Wissenschaftliche Aussprache zur Dissertation

Achieving stringent climate targets: An analysis of the role of transport and variable renewable energies using energy-economy-climate models

vorgelegt von

Diplom-Physiker

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der Technischen Universität Berlin

zur Erlangung des akademischen Grades

Doktor der Wirtschaftswissenschaften

Dr. rer. oec.

Berlin, den 21. Oktober 2014

Premises

*"**Human influence on the climate system is clear**. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system"*

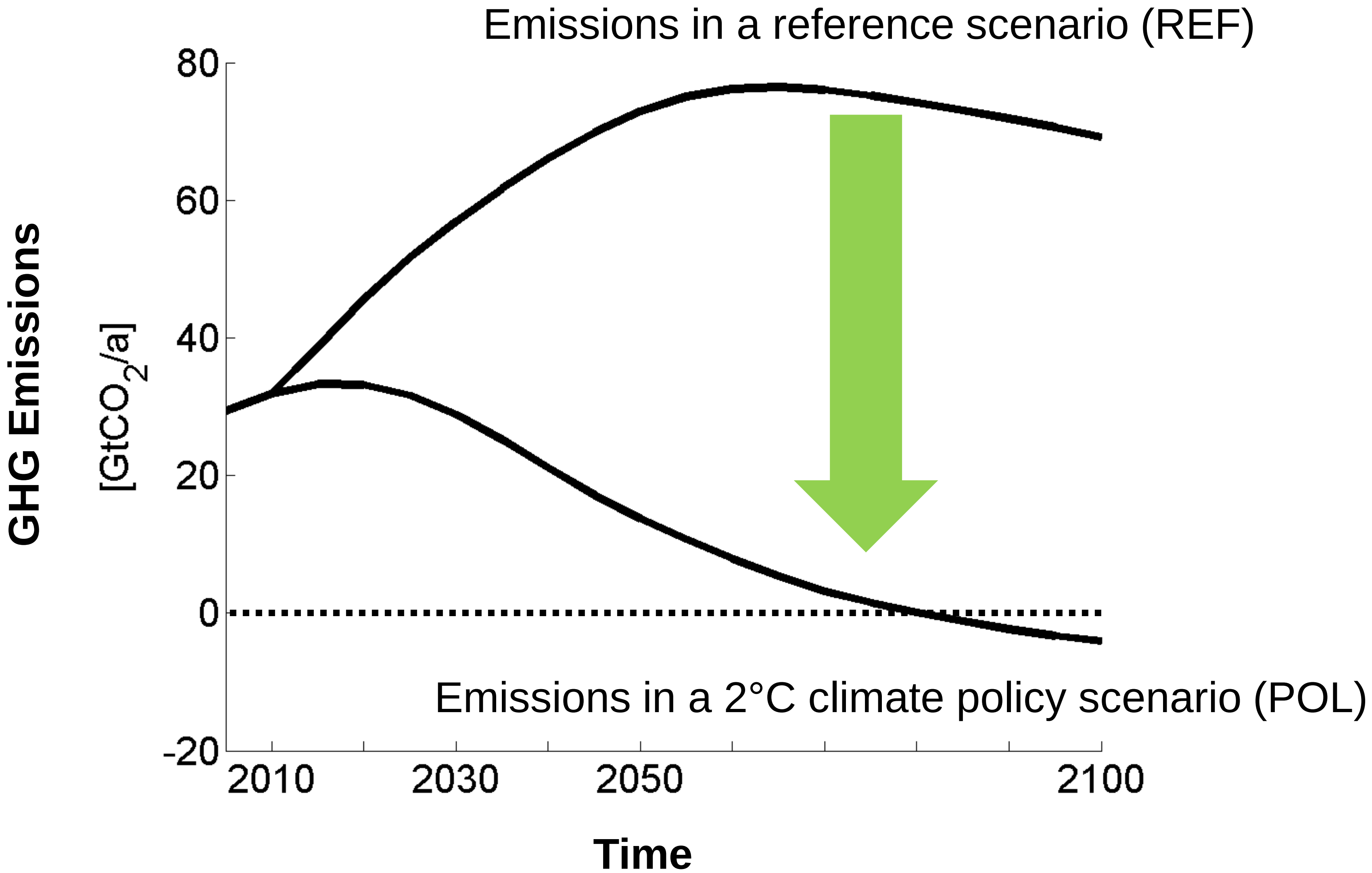
AR5, IPCC 2014

*"The **ultimate objective** of this Convention […] is to achieve […] stabilization of greenhouse gas concentrations in the atmosphere at a level that would **prevent dangerous anthropogenic interference** with the **climate system**"*

(UNFCCC Secretariat, 1992)

Integrated Assessment Models (IAMs) are useful tools to determine key actions and critical bottlenecks for emission reductions

Scope of the challenge to achieve 2°C target



Are stringent climate targets achievable, and what determines their achievability?

Thesis Structure

Achievability of stringent climate targets

5 What are economic costs and challenges of different climate targets?

Variable Renewable Energies

3 How important is solar for power sector decarbonization?

2 What do different IAMs say about the role of renewable energies for climate change mitigation?

Transport

4 How can transport be decarbonized?

Achievability of stringent climate targets

1 What are key sectors and technologies for climate change mitigation?

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Achievability of stringent climate targets

5 Luderer, **Pietzcker**, Bertram, Kriegler, Meinshausen, Edenhofer

Environmental Research Letters (2013)

Variable Renewable Energies

3 **Pietzcker**, Stetter, Manger, Luderer

Applied Energy (2014)

2 Luderer, Krey, Calvin, Merrick, Mima, **Pietzcker**, van Vliet, Wada

Climatic Change (2014)

Transport

4 **Pietzcker**, Longden, Chen, Fu, Kriegler, Kyle, Luderer

Energy (2014)

Achievability of stringent climate targets

1 Luderer, **Pietzcker**, Kriegler, Haller, Bauer

Energy Economics (2013)

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The REMIND model

Hybrid energy-economy-climate model

- Global scope, 11 world regions, international trade
- Time horizon: 2005-2100

Economy:

- Ramsey-type growth model, maximizes intertemporal welfare
- Pareto-optimal solution with intertemporal equilibrium of capital, energy and goods markets

Energy:

- ~70 conversion technologies with full capital vintaging
- Represents endogenous technological improvement (learning curve)

Climate:

- Soft-coupled to MAGICC

Variable Renewable Energies

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ARTICLE IN PRESS

Applied Energy xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Using the sun to decarbonize the power sector: The economic potential of photovoltaics and concentrating solar power ☆

Robert Carl Pietzcker [a,*], Daniel Stetter [b], Susanne Manger [c], Gunnar Luderer [a]

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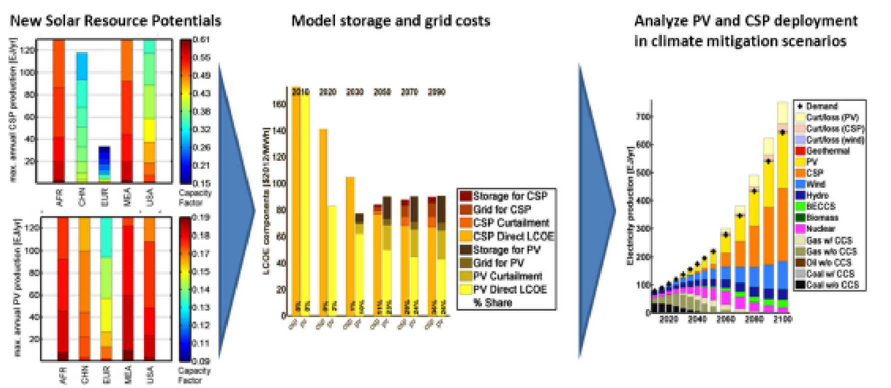
[c] Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany

H I G H L I G H T S

- We calculate a consistent global resource potential dataset for PV and CSP.
- We develop a simplified representation of system integration costs of wind and solar.
- We analyze the economic potential of PV & CSP with the energy-economy-model REMIND.
- Solar power produces 48% of the cumulated 2010–2100 electricity in a 2 °C scenario.
- PV is deployed first, but CSP catches up due to lower system integration costs.

G R A P H I C A L A B S T R A C T



A R T I C L E I N F O

A B S T R A C T

Solar Power Technologies

Photovoltaics (PV)

- Can use indirect light – high latitudes
- Easily scalable

Concentrating Solar Power (CSP)

- Needs direct light – low latitudes
- Thermal power production

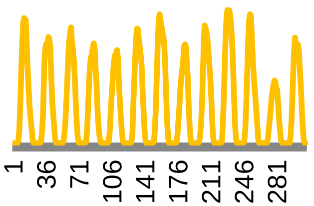
  ➔ Heat can be stored cheaply

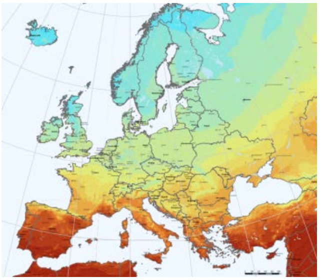
Driver 1: VRE Integration

Two main characteristics of Solar

1. Temporal variability

2. Heterogeneity in space





PVGIS © European Union, 2001-2012

Modeling Challenge:

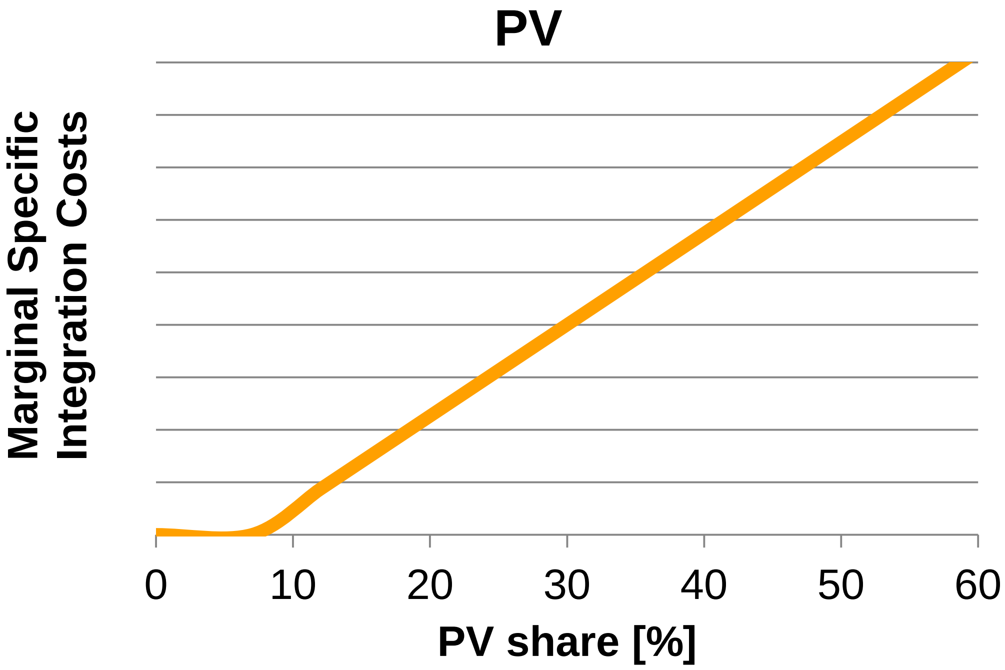
How to bridge the scales between

Reality		IAM
Hourly fluctuations	versus	5-year time steps
Irradiance differs on ~100km	versus	Continental scale

New generic approach – cost markups

Basic idea of approach:

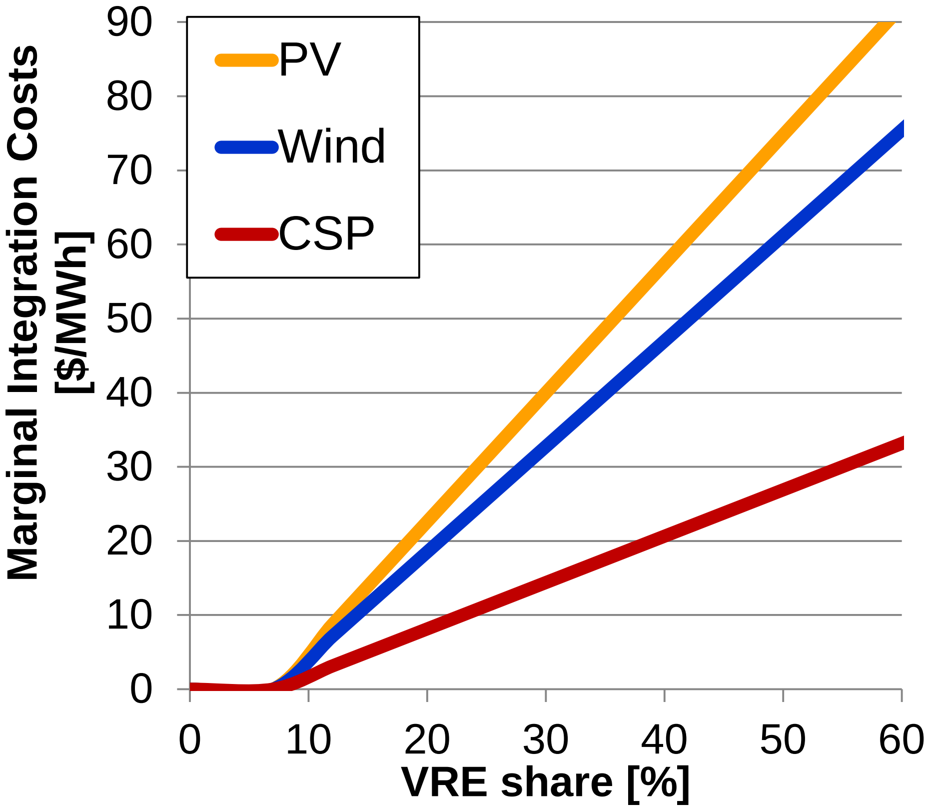
- Integration challenges increase with the share of each VRE



- Variability can be reduced by storage, else results in curtailment
- Parameters based on battery and H2 electrolysis costs, detailed modeling

Resulting integration cost markups

Specific integration costs (per kWh)

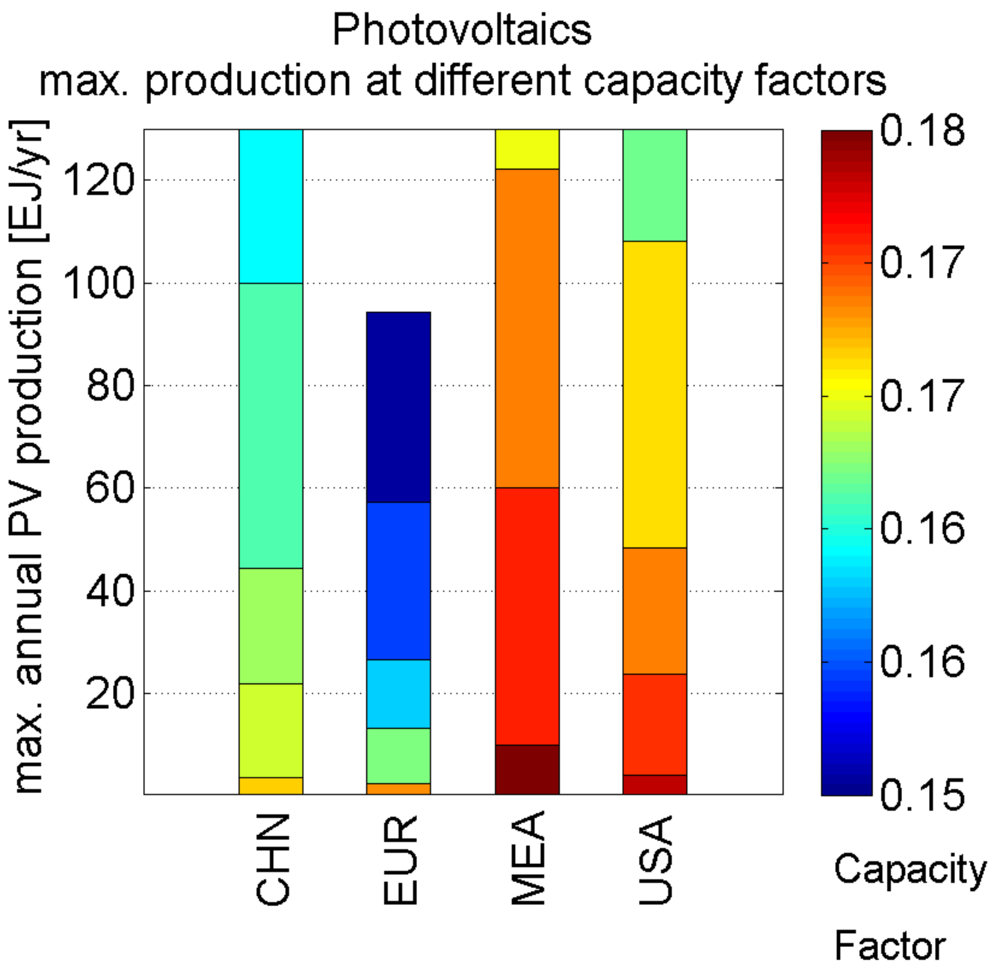


Main takeaways:

- Integration costs can be of substantial size and need to be represented
- Generic, flexible approach that can easily be adopted

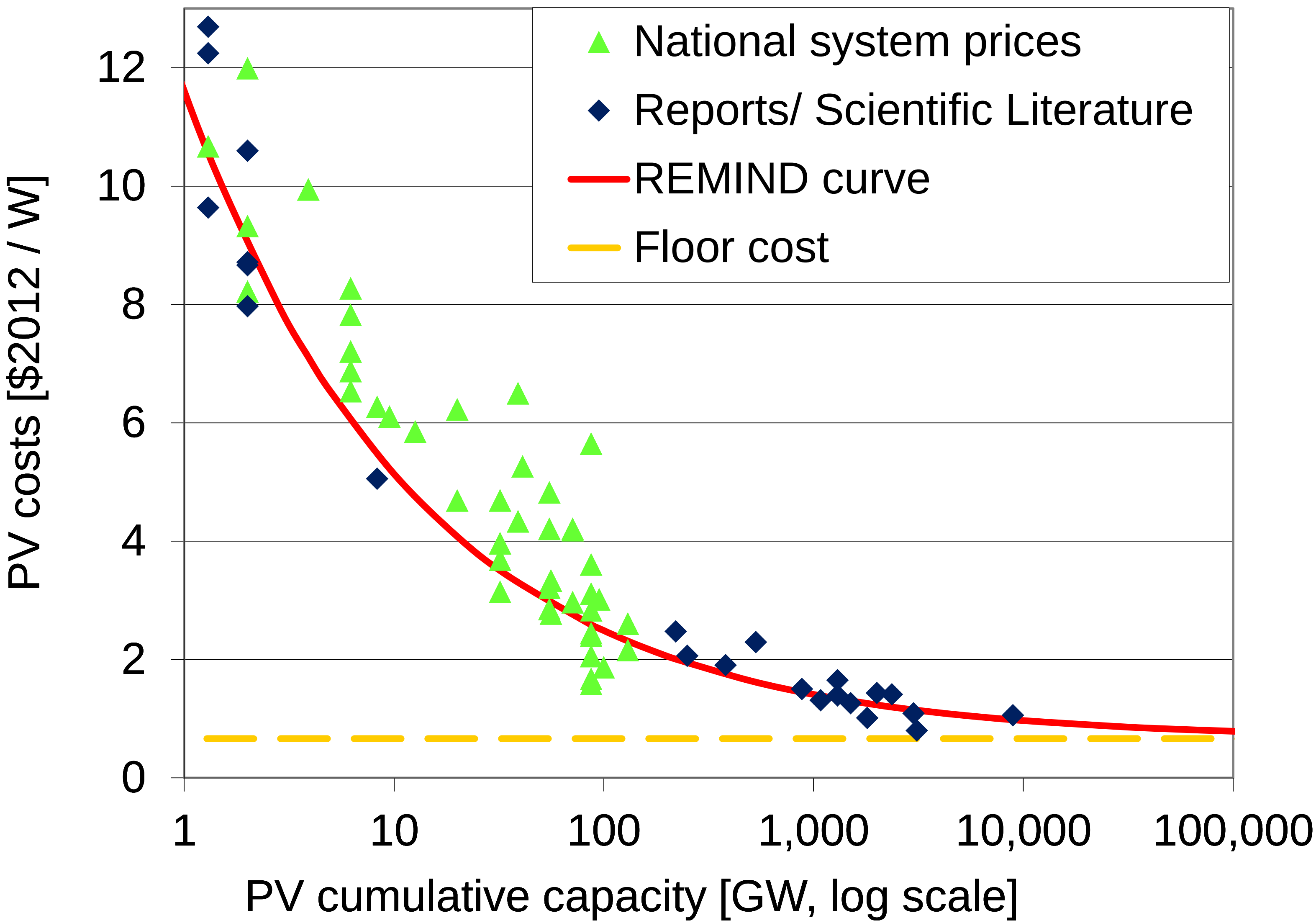
Pietzcker, Stetter, Manger, Luderer (2014) „How important is solar for the power sector?"

Driver 2: Resource Potential



Pietzcker, Stetter, Manger, Luderer (2014) „How important is solar for the power sector?"

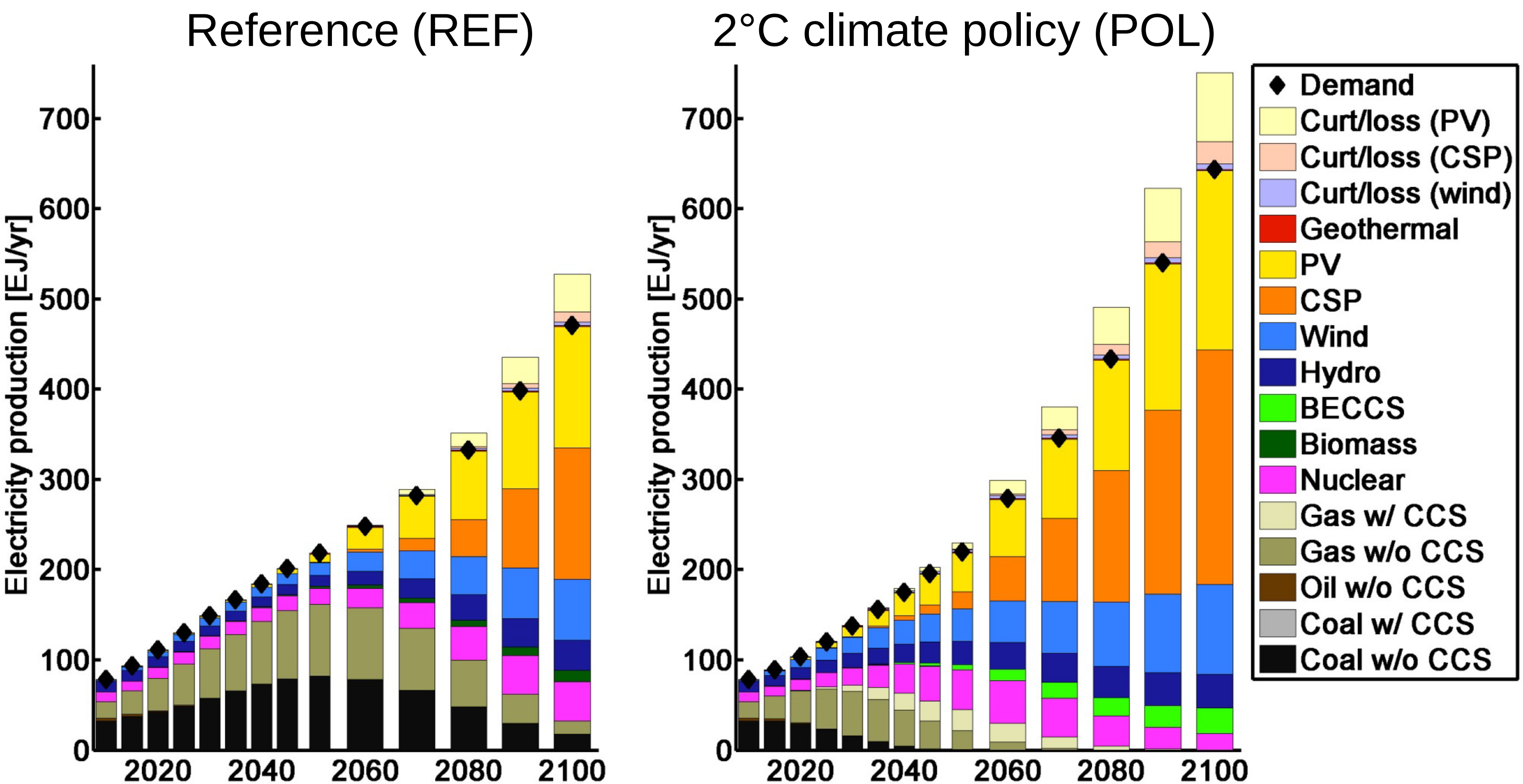
Driver 3: Technology Costs



Pietzcker, Stetter, Manger, Luderer (2014) „How important is solar for the power sector?“

Results from improved REMIND

Solar main source of low-carbon electricity



➔ In cost-optimal climate policy scenarios,

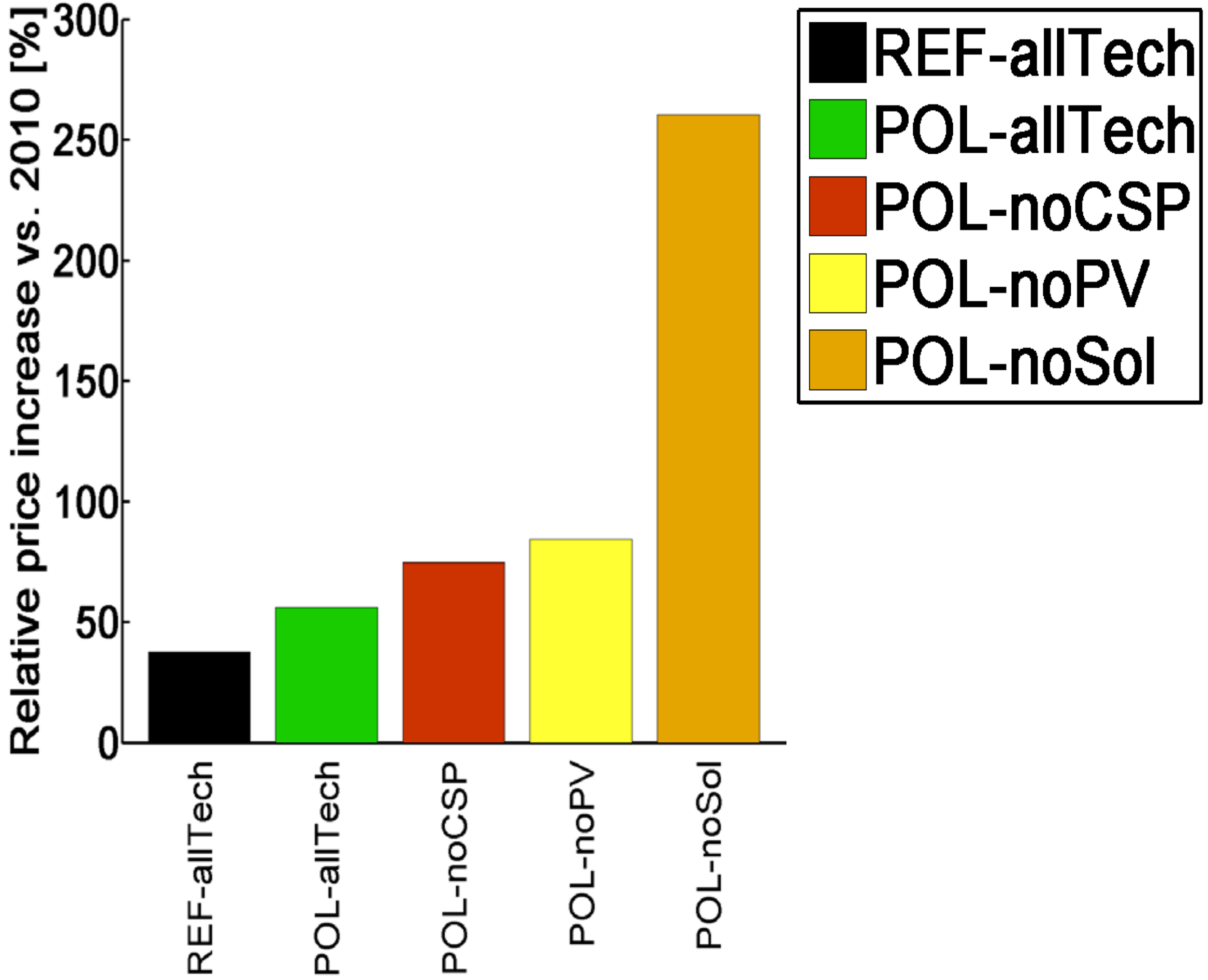
- PV, CSP and wind are scaled up much earlier and to a larger extent
- Solar supplies 48% of cumulated 2010-2100 power

Pietzcker, Stetter, Manger, Luderer (2014) „How important is solar for the power sector?“

Solar power has large impact on electricity prices

Average electricity price 2050-2100

Increase over 2010



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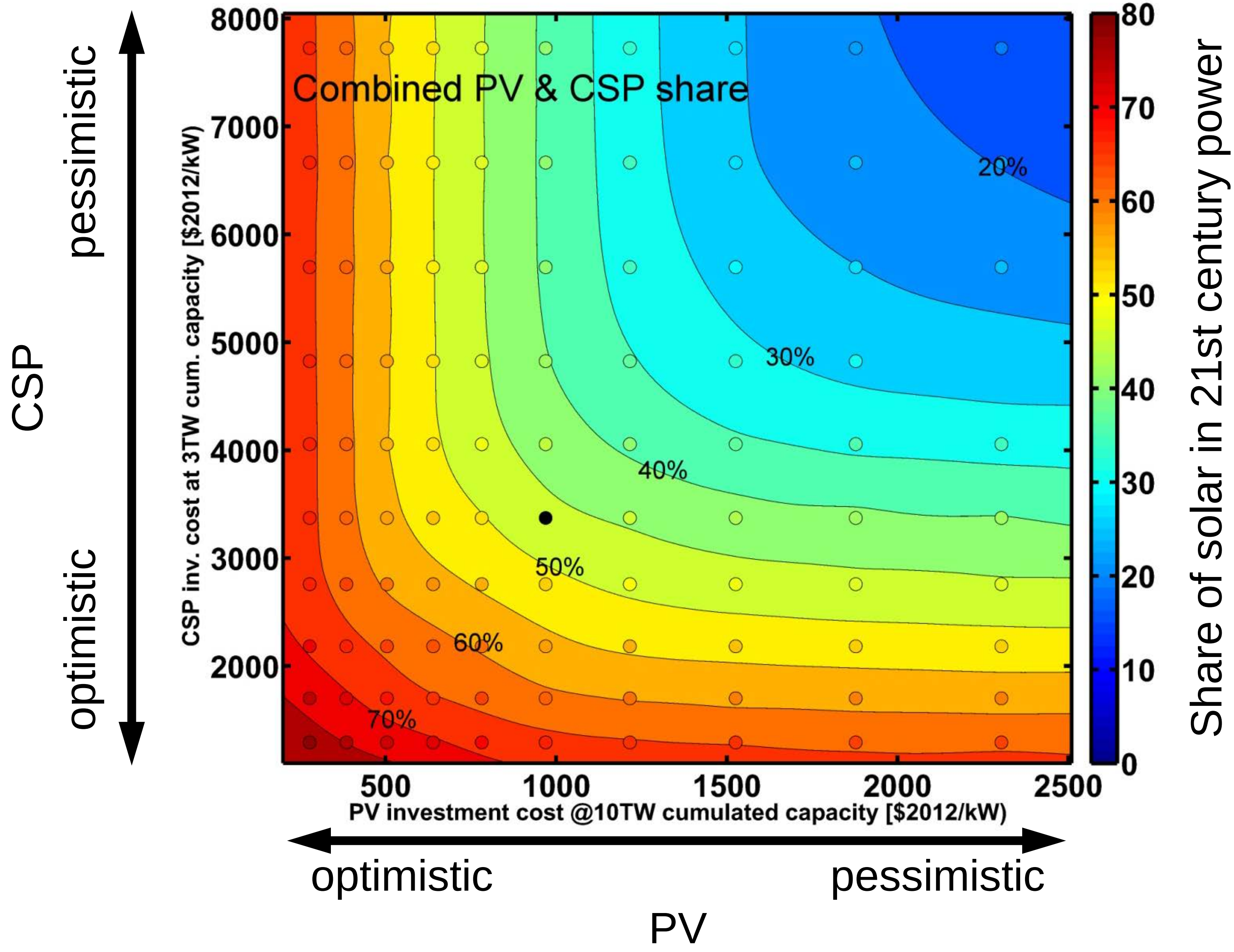
Results are robust to learning curve assumptions



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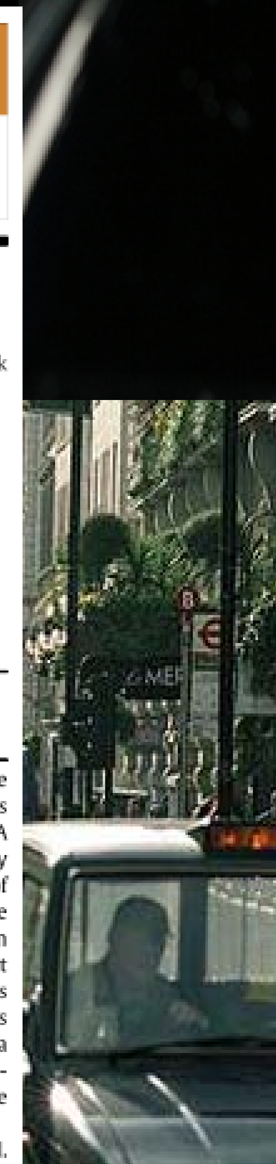
Transport



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Energy

journal homepage: www.elsevier.com/locate/energy

Long-term transport energy demand and climate policy: Alternative visions on transport decarbonization in energy-economy models

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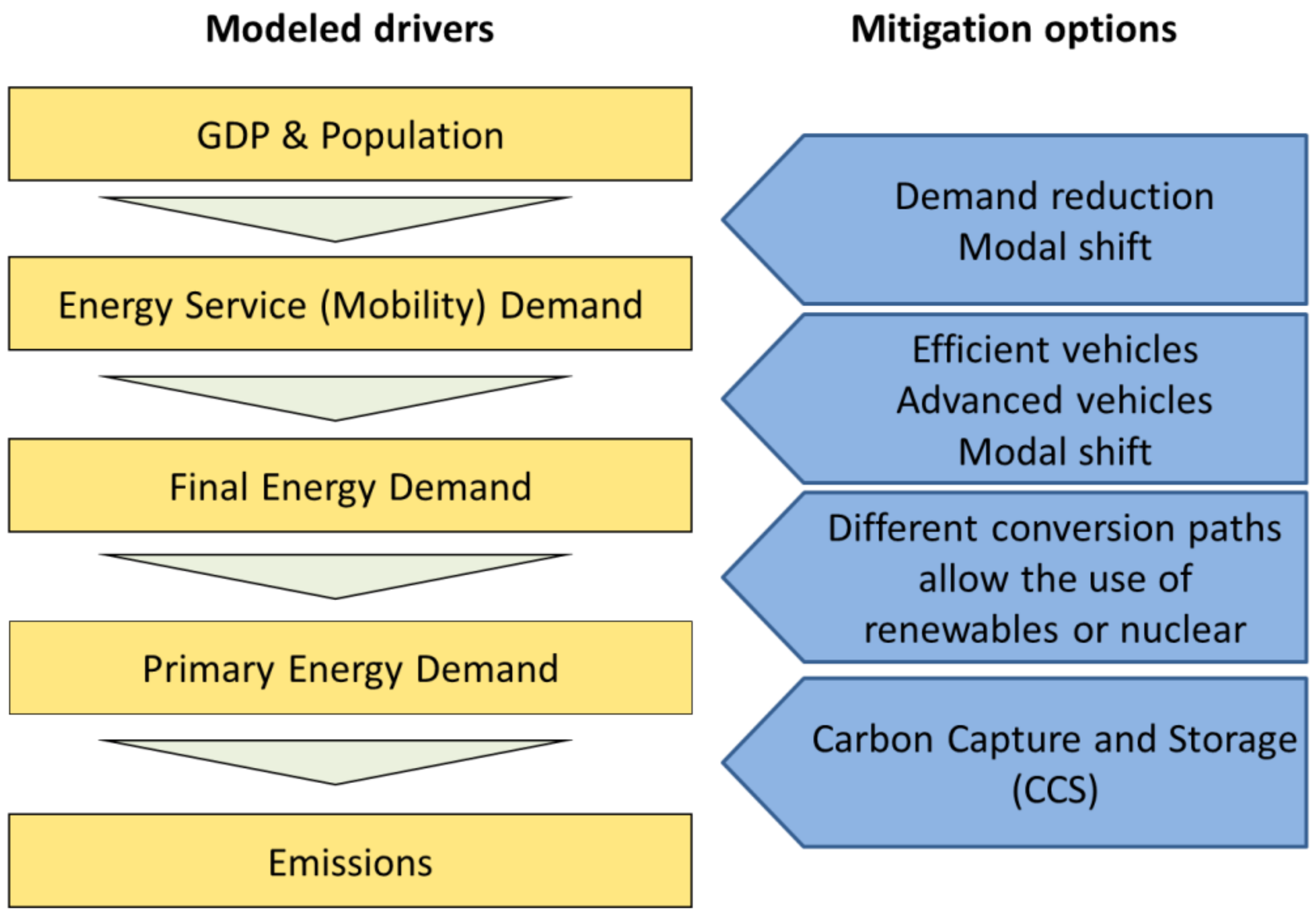
Hydrogen
Energy-economy modeling
BEVs (Battery electric vehicles)
Mobility demand reduction

ABSTRACT

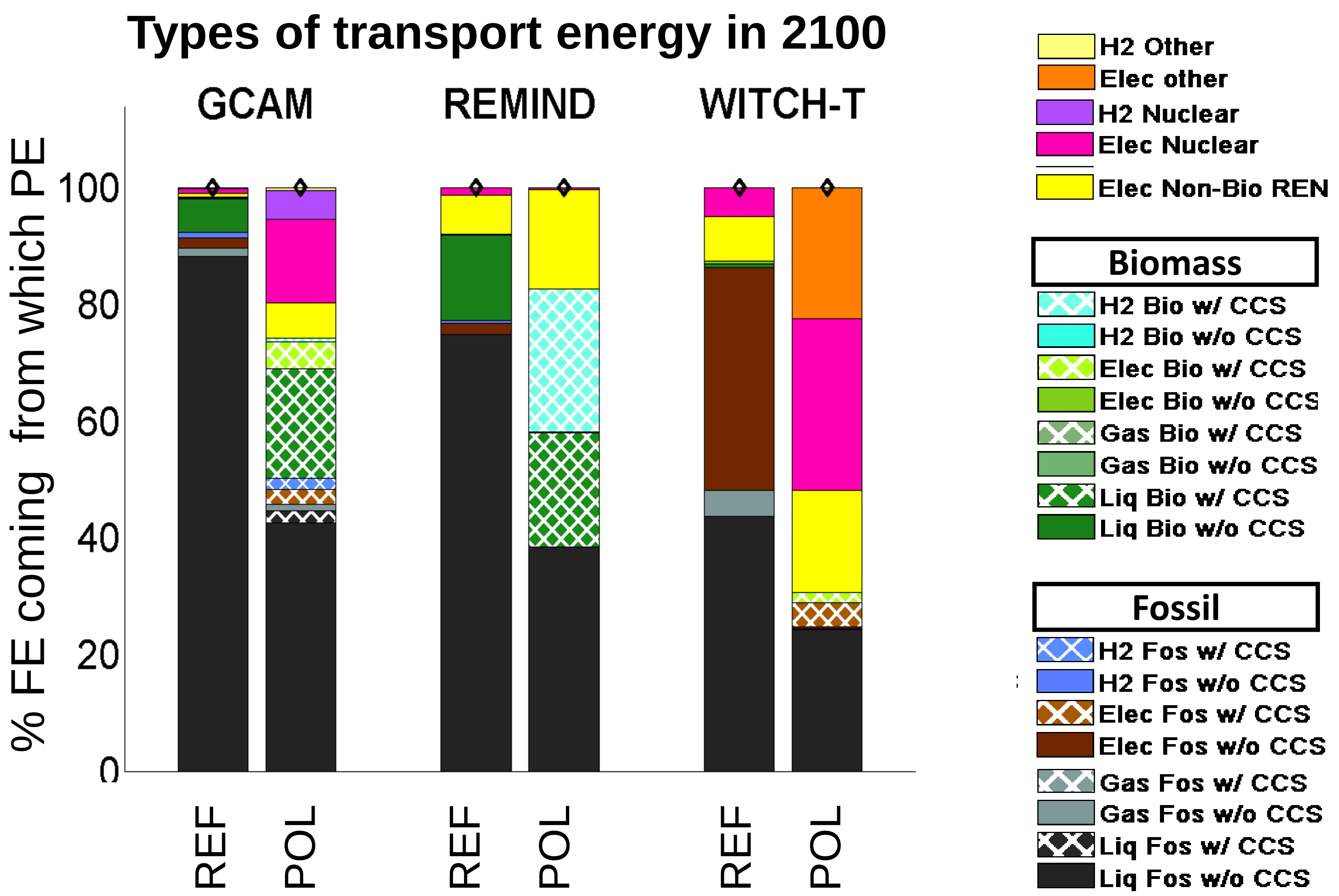
Decarbonizing transport will be necessary to limit global warming below 2 °C. Due to persistent reliance on fossil fuels, it is posited that transport is more difficult to decarbonize than other sectors. To test this hypothesis, we compare long-term transport energy demand and emission projections for China, USA and the world from five large-scale energy-economy models. We diagnose the model's characteristics by subjecting them to three climate policies. We systematically analyze mitigation levers along the chain of causality from mobility to emissions, finding that some models lack relevant mitigation options. We partially confirm that transport is less reactive to a given carbon tax than the non-transport sectors: in the first half of the century, transport mitigation is delayed by 10–30 years compared to non-transport mitigation. At high carbon prices towards the end of the century, however, the three global models achieve deep transport emission reductions by >90% through the use of advanced vehicle technologies and low-carbon primary energy; especially biomass with CCS (carbon capture and sequestration) plays a crucial role. The extent to which earlier mitigation is possible strongly depends on implemented technologies and model structure. Compared to the global models, the two partial-equilibrium models are less flexible in their reaction to climate policies.

Chain of Causality in the Transport Sector



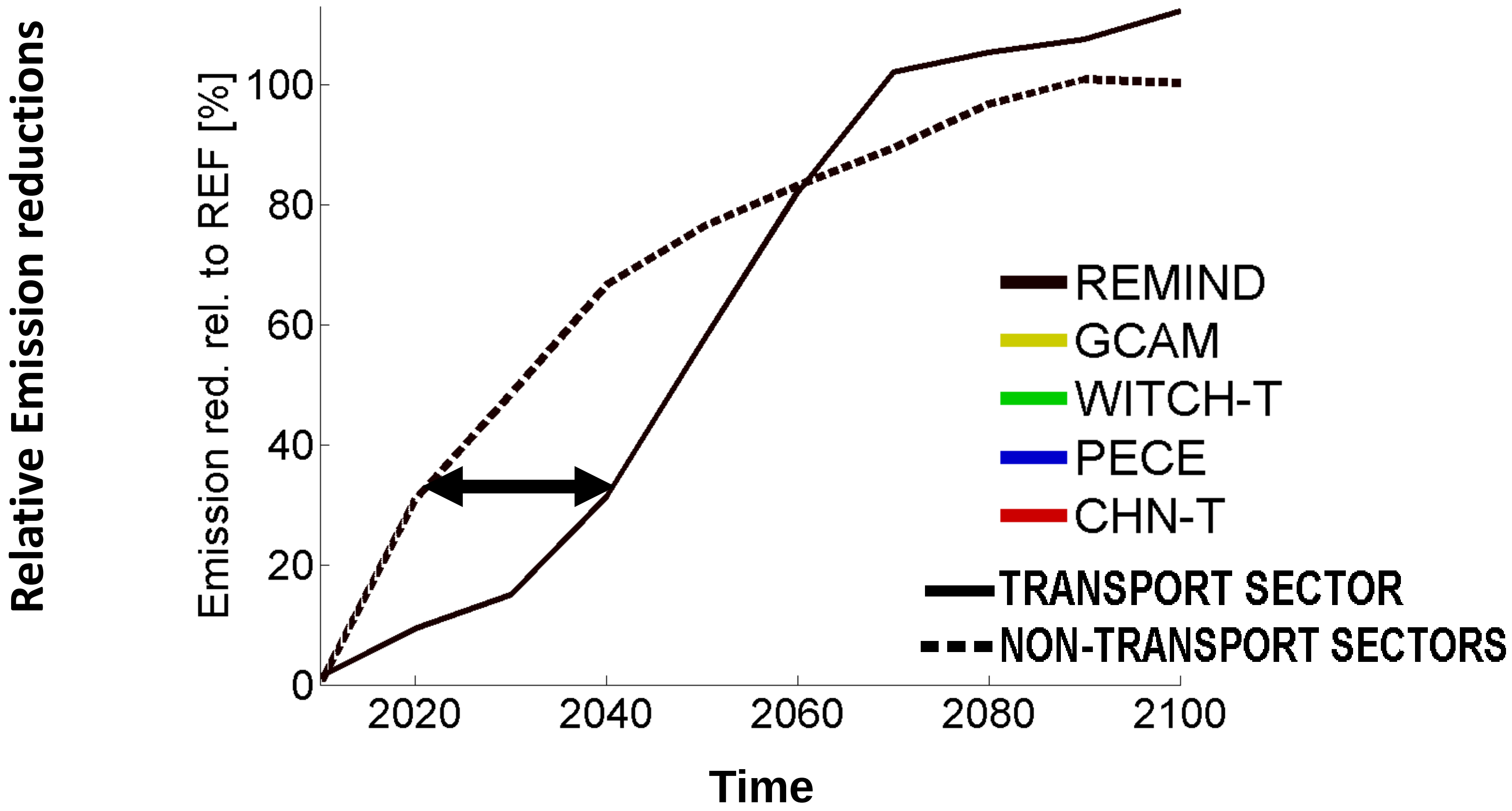
Pietzcker, Longden, Chen et al. (2014) „How can transport be decarbonized?"

Different views of future transport technologies



Pietzcker, Longden, Chen et al. (2014) „How can transport be decarbonized?"

Robust finding: Transport mitigation lags behind



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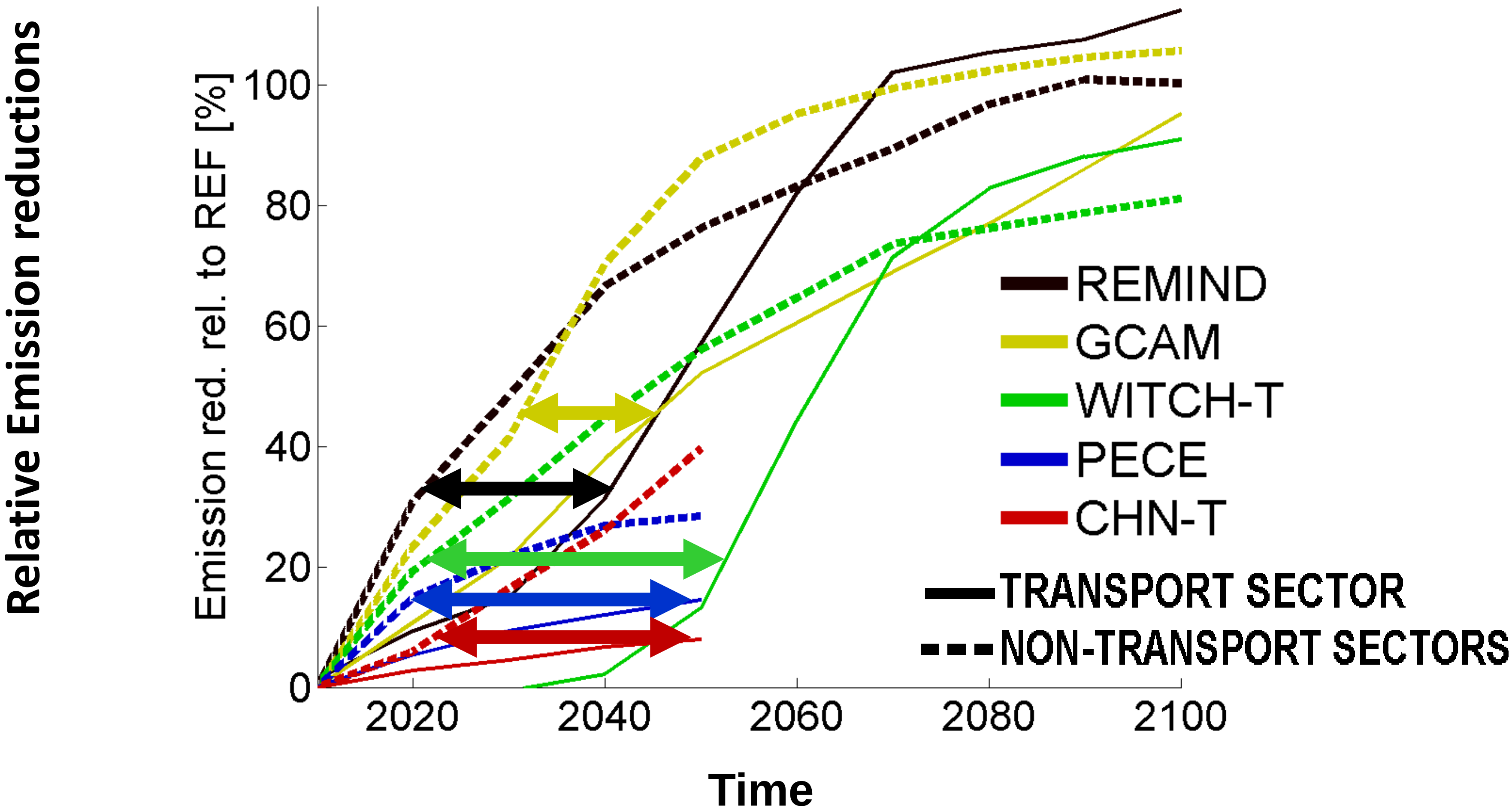
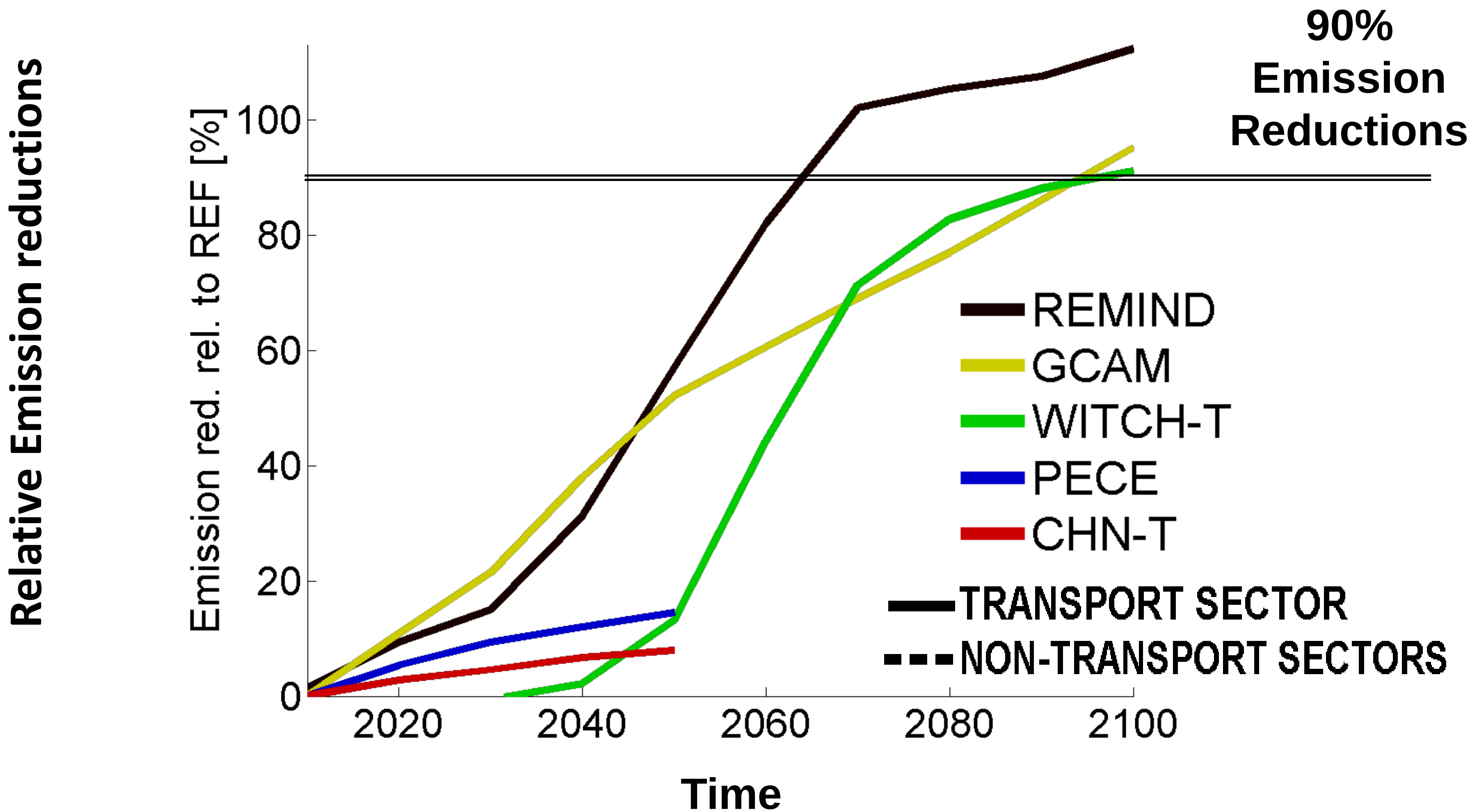
Robust finding: Transport mitigation lags behind



Pietzcker, Longden, Chen et al. (2014) „How can transport be decarbonized?"

Robust finding 2: Deep reductions possible



Pietzcker, Longden, Chen et al. (2014) „How can transport be decarbonized?"

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IOP PUBLISHING ENVIRONMENTAL RESEARCH LETTERS
Environ. Res. Lett. **8** (2013) 034033 (8pp) doi:10.1088/1748-9326/8/3/034033

Economic mitigation challenges: how further delay closes the door for achieving climate targets

Gunnar Luderer[1], Robert C Pietzcker[1], Christoph Bertram[1], Elmar Kriegler[1], Malte Meinshausen[1,2] and Ottmar Edenhofer[1,3,4]

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[2] School of Earth Sciences, University of Melbourne, Victoria 3010, Australia
[3] Technische Universität Berlin, D-10632 Berlin, Germany
[4] Mercator Research Institute on Global Commons and Climate Change, D-10829 Berlin, Germany

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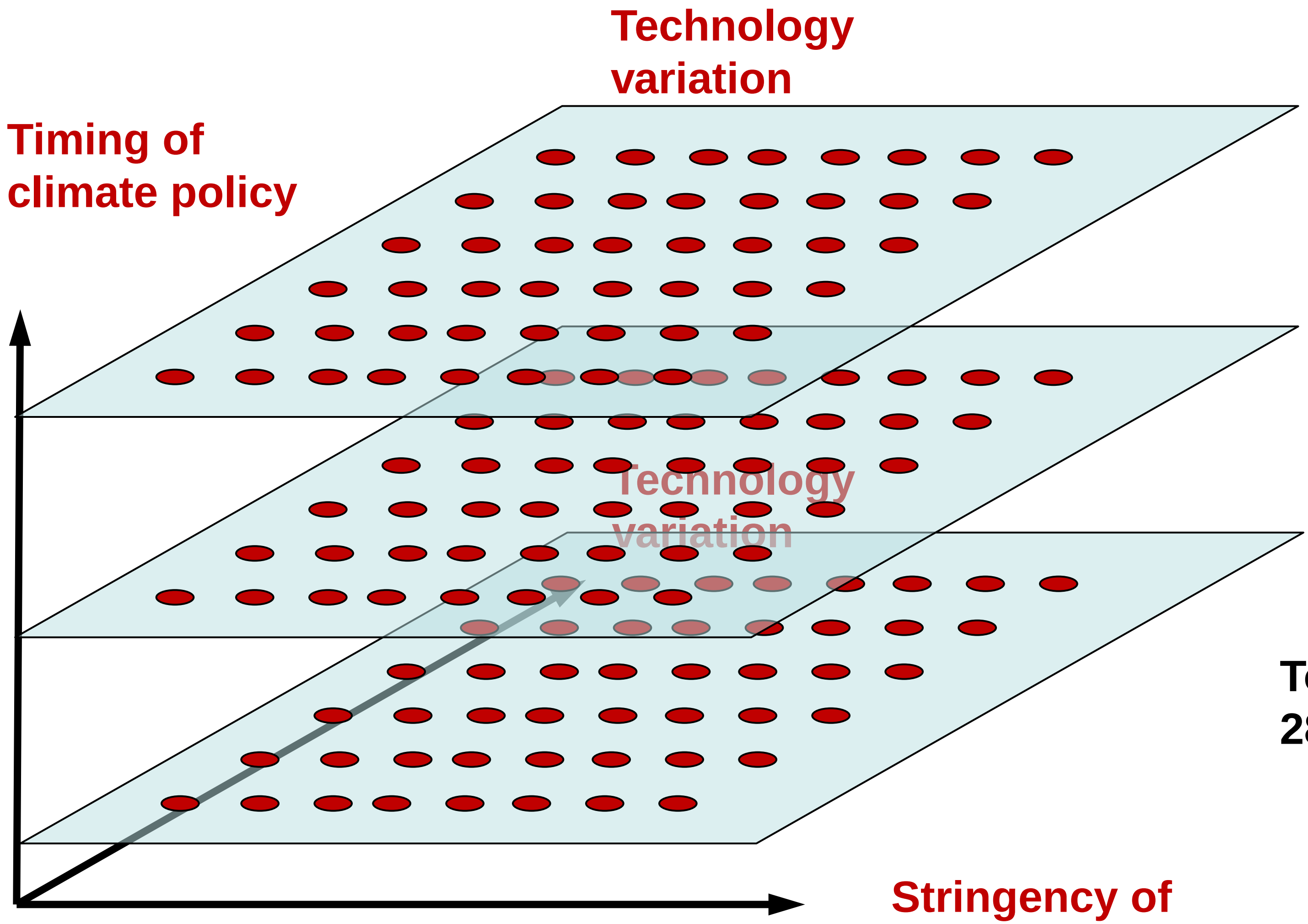
Abstract
While the international community aims to limit global warming to below 2 °C to prevent dangerous climate change, little progress has been made towards a global climate agreement to implement the emissions reductions required to reach this target. We use an integrated energy–economy–climate modeling system to examine how a further delay of cooperative action and technology availability affect climate mitigation challenges. With comprehensive emissions reductions starting after 2015 and full technology availability we estimate that maximum 21st century warming may still be limited below 2 °C with a likely probability and at moderate economic impacts. Achievable temperature targets rise by up to ~0.4 °C if the implementation of comprehensive climate policies is delayed by another 15 years, chiefly because of transitional economic impacts. If carbon capture and storage (CCS) is unavailable, the lower limit of achievable targets rises by up to ~0.3 °C. Our results show that progress in international climate negotiations within this decade is imperative to keep the 2 °C target within reach.

Explore the full map of climate mitigation paths

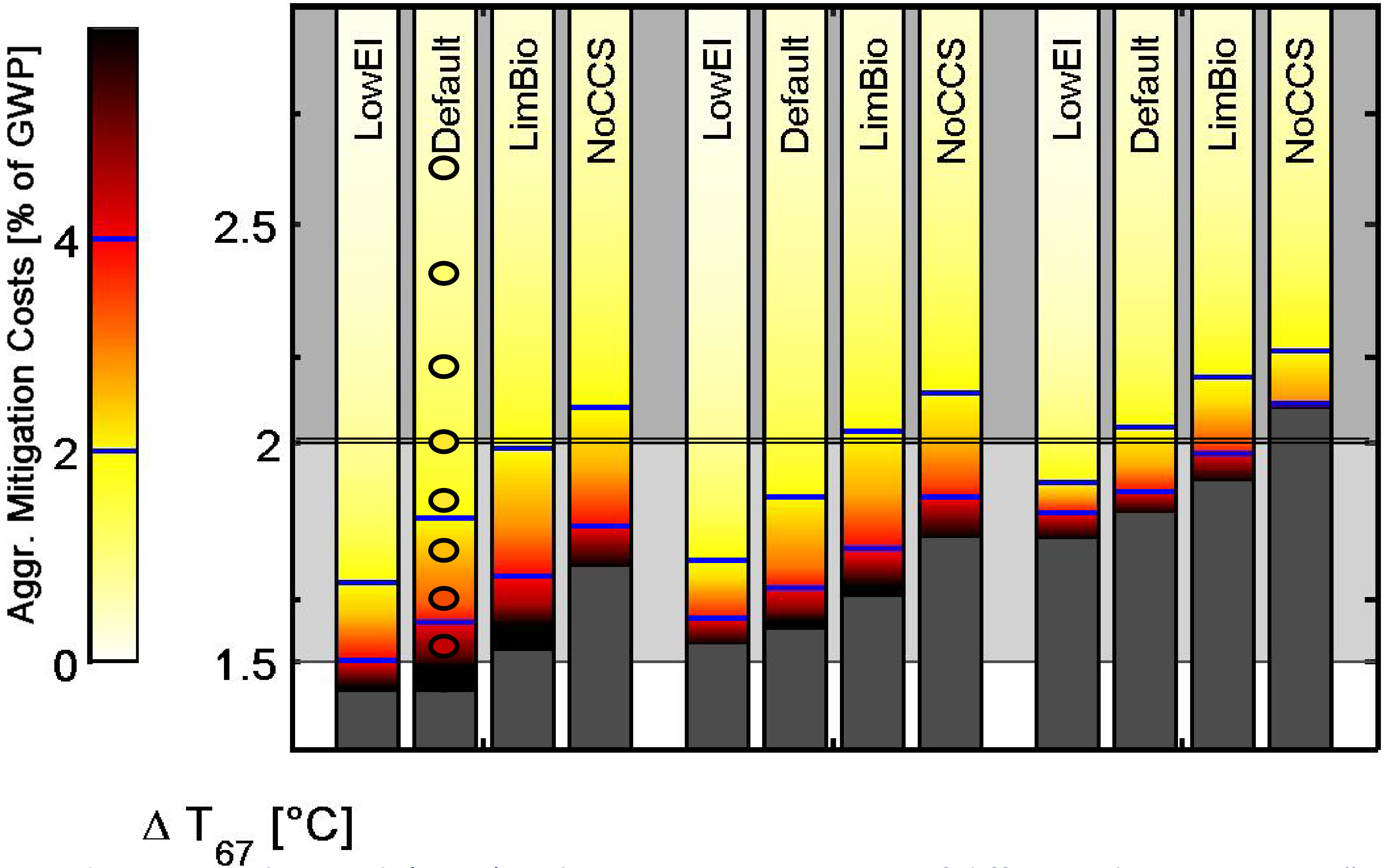


Total:
285 Sceenarios

Luderer, **Pietzcker** et al. (2013) „What are economic costs of different climate targets?"

Economic challenges of mitigation

Long-term mitigation costs



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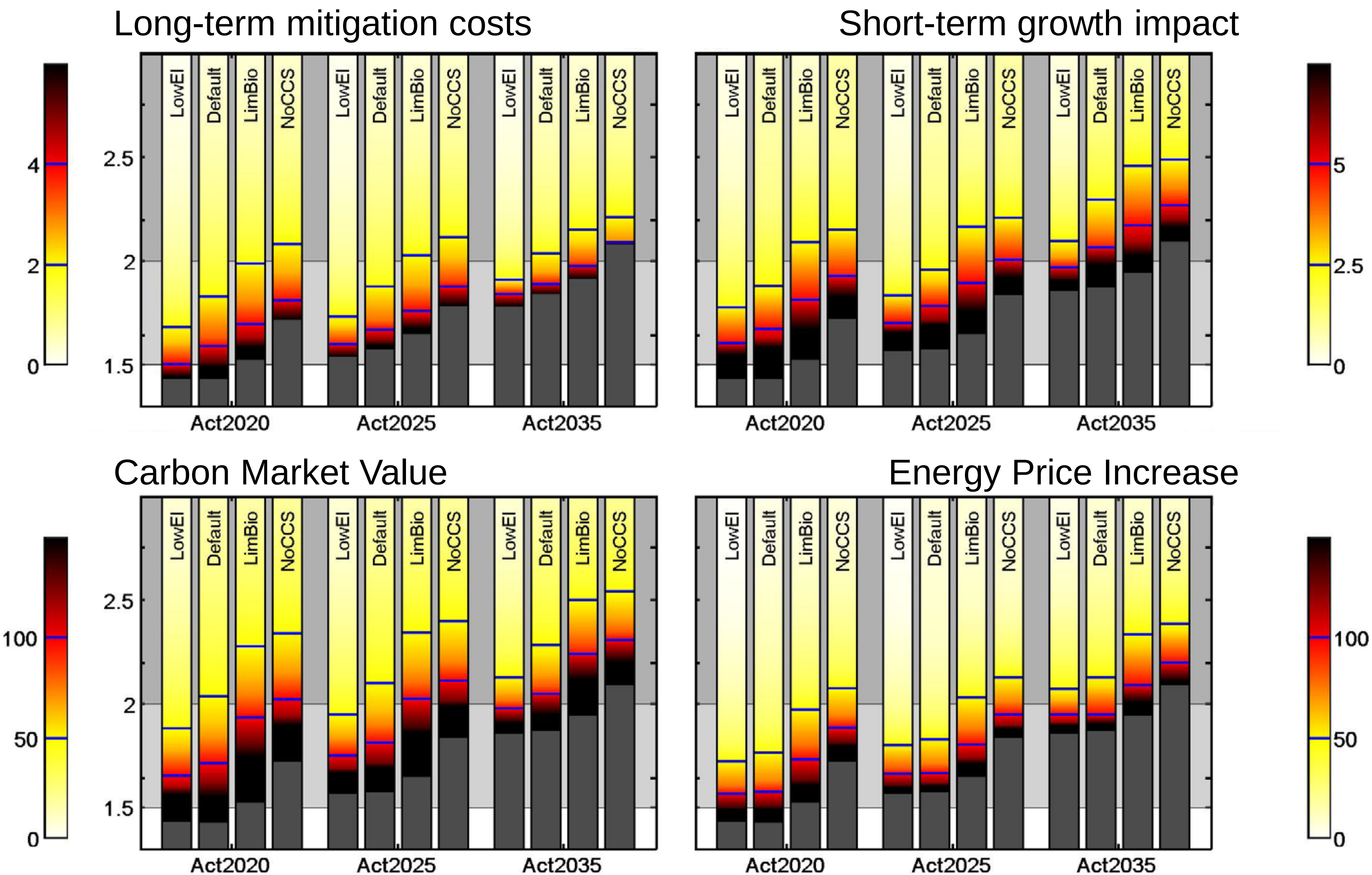

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Summary

Variable Renewable Energies

- In cost-optimal 2 C scenarios, solar power supplies almost half of the total electricity production in the 21st century

- If neither photovoltaics nor concentrating solar power are available, electricity prices will rise strongly in climate mitigation scenarios

Methodological:

- Integration challenges need to be adequately represented

Summary

Transport Sector

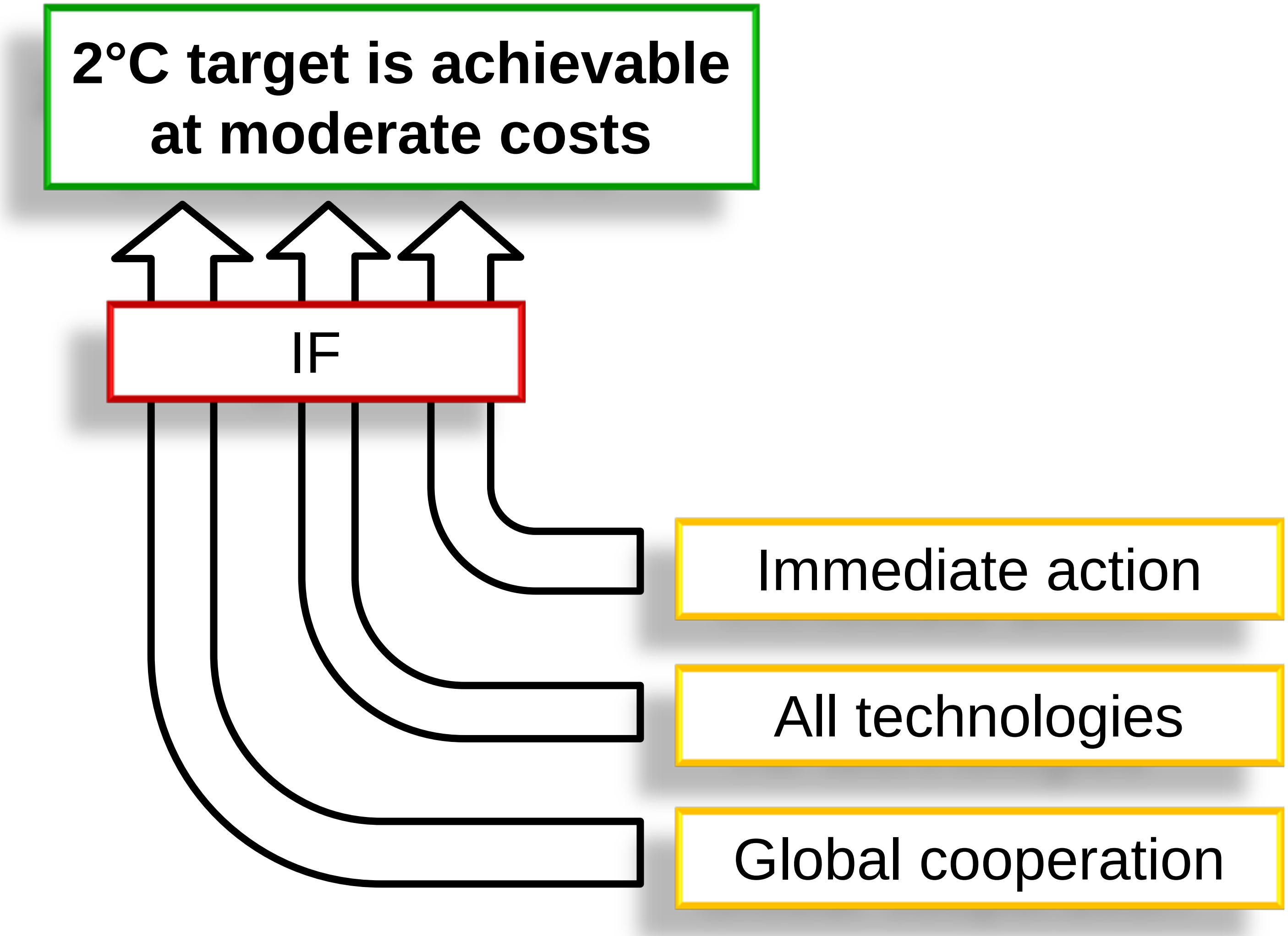
- Different models have different ideas about which technologies will be used to decarbonize transport

- The transport sector only reacts weakly to moderate carbon prices, and mitigation lags 10-30 years behind mitigation in the other sectors

- In the long term, transport emission reductions can be deep (>90%)

Summary

Achievability of stringent climate targets



Top 4 policy implications

1. **Fast climate policy action is key**. Delay increases short-term challenges substantially

2. The **power sector** is a low-hanging fruit: **variable renewable energies** offer decarbonization with comparatively **low side effects** or risks. Flexibility options need to be further improved and tested.

3. Policy support has achieved impressive **cost reductions** and market growth for **photovoltaics**. If policy makers want to sustain the dynamic and enable cheap power decarbonization, **moderate support** is still needed.

4. There is no silver bullet for transport decarbonization. Understanding and **influencing non-monetary drivers** is important.

Thank you for your attention!

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“What are economic costs and challenges of different climate targets?”:
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