Transforming the Global Energy System –
Pathways Towards a Sustainable Energy Supply

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Has global warming stopped?

- Looking at the last 10 years, global warming seems to have slowed down or even stopped.

- Has the IPCC made a major mistake?

- Is global warming real?
The influence of cutting the data!

Multiple reasons for stable temperatures in last decade:
- “Slow down” last decades within natural variation
- 1997/98 exceptionally warm due to El Niño
- Cooling effect of increasing air pollution, particularly sulphur
  - *Temperatures likely to increase once clean air policies are commissioned also in newly industrializing countries*
- Looking at longer trends makes it obvious that global warming has not stopped at all
Long term trends show clear evidence

- Temporal slow downs of global warming have occurred already in the past
- Recent independent examination of IPCC results (Berkeley Earth Surface Temperature Project) has confirmed results
Climate Policy as an Insurance

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

Figure 1: Rise in global CO₂ emissions despite decreasing energy intensity in the world economy

Population and economic growth as drivers of global CO₂ emissions

Source: IEA 2011a, c

Edenhofer and Flachsland (2012)
We are not on Track – Renaissance of Coal!

Kaya decomposition of global CO$_2$ emissions.

SRREN (IPCC, 2011)
Renaissance of Coal?

Prices of Energy Commodities
(U.S. dollars a barrel of oil equivalent)

Asian liquefied natural gas

U.S. gas

Australian coal

Oil

Source: IMF (2011)
The BAU Scenarios could exceed the Level of Greenhouse Gas Concentration of 600ppm (~4°C Temperature Increase)
Drivers and Options for Solving the Climate Problem

[Diagram showing various pathways and options for CO₂ mitigation, including population, per capita production, energy intensity, non-fossil energy, CO₂ capture at plant (CCS), fraction CO₂ released, carbon cycle, direct ecosystem impacts, ocean acidification, climate impacts, adaptation, and SRM.]

Edenhofer and Seyboth (2013)
Ambitious Climate Policy – A Challenge

Global emissions projections in a baseline («business as usual») energy policy scenario compared with three reduction pathways which would reach the 2°C target with varying degrees of probability (75%, 50% or 15%). The difference between the baseline scenario and the reduction pathways is the «emissions reduction gap».

Source: Edenhofer et al. 2010a, p. 23
China & India: Strong Increase in Energy Demand

Growth in primary energy demand 2010-2035 by region

Million tonnes of oil equivalent (Mtoe)

- China
- India
- Africa
- Middle East
- Latin America
- Rest of the World
- OECD

Source: IEA 2011b, p. 3
Is a decoupling possible?

Luderer et al. (2011)
The Atmosphere as a Global Common

Atmosphere: Limited Sink
~ 230 GtC

Resource Extraction
> 12,000 GtC
Current Use of the Atmosphere

The area under the curve shows the total amount of global CO₂ emissions from energy consumption.

Source: Based on World Resources Institute 2012

Edenhofer and Flachsland (2012)
• Specialization is only one component determining trade-related emissions
• Net imports are an inappropriate indicator for burden sharing schemes
- Australia’s ETS from 2015 on will be among the world’s biggest
- Linking to other carbon markets would increase the abatement possibilities and increase the efficiency of the system
- BUT: Many offset possibilities could be problematic with respect to linking as their environmental integrity is often difficult to assess (see CDM)
Global RE Primary Energy Supply from 164 Long-Term Scenarios versus Fossil and Industrial CO$_2$ Emissions

SRREN SPM, Figure SPM.9
Global RE Primary Energy Supply from 164 Long-Term Scenarios versus Fossil and Industrial CO₂ Emissions

2050

Renewable Primary Energy Supply [EJ/yr]

CO₂ Emissions from Fossil Fuels and Industrial Processes [Gt CO₂/yr]

N=164

2007

CO₂ Concentration Levels
- Category I (<400 ppm)
- Category II (400-440 ppm)
- Category III (440-485 ppm)
- Category IV (485-600 ppm)
- Baselines

SRREN SPM, Figure SPM.9
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SRREN SPM, Figure SPM.9
The cost of mitigation depend on several key factors:

Costs hinge critically on:
- The stabilization target
- The biomass potential
- The availability of technologies, RE and CCS in particular
The Current Global Energy System is dominated by Fossil Fuels

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

- Coal: 28.4%
- Gas: 22.1%
- Oil: 34.6%
- Nuclear Energy: 2.0%
- RE: 12.9%
- Bioenergy: 10.2%
- Wind Energy: 0.2%
- Hydropower: 2.3%
- Geothermal Energy: 0.1%
- Direct Solar Energy: 0.1%
- Ocean Energy: 0.002%

SRREN (IPCC, 2011)
The Costs of Renewables are often still higher than those of Non-Renewables but...

IPCC SRREN (2011)
Some Technologies can already be competitive today

The lower end of the cost ranges represents favourable geographic and economic conditions.

Examples should not be misinterpreted to suggest a generally valid ordering of specific technologies from least to highest cost.

SRREN, Edenhofer et al. (2011)
Learning-by-Doing

![Graph showing the relationship between average price and cumulative global capacity for different types of power plants over time. Key data points include:
- 1976: 65 USD/W
- 1981: 4.3 USD/W
- 2010: 1.4 USD/W
- 2009: 1.9 USD/W

Legend:
- Blue diamonds: Produced Silicon PV Modules (Global)
- Red squares: Onshore Wind Power Plants (Denmark)
- Red diamonds: Onshore Wind Power Plants (USA)
What are the total Costs of variable Renewables (VRE)?

Additional system costs can be crucial. The LCOE indicator needs to be extended.
Integration Options for Renewables

- **Improved weather forecast**
  - better planning of renewable electricity feed-in

- **Demand side management**
  - adjust demand to renewable electricity feed-in

- **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 CO₂ emission reduction in 2050 vs. 1990

(Ueckerdt et al., 2011)
• Demand: Fluctuating, Supply: Conventional only
• Price set by marginal plant, mostly natural gas
• Avg. price close to marginal cost of natural gas plants
• High price span due to supply curve curvature
The Energy Transformation in Germany: Increasing the Share of Renewable Energy in Electricity Generation

x: government target
- **RES** entering the market at zero marginal costs
  → Peaking plants and less efficient natural gas no longer needed: Plants **decommissioned**
  → Low **average price** reduces invest. incentive for **plants**
  → Low **price span** reduces invest. incentive for **storage**
• But: **Fluctuations** matter if share of RES is high!
  → “Left shift” of convent. supply if RES supply is low
  → Insufficient supply if demand is high at the same time
  → **Reliability/security of supply** endangered
New Challenges for the next few Decades

- Carbon Pricing / Technology Policies
- Support Schemes for RES
- Integration of RES