor Ostrom (1933)

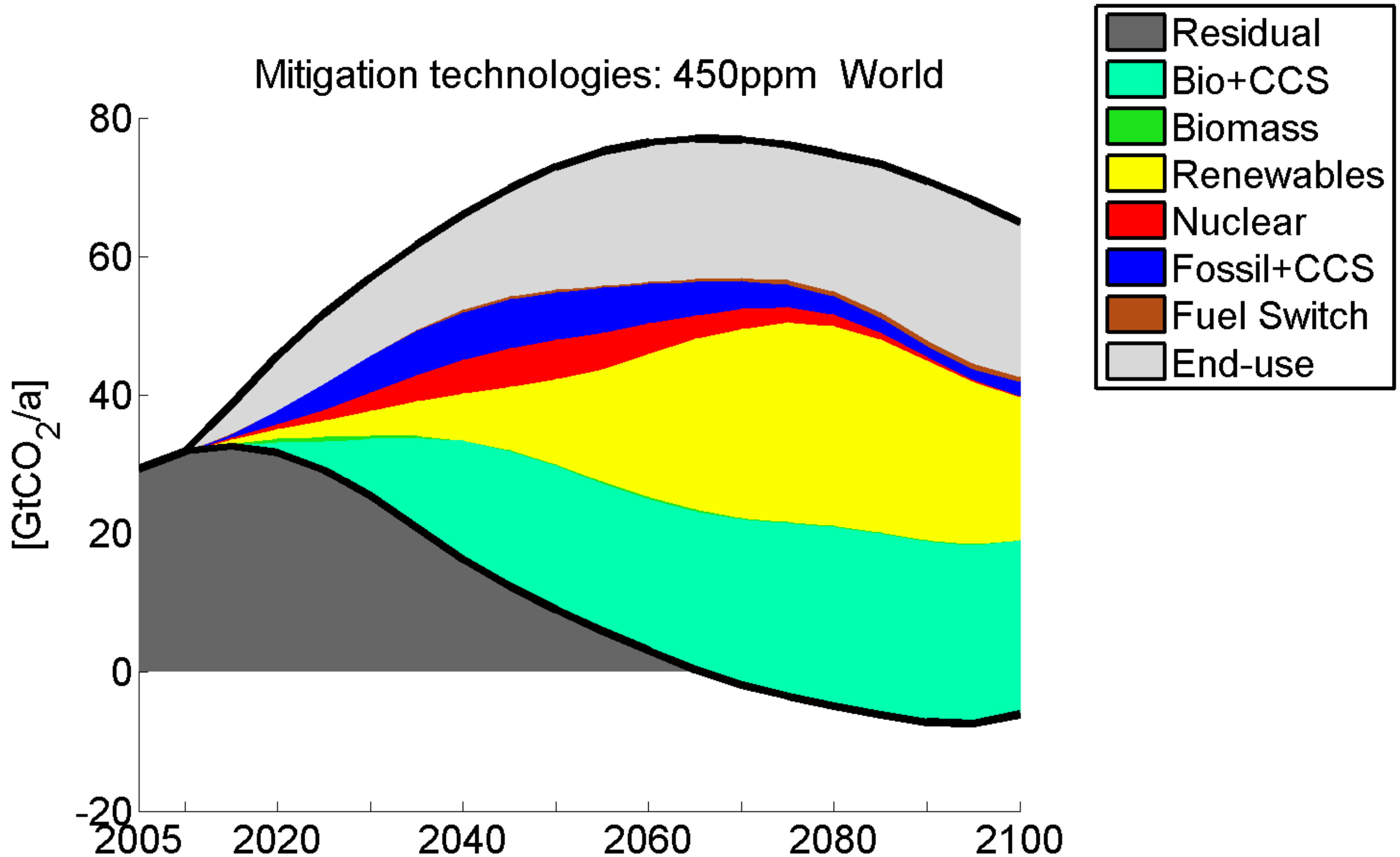
# Climate Policy as an Insurance




GHG emissions resulting from the provision of energy services contribute significantly to the increase in atmospheric GHG concentrations.

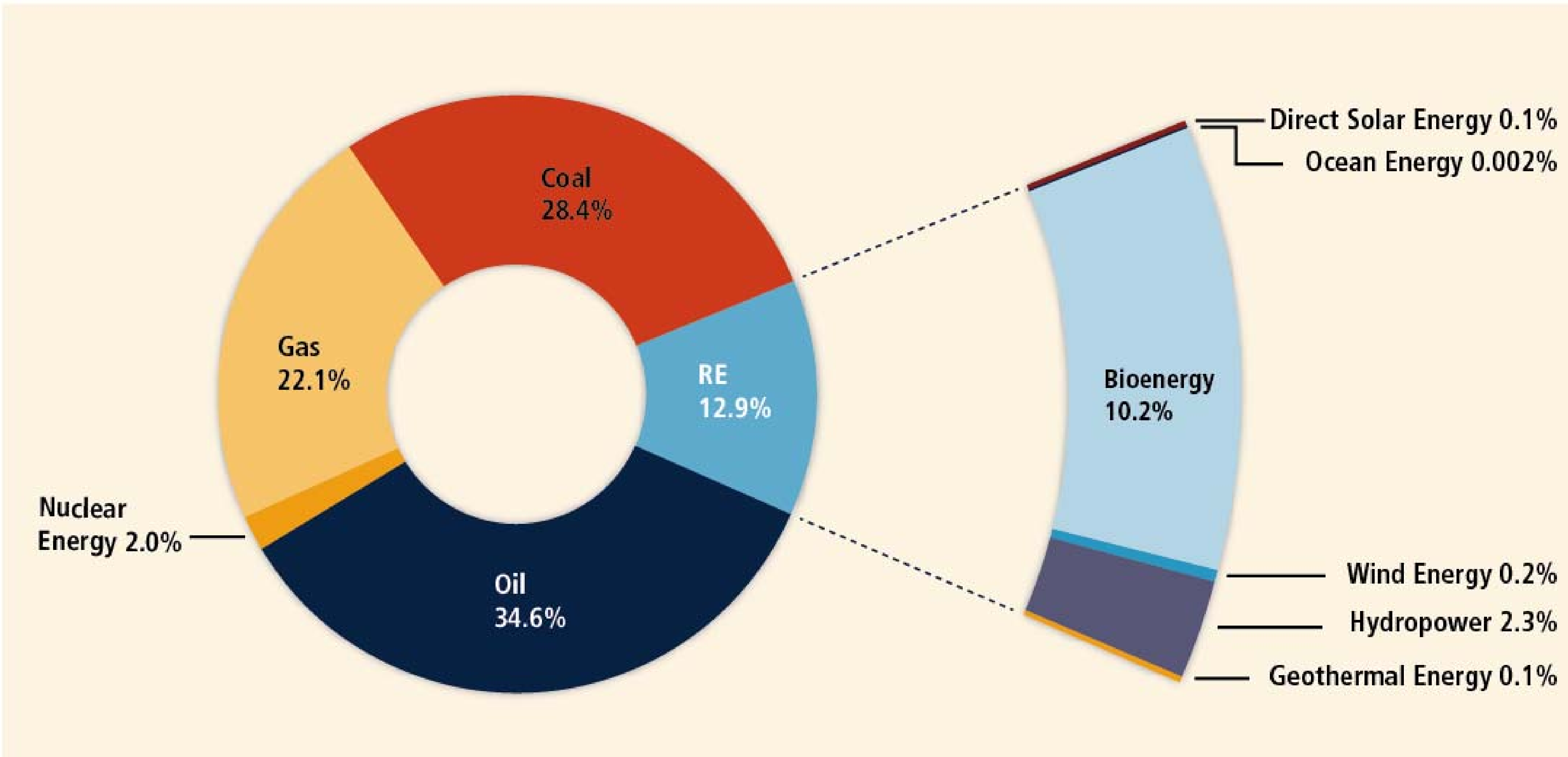
SRREN, Edenhofer et al. (2011)

# The Great Transformation




Luderer et al. (2011)

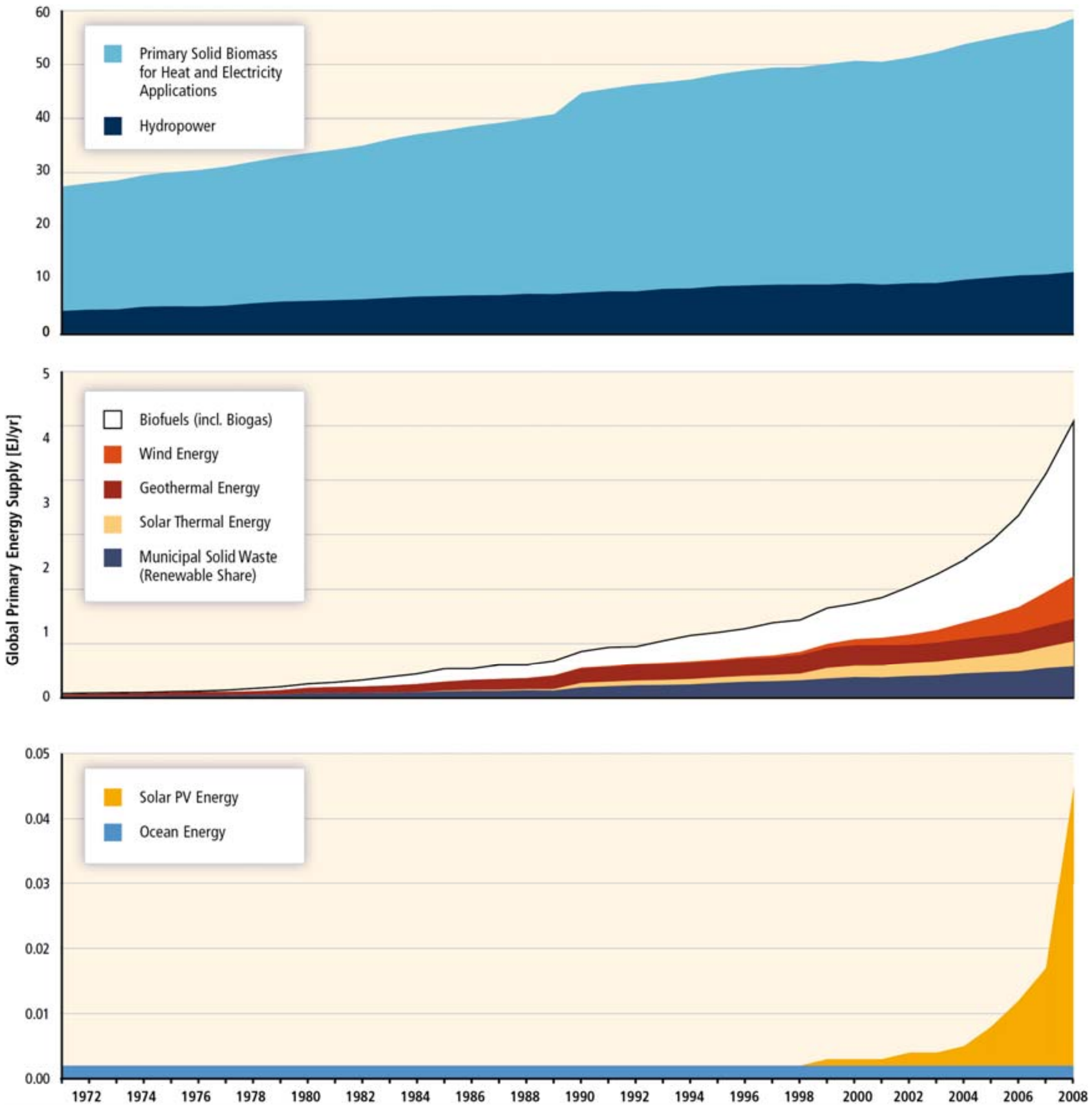
# The current global energy system is dominated by fossil fuels.




Shares of energy sources in total global primary energy supply in 2008

SRREN, Edenhofer et al. (2011)

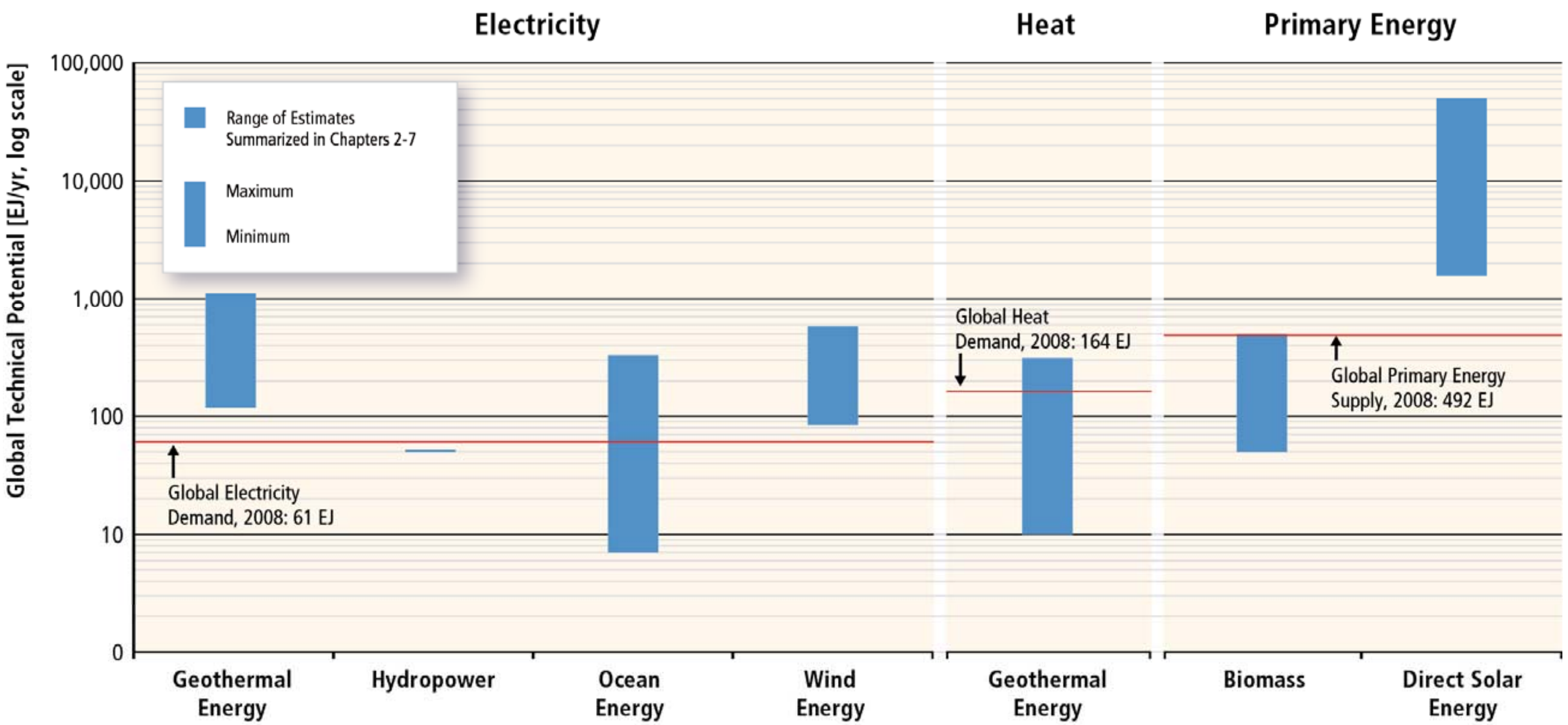
# RE growth has been increasing rapidly in recent years




150 GW of new RE power plant capacity was built in 2008-2009.

This equals 50% of all power plants built during that period.

# The Technical Potential of Renewable Energies

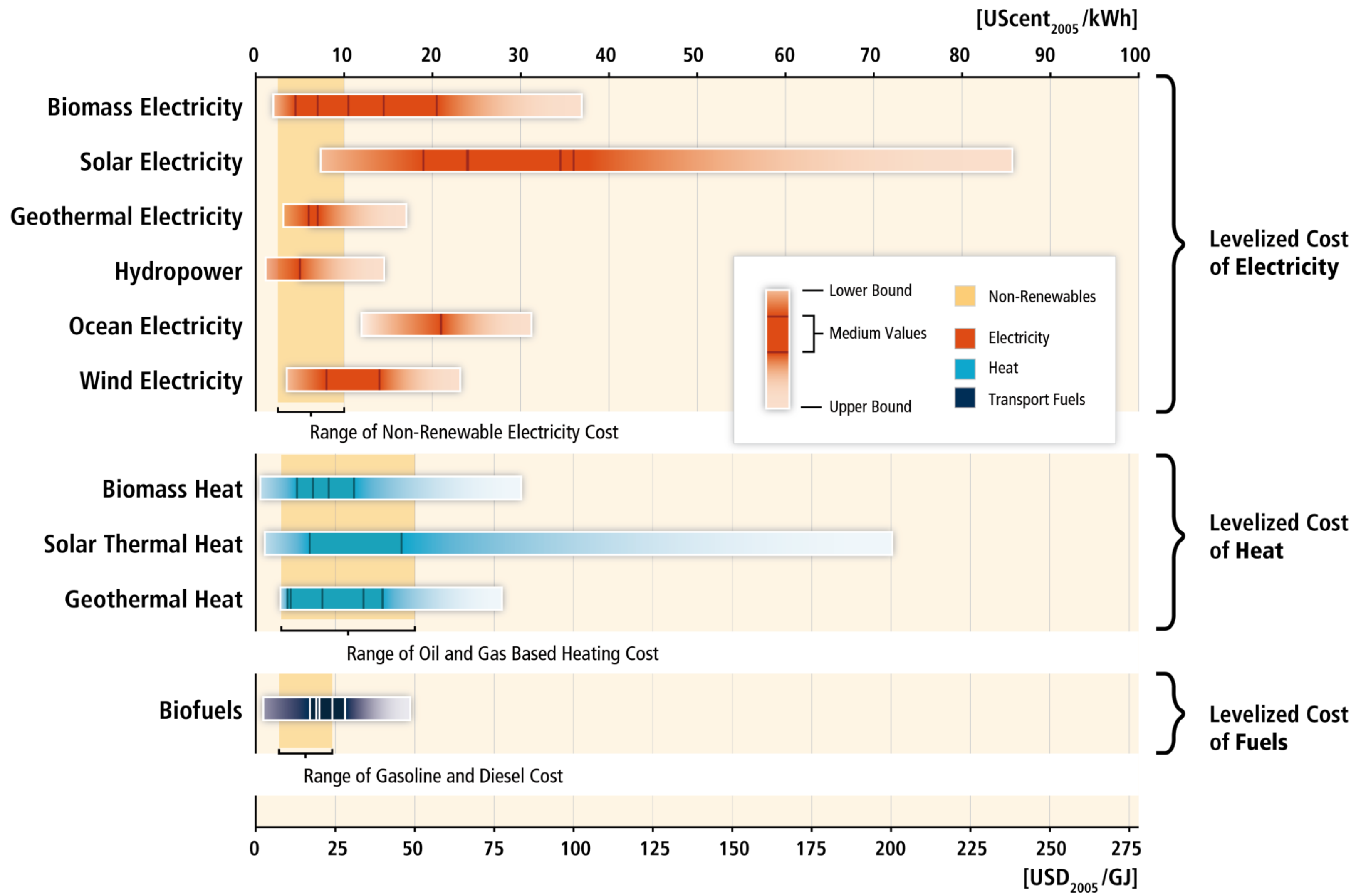



Range of Estimates of Global Technical Potentials

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Max (in EJ/yr) | 1109 | 52 | 331 | 580 | 312 | 500 | 49837 |
| Min (in EJ/yr) | 118 | 50 | 7 | 85 | 10 | 50 | 1575 |

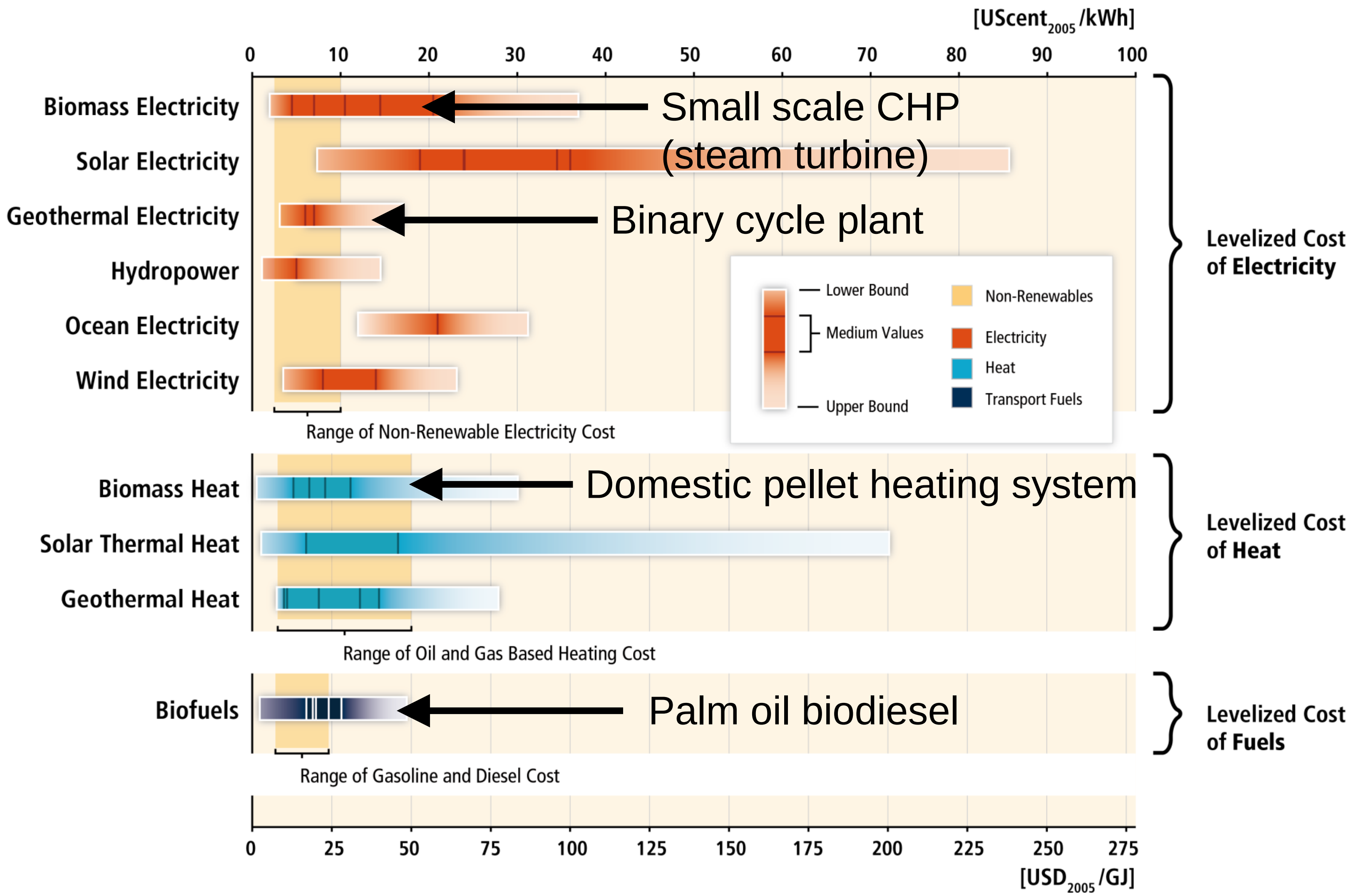
SRREN, Edenhofer et al. (2011)

# The Costs of Renewables Are Often Still Higher Than Those of Non-Renewables But…



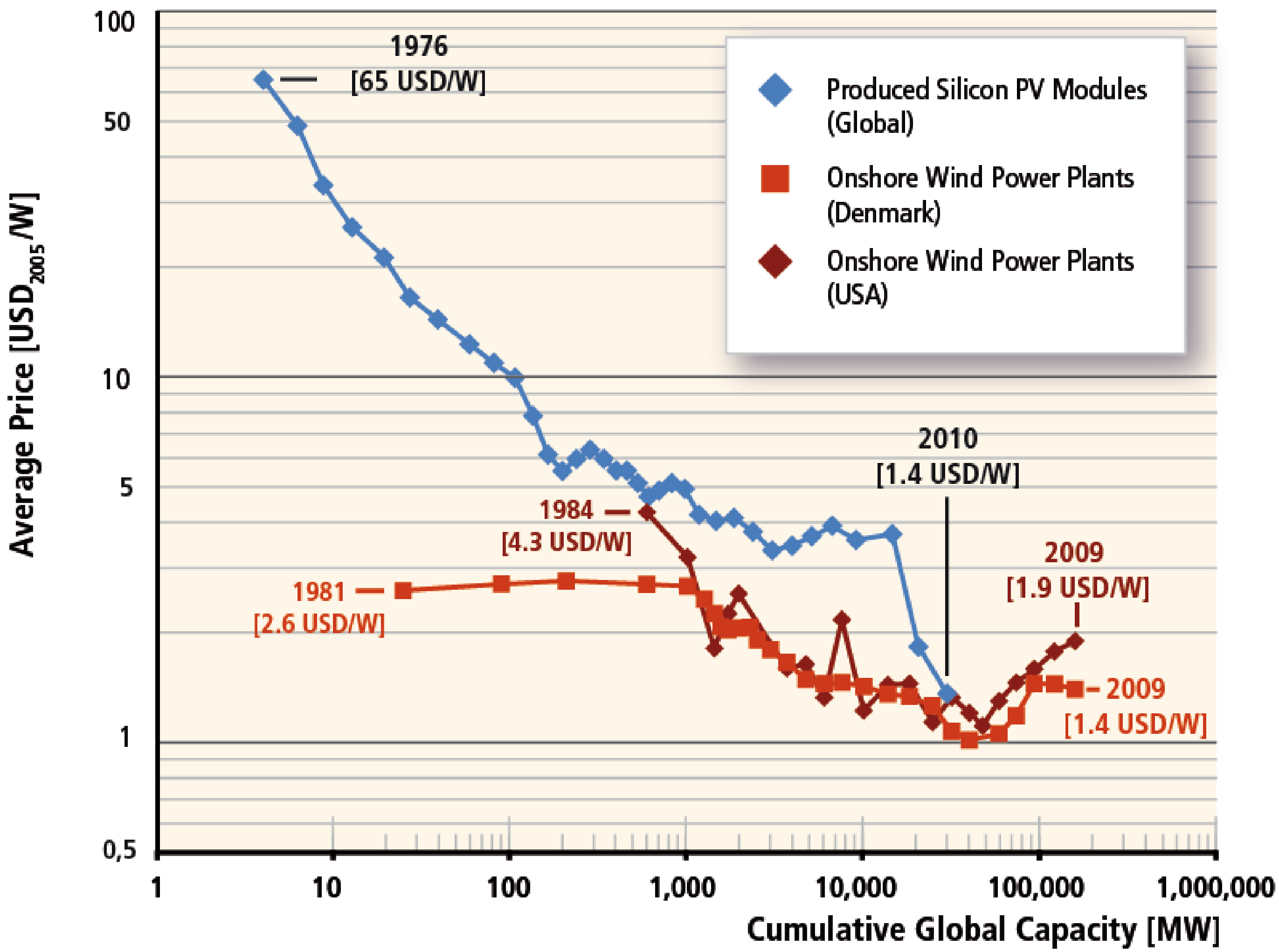

SRREN, Edenhofer et al. (2011)

# ...Some RE Technologies Are Already Competitive



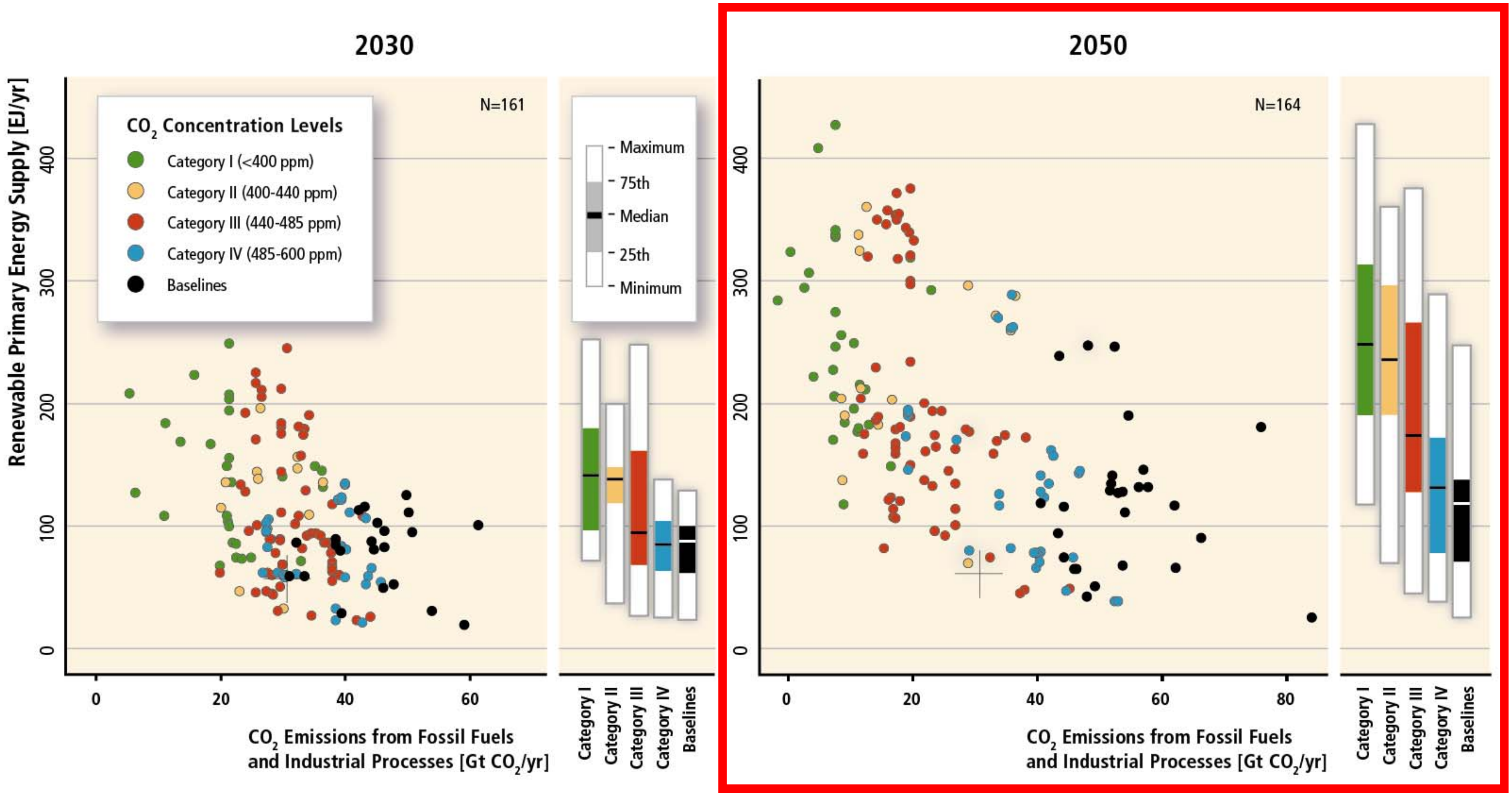

SRREN, Edenhofer et al. (2011)

# Renewable Energies Have a Potential to Lower Costs




SRREN, Edenhofer et. al. 2011

# Global RE Primary Energy Supply from 164 Long-Term Scenarios versus Fossil and Industrial $CO_2$ Emissions

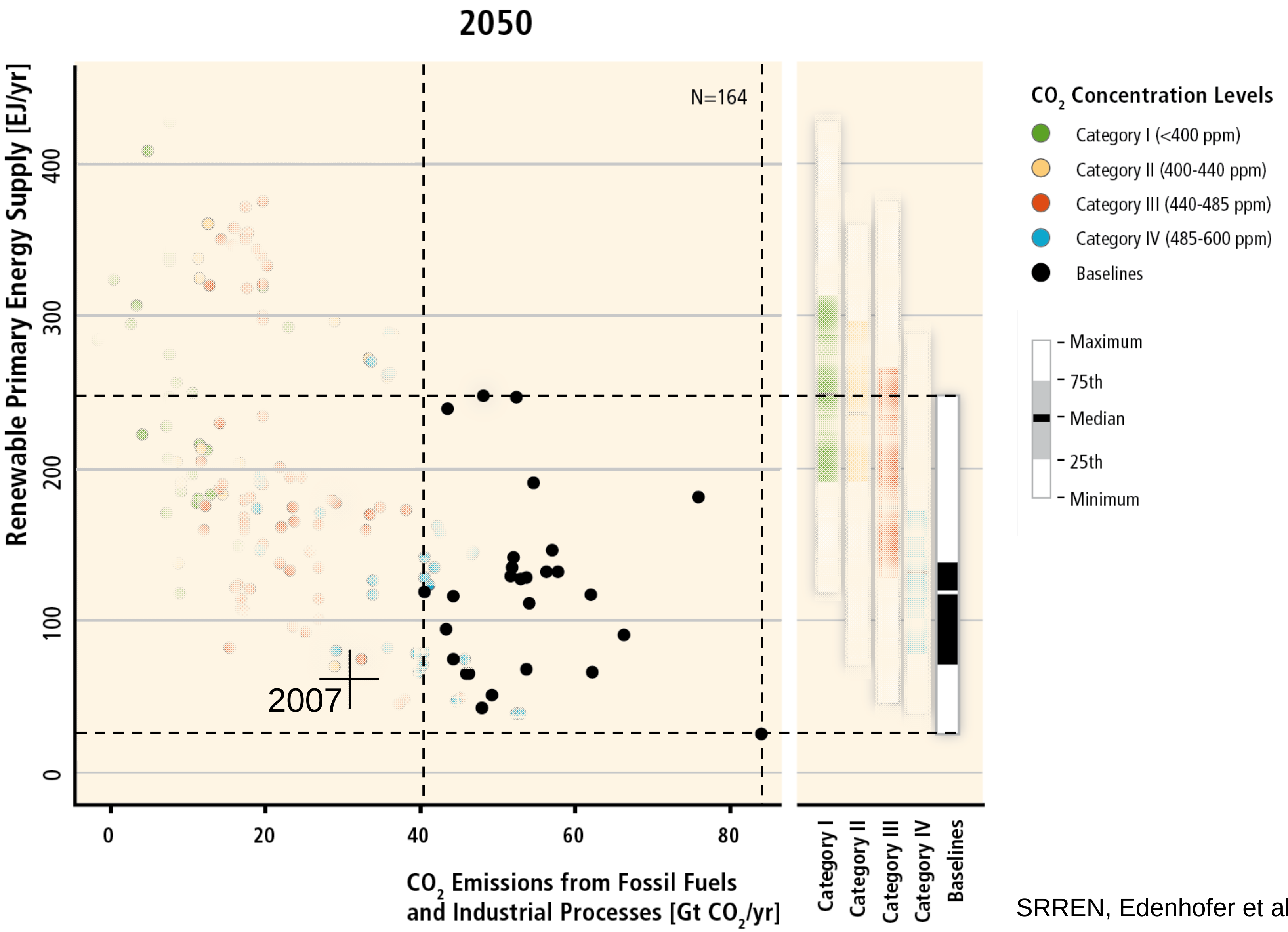



SRREN, Edenhofer et al. (2011)

# RE can contribute to sustainable development

- RE can accelerate access to energy, particularly for the 1.4 billion people without access to electricity and the additional 1.3 billion people using traditional biomass
- RE deployment can reduce vulnerability to supply disruptions and market volatility
- Low risk of severe accidents
- Environmental and health benefits

# Global RE Primary Energy Supply from 164 Long-Term Scenarios versus Fossil and Industrial $CO_2$ Emissions




SRREN, Edenhofer et al. (2011)

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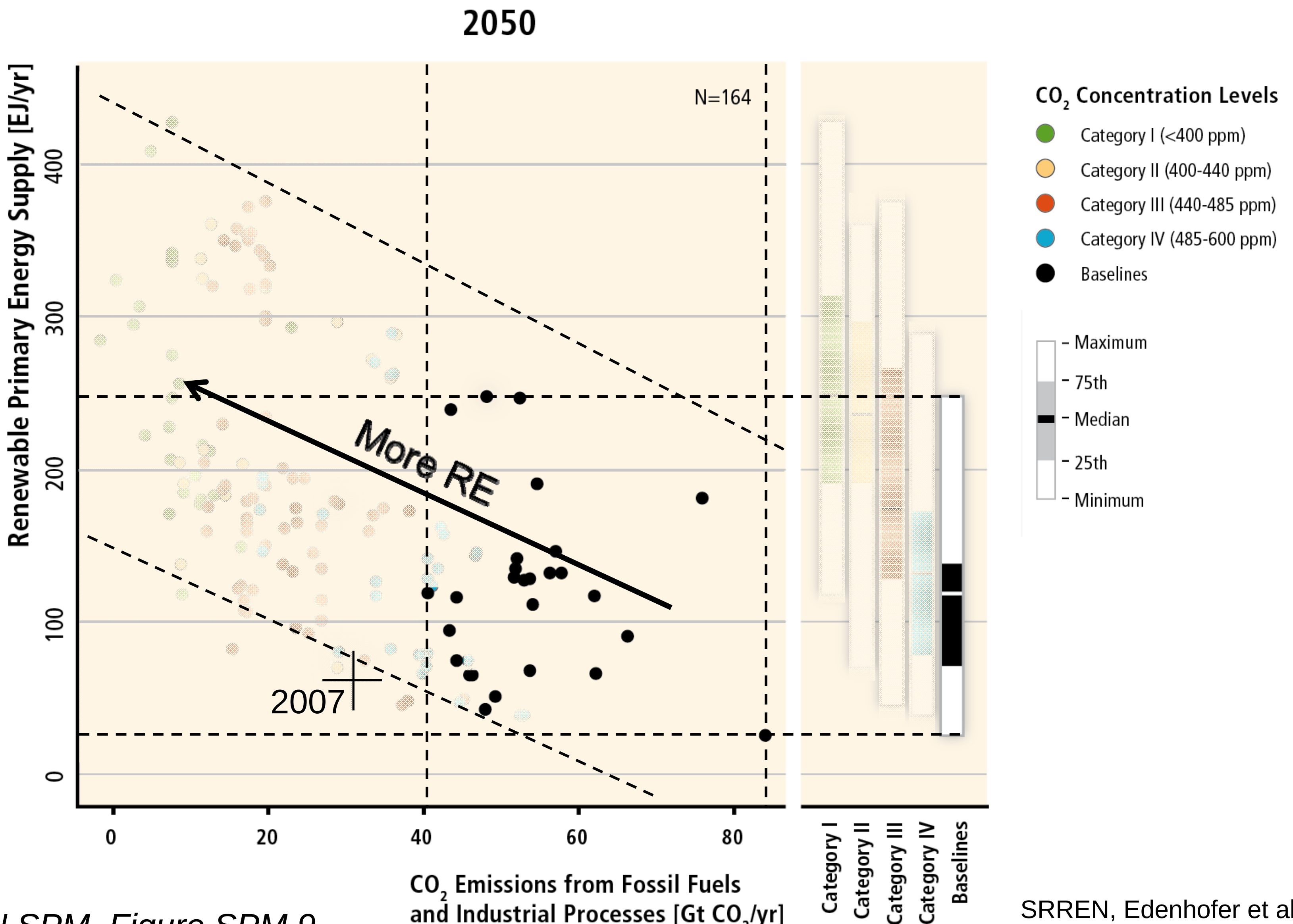
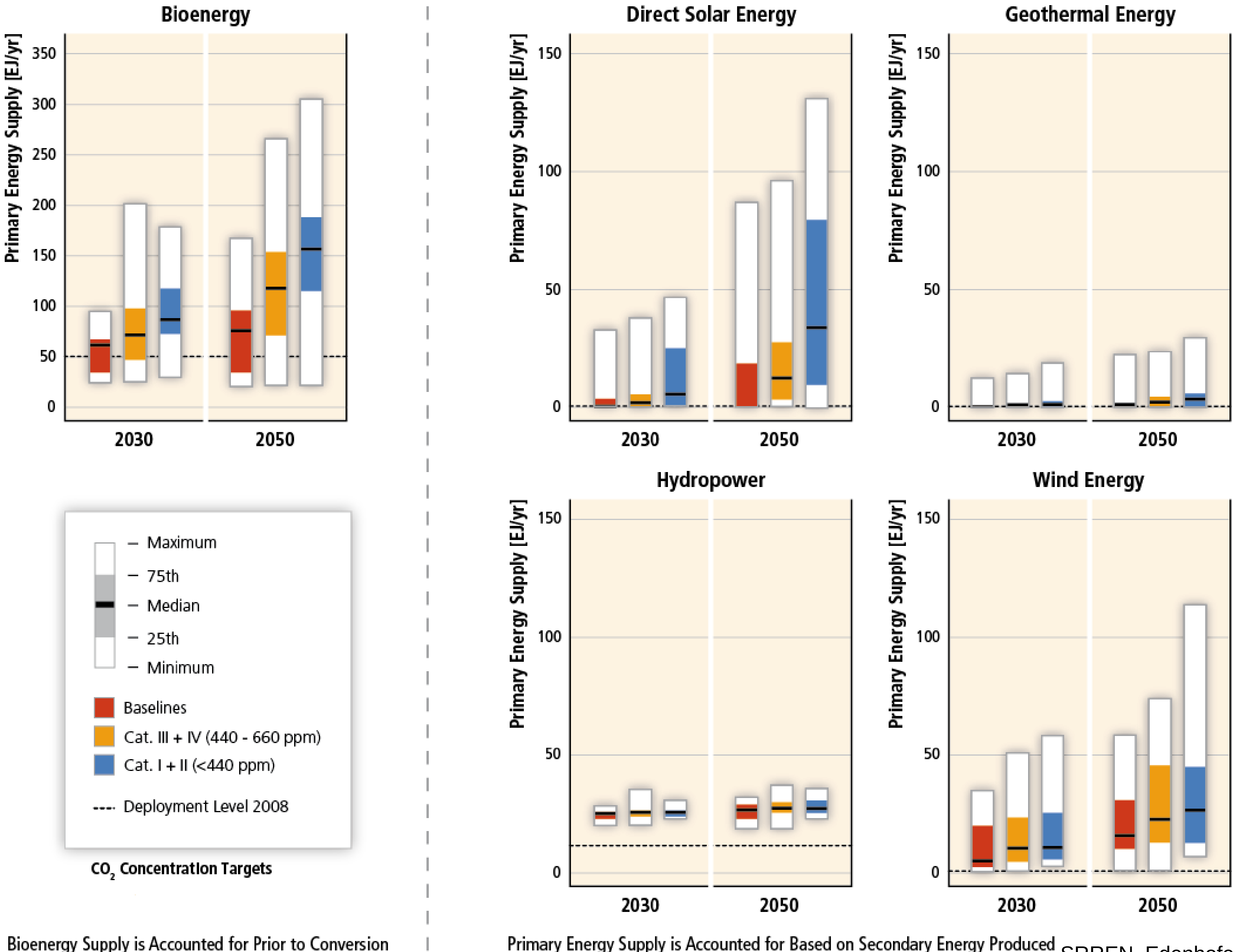



*SRREN SPM, Figure SPM.9*

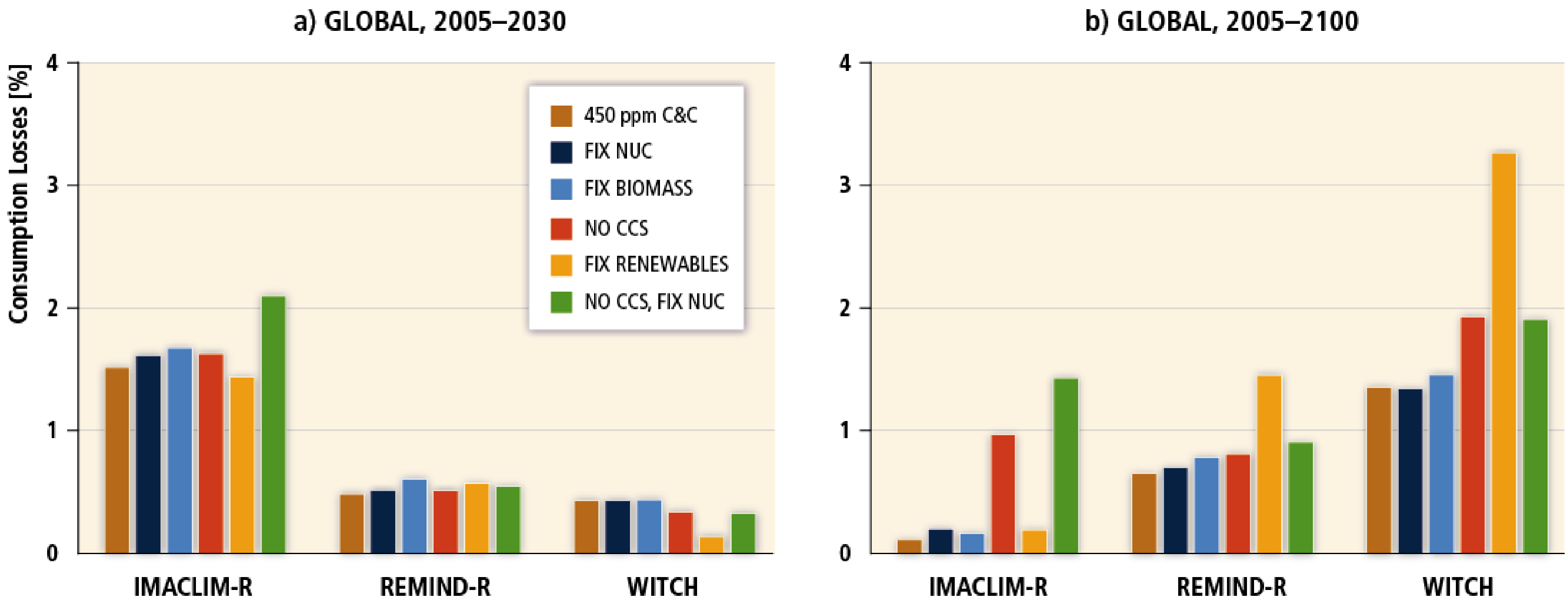
SRREN, Edenhofer et al. (2011)

# Potential Role of Renewables




SRREN, Edenhofer et al. (2011)

# Macroeconomic Costs




Limited availability of technologies

SRREN, Edenhofer et al. (2011)

# Numerical Limitations of Integrated Assessment Models

**Time resolution:**
Time steps of several years

→ Fluctuations of renewables neglected

**Geographical resolution:**
Aggregate world regions

→ Infrastructure neglected (e.g. grids)

**Technological challenge with large shares of fluctuating renewables:**

The electricity grid requires an exact match of supply and demand at **any time** and at **any place**.

# Integration Options for Renewables

- **Improved weather forecast**
  → Better planning of renewable electricity feed-in

- **Demand side management**
  → Adjust demand to renewable electricity feed-in

**Important Supply Side Options**

- **Flexible power plants**
  → Provide residual load

- **Grid extension**
  → Large area pooling of uncorrelated fluctuations (>300km):
  Import / Export between countries

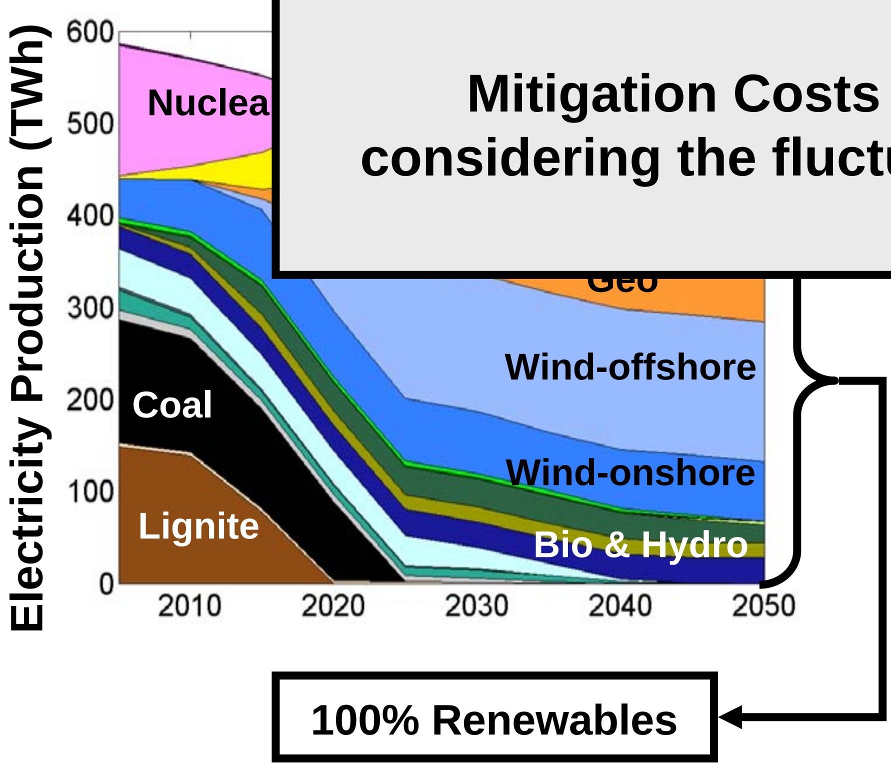
- **Energy storage**
  → Remove electricity from the grid in times of high renewable generation and feed-in electricity in times of low generation

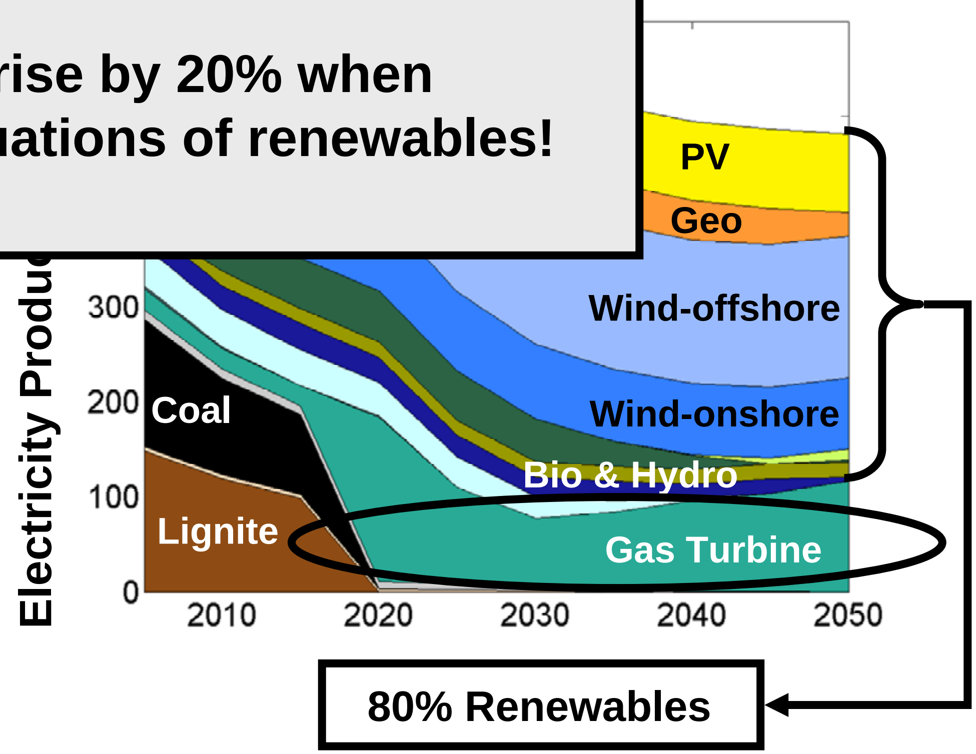
# Impact of Considering Fluctuations in an Energy System Model of Germany

Most models do not take into account fluctuations explicitly:

Same scenario with consideration of fluctuations:

**Mitigation Costs rise by 20% when considering the fluctuations of renewables!**




**Scenario: 80% domestic $CO_2$ emission reduction in 2050 vs. 1990**

(Ueckerdt et al., 2011)

# Integration Options for Renewables

- **Improved weather forecast**
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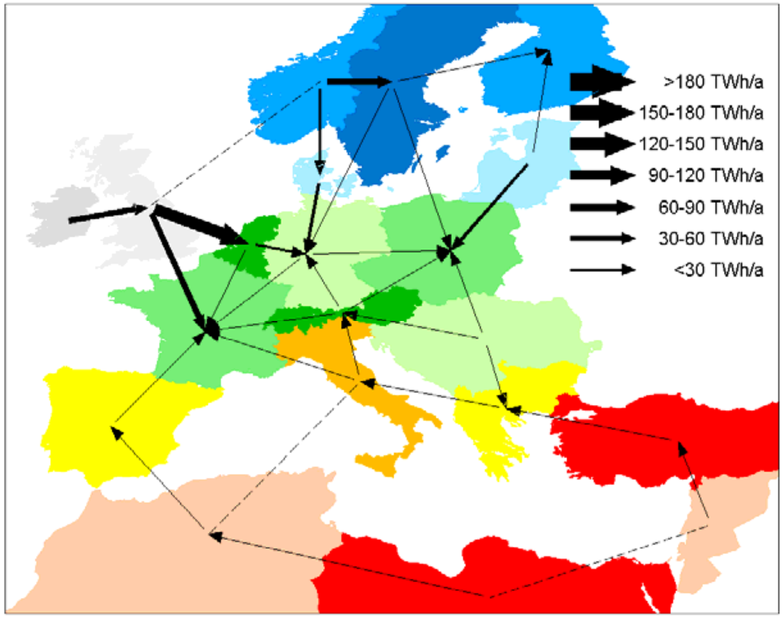
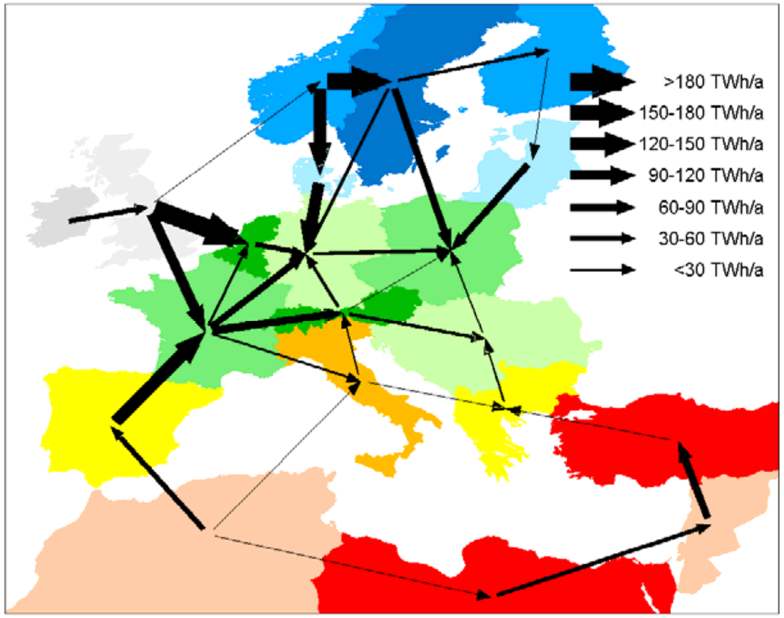
# Aggregate Transmission in 2050 in an Electricity Sector model of Europe

Baseline,
no climate policy:




90% $CO_2$ reduction
in electricity sector:

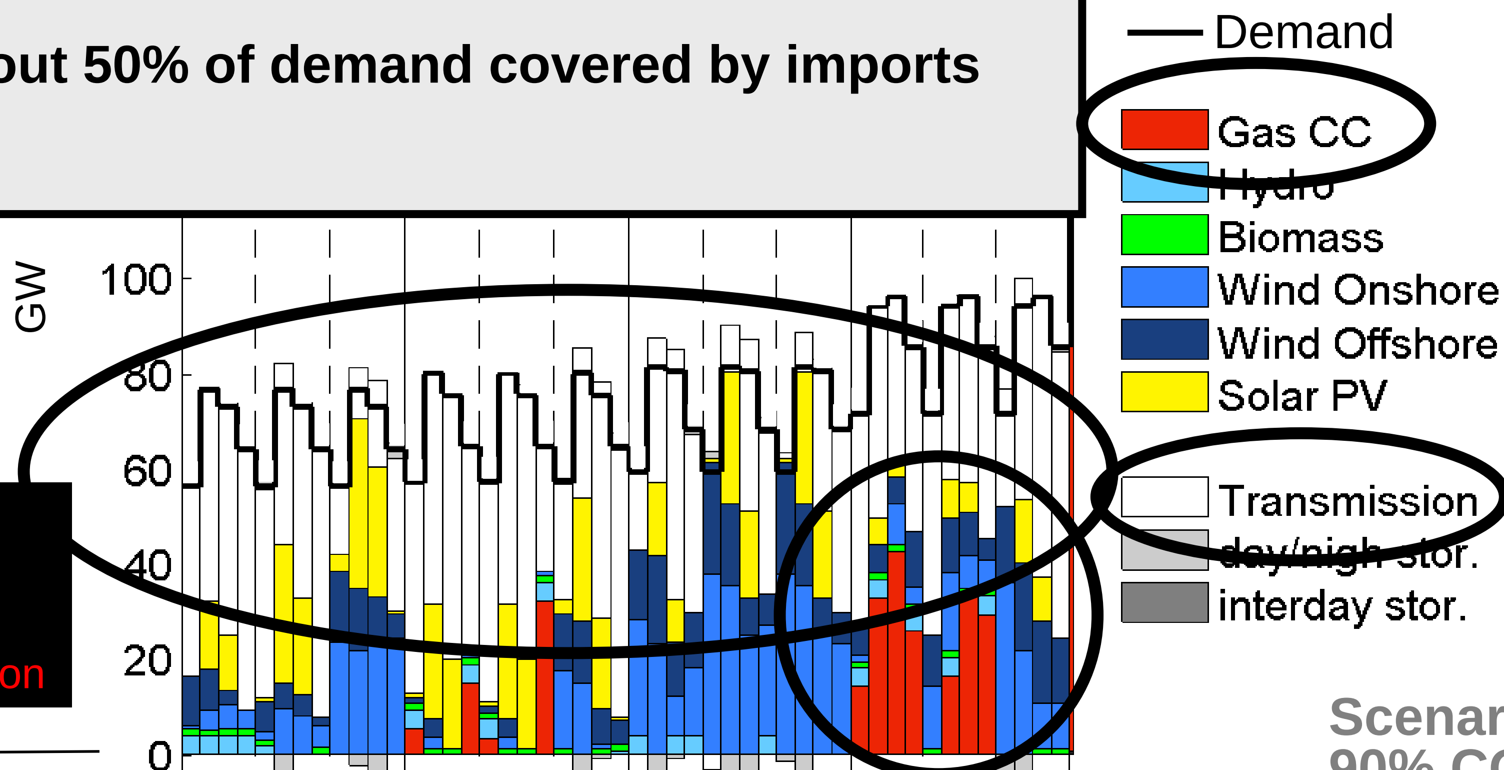



(Haller et al., 2011, submitted)

# Germany 2050: Electricity production with network expansion (European Interconnectors)

**About 50% of demand covered by imports**

- Storage outflow
- Import
- Production




- Export
- Storage inflow

**Large capacities of natural gas power plants required, especially in winter**

**Scenario: 90% $CO_2$ emission reduction in electricity sector**

(Haller et al., 2011, submitted)

# Integration Options for Renewables

- **Improved weather forecast**
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- **Grid extension**
  → Large area pooling of uncorrelated fluctuations (>300km): Import / Export between countries

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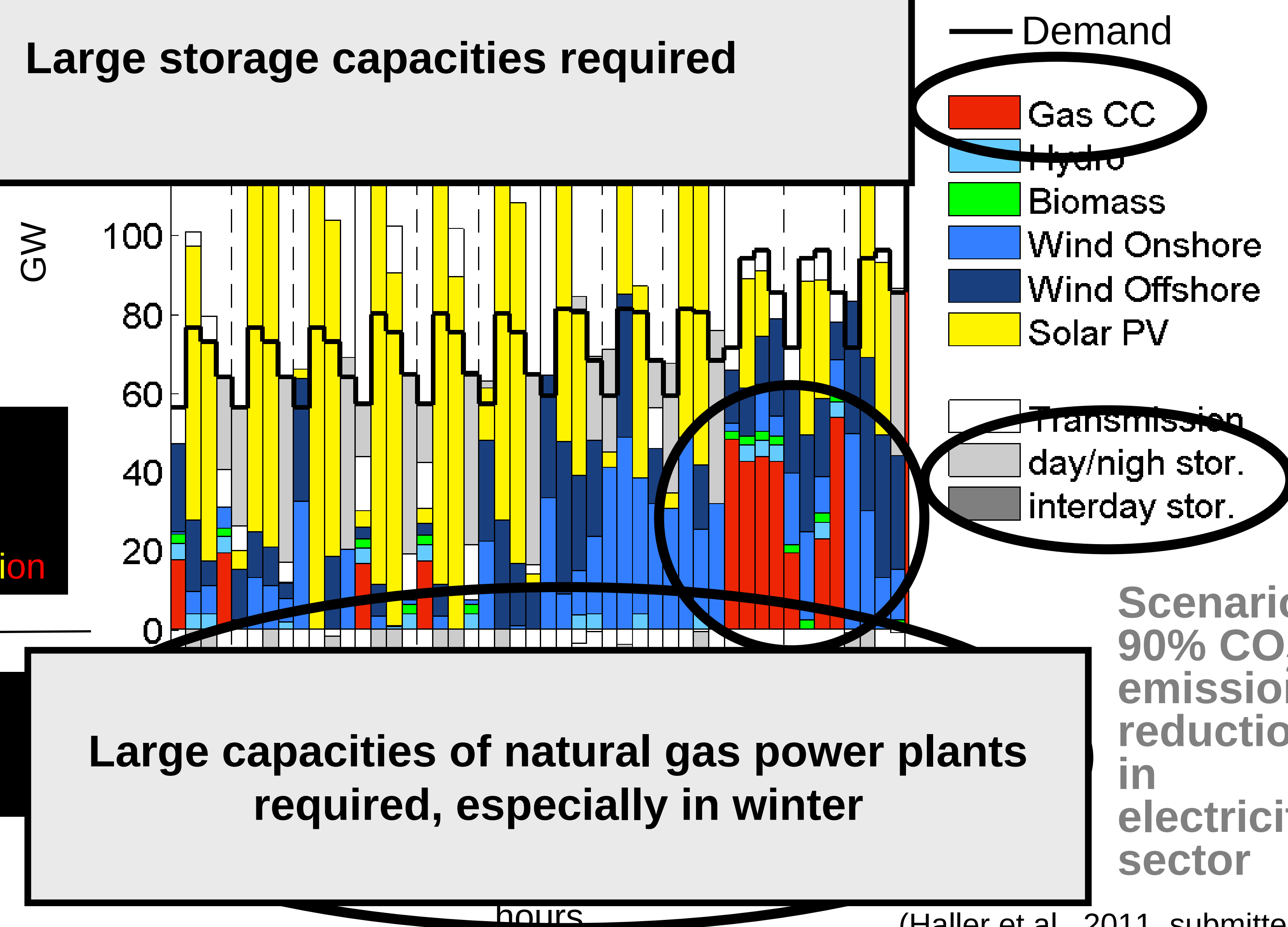
# Germany 2050: Electricity production without network expansion (Autarkic Germany)

**Large storage capacities required**




- Storage outflow
- Import
- Production

- Export
- Storage inflow

**Large capacities of natural gas power plants required, especially in winter**

**Scenario: 90% $CO_2$ emission reduction in electricity sector**

(Haller et al., 2011, submitted)

## Interim Synthesis

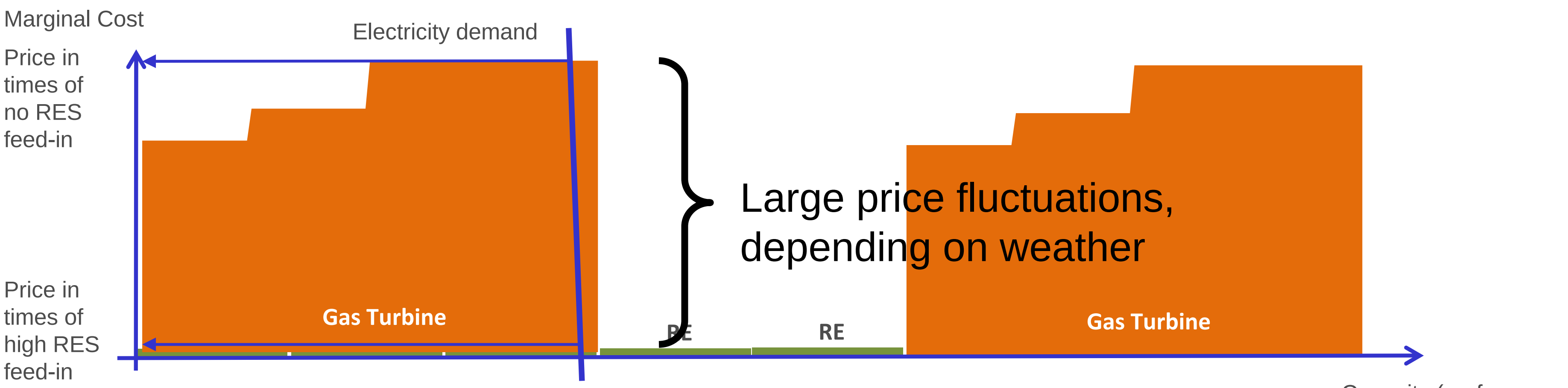
Large back-up capacities of flexible gas power plants are required to provide residual load in extended times of low renewable electricity generation (European winter)…

…even with a European integrated electricity grid

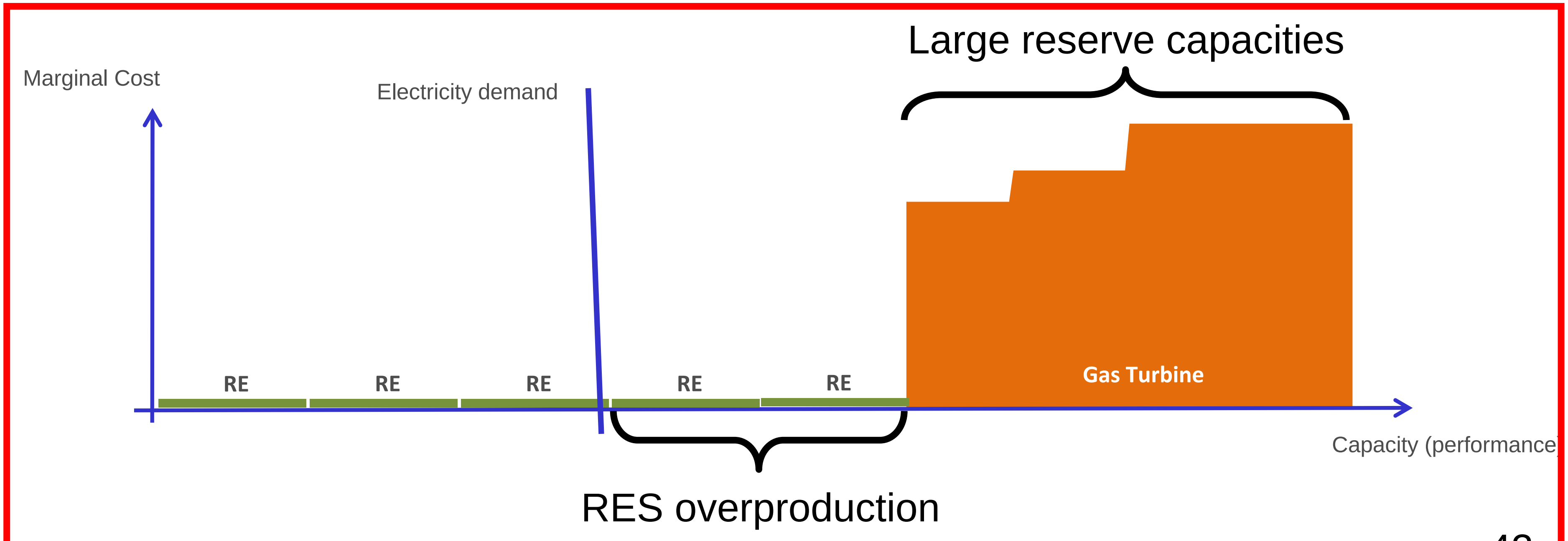
…even with large day/night or medium-term storage capacities (e.g. pumped hydro)

What are the implications for the electricity market,
$CO_2$ emissions of the electricity sector,
and what is the potential role of methanisation?

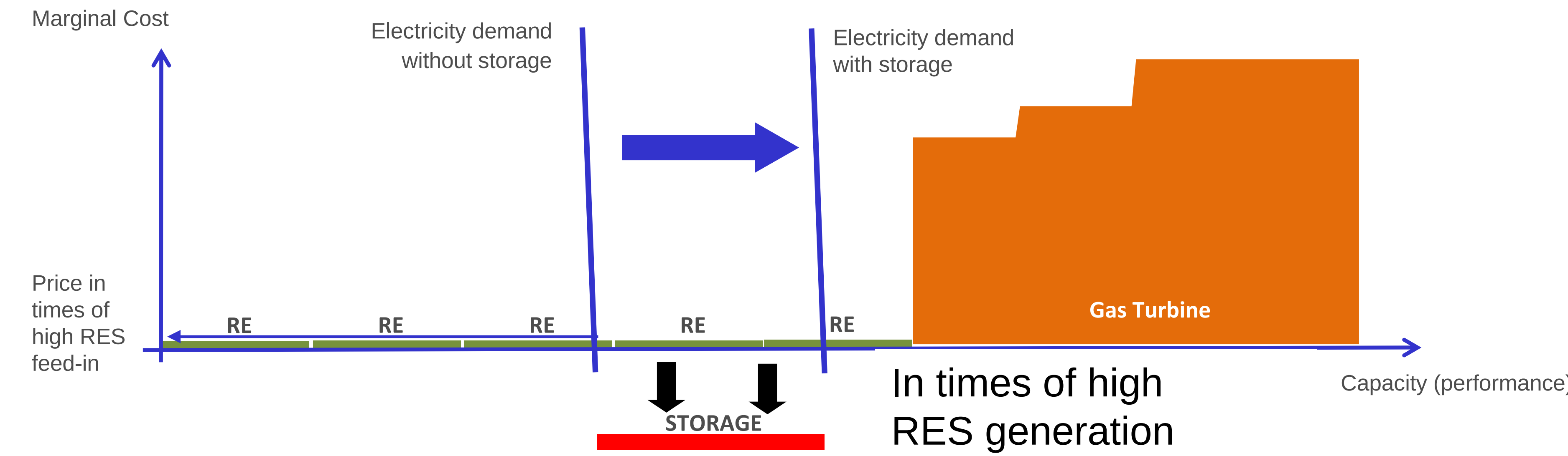
# The Future Market System? Merit Order Pricing with high Renewable Shares and Flexible Gas Plants Only



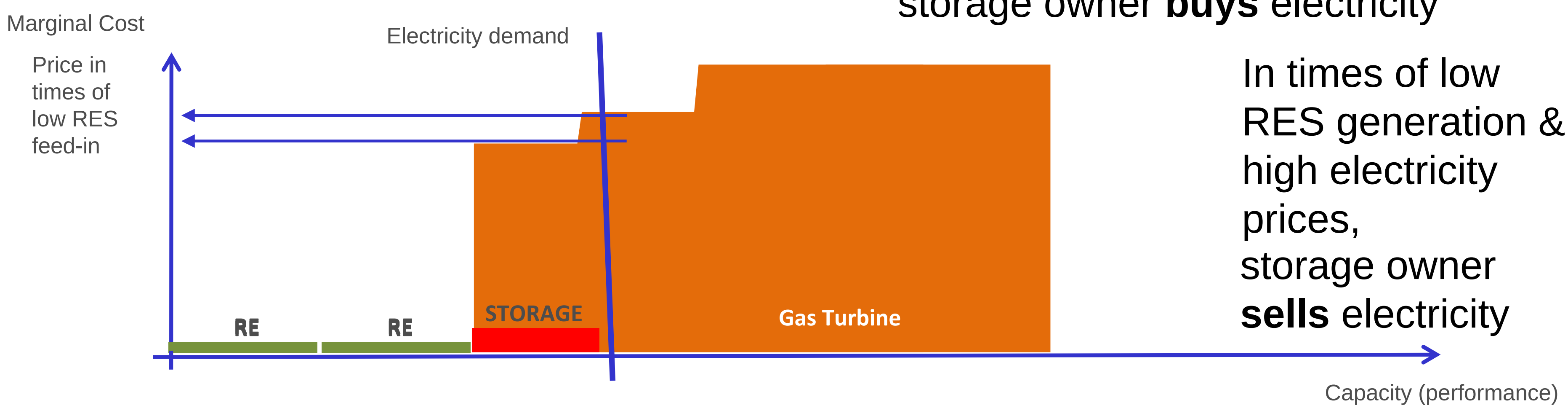

Situations with high renewable feed-in



# The Role of Classical Storage (e.g. Pumped Hydro)

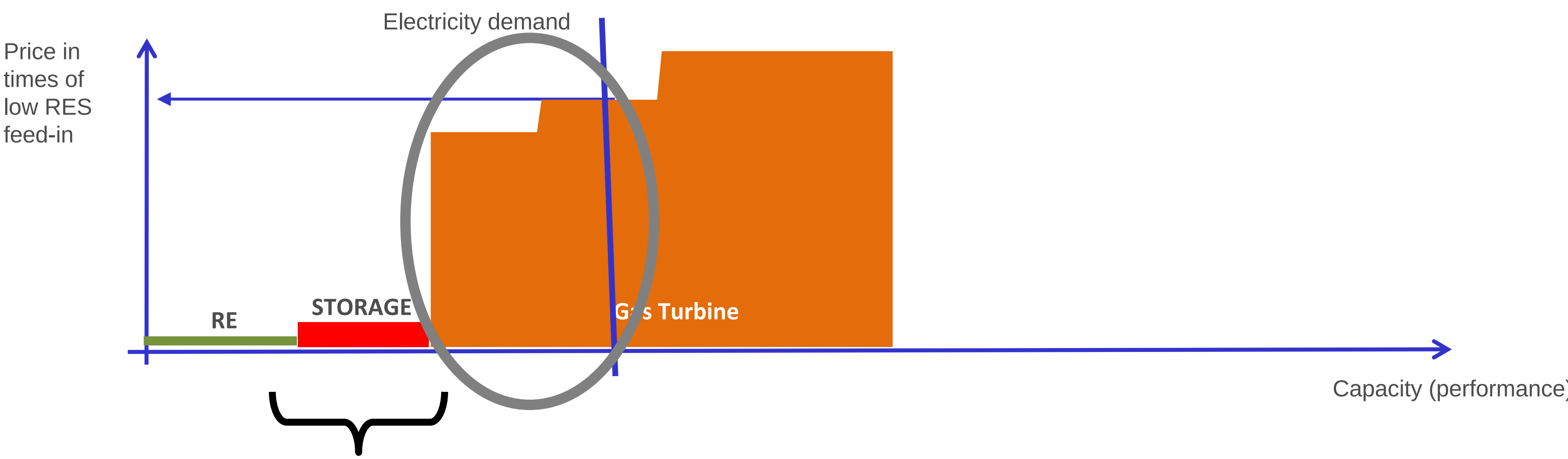



In times of high RES generation & low electricity prices, storage owner **buys** electricity




In times of low RES generation & high electricity prices, storage owner **sells** electricity

# Insufficiency of Pumped Hydro Storage in Europe




Pumped hydro storage is very limited in Europe

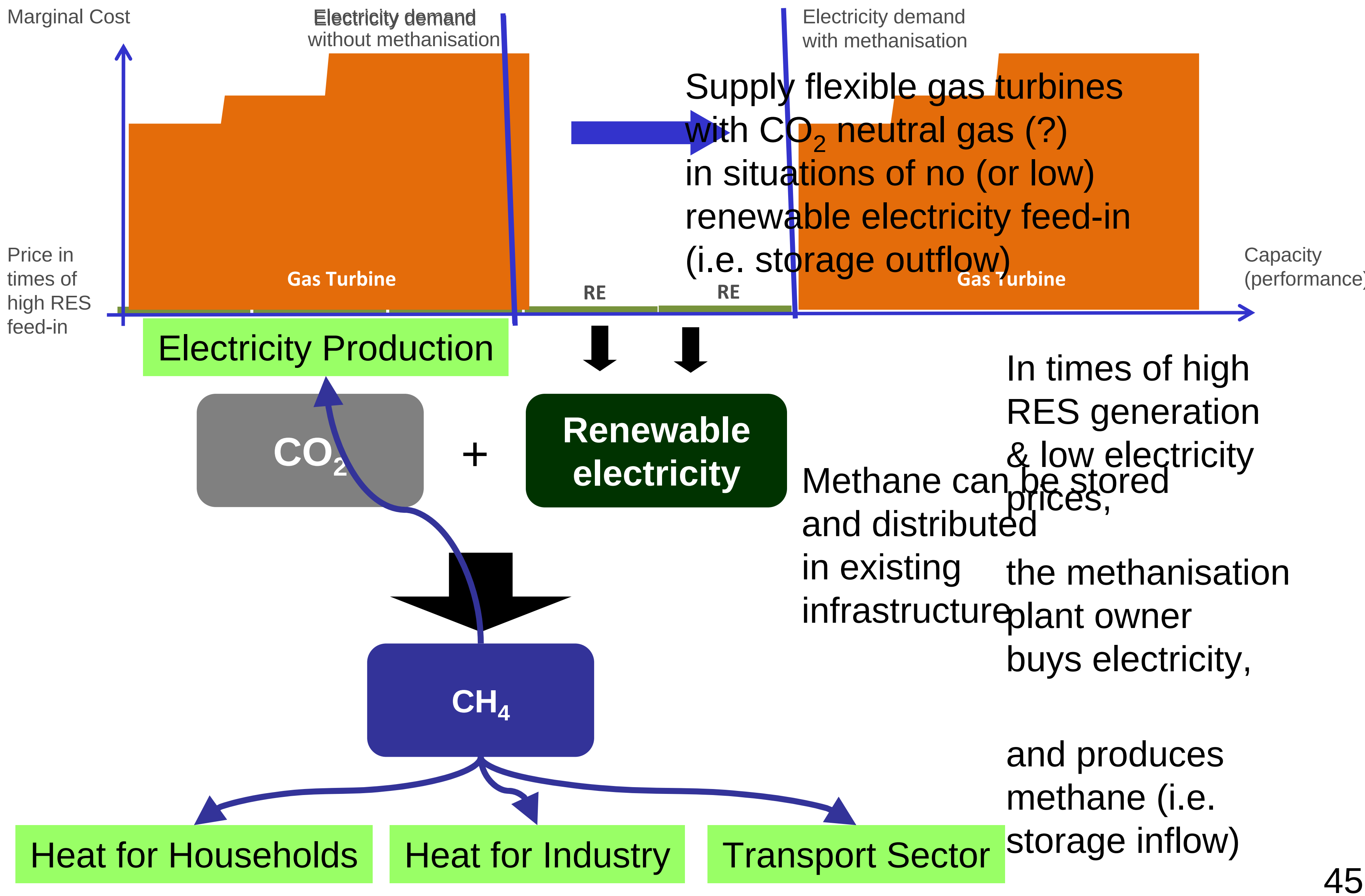
Gas turbines need to provide residual load, whenever renewable generation is insufficient to meet demand

!

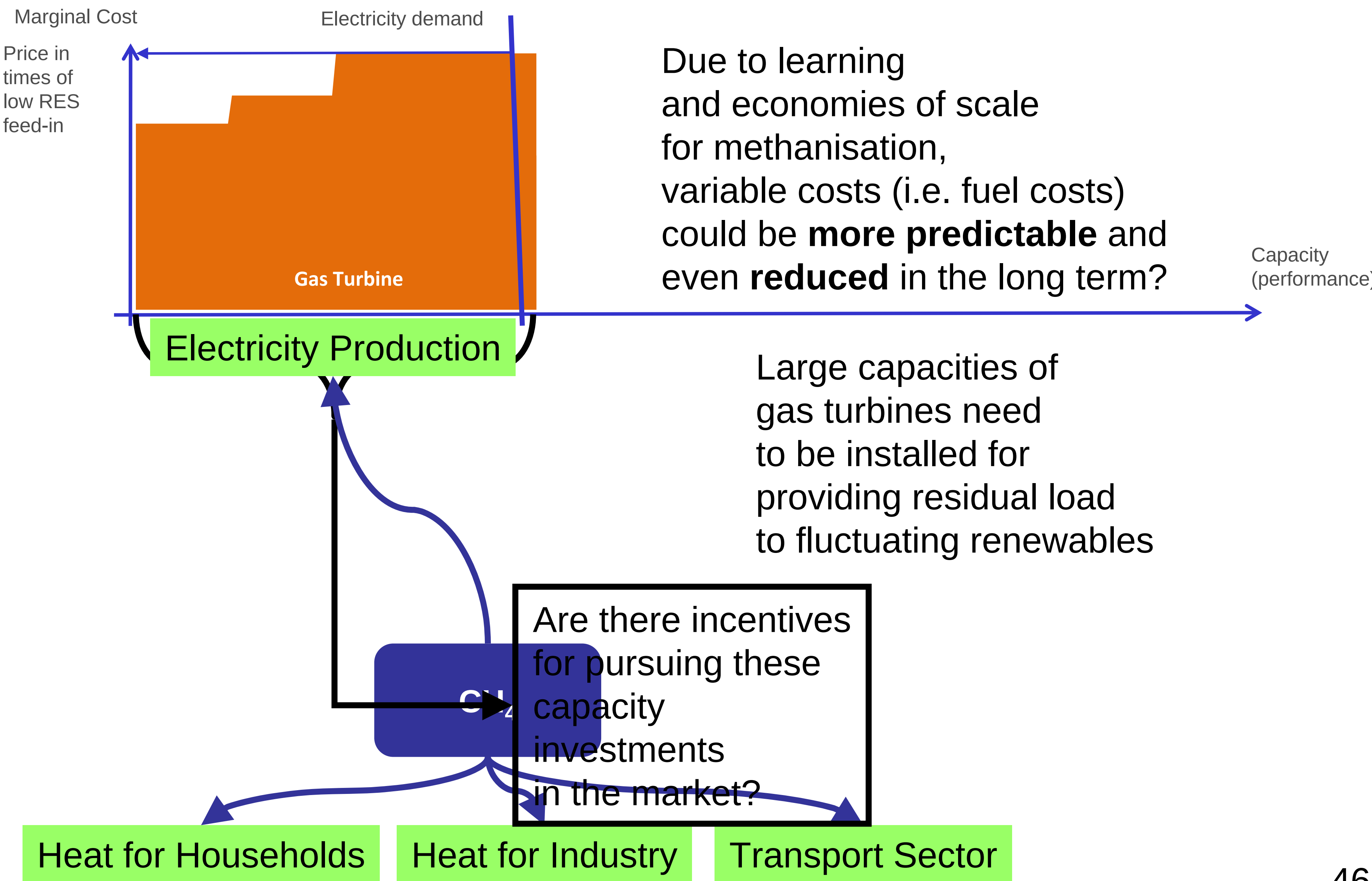
→ Natural Gas incurs $CO_2$ Emissions

→ Natural Gas is a scarce resource and may be subject to severe price increases in the future

# The Potential Role of Methanisation



# The Potential Role of Methanisation



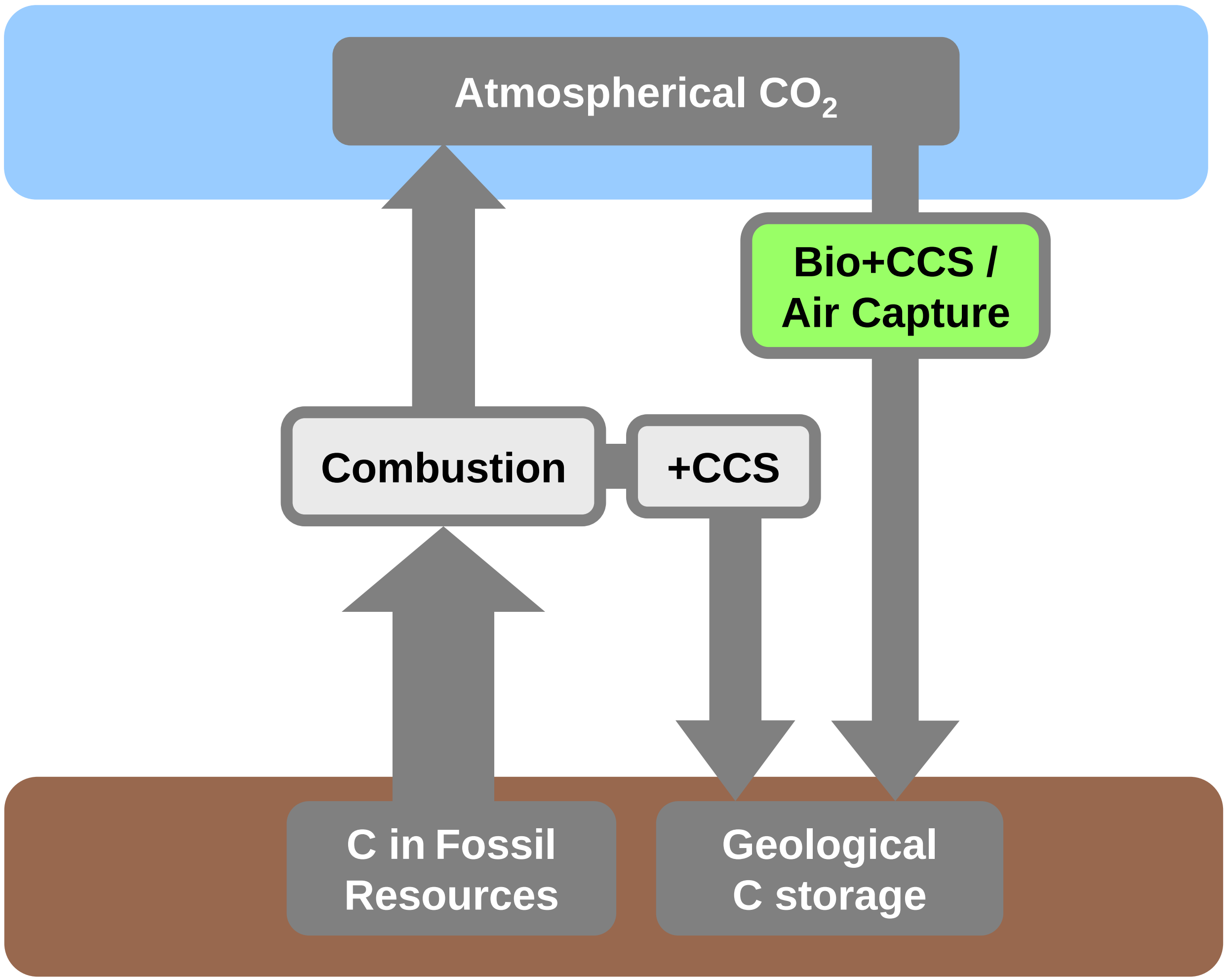

Due to learning
and economies of scale
for methanisation,
variable costs (i.e. fuel costs)
could be **more predictable** and
even **reduced** in the long term?

Large capacities of
gas turbines need
to be installed for
providing residual load
to fluctuating renewables

Are there incentives
for pursuing these
capacity
investments
in the market?

# Carbon Capture and …

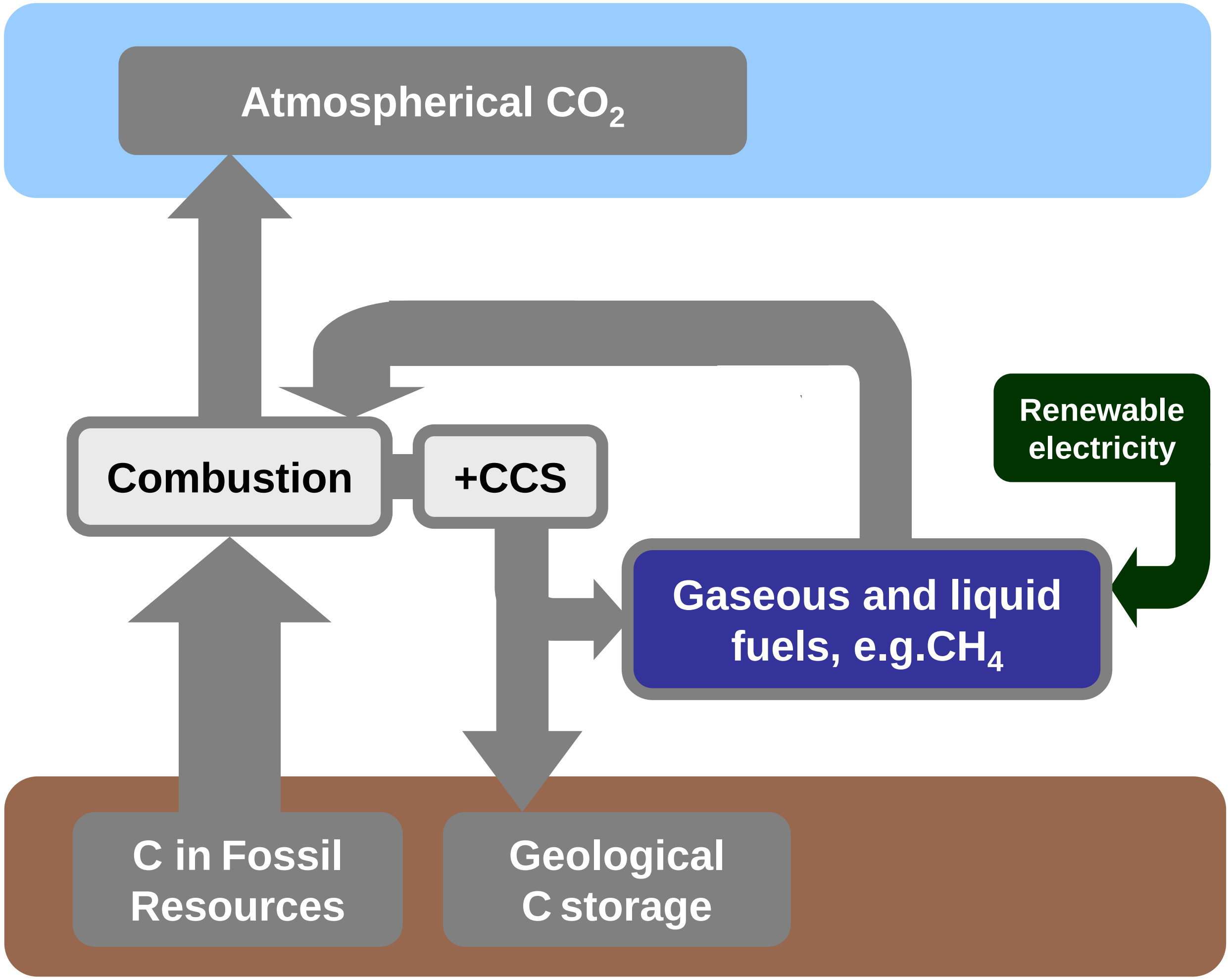
## …storage (CCS)




**Not fully sustainable**

# Carbon Capture and …

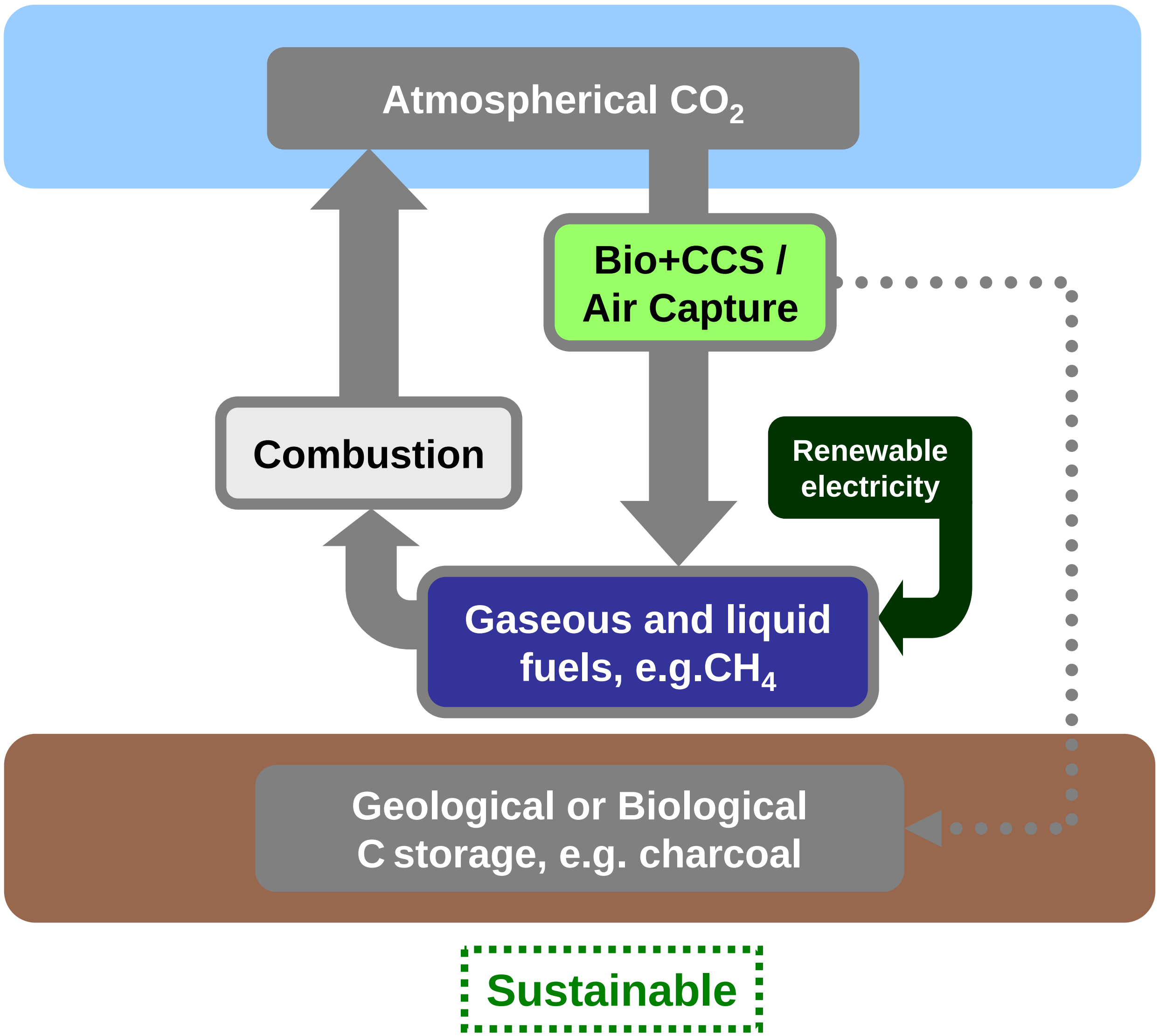
## …use (CCU)




Transitional

# Carbon Capture and …

## …cycling(CCC)




http://srren.ipcc-wg3.de/report

## Recommendable Literature

http://srren.ipcc-wg3.de/report