Global Sustainability Summer School
Santa Fe Institute
21 Jul 2010

State of Climate Economics & Policy

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Potsdam Institute for Climate Impact Research

Outline

Part A: Economic and Technical Instruments

1. Energy System Transformation
2. Economic Instruments & Incentives
3. Seven Cardinal Innovations
4. Transition Management

Part B: International Climate Policy

1. The „Post-Copenhagen Syndrome“
2. The Budget Approach
3. More Pragmatic Approaches
4. Beyond CO_2

Part A: Economic and Technical Instruments

1. Energy System Transformation

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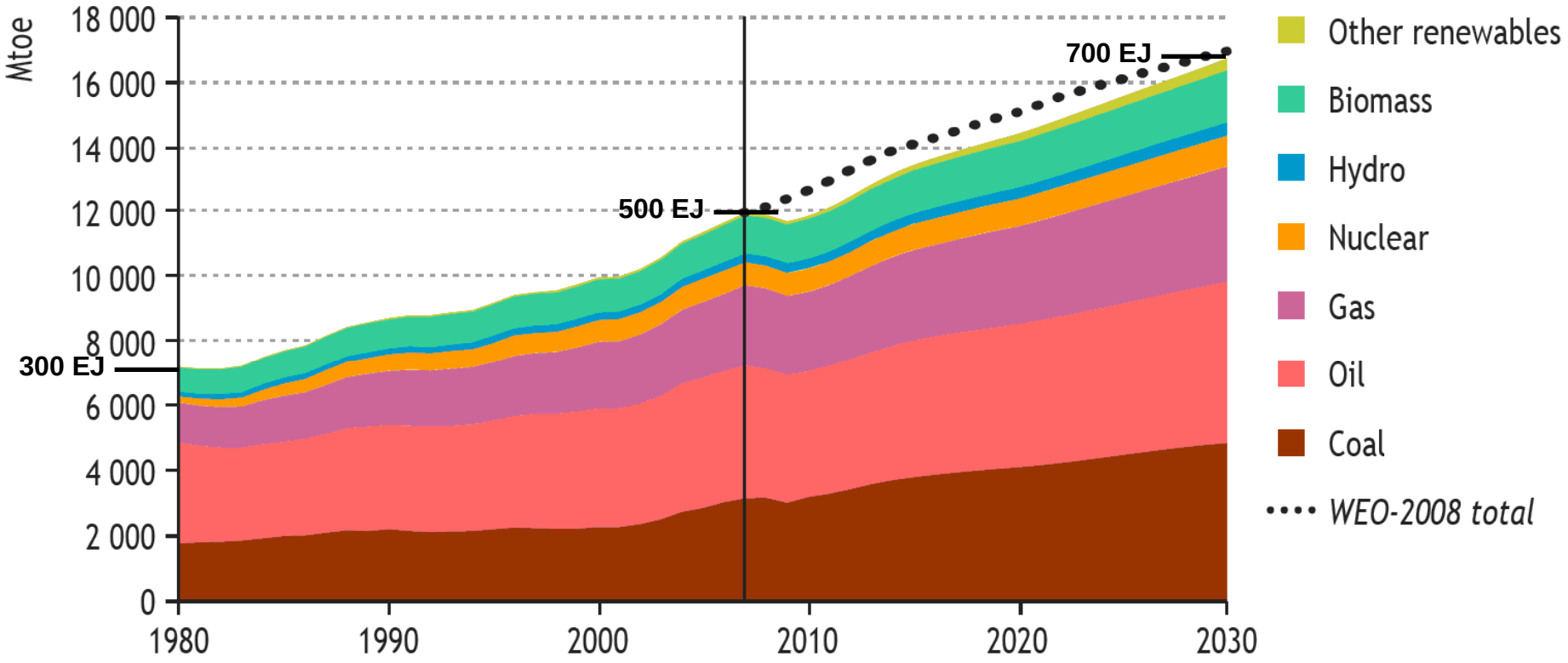
World Primary Energy Demand by Fuel in the Reference Scenario



Source: World Energy Outlook 2009

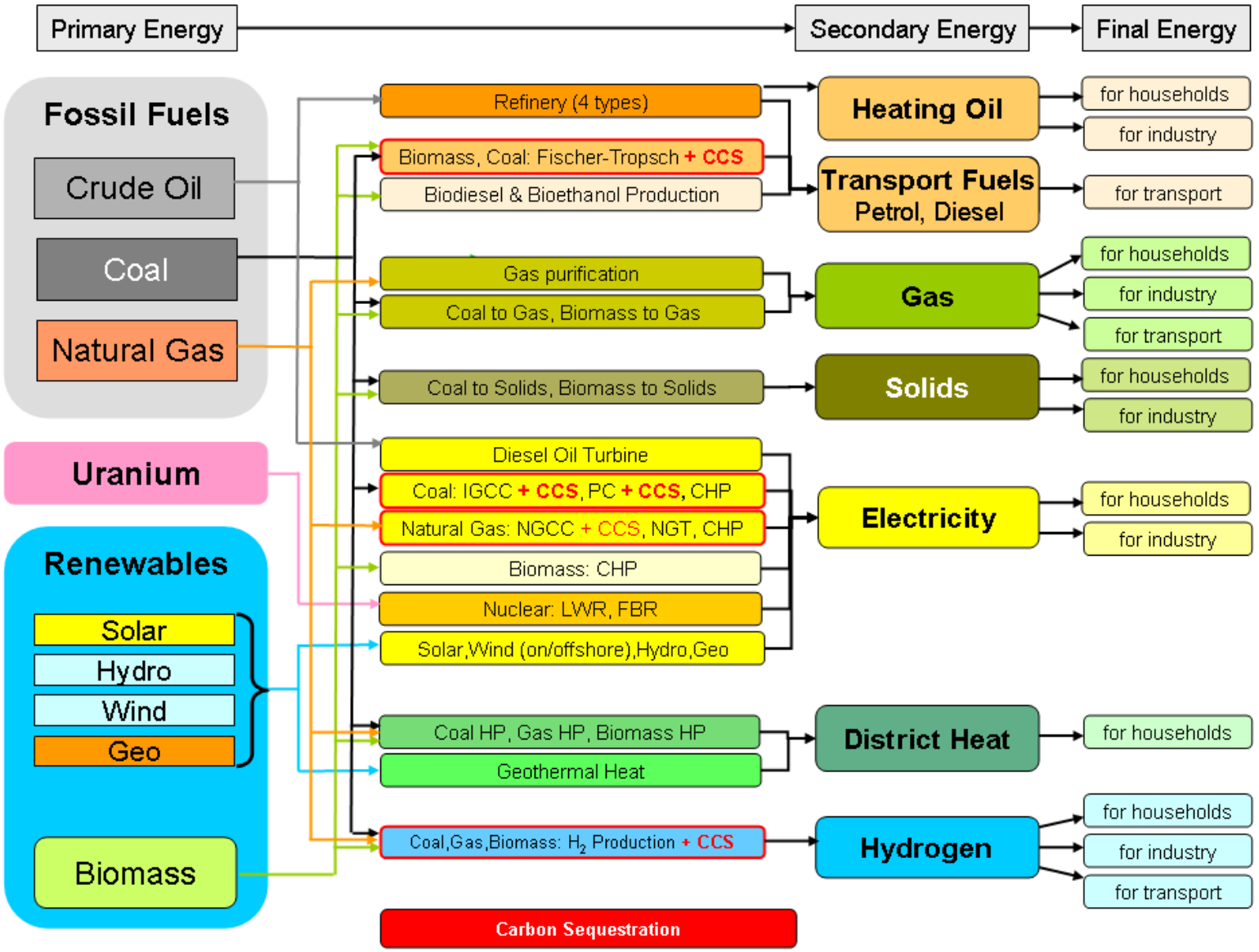
Feasibility of Low Stabilization Pathways

ADAM Model Comparison

Members:

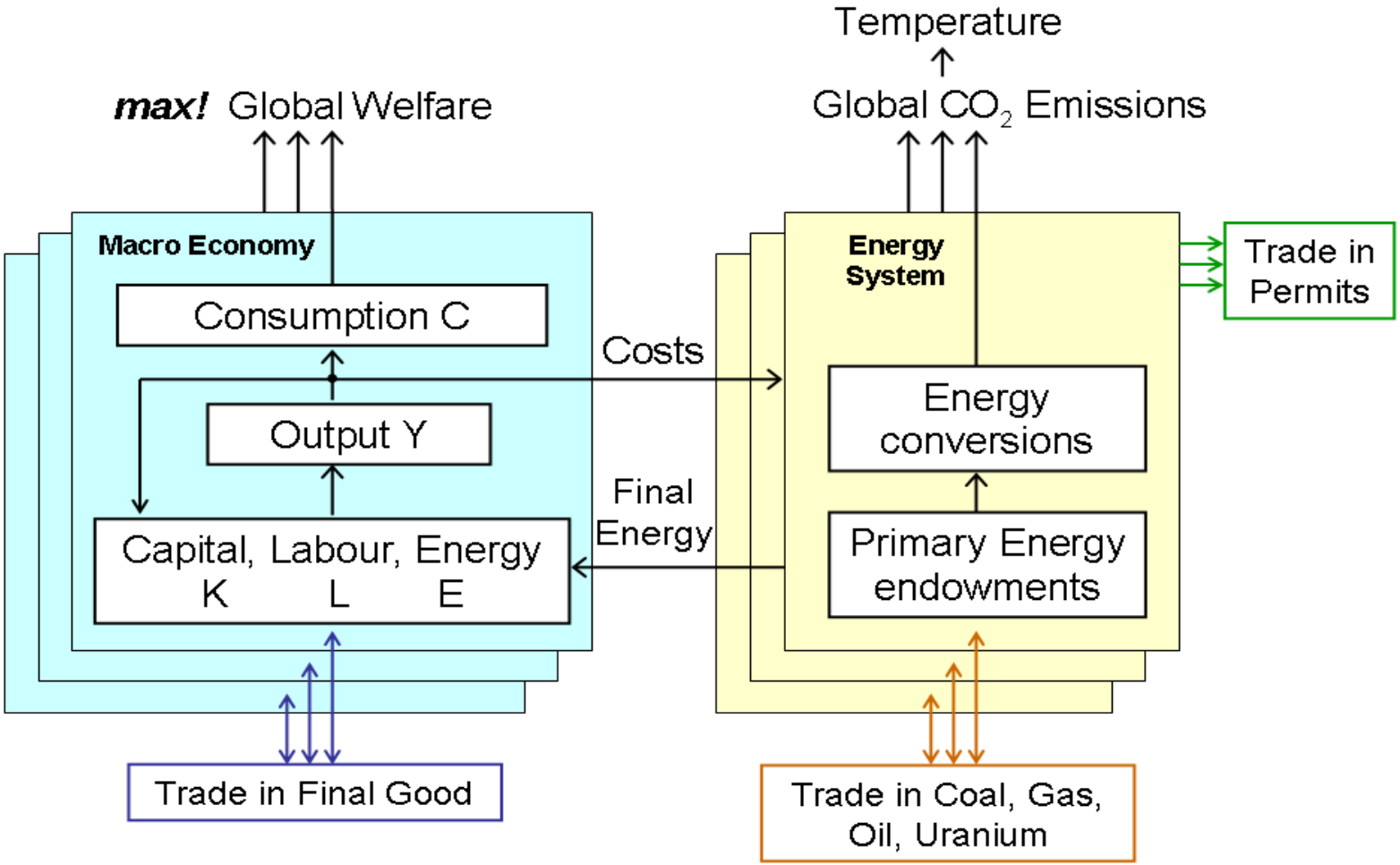
PIK (REMIND model):	O. Edenhofer, M. Leimbach. L. Baumstark, B. Knopf
PSI (MERGE model):	T. Hal, S. Kypreos, B. Magné
U Cambridge (E3MG model):	T. Barker, S. Scrieciu
ENERDATA (POLES model):	A. Kitous, E. Bellevrat, B. Chateau, P. Criqui
PBL (TIMER):	D. van Vuuren, M. Isaac
Compilation of comparison:	B. Knopf

The Energy System in REMIND



(Edenhofer et al. 2010)

Economic feasibility
Structure of REMIND

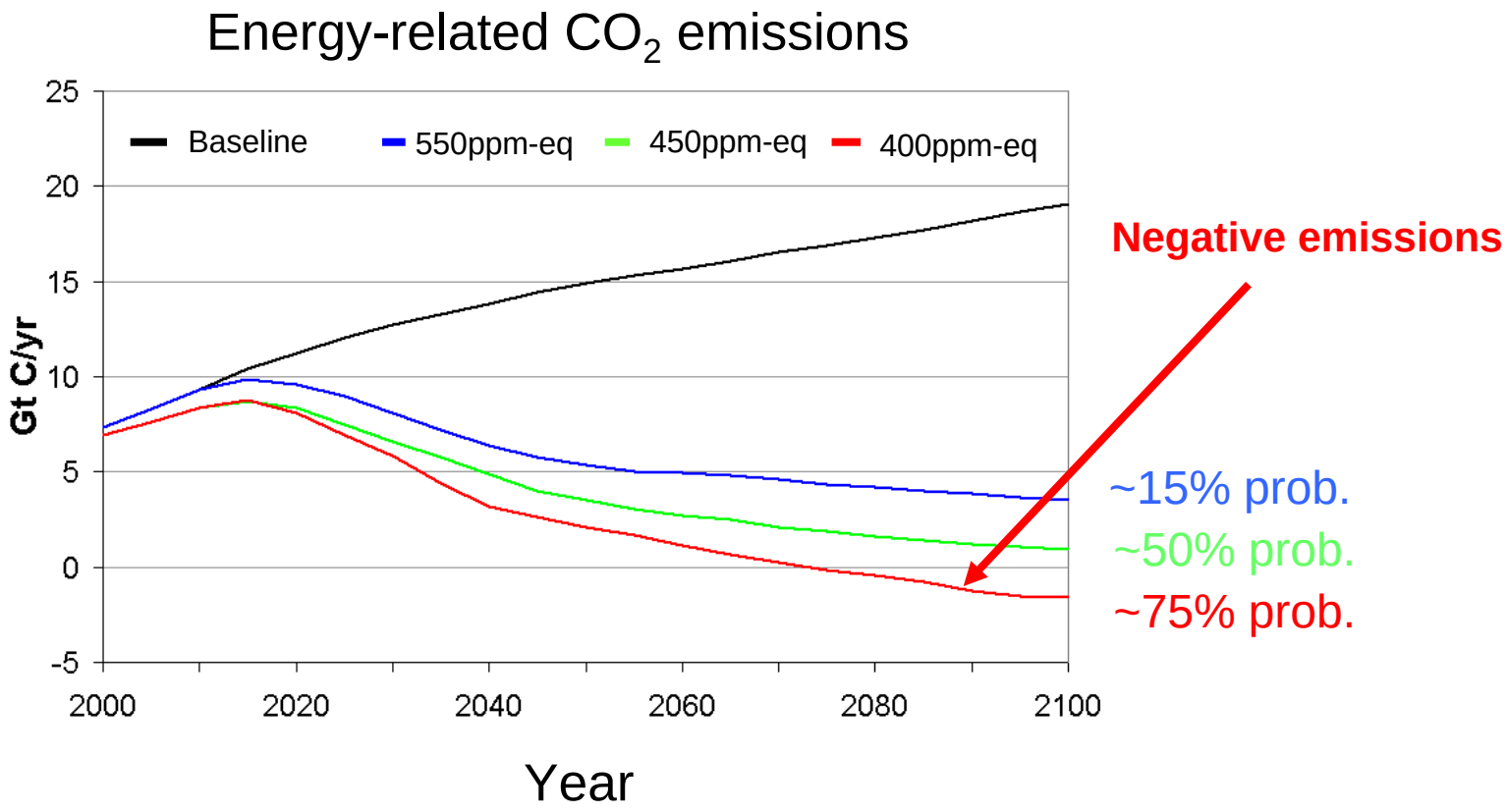


(Edenhofer et al. 2010)

Exemplary Stabilization Pathways

ADAM model comparison:

Analysis of 3 stabilisation targets with different probabilities to reach the 2° target: 550ppm-eq, 450ppm-eq, 400ppm-eq



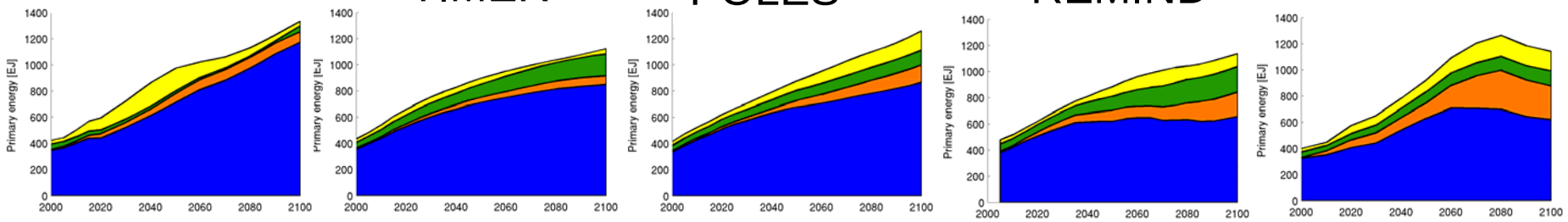
(Knopf, Edenhofer et al. 2009)

Transformation of the Energy System

models →

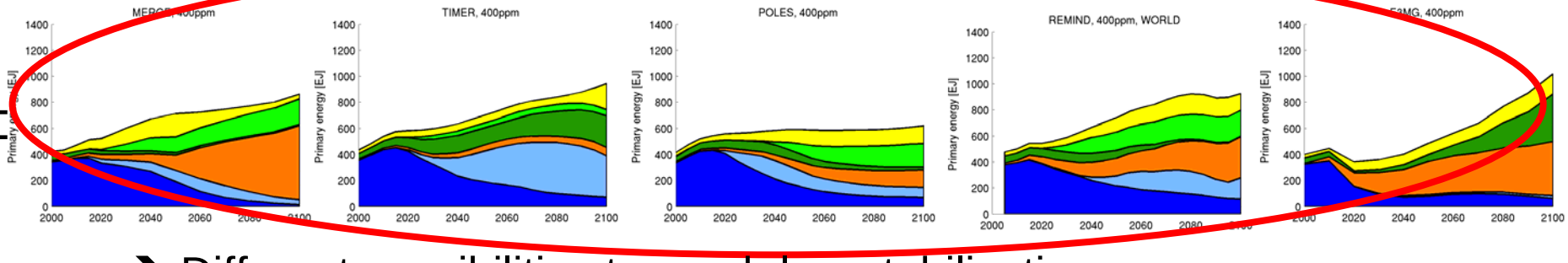
Baseline

MERGE | TIMER | POLES | REMIND | E3MG



Many different pathways to transform the energy system

400 ppm-eq



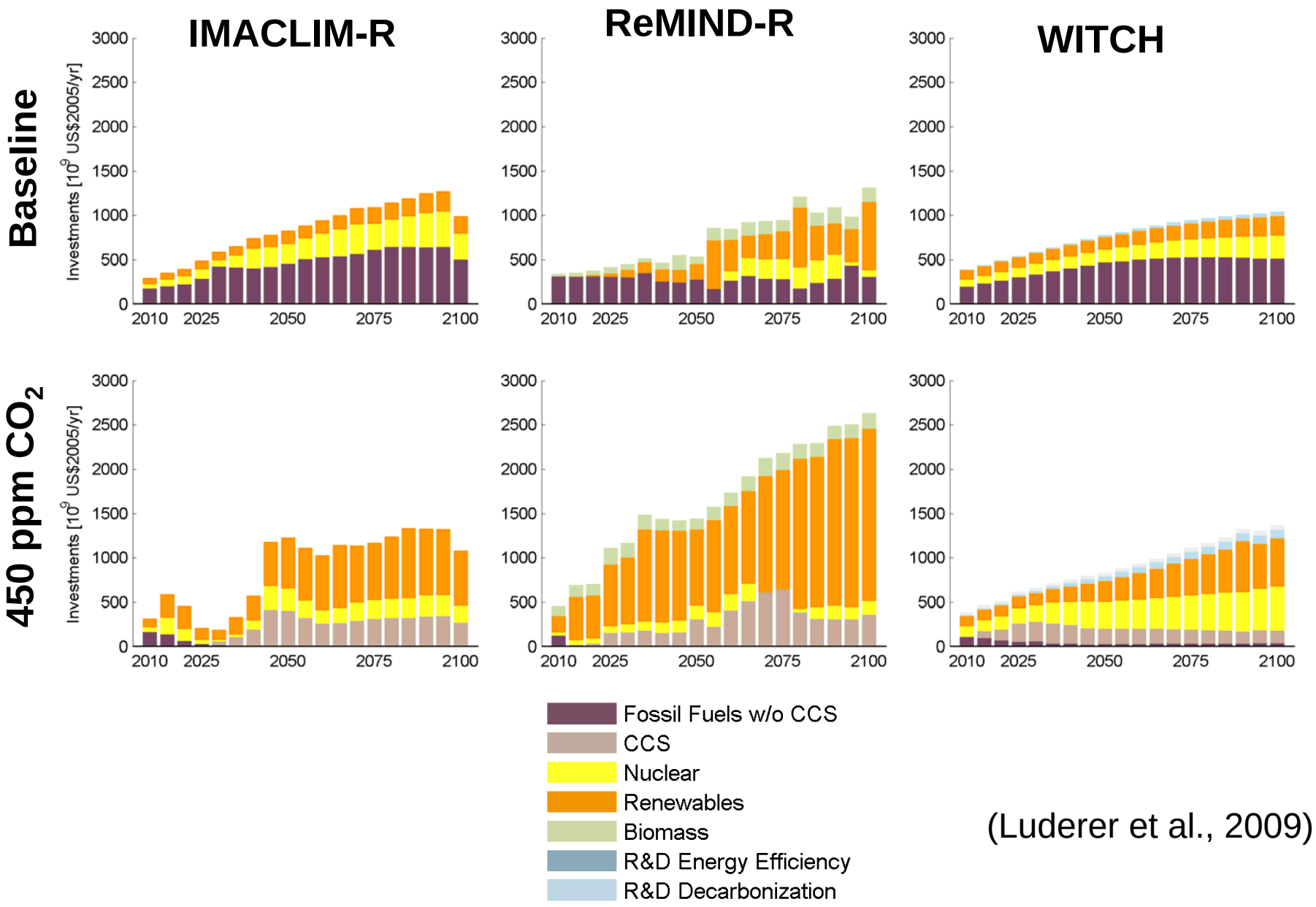
➔ Different possibilities to reach low stabilisation

➔ 400ppm can be achieved by all models

(Knopf, Edenhofer et al. 2009)

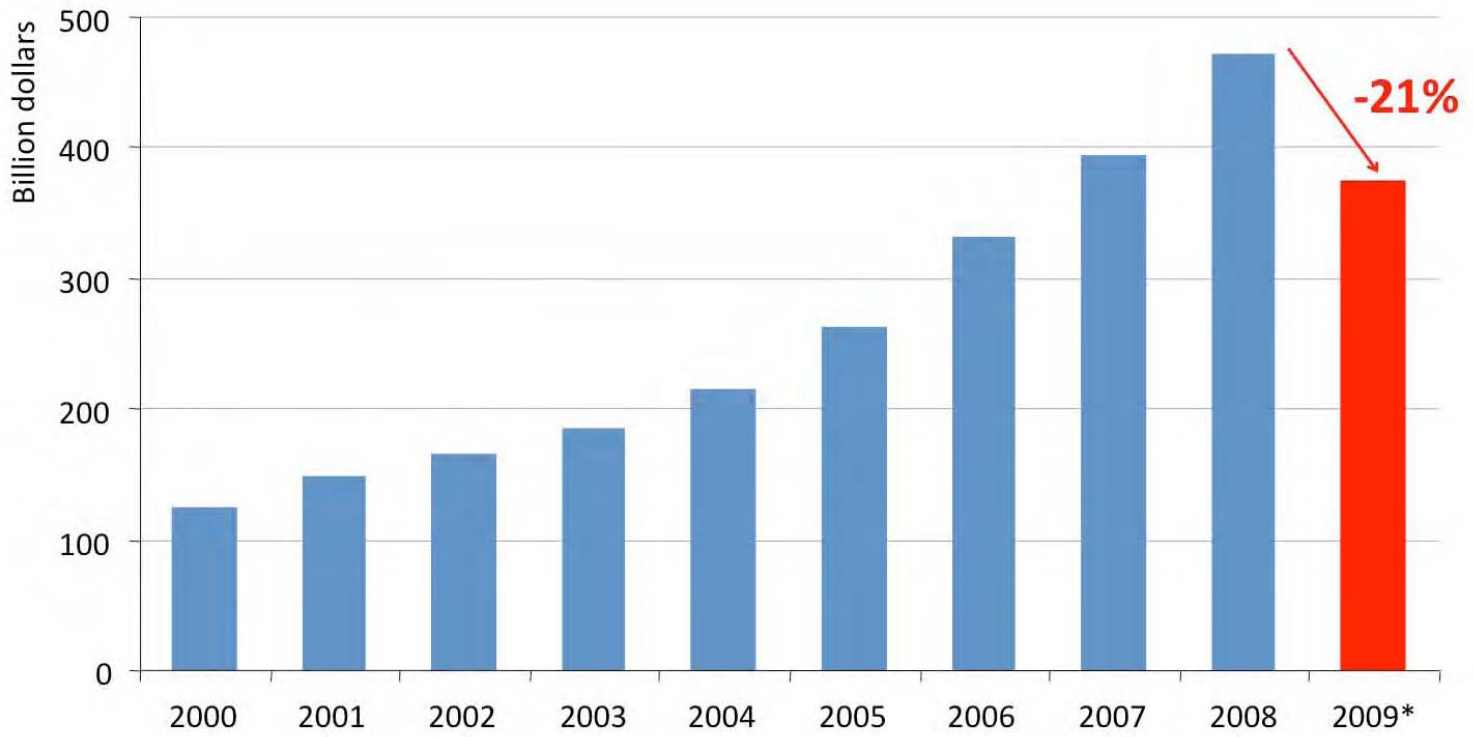
Investment Strategies – Insights From RECIPE

Energy System Investments



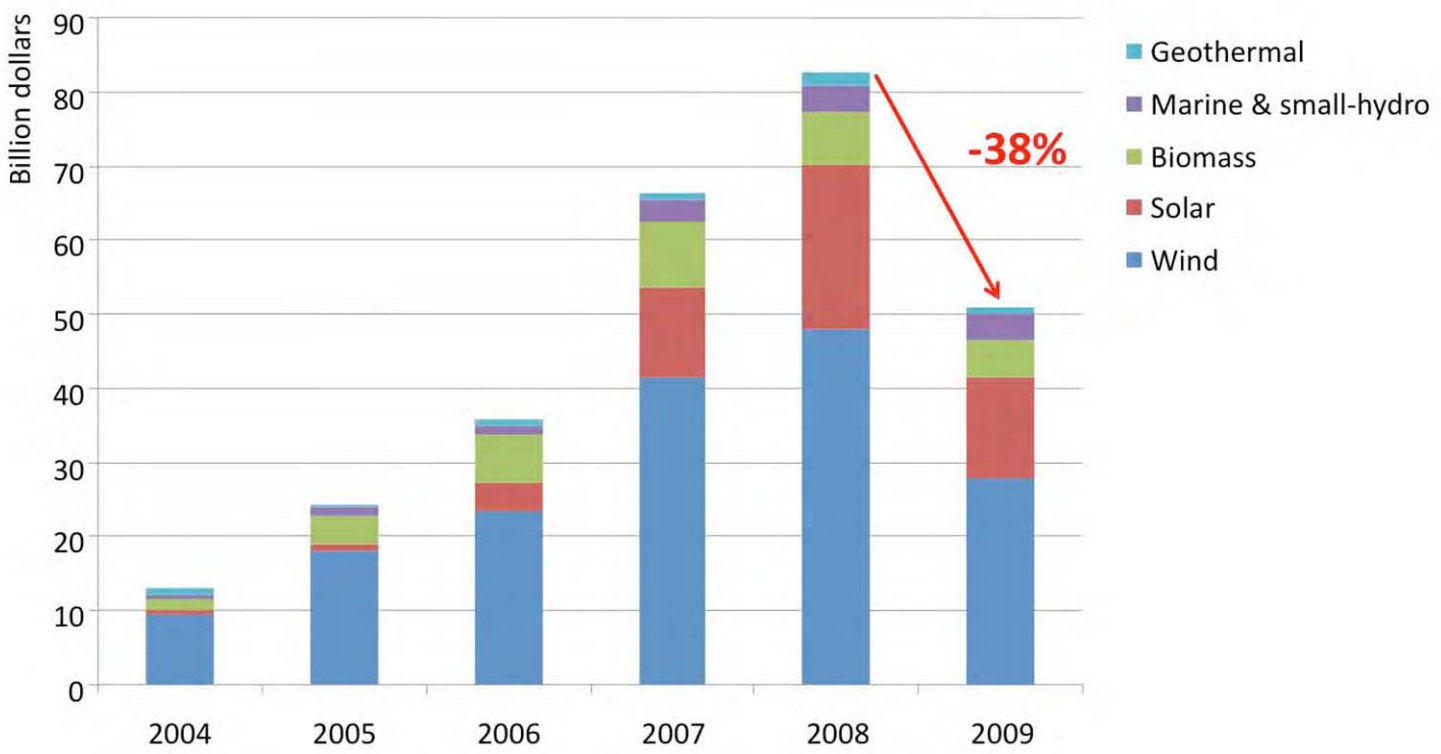
(Luderer et al., 2009)

Global Investments in Upstream Oil and Gas



Source: IEA, 2009

Global Investments in New Renewables



Source: IEA, 2009

Part A: Economic and Technical Instruments

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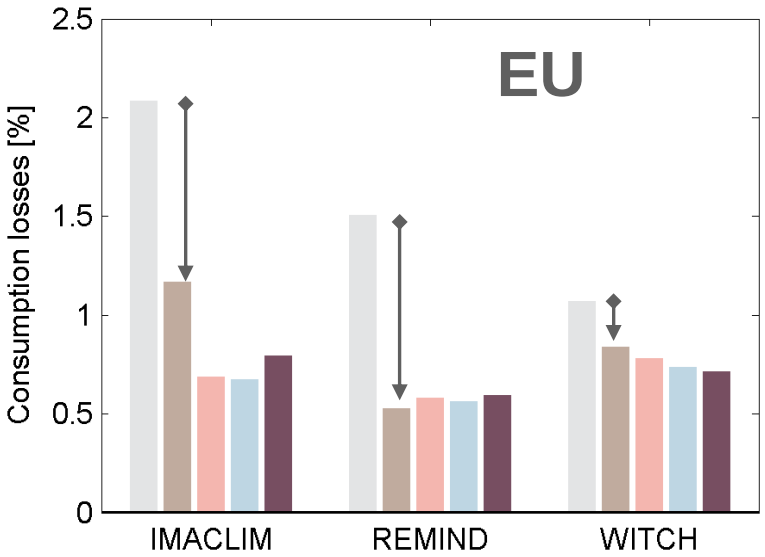
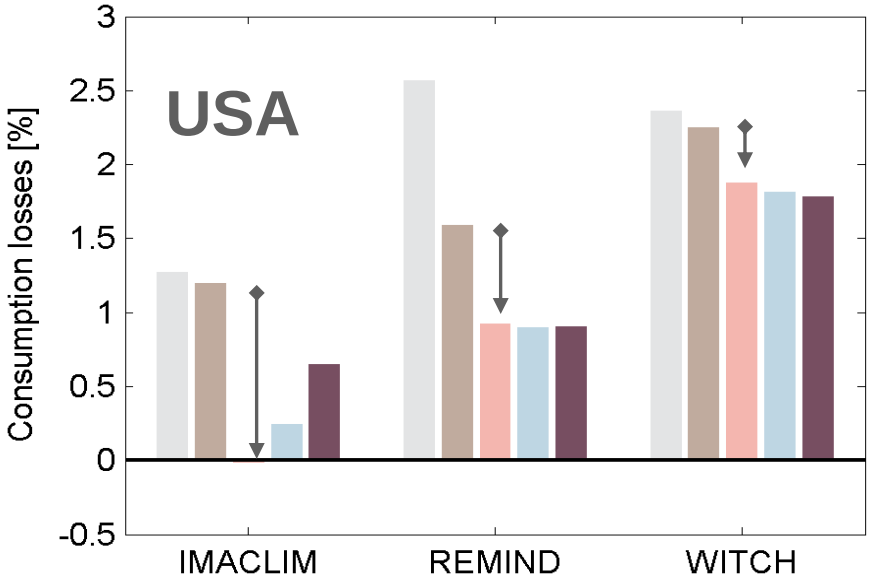
The Case for Early Action





Delay 2020
EU 2010, others 2020
Annex I 2010, others 2020
Annex I + CHN + IND 2010
All 2010

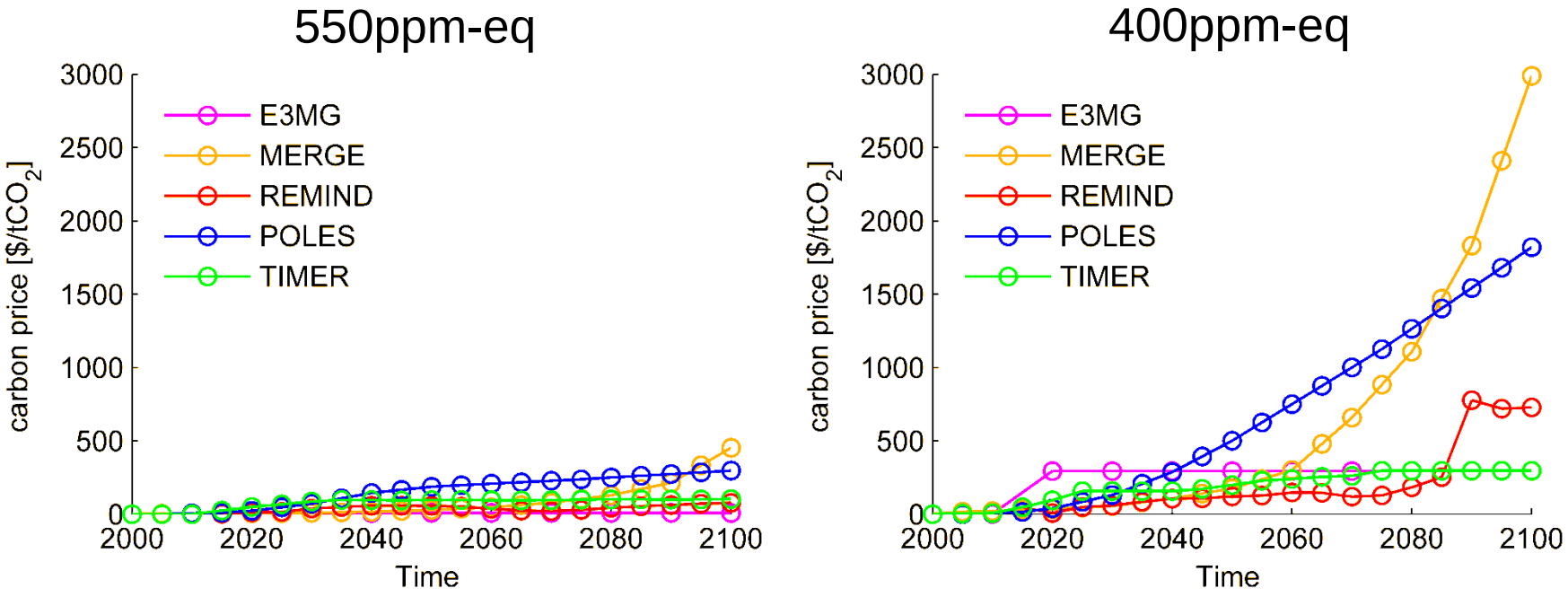
Luderer et al., 2009;
Jakob et al., in prep.

➔ If a global climate agreement is delayed until 2030, stabilization at 450ppm CO_2 or below will become infeasible

➔ The EU and USA enjoy a 'first mover advantage', i. e. lower mitigation costs even if other countries start later → benefit of anticipation

Instruments of Change

Carbon Price Development



Neo-classical approach (e.g., in REMIND, MERGE): perfect market, perfect foresight

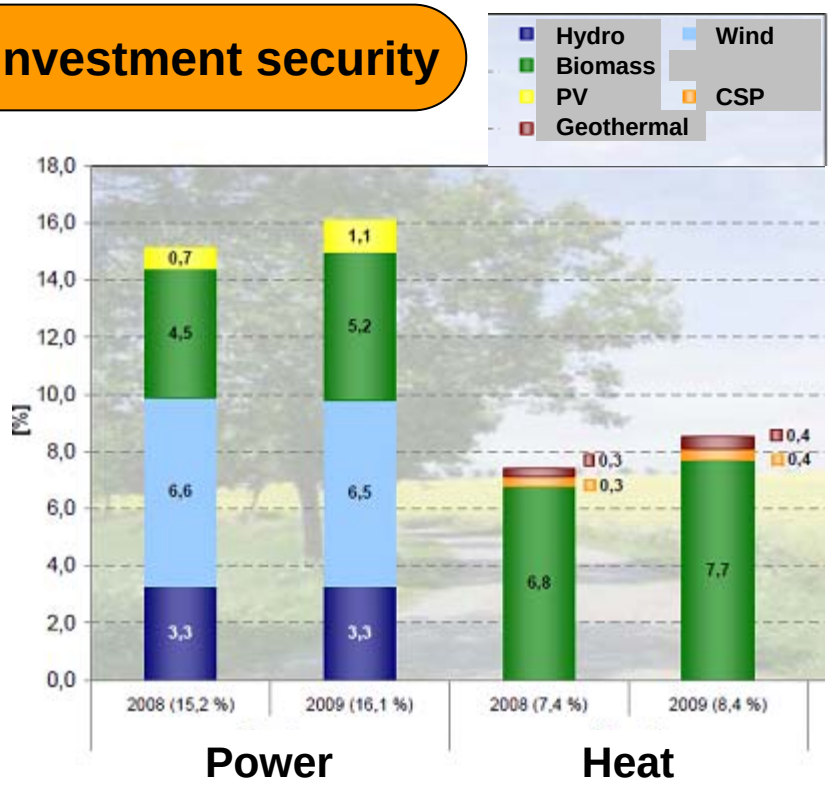
→ equivalence of emission trading and tax system

(Edenhofer et al. 2010)

Feed-in Tariffs in Germany

- **Guaranteed grid access for renewable energy projects: priority connection**
- **Feed-in priority for renewable power into the grid**
- **Fixed feed-in tariffs guaranteed by law: investment security**

Technology	Payment time [years]	Feed-in tariff [€cent/kWh]	Annual degression
Wind power (onshore)	20	9.70 (...5.02)**	1,0 %
Wind power (offshore)	20	15.0 (...3.5)**	5 % as of 2015
Photovoltaics	20	31.94 –43.01	8 % -10 %
Hydro power < 5 MW	20	7.65 -12.67	-
Large hydro > 5 MW	15	3.50 -7.29	-
Biomass	20	7.79 -11.67	1 %
Geothermal energy	20	10.5 –16.0	1 %



* Additional bonus up to 13 €ct/kWh if renewable raw material is used
** The tariff is paid in the beginning and is reduced during the payment time to the lower level
Sources: Renewables Academy (RENAC); RESA; Ministry for the Environment (BMU)

Global System of Feed-in Tariffs

The St. James's Palace Memorandum
Action for a Low Carbon and Equitable Future
London 26-28 May 2009

ST. JAMES'S PALACE NOBEL LAUREATE SYMPOSIUM

The St James's Palace Memorandum Memorandum has been signed by the following Nobel Laureates:

Prof. Peter Agre, Chemistry 2003, USA
Prof. Kenneth Arrow, Economic Sciences 1972, US
Prof. Paul Berg, Chemistry 1980, USA
Prof. Mario Capecchi, Medicine 2007, USA
Prof. Paul Crutzen, Chemistry 1995, Germany
Prof. Johann Deisenhofer, Chemistry 1988, Germany
Dr. Mohammed ElBarade, Peace 2005, Austria
Prof. Peter Doherty, Medicine 1996, Australia
Prof. Richard Ernst, Chemistry 1991, Switzerland
Prof. Gerhard Ertl, Chemistry 2007, Germany
Dr. Nadine Gordimer, Literature 1991, South Africa
Prof. Paul Greengard, Medicine 2000, USA
Prof. David Gross, Physics 2004, USA
Prof. Roger Guillemin, Medicine 1977, USA
Prof. Lee Hartwell, Medicine 2001, USA
Prof. Alan Heeger, Chemistry 2000, USA
Prof. Sir Anthony Hewish, Physics 1974, UK
Prof. Roald Hoffmann, Chemistry 1981, USA
Prof. Sir Aaron Klug, Chemistry 1982, UK
Prof. Masatashi Koshiba, Physics 2002, Japan
Prof. Sir Harold Kroto, Chemistry 1996, UK
Prof. Yuan Tseh Lee, Chemistry 1986, USA

"Delivering a low carbon energy infrastructure

Actions in the following areas are needed:

• […]

• Technology sharing and financial support, through mechanisms such as globally supported feed-in tariffs for renewable energy, to help developing countries leapfrog to a low carbon economy."

Prof. Eric Maskin, Economic Sciences 2007, USA
Prof. Sir James Mirrlees, Economic Sciences 1996, UK
Prof. Dr. Erwin Neher, Medicine 1991, Germany
Prof. Ryoji Noyori, Chemistry 2001, Japan
Dr. Rajendra Pachauri on behalf of IPCC, Peace 2007, India
Prof. John Polanyi, Chemistry 1986, Canada
Prof. F Sherwood Rowland, Chemistry 1995, USA
Prof. Carlo Rubbia, Physics 1984, Italy
Prof. Wole Soyinka, Literature 1986, Nigeria
Prof. Jack Steinberger, Physics 1988, USA
Prof. Klaus von Klitzing, Physics 1985, Germany
Prof. Sir John Walker, Chemistry 1997, UK

Part A: Economic and Technical Instruments

1. Energy System Transformation
2. Economic Instruments & Incentives
3. Seven Cardinal Innovations
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The Seven Cardinal Innovations

1. **Integration of Renewable Energy Sources (“Supersmart Grids“)**
2. **Plus-Energy Houses („Power Houses“)**
3. **Modular E-Mobility („Beyond Storage“)**
4. **Systems-optimized Industrial Production („Cradle to Cradle“)**
5. **Holistic Urban and Regional Planning („Reinvention of Urbanity & Rurality“)**
6. **Sustainable Biomass Management („De- & Anti-Carbonisation“)**
7. **Regenerative Water Supply („Solar Desalination“)**

The Seven Cardinal Innovations

1. Integration of Renewable Energy Sources (“Supersmart Grids“)

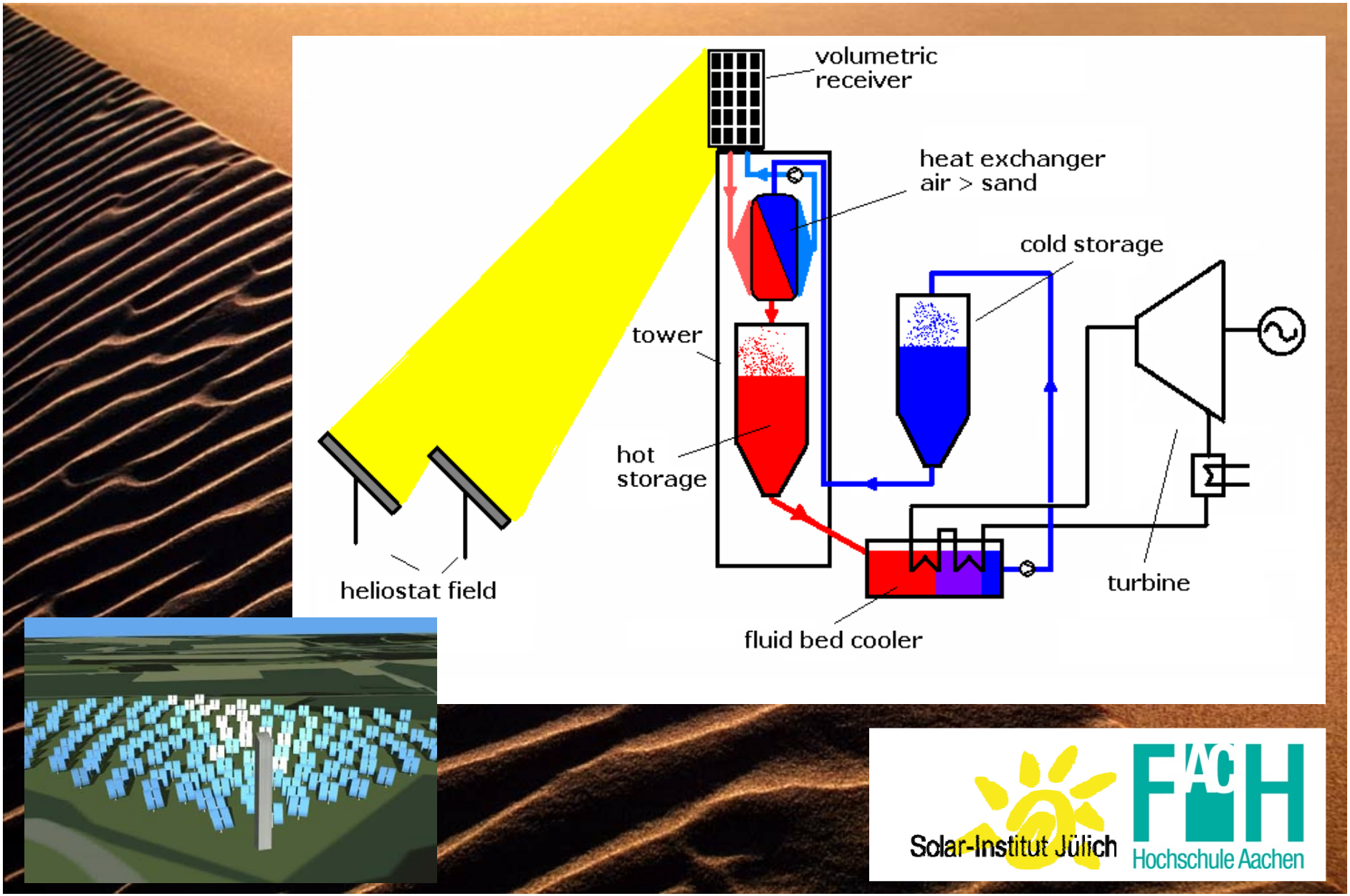
DESERTEC Consortium

Objectives: solar thermal power plants in deserts of North Africa largely fulfill the electricity demand of producer countries and supply 15% of European electrical power

Estimated costs: EUR 400 billion

RWE
HSH NORDBANK
ABB
SCHOTT solar
ABENGOA SOLAR
SIEMENS
ceVital
m+w zander
Deutsche Bank
MAN Solar Millennium
e·on
Münchener Rück
Munich Re Group

Sand Storage Concept



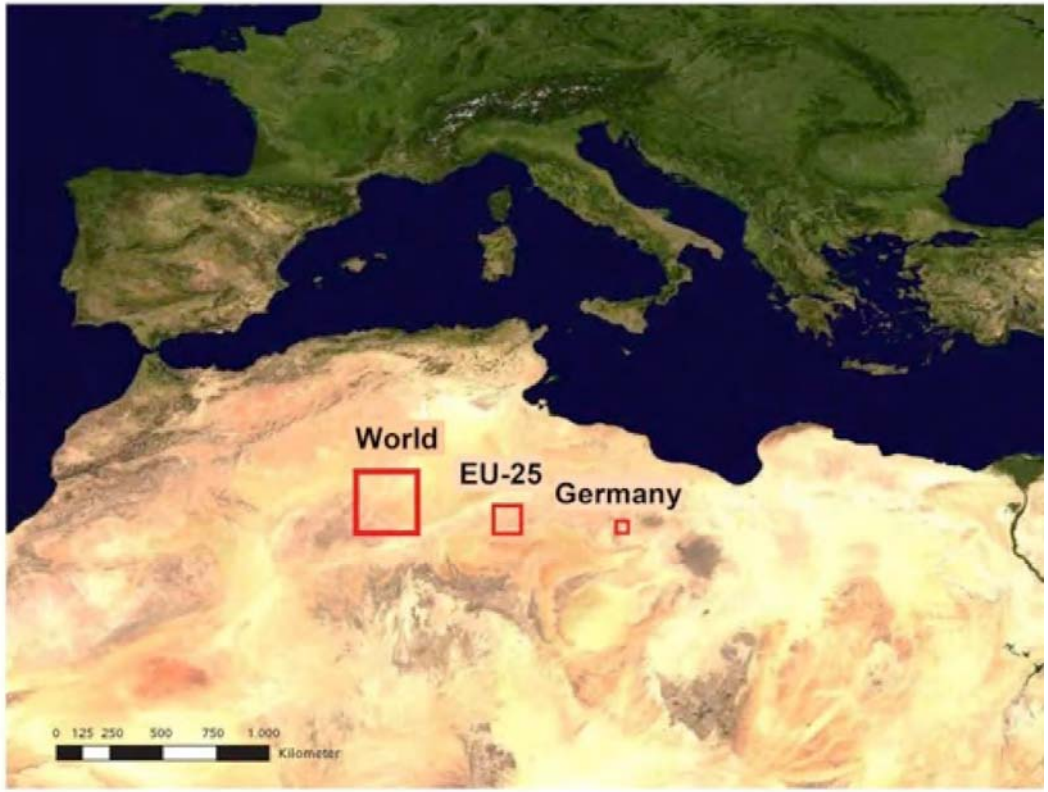
Solar-Institut Jülich

FH AC Hochschule Aachen

Required Area for Current Demand

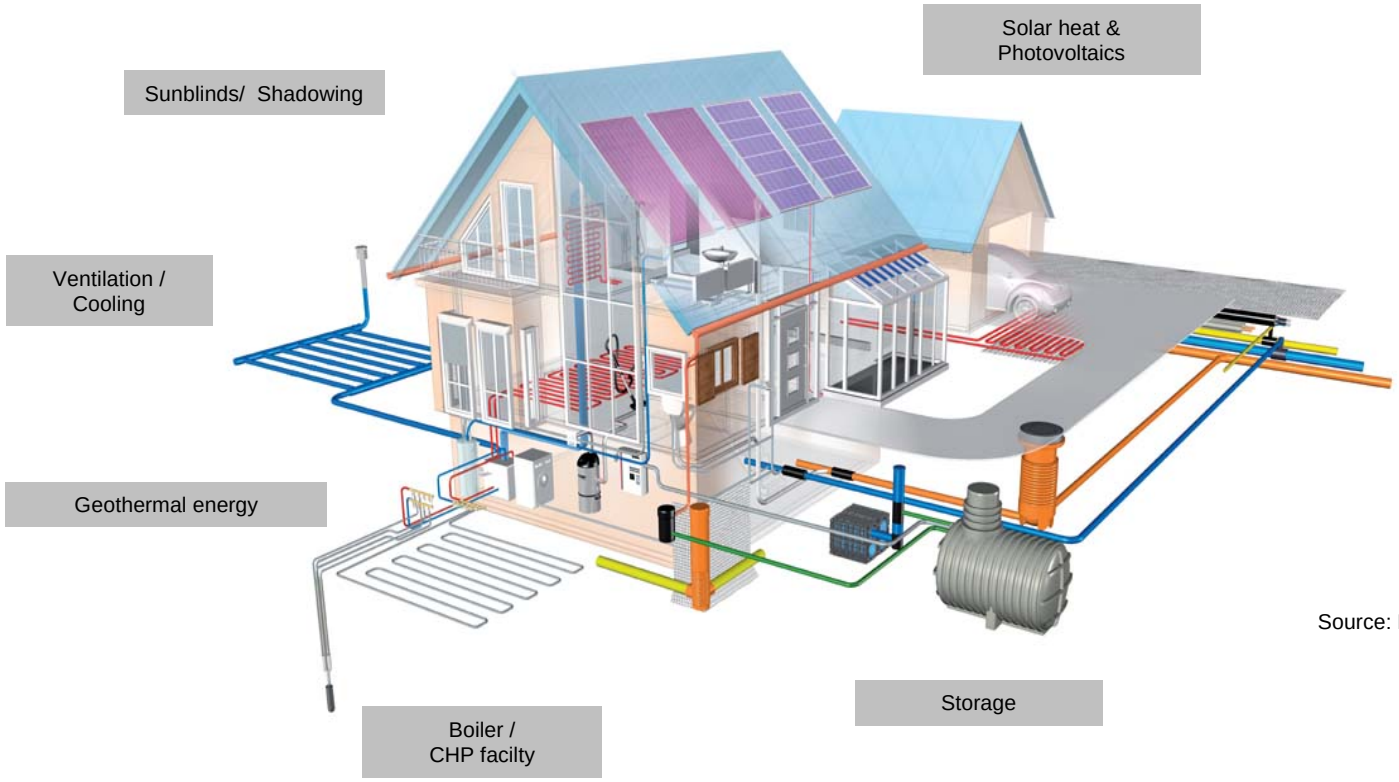
Required desert area for the sustainable supply of electricity

World 300 x 300 km²
EU-25 150 x 150 km²
Germany 50 x 50 km²



The Seven Cardinal Innovations

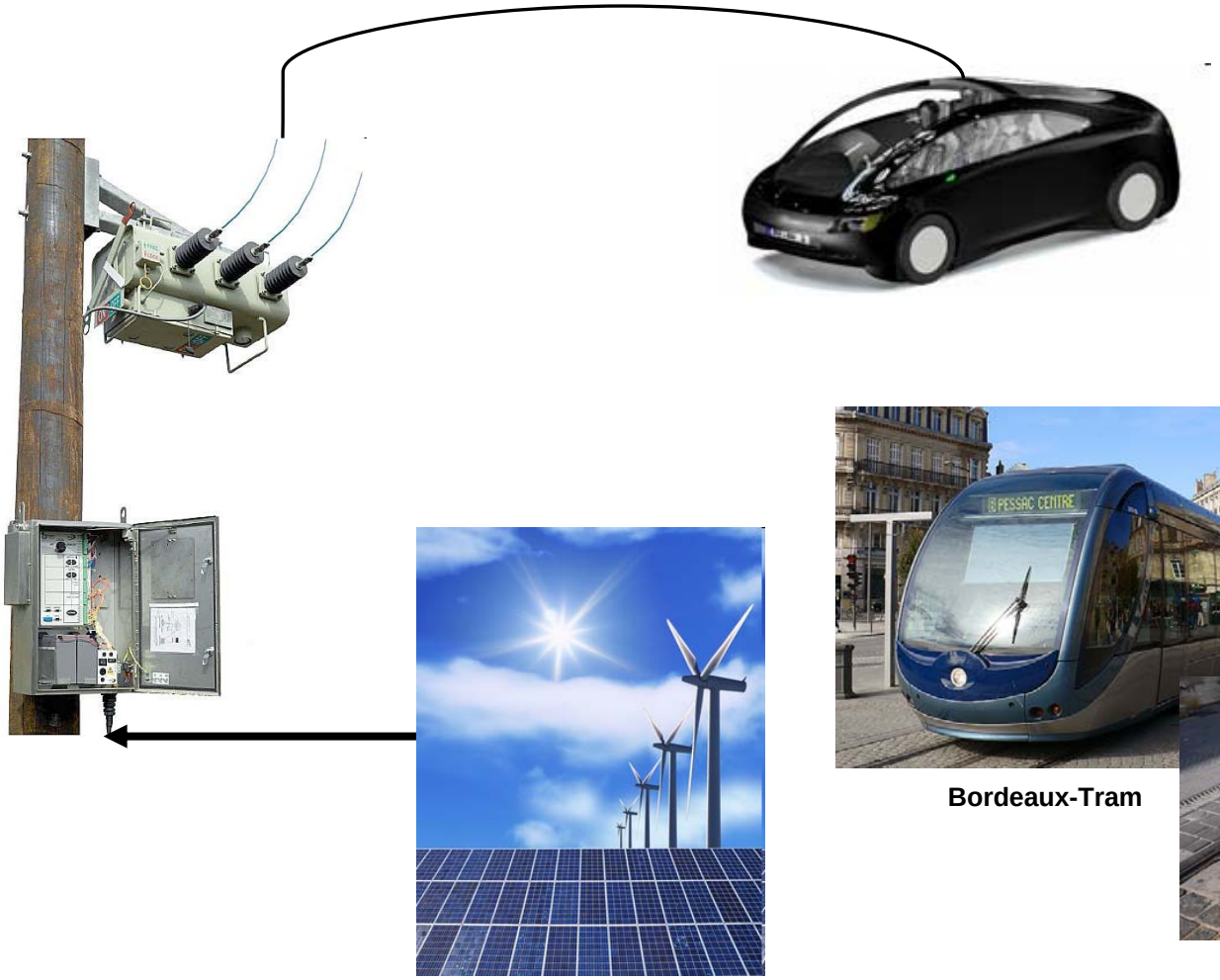
2. Plus-Energy House („Power Houses“)



Source: REHAU AG + Co.

The Seven Cardinal Innovations

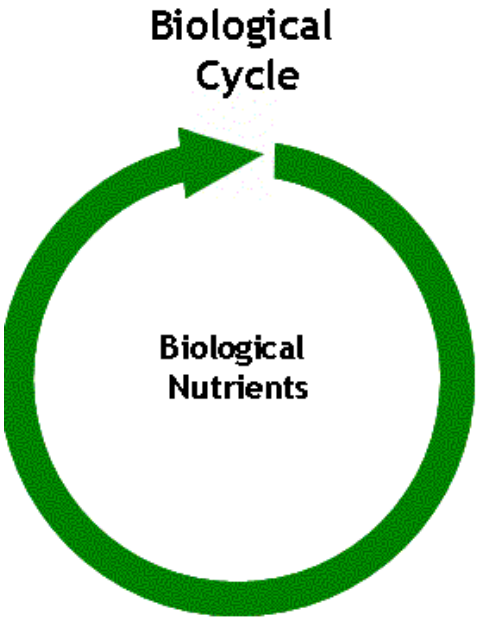
3. Modular E-Mobility („Beyond Storage“)

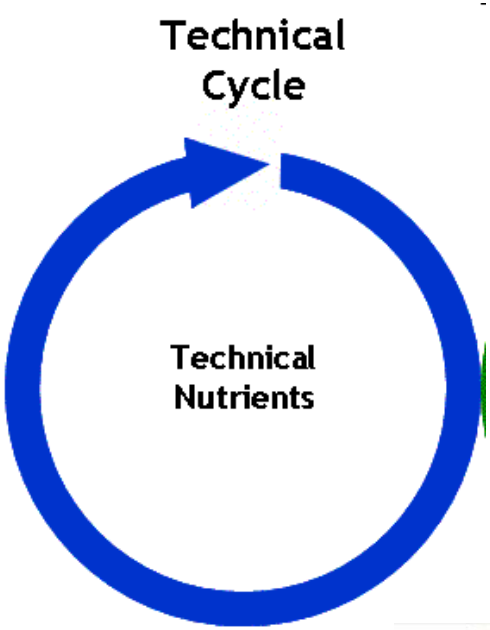


Bordeaux-Tram

The Seven Cardinal Innovations

4. Systems-optimized Industrial Production („Cradle to Cradle“)





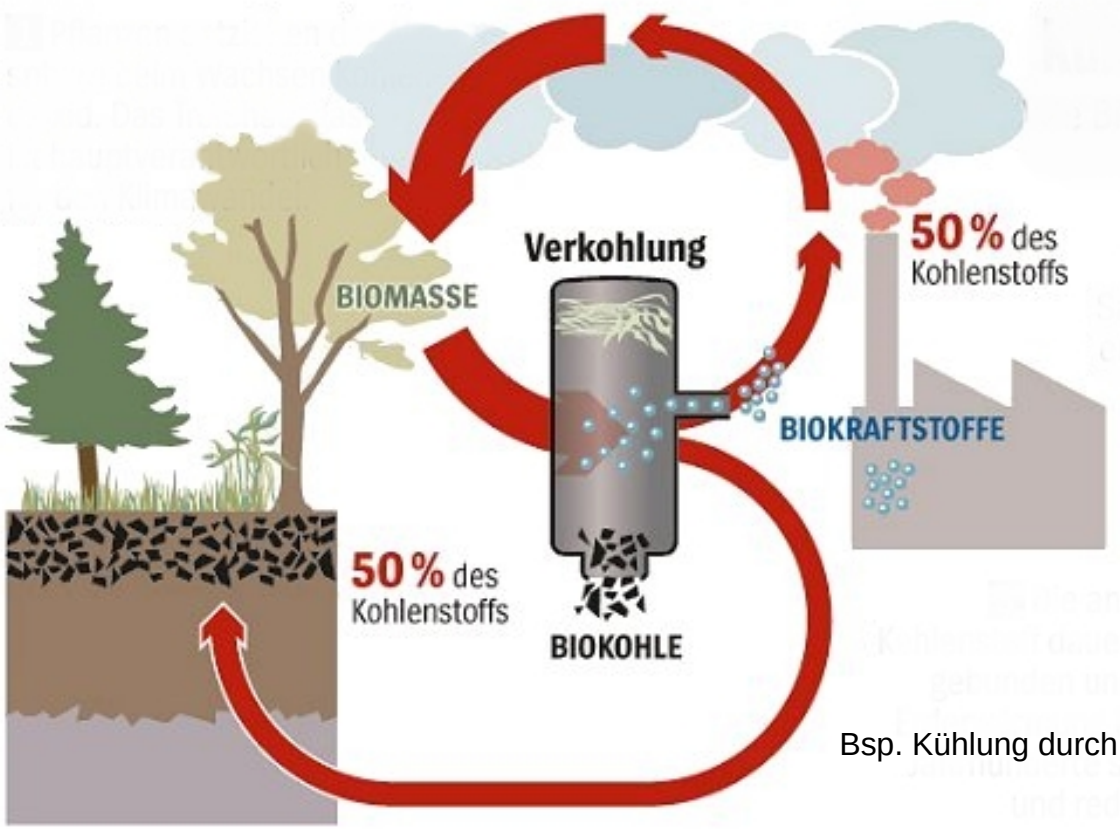
The Seven Cardinal Innovations

5. Holistic Urban and Regional Planning („Reinvention of Urbanity & Rurality“)

Vision for Masdar City

The Seven Cardinal Innovations

6. Sustainable Biomass Management („De- & Anti-Carbonisation“)



Bsp. Kühlung durch Biokohle

The Seven Cardinal Innovations

7. Regenerative Water Supply („Solar Desalination“)

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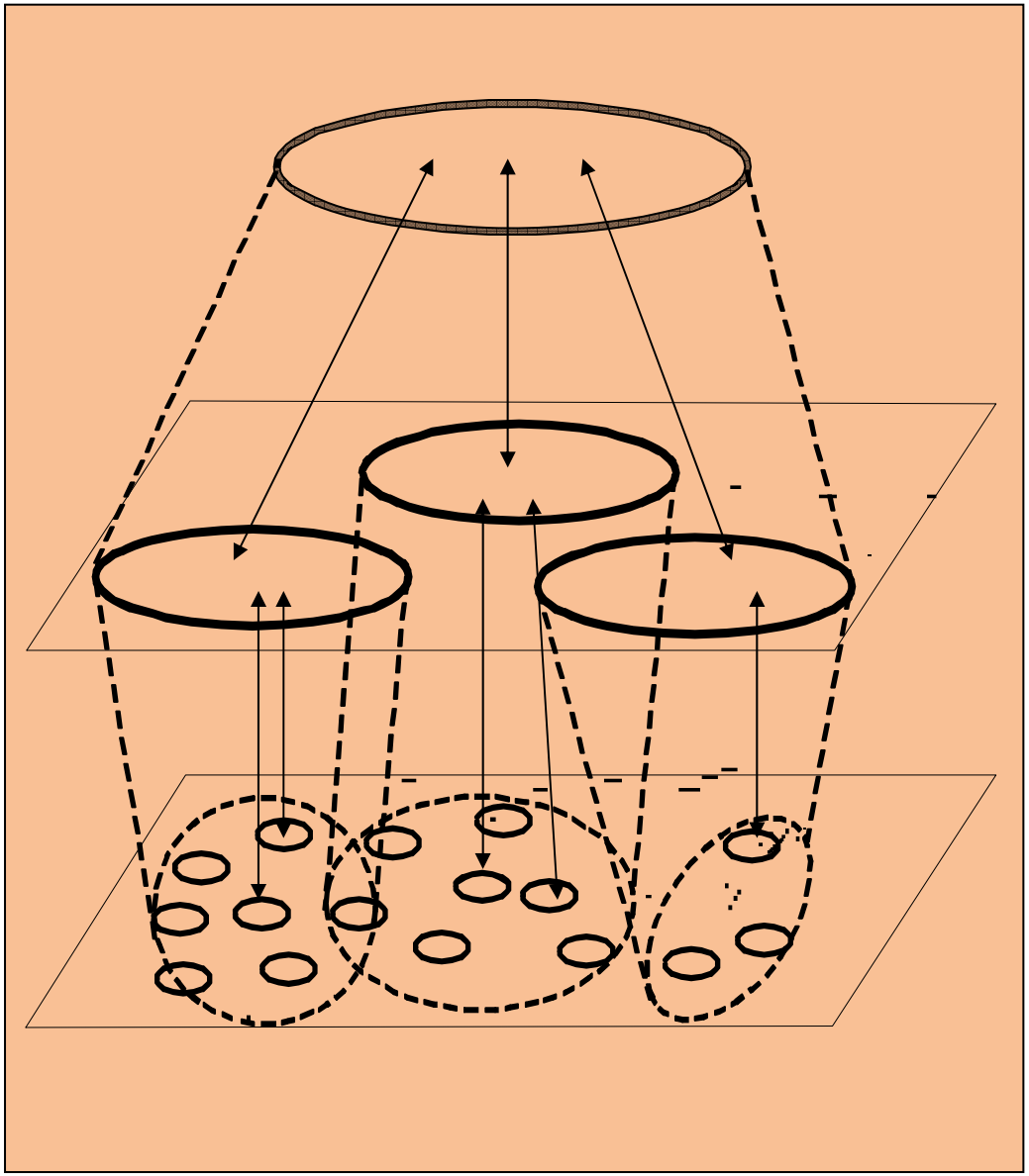
Multiple Levels



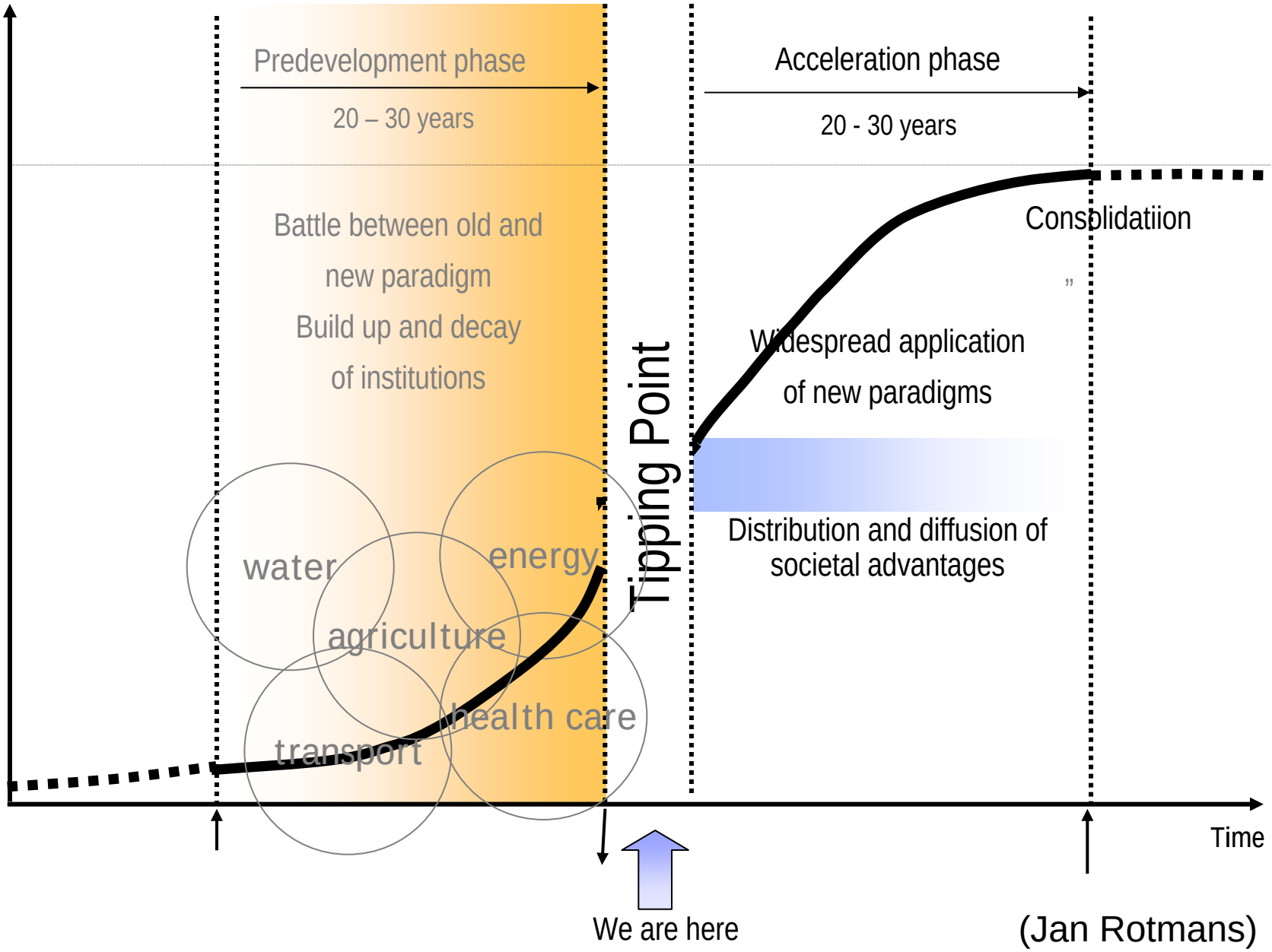
Macro-level
autonomous trends, paradigms, slow developments

Meso-level
regime: dominant structures, cultures and practices (but also niche regimes)

Micro-level
fast developments: innovative ideas, projects, techniques, niche actors

(Jan Rotmans)

Breakthrough to Sustainable Societies



Micro-Stimulation of Sustainability Transition

Illustration:

Cloud Seeding

Part B: International Climate Policy

1. The „Post-Copenhagen Syndrome“

2. The Budget Approach

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The Remains of COP 15

‘Copenhagen Accord‘

- 2°C-guardrail
- Pledge and review; submissions by 31 Jan 2010
- Financial commitments: “new and additional funding”; short-term (2010-12): USD 30 billion; long-term (by 2010): USD 100 billion per year
- Copenhagen Green Climate Fund
- Technology Mechanism

Formal Decision

Decision -/CP.15

The Conference of the Parties,

Takes note of the Copenhagen Accord of 18 December 2009.

Subscription Sheet

76 submitted their pledges

e.g., US submission; emissions reduction in 2020 (base year 2005):

„In the range of 17%, in conformity with anticipated U.S. energy and climate legislation, recognizing that the final target will be reported to the Secretariat in light of enacted legislation.” (Source: www.unfccc.org)

„Under the condition…“- pledges submitted to date

30% (1990), **provided that** other developed countries commit themselves to comparable emissions reductions and that developing countries contribute adequately according to their responsibilities and respective capabilities (EU)

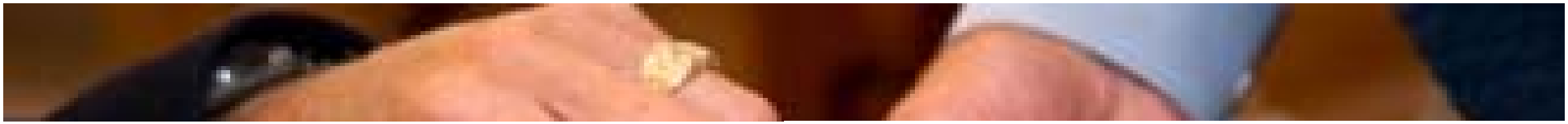
40 % (1990), **as part of a global and comprehensive agreement** for the period beyond 2012 where major emitting Parties agree on emissions reductions in line with the 2 degrees Celsius target (Norway)

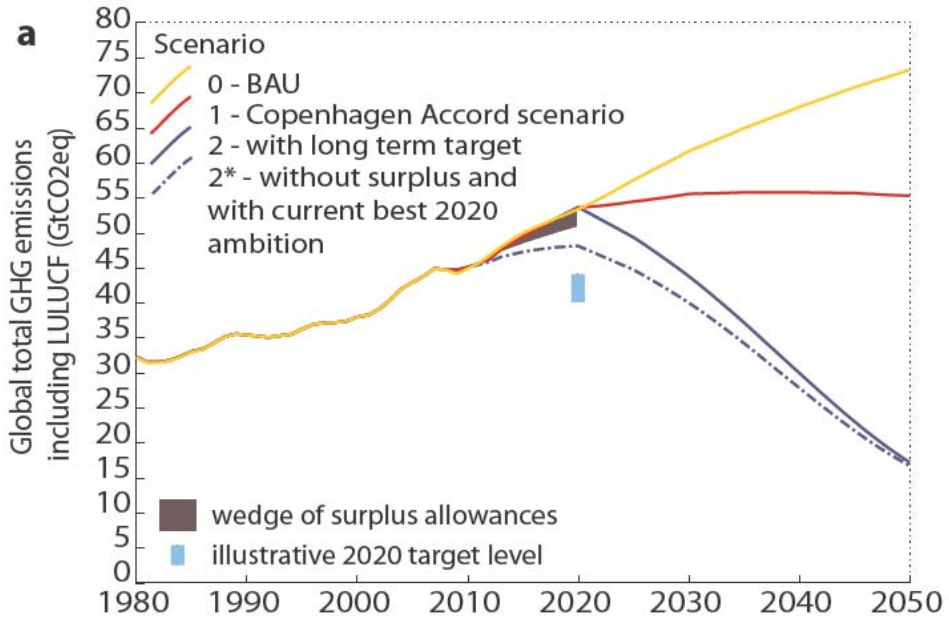
15 -20 % (1990), **under the following condition**: Undertaking by all major emitters the legally binding obligations to reduce anthropogenic GHG emissions (Russia)

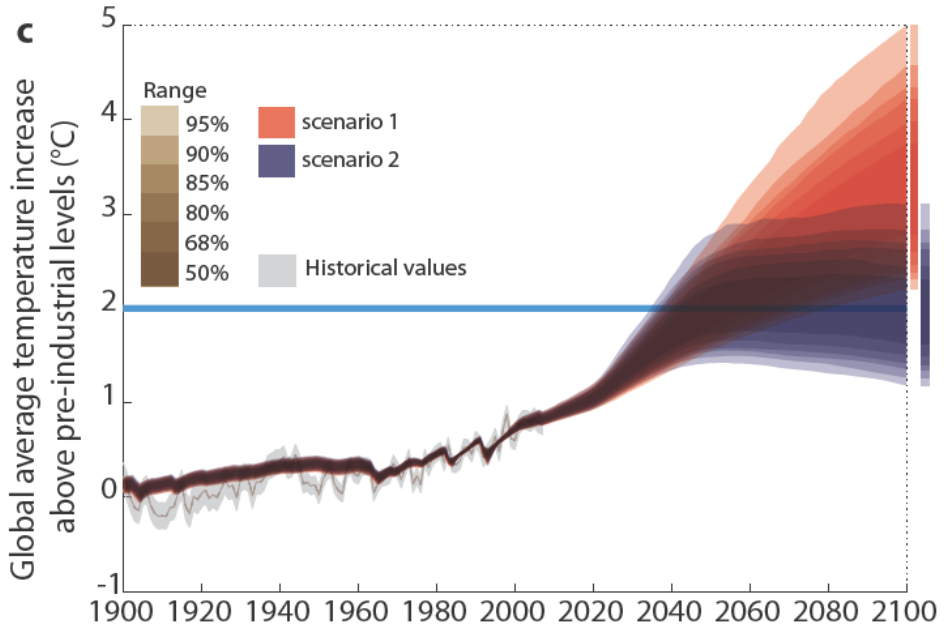
Achieve carbon neutrality as a country by 2020 (Maledives)

Copenhagen – What Ended Up on the Collection Plate?

Agreeing on 2°C, but heading for > 3°C







(Rogelj et al. Nature 2010)

Part B: International Climate Policy

1. The „Post-Copenhagen Syndrome“

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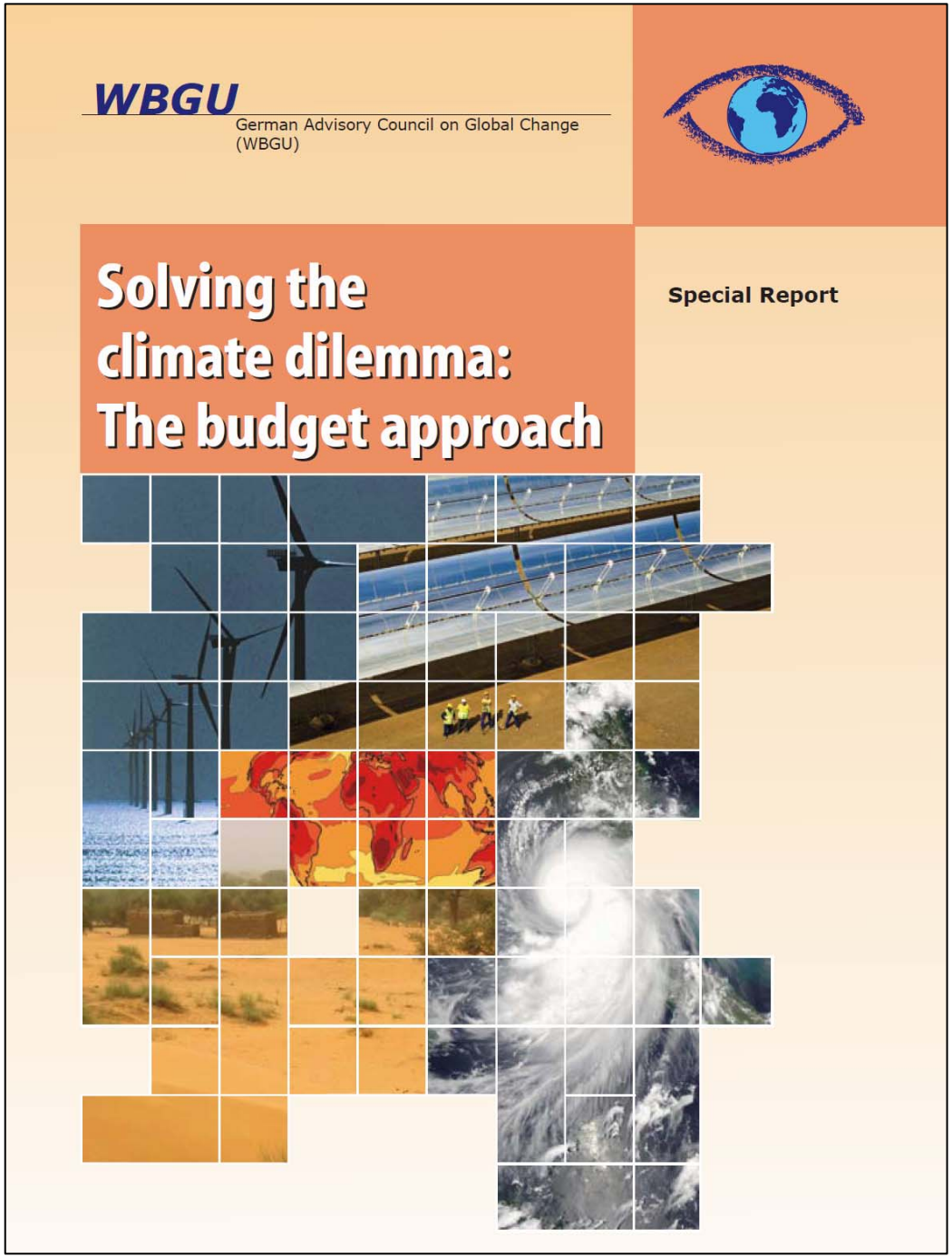

Keeping the Carbon Dose Sub- lethal

“World Formula” for Climate Policy

$$C_{glob}(p) = \int_{T_1}^{T_2} E_{glob}(t)dt$$

Total global CO_2 budget in period $[T_1,T_2]$ that keeps global warming below 2°C with probability p

Integral over global profile of CO_2 emissions

$$C_{nat} = \int_{T_1}^{T_2} E_{nat}(t)dt = C_{glob}(p)\frac{M_{nat}(T_M)}{M_{glob}(T_M)}$$

National CO_2 budget in $[T_1,T_2]$

Integral over national emission profile

Fraction of global CO_2 budget as determined by ratio of national population M_{nat} to world population M_{glob} at time T_M

“World Formula” for Climate Policy

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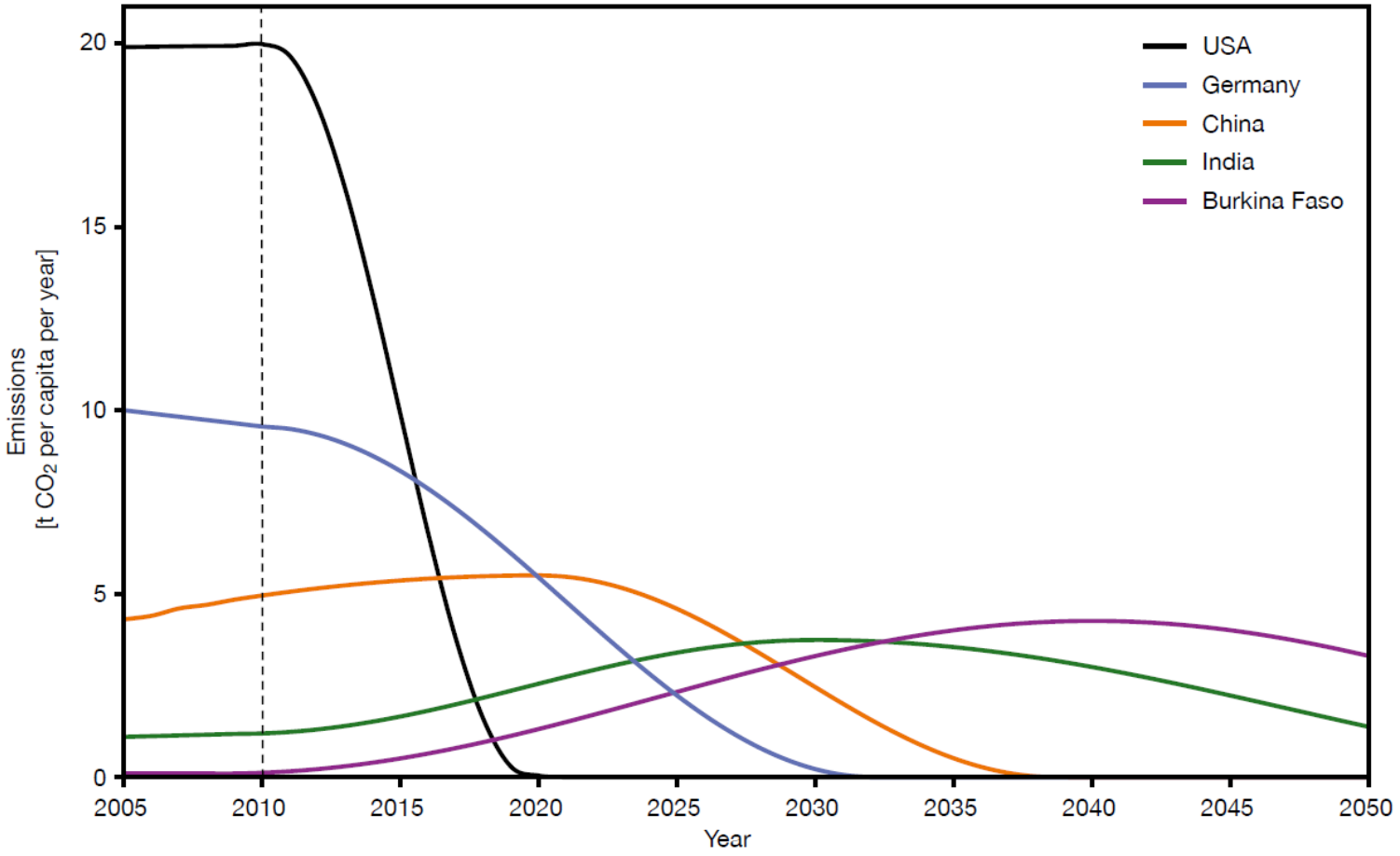
National CO_2 budget in $[T_1,T_2]$

Integral over national emission profile

Fraction of global CO_2 budget as determined by ratio of national population M_{nat} to world population M_{glob} at time T_M

Four political parameters

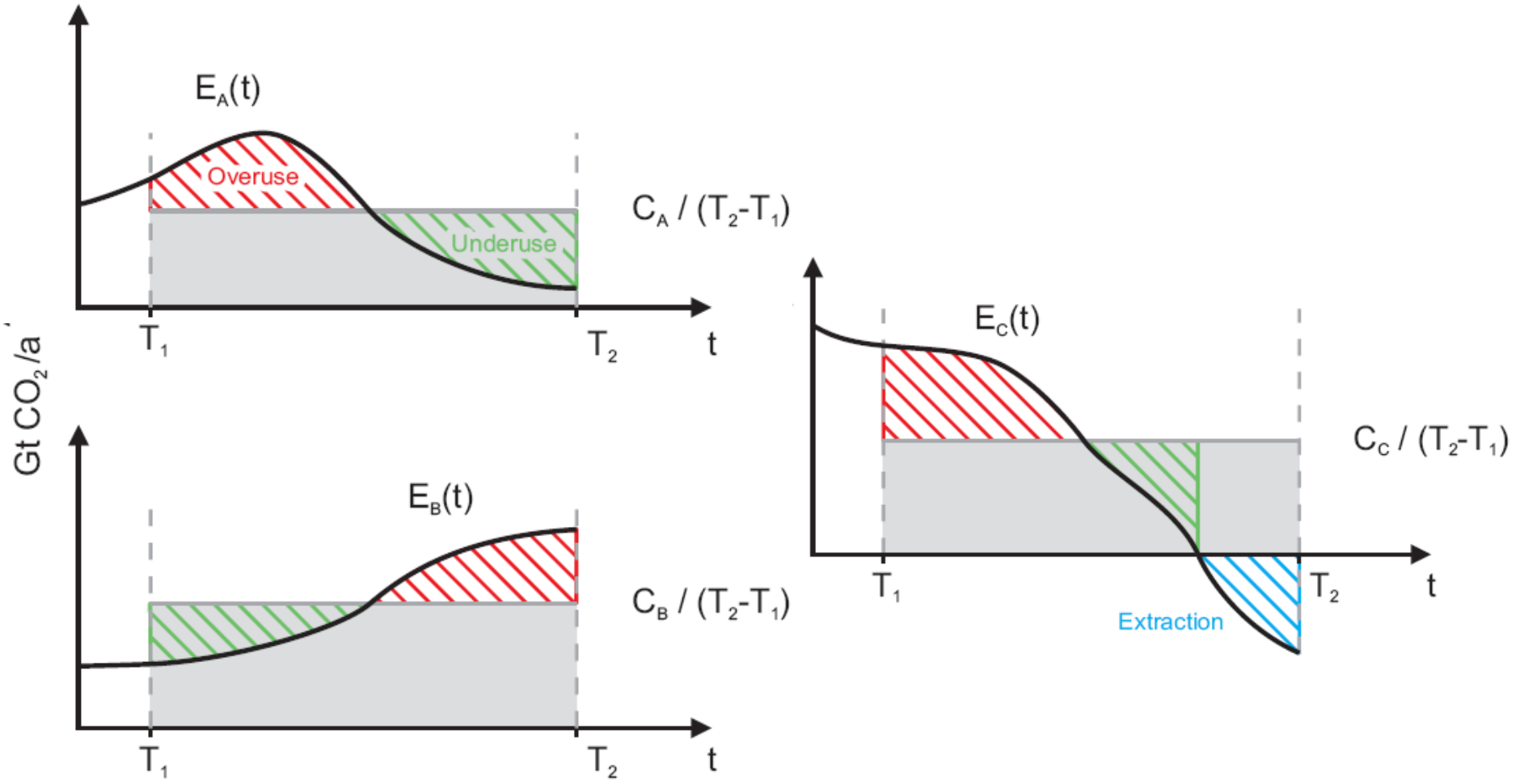
Examples of Theoretical Emissions Trajectories



Examples of equal per-capita emissions of selected countries for 2010–2050, without emissions trading. Trajectories start from current emission levels.

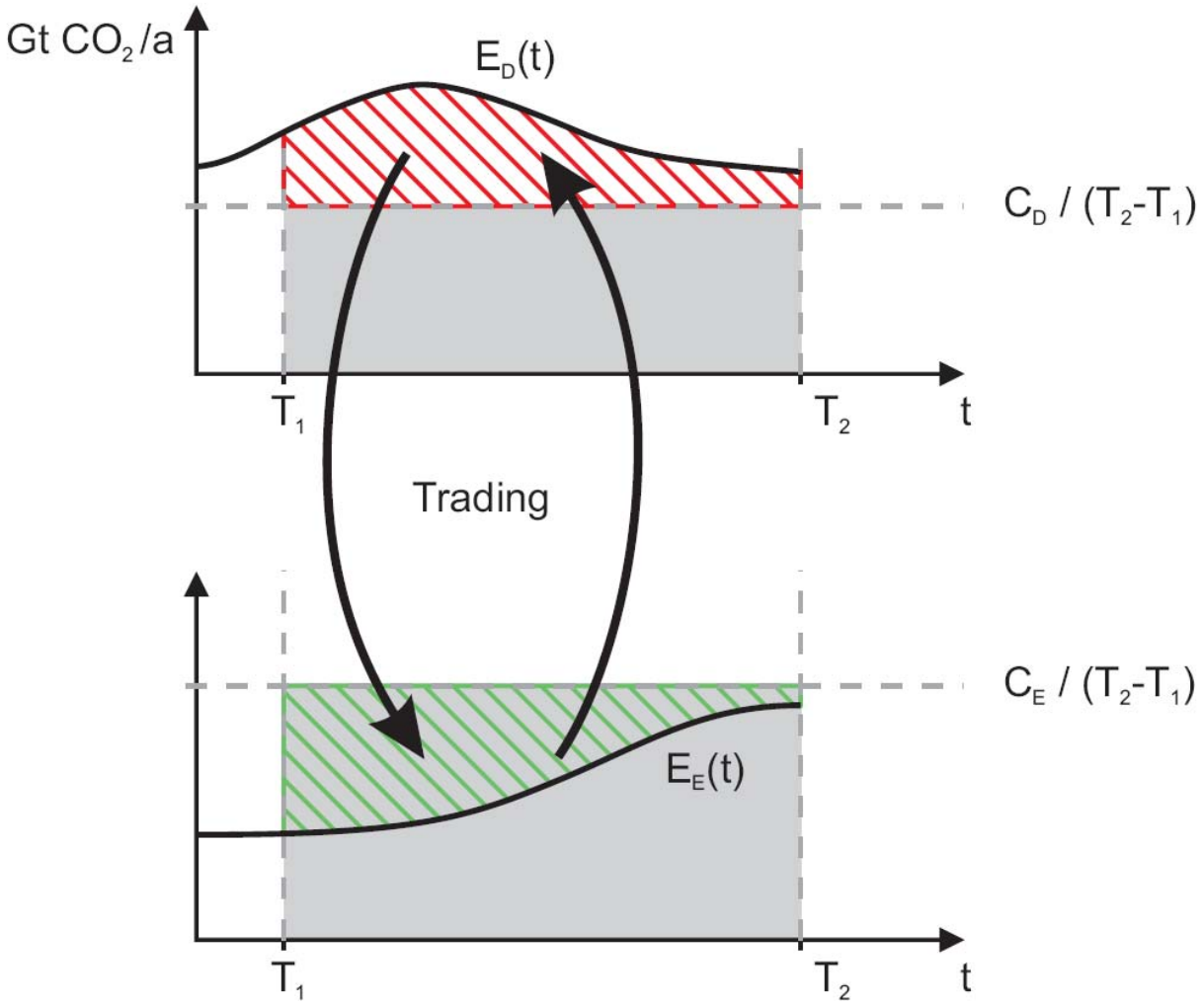
(WBGU Special Report, 2009)

Inter-Temporal Flexibility



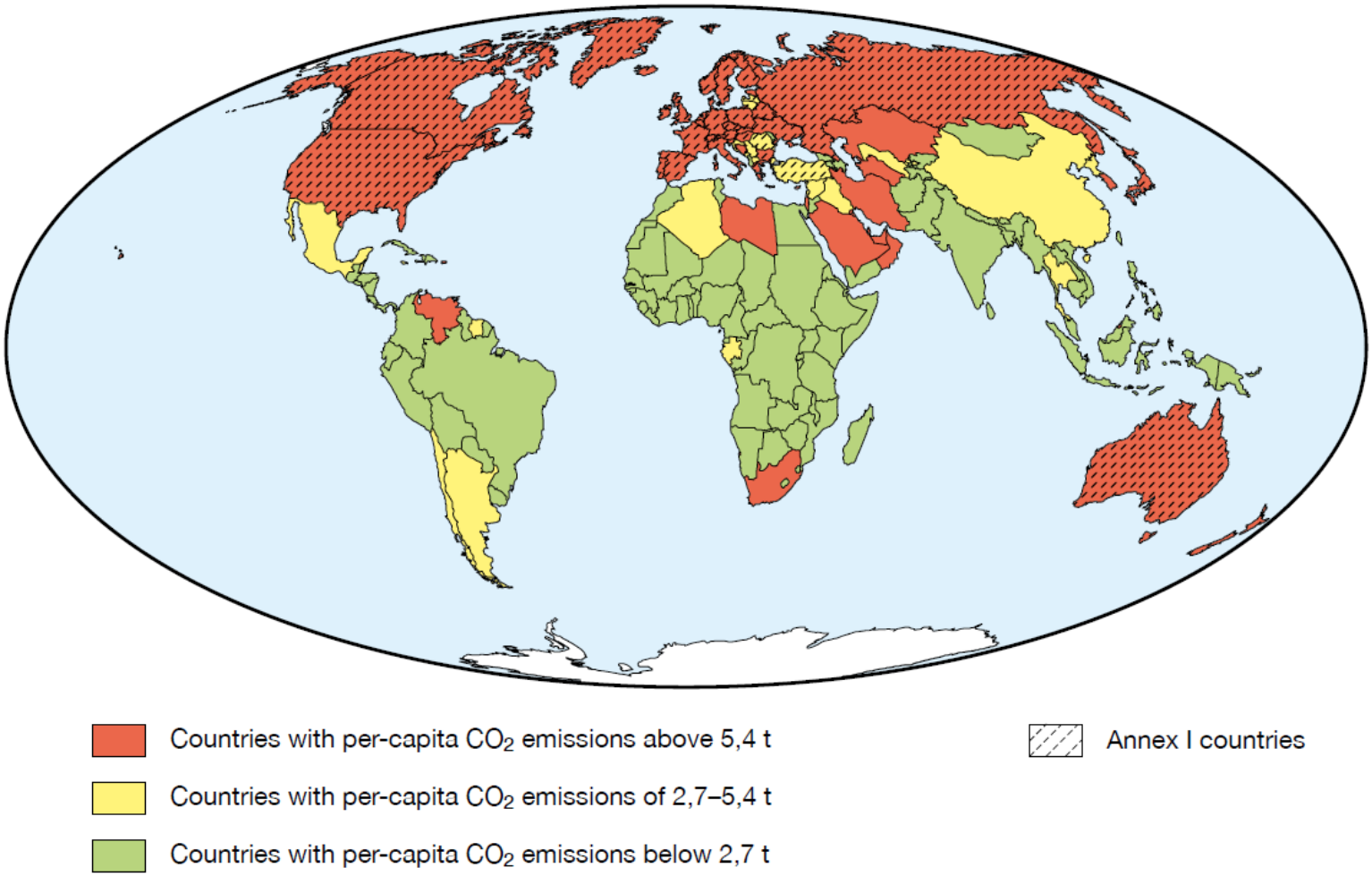
National emission profiles respecting national CO_2 budgets.

Inter-Regional Flexibility



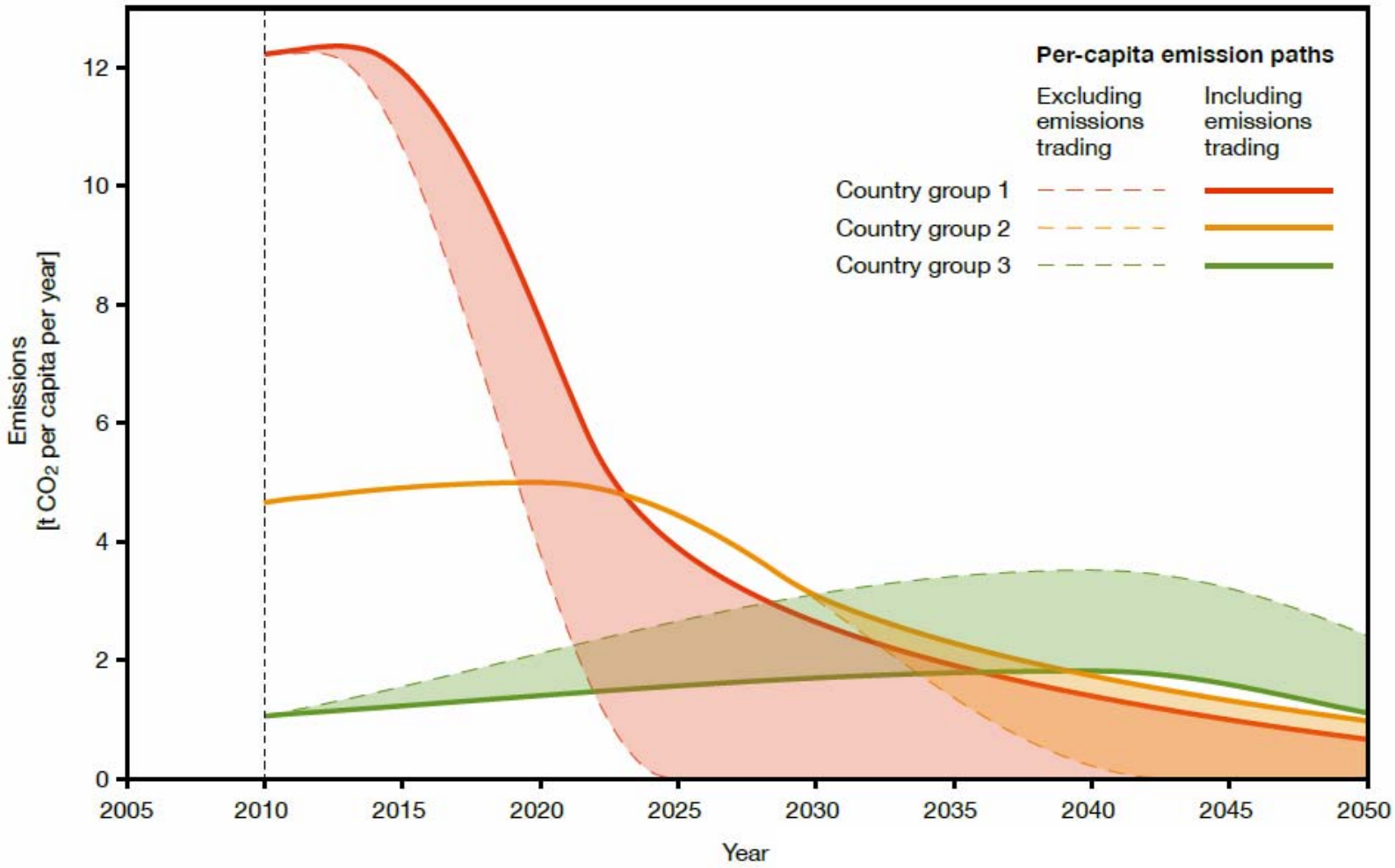
Exemplary emissions trading between two countries D and E.

CO_2 Emissions by Country



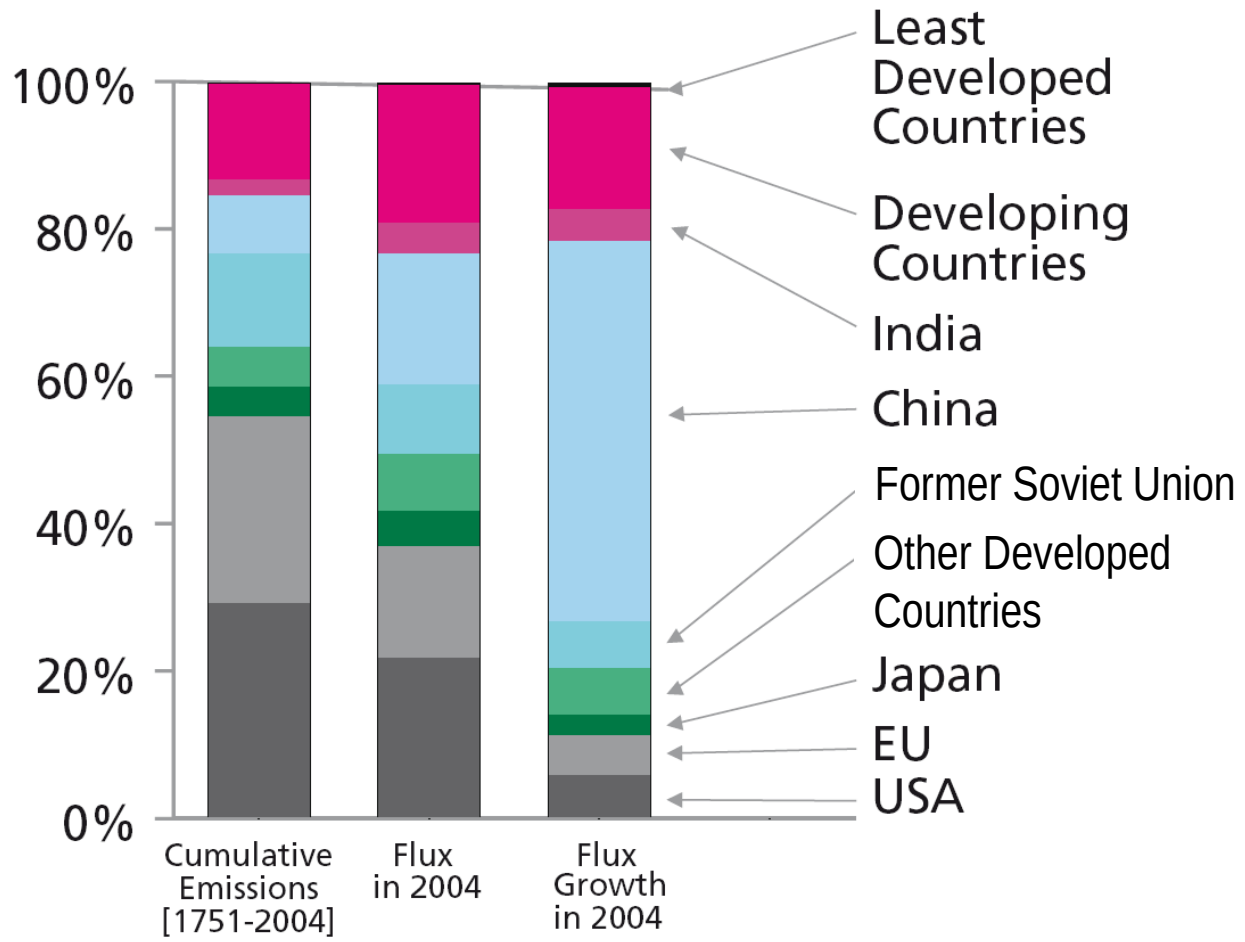
Per-capita CO_2 emissions in 2005, differentiated by emission levels and country.

Examples of Per-Capita Emissions Paths of CO_2 for Three Groups of Countries *with* and *without Emissions Trading*



(WBGU Special Report 2009)

Stocks and Flows Problem

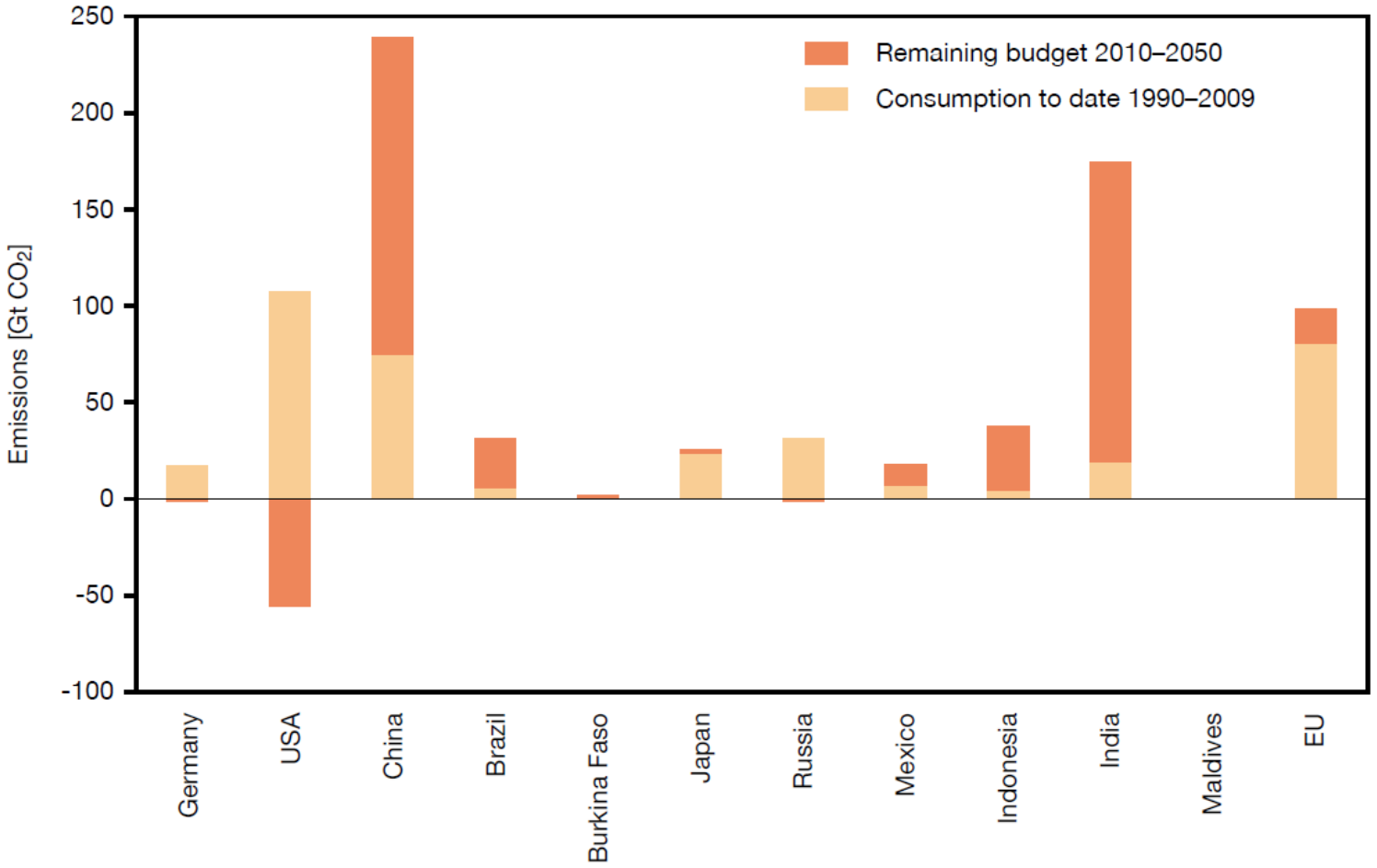


Stocks are dominated by the historical emissions from developed countries.
The rate of increase in emissions (flows) is dominated by developing countries.

(Figure 11 Synthesis Report)

Allocation Scenario Historical Responsibility

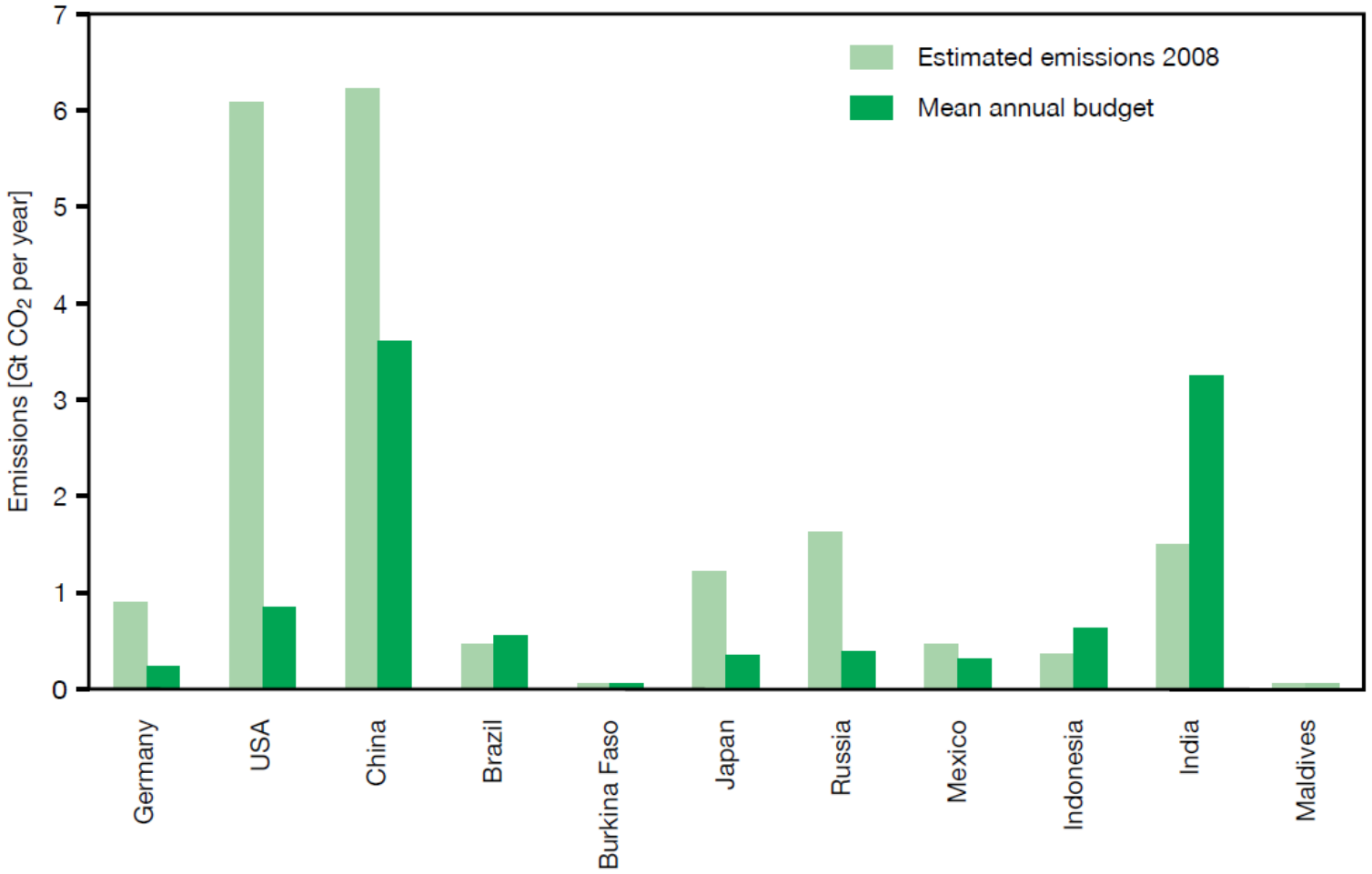
T_1 = 1990, T_2 = 2050, T_M = 1990, p = 3/4



Allocated budgets of CO_2 for 1990 – 2050 for selected countries, differentiated into already consumed portion (light color) and remaining budget (dark color).

Allocation Scenario: Future Responsibility

T_1 = 2010, T_2 = 2050, T_M = 2010, p = 2/3



CO_2 emissions in 2008 (light green) and permissible average annual budgets (dark green) according to the WBGU approach for selected countries.

Part B: International Climate Policy

1. The „Post-Copenhagen Syndrome“

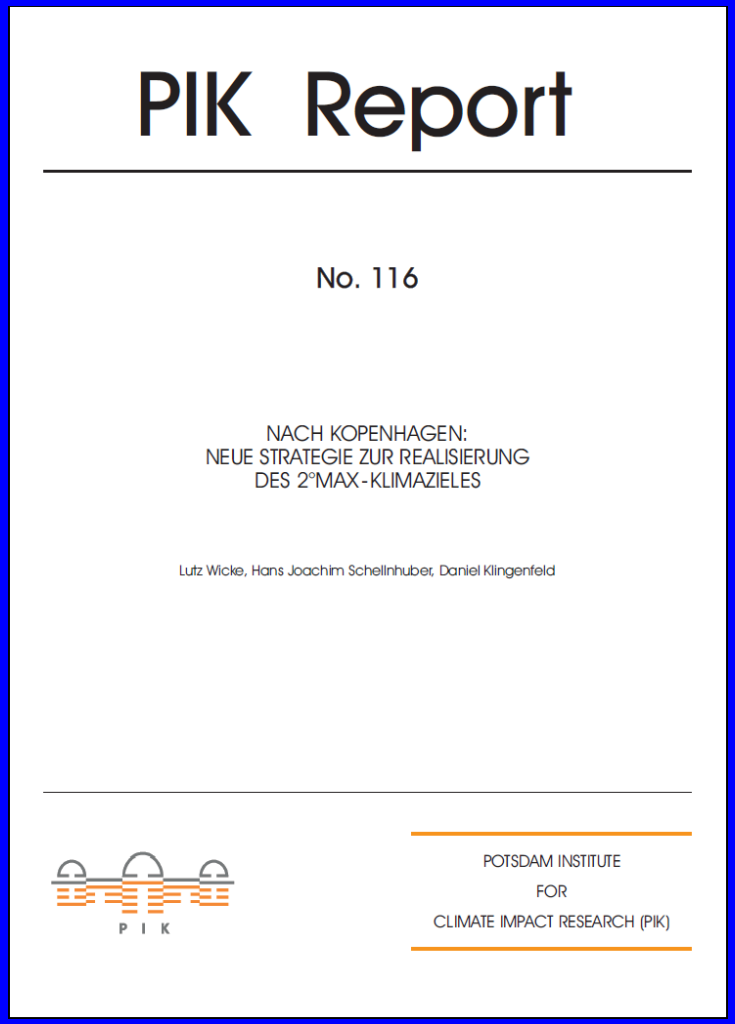
2. The Budget Approach

3. More Pragmatic Approaches

4. Beyond CO2

2°max – A Pragmatic Way Forward

- **A fixed, *global* emissions limit compatible with the 2°C guard rail: Emissions peak of 35 Gt CO_2 in 2015, stabilization phase and stepwise reduction**
- **Allocation principle "one human-one emissions right": Active participation of developing countries**
- **A global price for CO_2 by means of a global "Peak and Trade" emissions trading scheme targeting upstream carbon sources**
- **Integrated support and redistribution mechanisms to advance sustainable, low-carbon development while seeking a "balance of interests" among different country positions**



PIK Report

No. 116

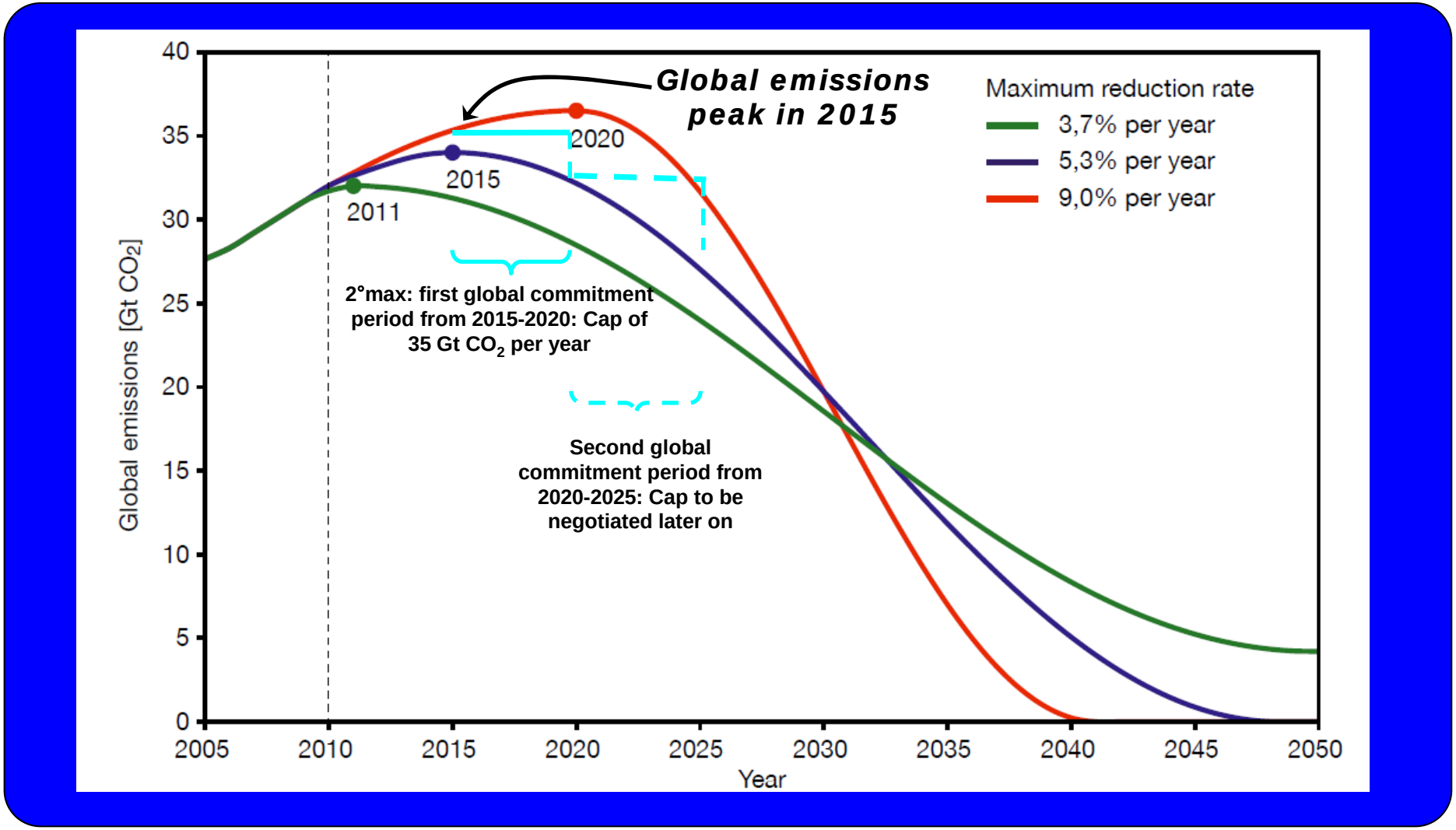
NACH KOPENHAGEN:
NEUE STRATEGIE ZUR REALISIERUNG
DES 2°MAX-KLIMAZIELES

Lutz Wicke, Hans Joachim Schellnhuber, Daniel Klingenfeld

P I K

POTSDAM INSTITUTE
FOR
CLIMATE IMPACT RESEARCH (PIK)

2°max – A Pragmatic Way Forward



Key Elements of More Pragmatic Approaches

Design Criteria	R.N. Stavins: „Comprehensive US Cap-and-Trade System“	J. Frankel: „Specific Formulas and Emission Targets for All Countries in All Decades“	L. Wicke et al.: „2°C max Strategy“	D. Klingenfeld: „Modular Carbon Market“
Main Policy Instrument	• Economy-wide cap-and-trade	• Global cap-and-trade scheme	• Global cap-and-trade scheme	• Modular cap-and-trade scheme
Point of Regulation/ Emissions Coverage	• Upstream/ Full coverage	• Not defined	• Upstream/ Full coverage	• Upstream/ Full Coverage
Key Features	• Increasing share of auctioned emissions allowances • High safety valve • Provisions for linking in order to raise overall efficiency in emissions abatement	• Six political constraints to derive national emissions budgets • Projected concentration outcomes of 500 ppm CO_2 and 460 ppm CO_2 by 2100 depending on level of constraint	• Initial equal-per-capita allocation; low, negotiated allowance transfer price among countries • Free certificate market among companies: one CO_2 price worldwide • Redistributive components	• Coalition of countries (rich and poor) as pioneers of an expanding global system • Full auctioning • Burden sharing via redistribution of auction proceeds among participants: any distributional principle possible

The WBGU Policy Paper

WBGU
German Advisory Council on Global Change

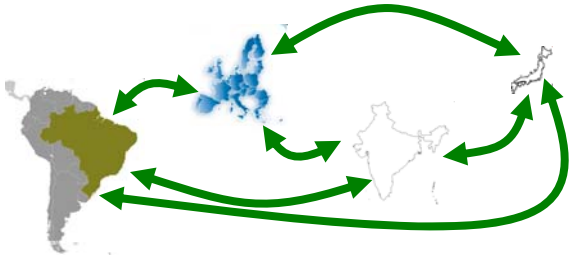
Policy Paper

Climate Policy Post-Copenhagen
A Three-Level Strategy for Success

6

Improving the UNFCCC process

Forming new multi-lateral climate partnerships and European leadership



Supporting „bottom-up“ climate actions in civil society

Sub-global Alliances of Climate Pioneers

WBGU
German Advisory Council on Global Change

Policy Paper

Alliances based on thematic areas, e.g.

- Forest Conservation
- Infrastructural Development
- Improving Energy Efficiency
- Expansion of Renewables

Part B: International Climate Policy

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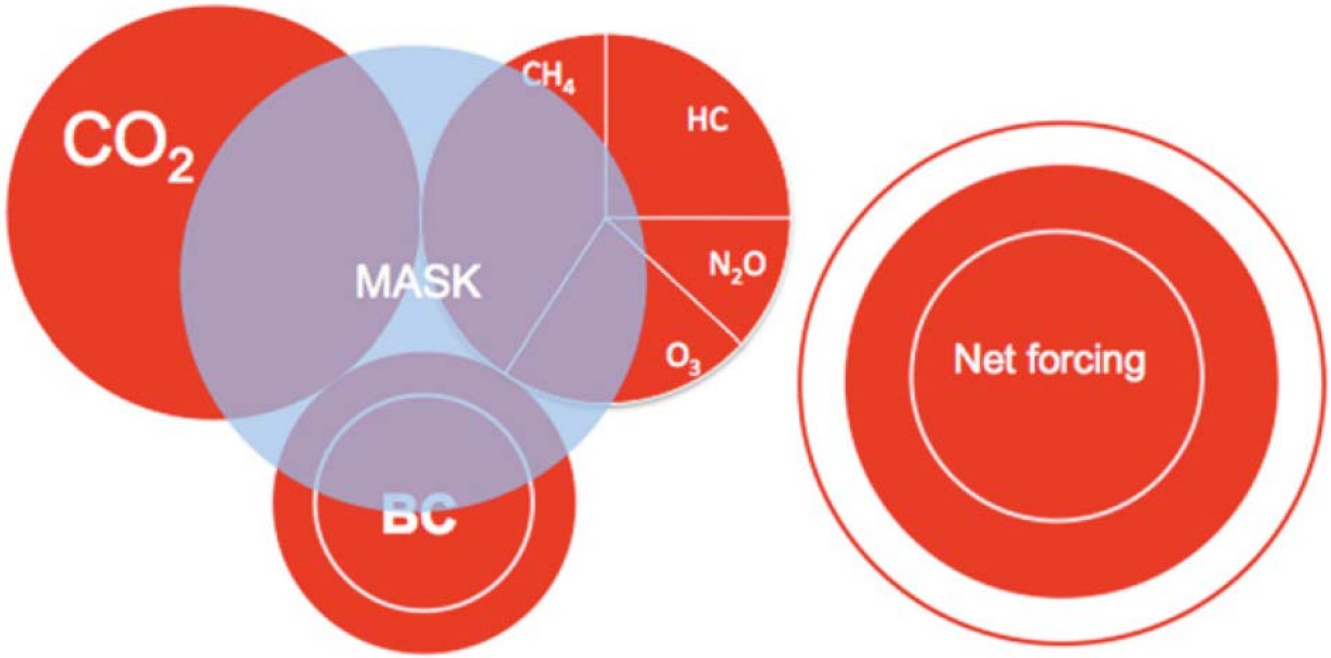
From the Carbon Budget to the Radiant Energy Budget



„Avenues for Managing the Watts“

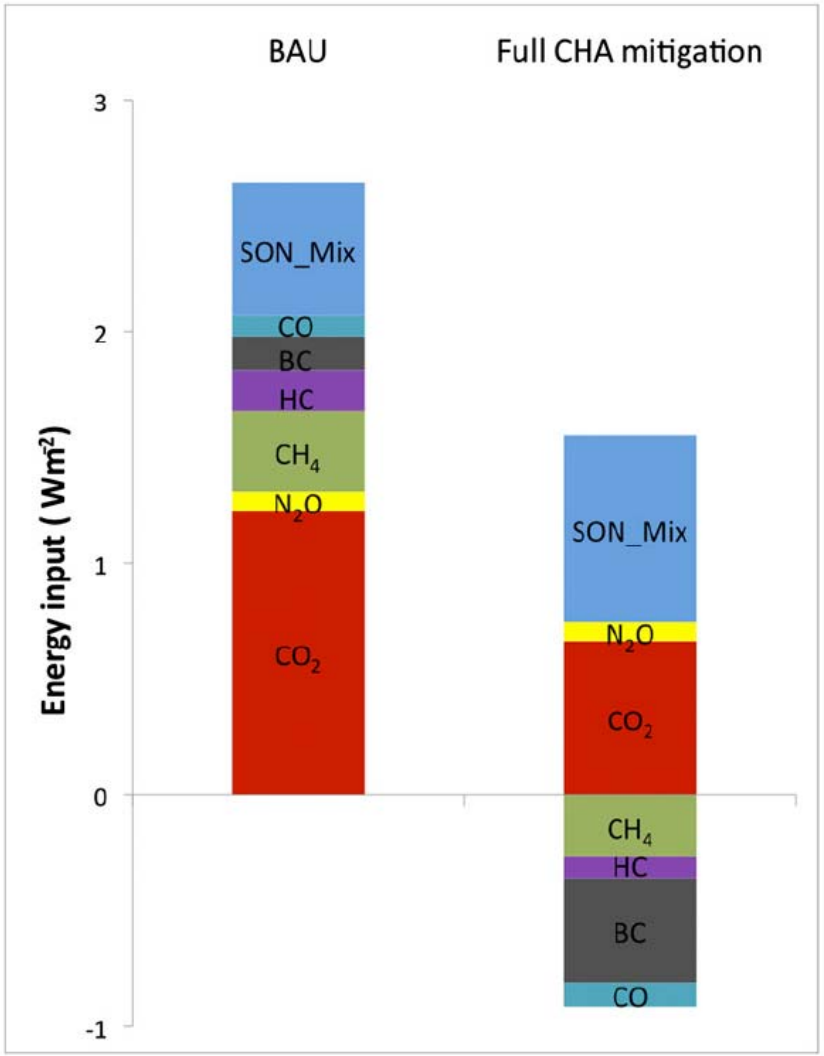
i. Reduce CO_2-emissions according to the carbon budget approach

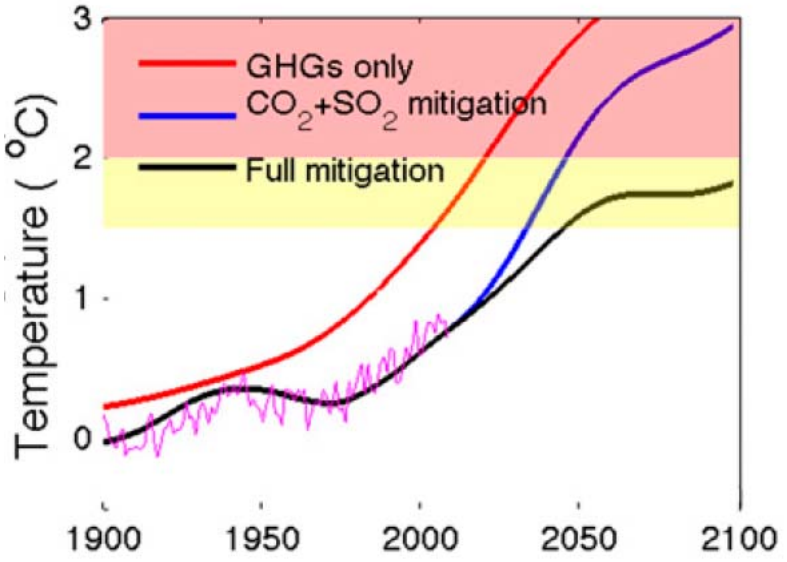
ii. Offset warming from the reduction of aerosol masking, i.e. reduce black carbon (BC), tropospheric ozone (O_3)

iii. Reduce emissions of short-lived greenhouse gases methane (CH_4) and halocarbons (HC)

(Ramanathan & Xu 2010 PNAS)

Radiant Energy Budget – Mitigation Scenarios



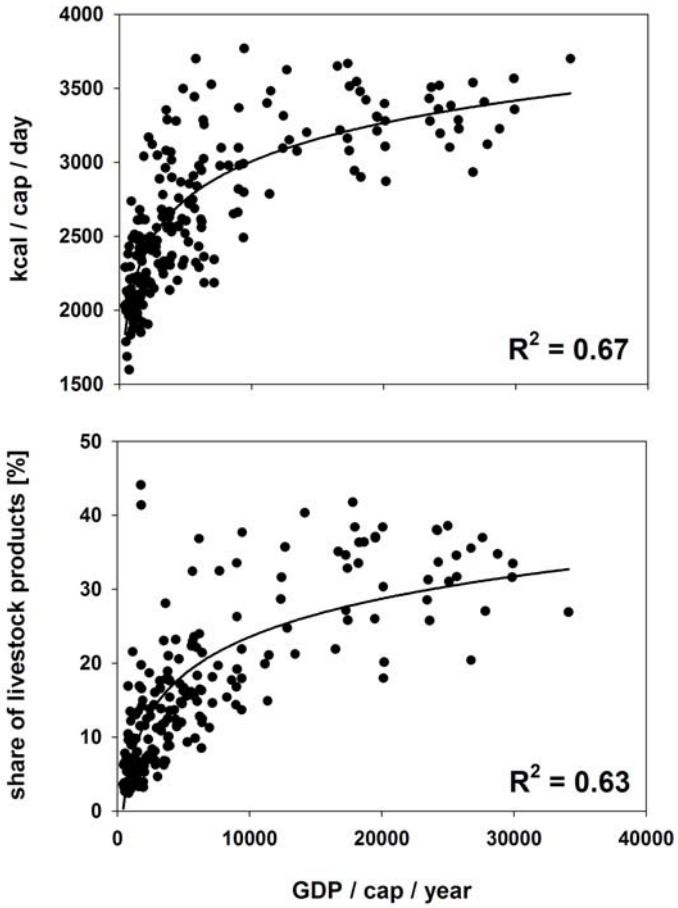


Full mitigation:

< 50% probability of exceeding 2 °C before 2100

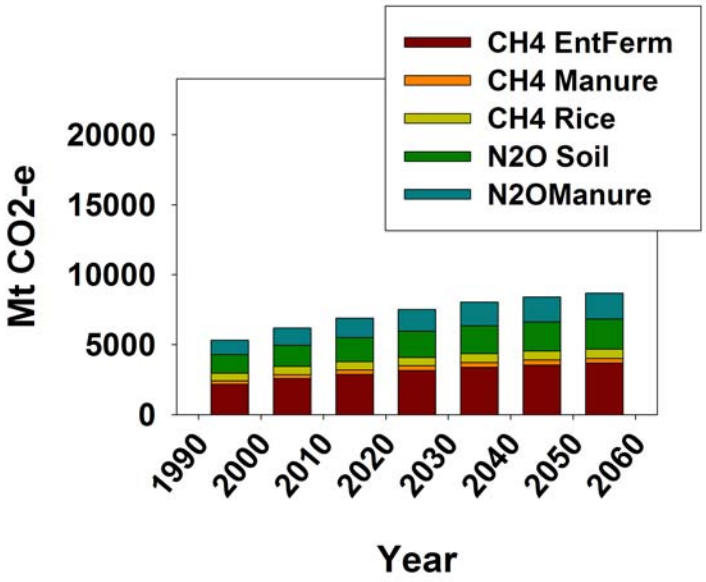
(Ramanathan & Xu 2010 PNAS)

Diet Shifts and Non-CO_2 GHGs from Agricultural Production



BAU: constant share of animal products in human diets

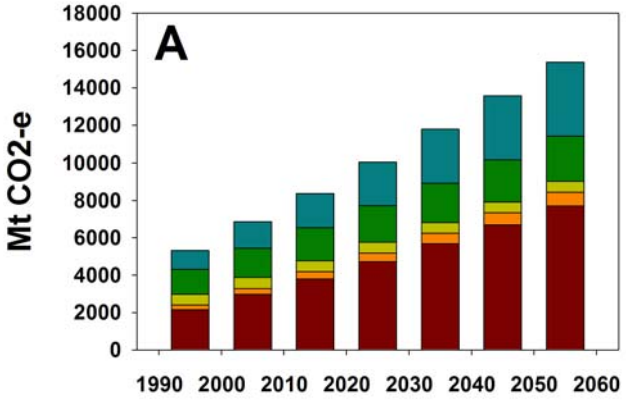
63% increase of CO2-e by 2055, compared to 1995



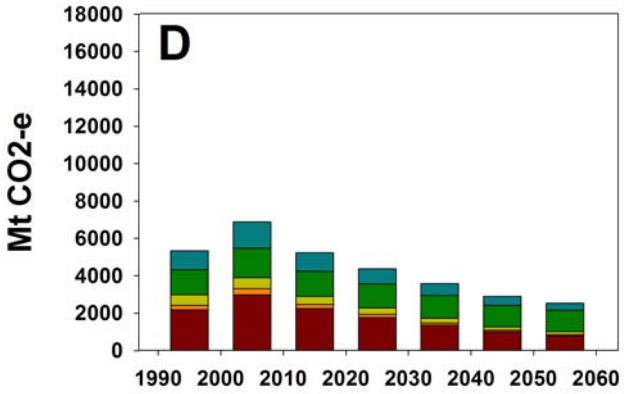
(Popp et al. 2010 Global Environmental Change)

Scope of agricultural methane and nitrous oxide emission reductions

Increased meat scenario

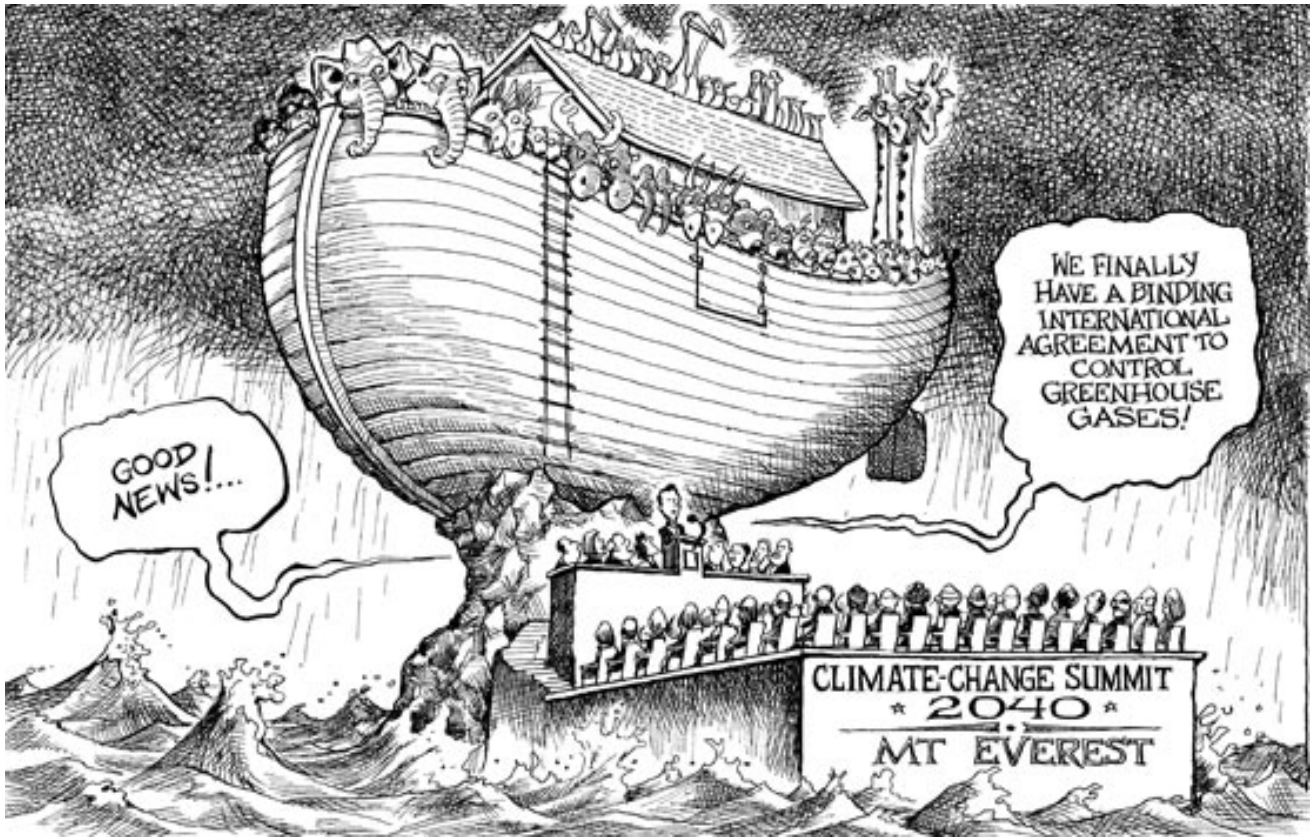


Decreased meat scenario
+ technical mitigation



When taking the link between GDP and food energy demand and the share of livestock products in total caloric intake into account projected methane and nitrous oxide emissions from agricultural production can be cut by more than 80% by 2055.

(Popp et al. 2010 Global Environmental Change)



Questions? Comments?