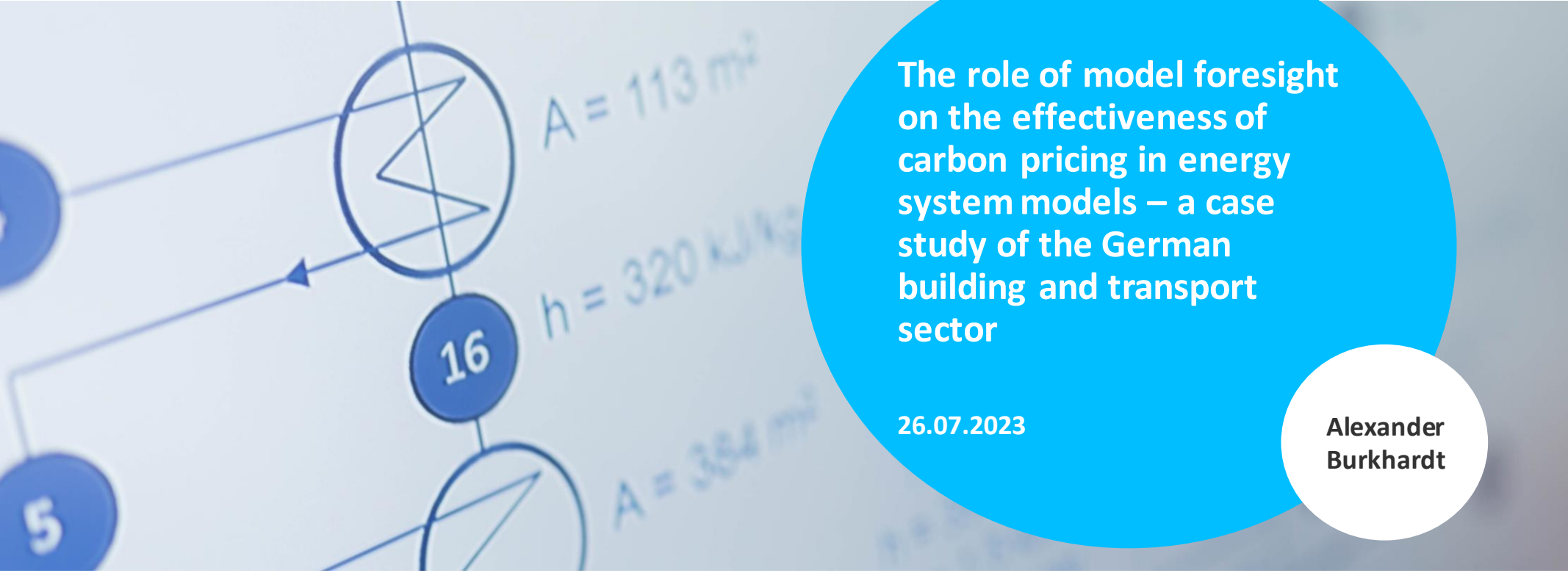
Universität Stuttgart
IER Institut für Energiewirtschaft
und Rationelle Energieanwendung



The role of model foresight on the effectiveness of carbon pricing in energy system models – a case study of the German building and transport sector

26.07.2023

Alexander Burkhardt

IER

Agenda

1. Motivation and research question
2. Methodology
3. Results
4. Conclusions and policy recommendations

The german buildings and transport sector

Tabelle 4: Zielwertvergleich der Emissionswerte aus der Berechnung der Emissionsdaten des Vorjahres des Umweltbundesamtes (UBA) für das Jahr 2022 mit den zulässigen Jahresemissionsmengen des Bundes-Klimaschutzgesetzes (KSG)

Sektor	Zielwert KSG 2022	Berechnung UBA 2022	Änderung in 2022 gegenüber 2021	KSG-Zielerreichung: Differenz BVE-Zielwert	Unsicherheit der BVE (95 %-Intervall)	Wahrscheinlichkeit für das Erreichen des KSG Sektorziels auf Basis der IPCC-Skala (Siehe Fußnote 8)
	[Mt CO_2-Äq.]	[Mt CO_2-Äq.]	[Mt CO_2-Äq.]	[Mt CO_2-Äq.]	[Mt CO_2-Äq.]	
Energie-wirtschaft	257,0	255,9	+10,7	-1,1	247–264	etwa ebenso wahrscheinlich wie nicht wahrscheinlich
Industrie	176,9	164,2	-19,1	-12,7	160–168	praktisch sicher
Gebäude	107,4	111,7	-6,3	+4,3	103–120	unwahrscheinlich**
Verkehr	138,8	148,5* 147,9	+1,7* +1,1	+9,7* +9,1	141–156* 140–156	besonders unwahrscheinlich
Landwirtschaft	67,6	61,7	-0,9	-5,9	48–75	wahrscheinlich
Abfallwirtschaft und Sonstiges	8,5	4,3	-0,2	-4,2	(-8)–17	wahrscheinlich
LULUCF	-	-1,8	-5,8	-	(-3)–(-1)	-
Gesamt (ohne LULUCF)	756,2	746,2* 745,6	-14,1* -14,7	-9,9* -10,6	722–770* 722–769	wahrscheinlich

- The buildings and transport sector missed their 2022 goals formulated in the german climate protection law, successfully reaching the goals in the coming years is deemed unlikely by experts
- National CO_2-price is implemented for those to sectors as a bridge to EU-ETS 2
- Intense debate in politics, science community and society about carbon prices vs. Bans and regulations
- Private actors are the deciscion makers in these sectors

1. Expertenrat für Klimafragen (2023): Prüfbericht zur Berechnung der deutschen Treibhausgasemissionen für das Jahr 2022. Prüfung und Bewertung der Emissionsdaten gemäß § 12 Abs. 1 Bundes-Klimaschutzgesetz. Online verfügbar unter: https://www.expertenrat-klima.de

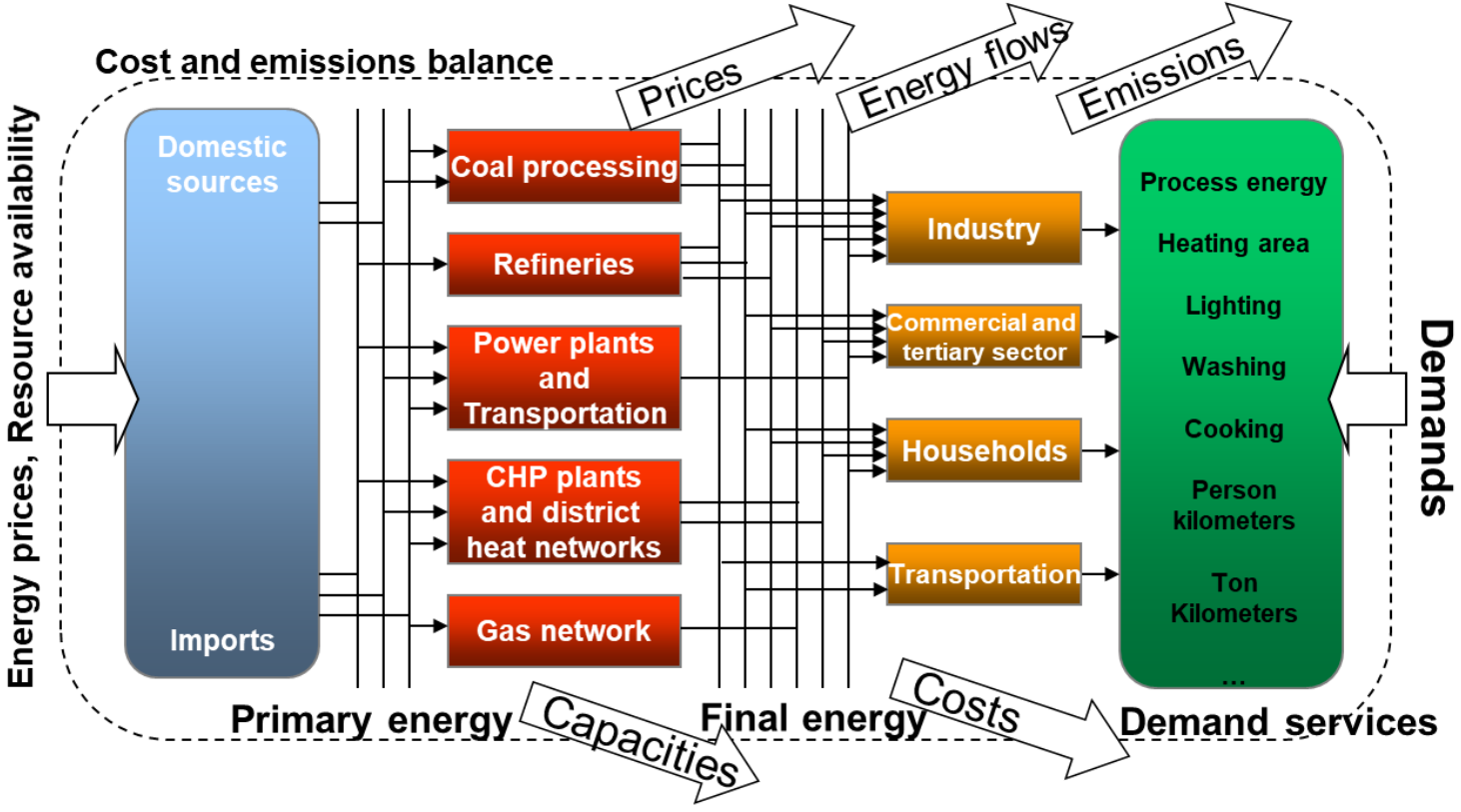
Research questions

1. What different outcomes do we see if we assume a limited foresight of actors when modelling the application of policy instruments?

2. Is myopic modelling, compared to perfect foresight, more suited for the modelling of carbon prices?

3. How does this affect the effectiveness in the buildings and transport sector, where the mayority of decisions is made by private actors? What are the policy implications?

The energy systems model TIMES PanEU



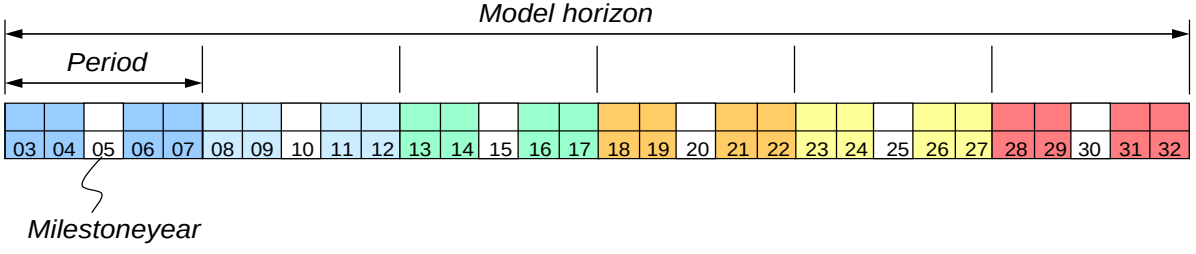
- 30 regions (EU27+Norway, Switzerland and UK)
- Time horizon 2010-2050
- All relevant sectors are represented in the model (Primary Energy Supply, Electricity, Heat, Industry, Commercial, Residential, Transport and Agriculture)
- Goal of the optimisation is the minimization of the intertemporal total system costs
- Can be solved under perfect foresight or myopia

→ Detailed analysis of the german/european energy system

Myopia vs. Perfect Foresight

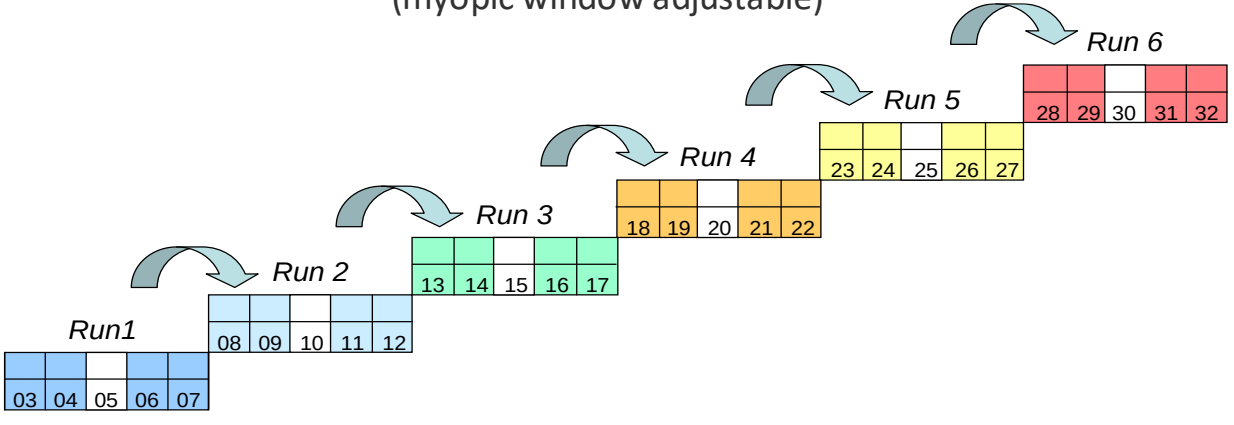
Perfect foresight

One optimization run over entire horizon



Myopic foresight

(myopic window adjustable)



Myopia and Perfect Foresight

Myopia

Optimization based on a **limited knwoledge about the future**, uncertanty about future prices, demands or technological development

Assumption: Current developments and prices will be similar in the future

Similiar to short-sighted decisions made in the real world

Costs are minimized only for the applied myopic window

Perfect Foresight

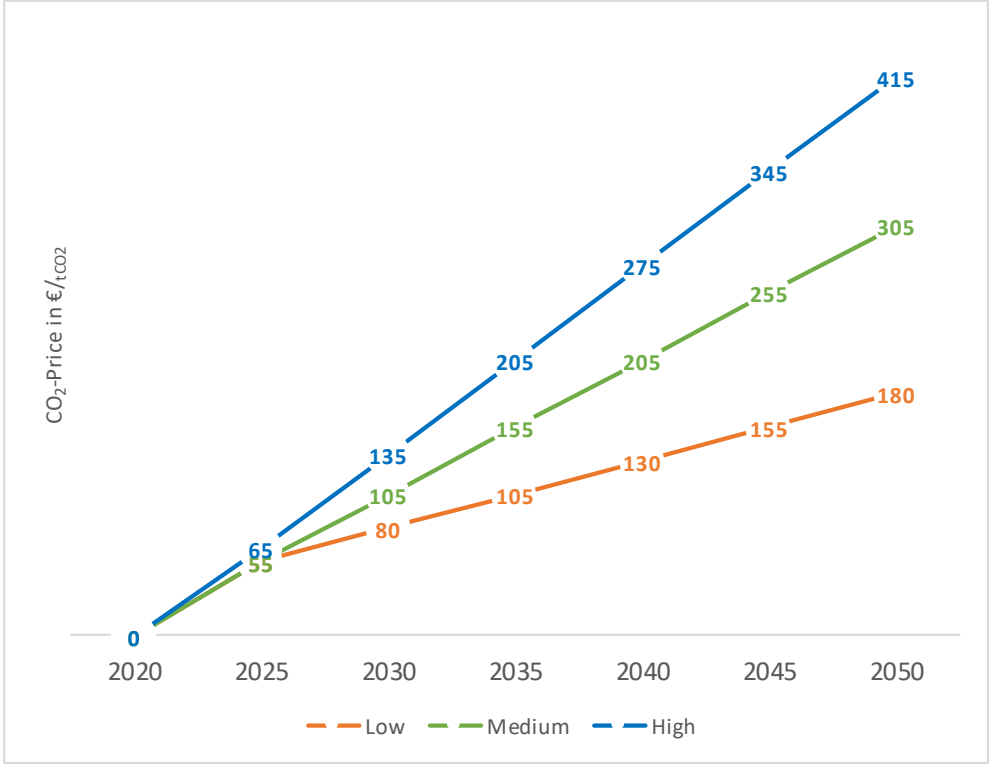
Model input is **know across the whole model horizon**, there are **no uncertanties**

Assumption: Future changes are known and foreseeable

Finds the optimal path given the boundaries/inputs

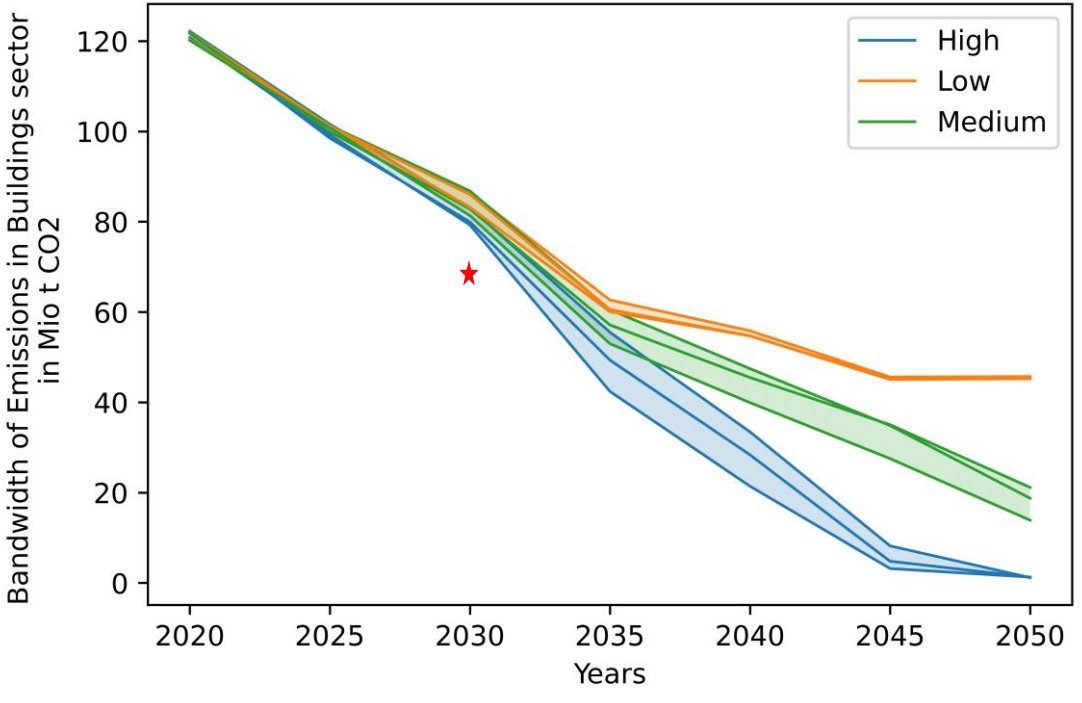
Costs are minimized over the whole time horizon, finds the intertemporal optimum

Methodology – Implemented CO_2-Pricepaths



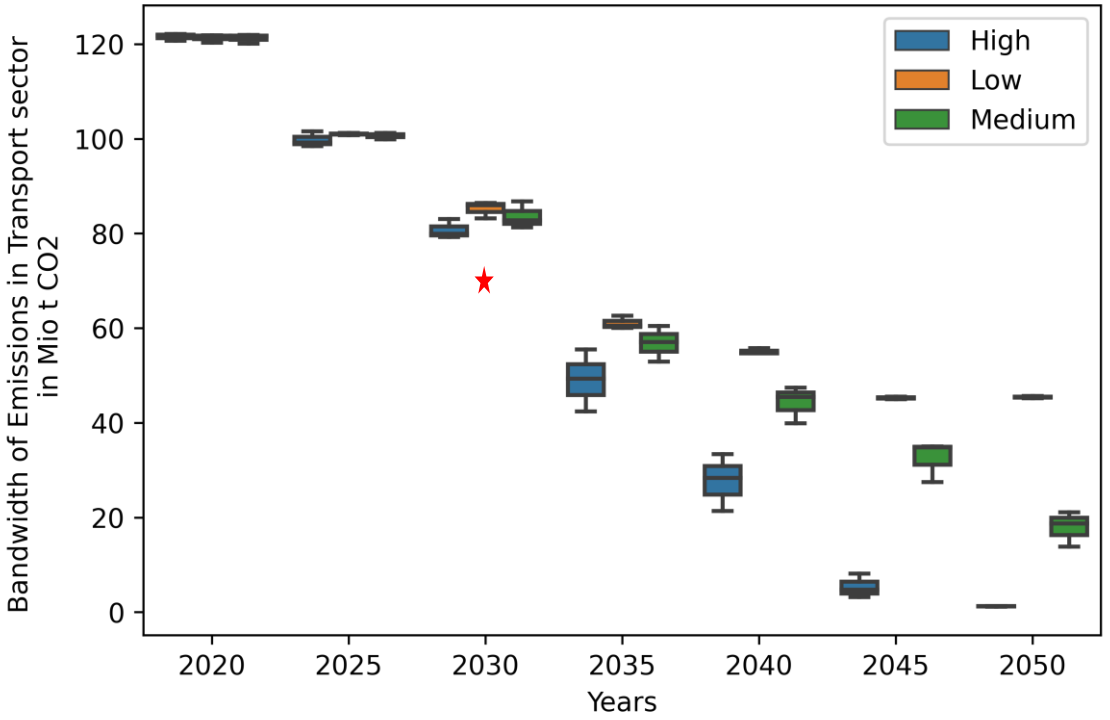
- 3 linear CO_2-price paths are modelled
- Comparison of one run under Perfect Foresight with runs under myopia, with different length of the myopic window (10, 20 years)
- Analyze differences in CO_2-emissions, final energy consumptions, investment decisions
- Untersuchung hinsichtlich möglicher Unterschiede bezüglich Emissionen, Energieträgerzusammensetzung und Investitionsentscheidungen

Results – Buildings sector



- Myopic modelling gives uncertainty range of the effectiveness of carbon prices
- In the buildings sector, more divergence can be seen for higher carbon prices
- For the high price path, there is a deep decarbonisation either way, but a lot more cummulative emissions
- Sector target of the climate protection law for 2030 (67 Mio t.) are missed in all scenarios

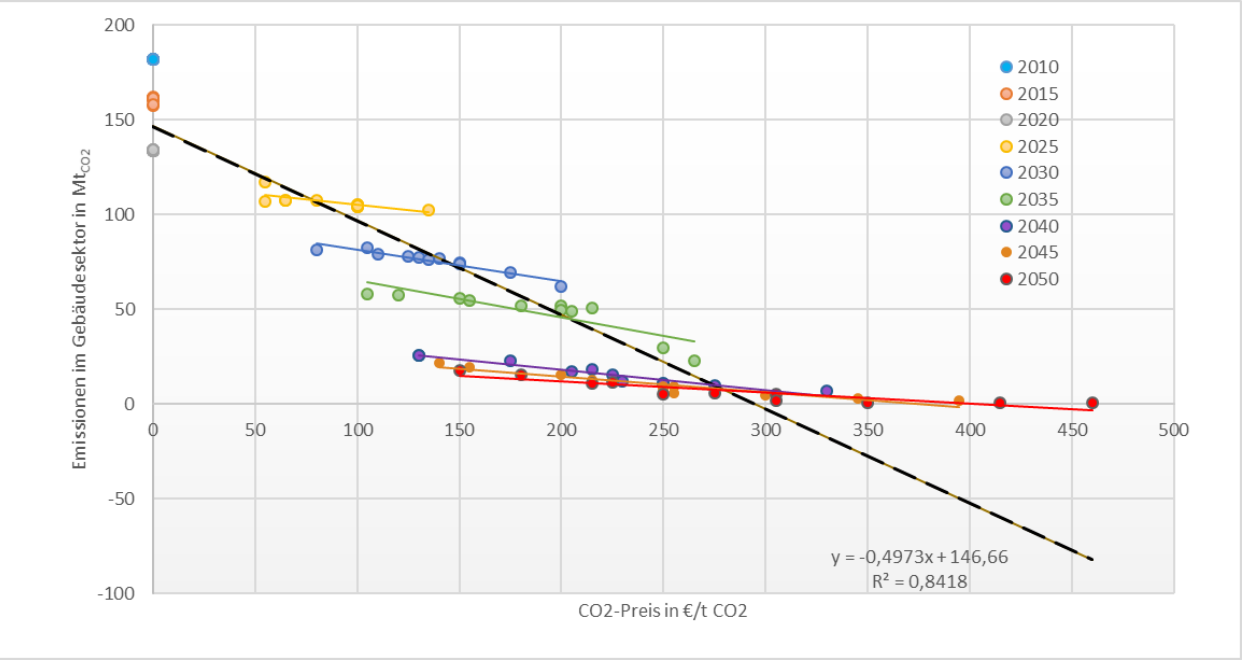
Results – Buildings sector

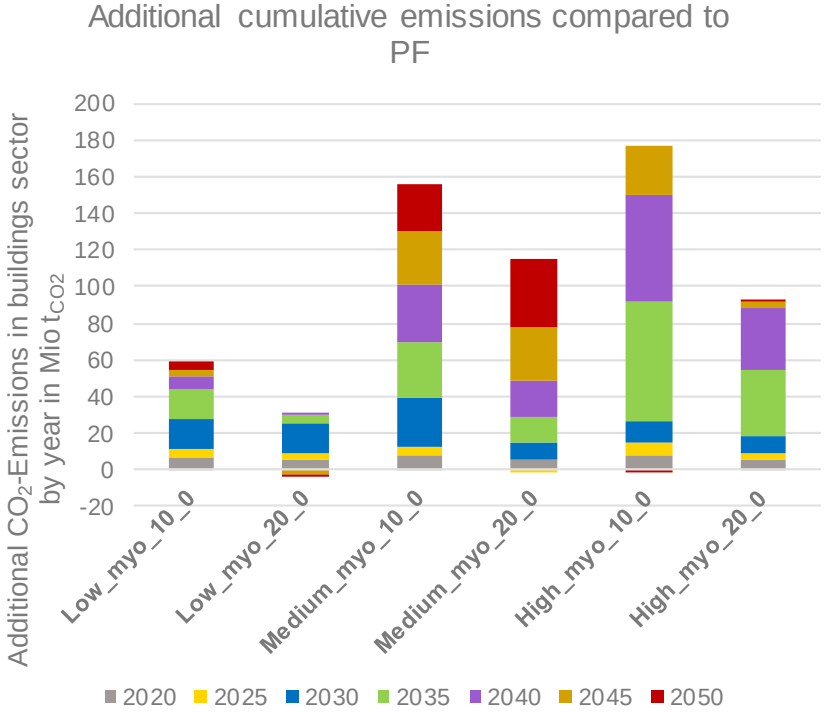


- Myopic modelling gives uncertainty range of the effectiveness of carbon prices
- In the buildings sector, more divergence can be seen for higher carbon prices
- For the high price path, there is a deep decarbonisation either way, but a lot more cummulative emissions
- Sector target of the climate protection law for 2030 (67 Mio t.) are missed in all scenarios

Results – Buildings sector

When do effects are observed

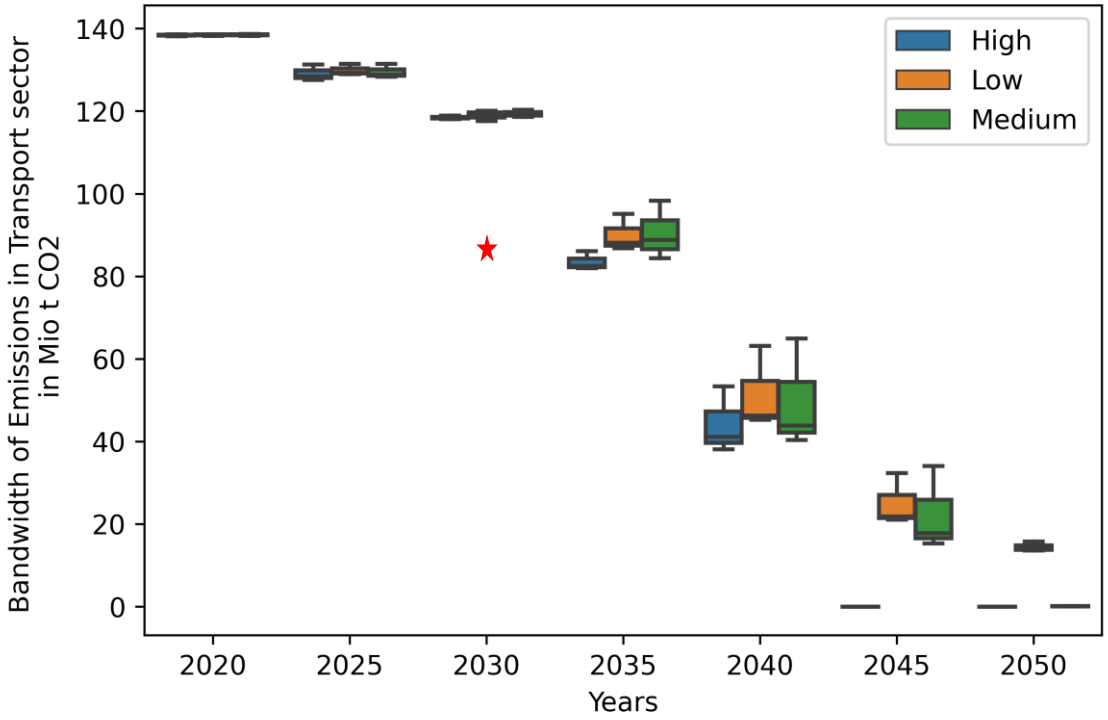




From previous work under perfect Foresight:
Highest effectiveness of high CO_2-prices in the 2030s

Myopia mostly affects the later periods (2035-2050)

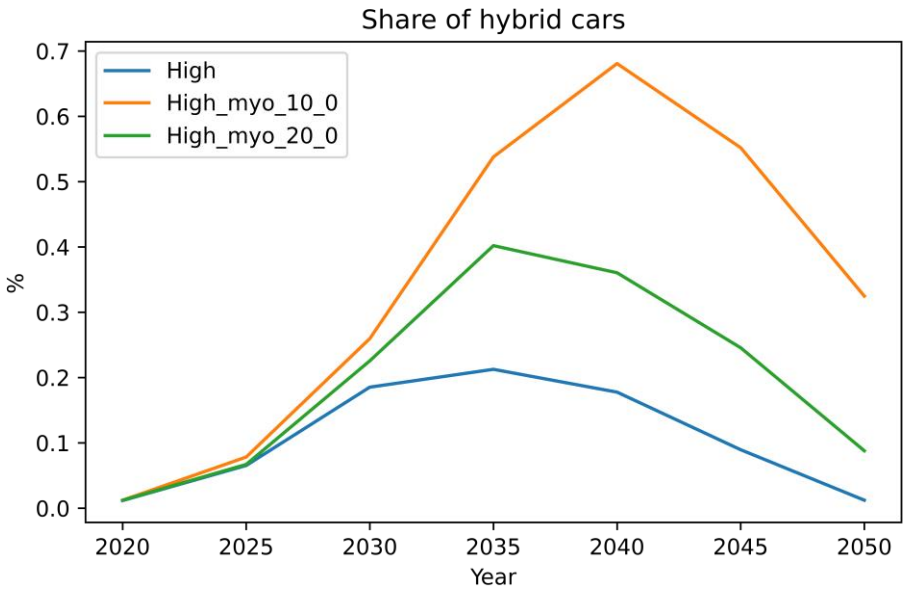
Results – Transport sector

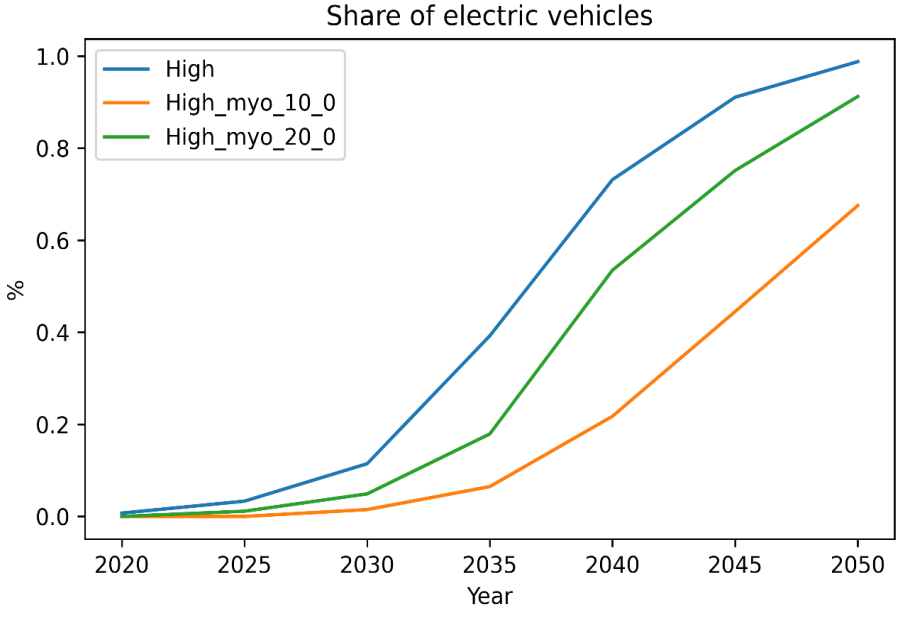


- Myopic modelling gives uncertainty range of the effectiveness of carbon prices
- In the transport sector, more divergence can be seen for lower carbon prices
- For the high price path, there seems to be only slight differences, in contrast to the buildings sector
- Sector target of the climate protection law for 2030 (84 Mio t.) are missed in all scenarios

Results – transport sector

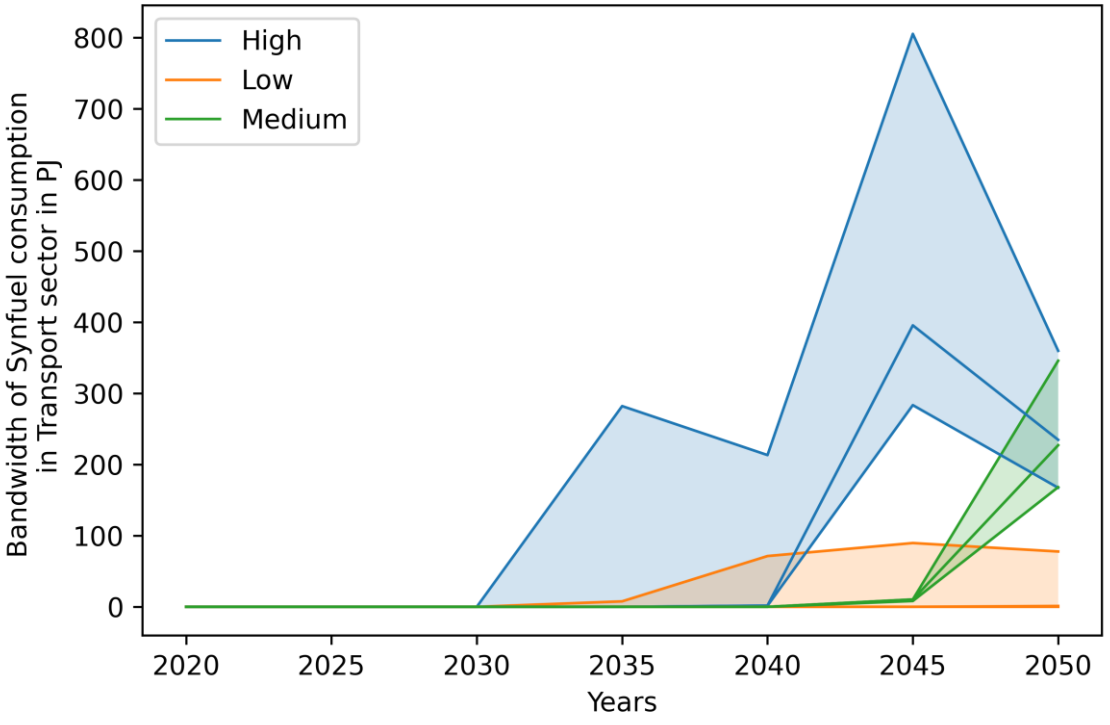
No effect for high scenario?





Results – transport sector

No effect for high scenario?



- For the high scenario, there is a big myopic effect on the results, however it is not affecting the CO_2-emissions
- The investment in hybrid cars made under myopia result in a significantly higher synfuel consumption in the transport sector
- Expensive long-term investements (BEVs, charging infrastructure) are postponed, therefore resulting in the need for expensive substitution of energy carriers when CO_2-prices rise further, thus increasing total system costs

Conclusions – for modelers

- Effects of the myopic modelling are largely in line with existing literature
- Especially the results of Nerini et al. (2017) are confirmed: The effectiveness of carbon prices under perfect foresight are **overestimated!**
- The extent of the effects of myopia depends a lot on model assumptions (e.g. global discount rate, technology specific growth constraints, RE-potentials, import prices for fossil fuels)
- Modelling with ESM ignores very relevant aspects for the effectiveness of carbon prices: investment constraints, personal preferences, landlord-tenant-dilemma, shortages in skilled workers -> **In reality, we would expect carbon prices to be even less effective, especially under myopia!**
- **If the effectiveness of policy measures is analyzed with ESMs, the uncertainty in terms of actors foresight should be considered!**

Conclusions – for policy makers

- CO_2-prices can contribute to the decarbonisation of the buildings and transport sector, but are more effective in the long run -> 2030 goals are all missed with realistic price paths
- A reliable, believable communication about rising CO_2-prices is essential for it to work!
- Eine verlässliche, glaubhafte Kommunikation über steigende CO_2-Preise ist essentiell, um deren Wirkung voll ausnutzen zu können
- **Only relying on CO_2-prices can lead to the missing of short-term goals (2030), but also an overshoot of the carbon budget of each sector**
- **Ideally, a policy mix is established, where rising carbon prices are one part of the puzzle**

Literature

- DeCarolis, Joseph; Daly, Hannah; Dodds, Paul; Keppo, Ilkka; Li, Francis; McDowall, Will et al. (2017): Formalizing best practice for energy system optimization modelling. In: Applied Energy 194 (2), S. 184–198. DOI: 10.1016/j.apenergy.2017.03.001.
- Fuso Nerini, Francesco; Keppo, Ilkka; Strachan, Neil (2017): Myopic decision making in energy system decarbonisation pathways. A UK case study. In: Energy Strategy Reviews 17, S. 19–26. DOI: 10.1016/j.esr.2017.06.001.
- Heuberger, Clara F.; Staffell, Iain; Shah, Nilay; Mac Dowell, Niall (2018): Impact of myopic decision-making and disruptive events in power systems planning. In: Nat Energy 3 (8), S. 634–640. DOI: 10.1038/s41560-018-0159-3.
- Keppo, Ilkka; Strubegger, Manfred (2010): Short term decisions for long term problems – The effect of foresight on model based energy systems analysis. In: Energy 35 (5), S. 2033–2042. DOI: 10.1016/j.energy.2010.01.019.
- Löffler, Konstantin; Burandt, Thorsten; Hainsch, Karlo; Oei, Pao-Yu (2019): Modeling the low-carbon transition of the European energy system - A quantitative assessment of the stranded assets problem. In: Energy Strategy Reviews 26, S. 100422. DOI: 10.1016/j.esr.2019.100422.
- Expertenrat für Klimafragen (2023): Prüfbericht zur Berechnung derdeutschen Treibhausgasemissionen für das Jahr 2022. Prüfung und Bewertung der Emissionsdaten gemäß § 12 Abs. 1 Bundes-Klimaschutzgesetz. Online verfügbar unter: https://www.expertenrat-klima.de

University of Stuttgart
IER Institute for Energy Economics
and Rational Energy Use

Thank you!

M. Sc. Alexander Burkhardt

e-mail alexander.burkhardt@ier.uni-stuttgart.de
phone +49 (0) 711 685- 87500
fax +49 (0) 711 685- 87883

Universität Stuttgart
IER – Institute for Energy Economics and Rational En
Heßbrühlstraße 49a, Stuttgart

Acknowledgment

This research was funded by the German Federal Ministry of Education and Research in the ARIADNE Project, grant number 03SFK5H0.