Pathways for Germany’s energy transition towards 2050

A model-based analysis on a federal level

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Agenda

1 Scenarios

3 Methodology

4 Results

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Scenarios

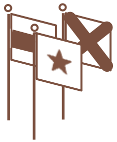
GREEN DEMOCRACY

- International dynamic towards peace, equality, and sustainability
- Main drivers*: climate protection, safety of supply, cost efficiency
- CO_2 reduction goals**: 2030: - 55 %; 2050: - 95 %

EUROPEAN ISLAND

- Strong European alliance with emphasis on solidarity and equality among member states
- Main drivers*: cost efficiency, safety of supply, climate protection
- CO_2 reduction goals**: 2030: - 40 %; 2050: - 80 %

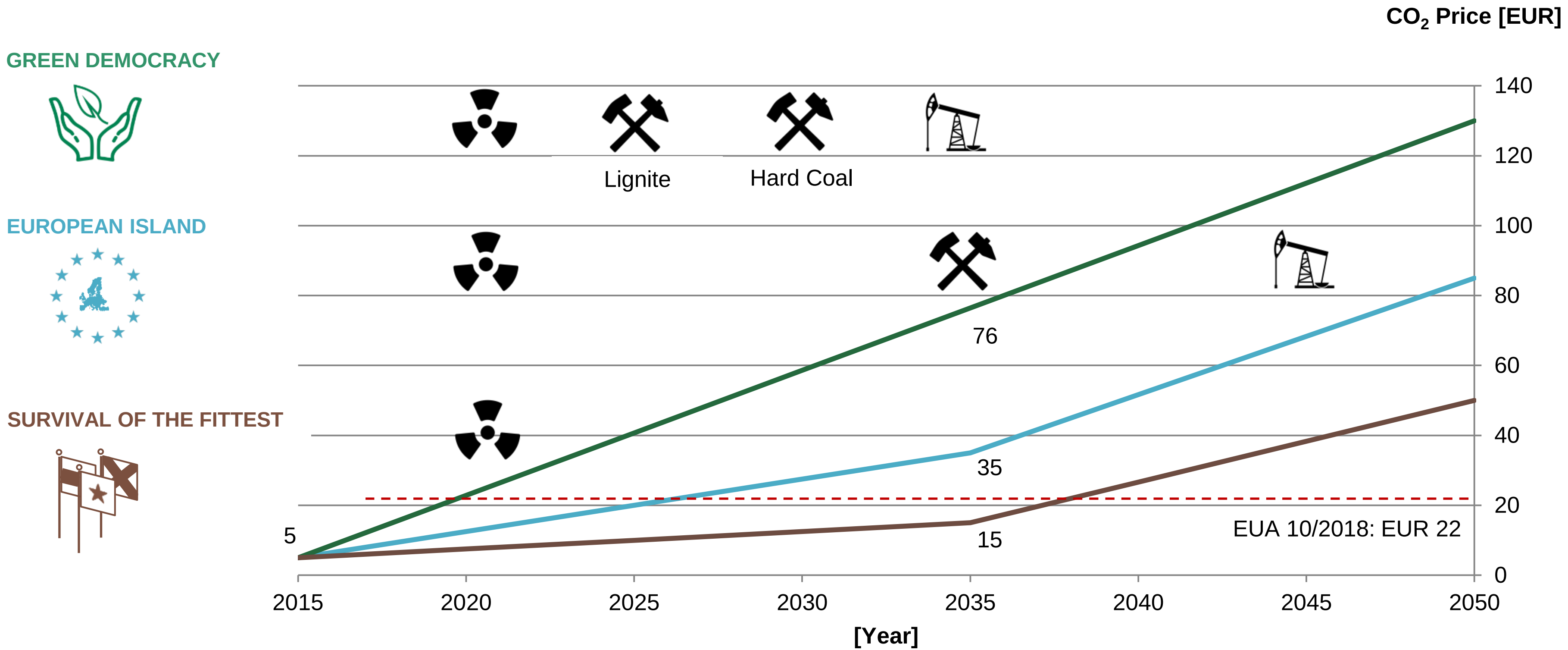
SURVIVAL OF THE FITTEST



- Conservative and nationalist movements especially in the EU
- Main drivers*: safety of supply, cost efficiency, climate protection
- No CO_2 reduction goals

*in order of priority **compared to the year 1990

Main Policy Measures—Phase-outs and CO_2 Pricing



Öko-Institut (2015): Klimaschutzszenario 80 (KS 80); UBA (2013): Energiewende Szenario (EWS); UBA (2013): Aktuelle Politik Szenario (APS)

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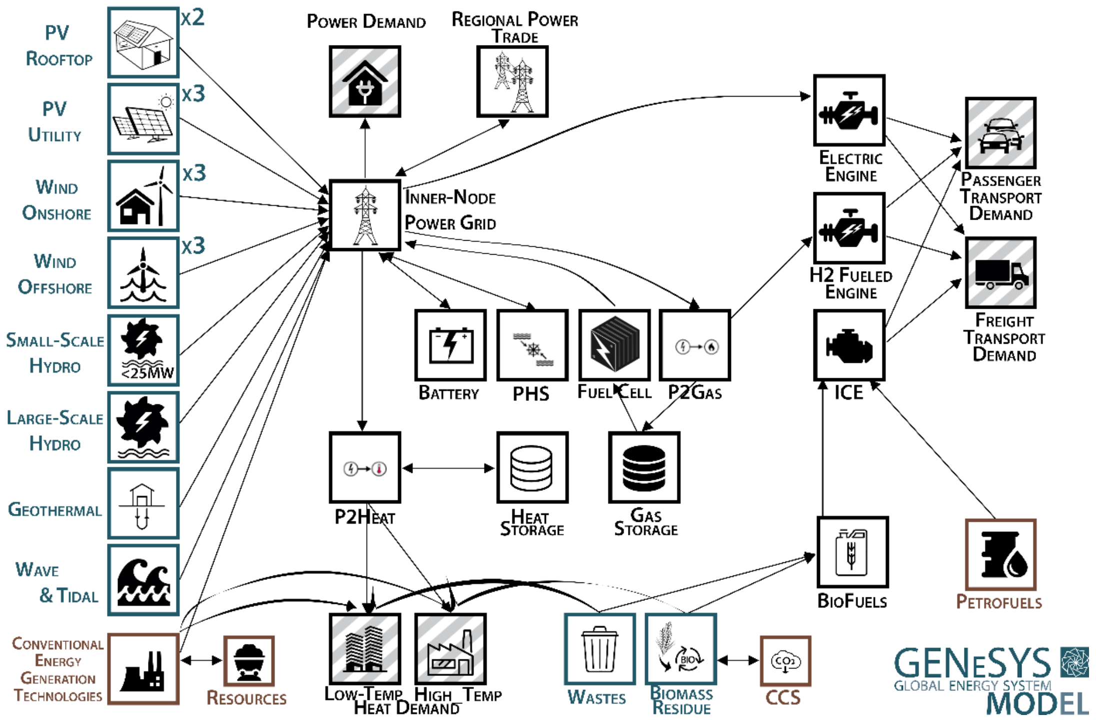
GENeSYS-MOD

- Flow-based optimization model
- Network design by interconnected *Nodes*
- Exogenous variables
  - Energy demand
  - Investment costs
  - Fuel costs
  - O&M costs
  - Trade costs
  - CO_2 costs
- Endogenous variable
  - Energy mix
  - Overall system costs



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Germany’s Energy Mix in the Scenarios

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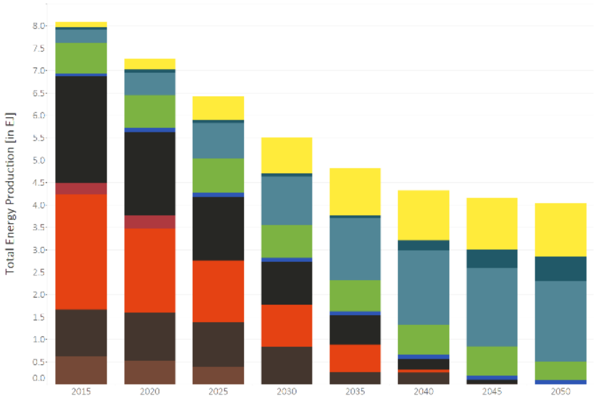

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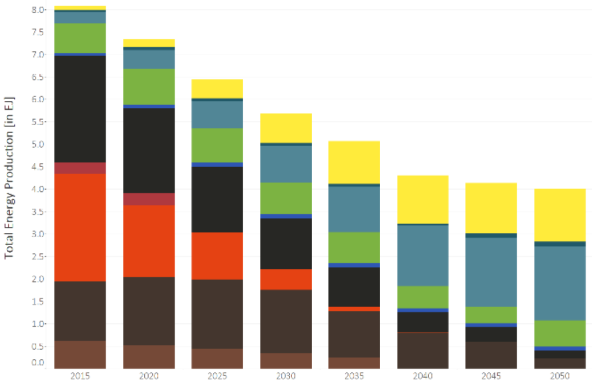

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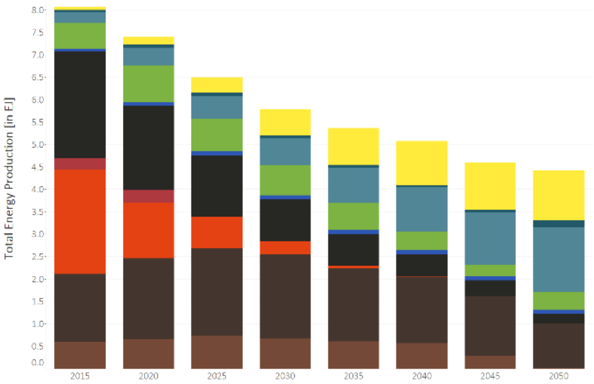


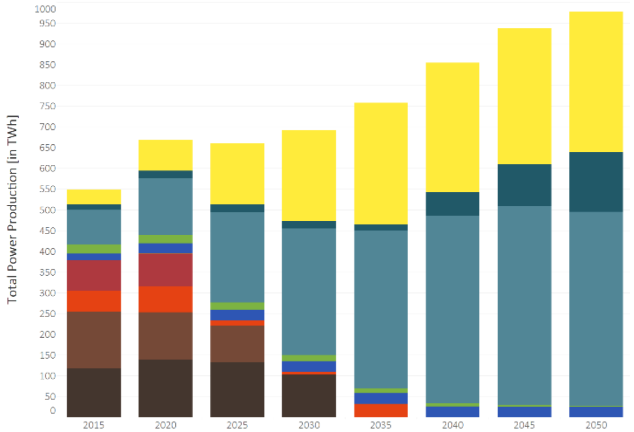
Technology

■ Coal ■ Lignite ■ Gas [Natural Gas] ■ Nuclear ■ Geothermal ■ Hydro ■ Ocean

■ Wind Offshore ■ Wind Onshore ■ Photovoltaics ■ Biomass ■ Oil

Germany’s Electricity Production in the Scenarios

GREEN DEMOCRACY



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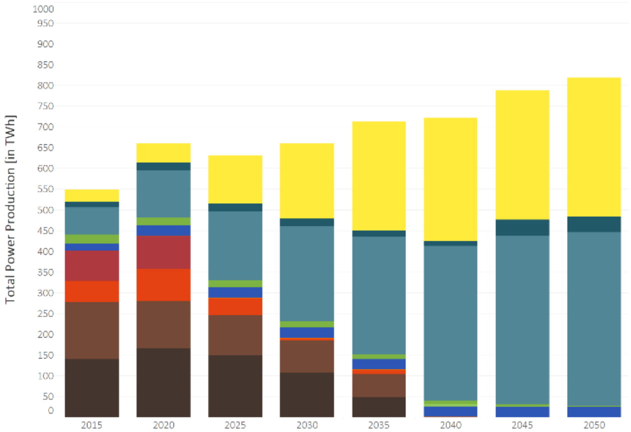

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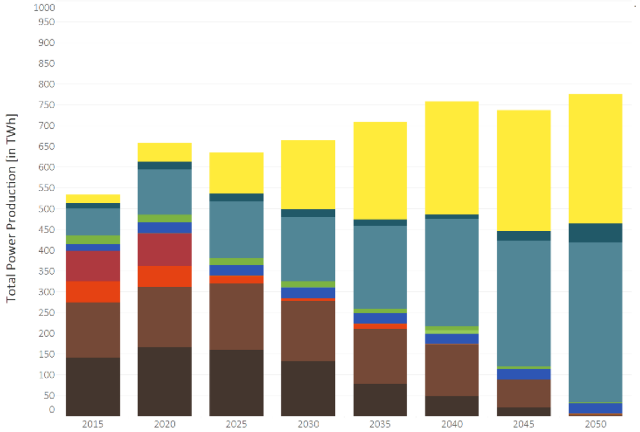
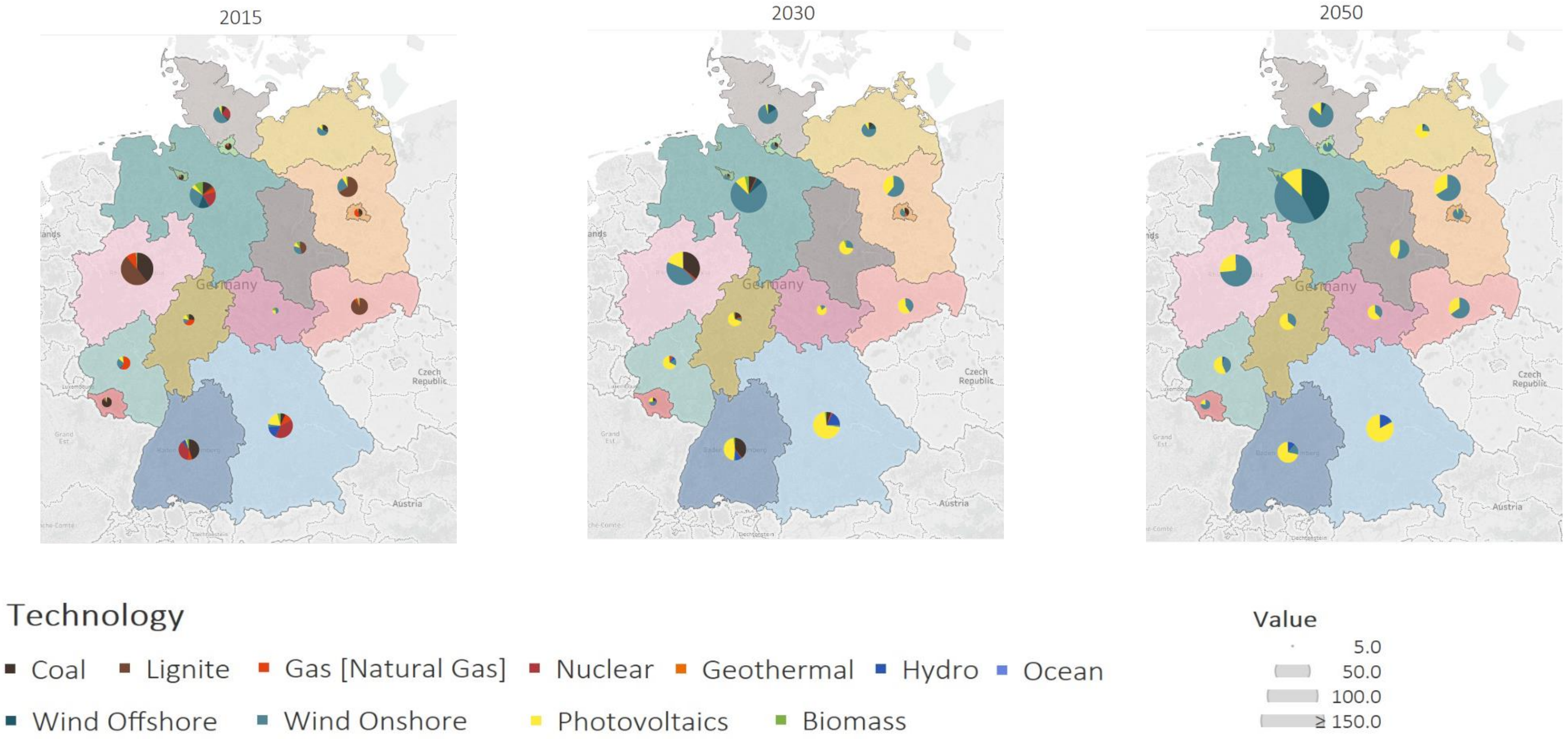


Technology

- Coal
- Lignite
- Gas [Natural Gas]
- Nuclear
- Geothermal
- Hydro
- Ocean
- Wind Offshore
- Wind Onshore
- Photovoltaics
- Biomass

Power Generation – GD Scenario



Heat Low and Heat High

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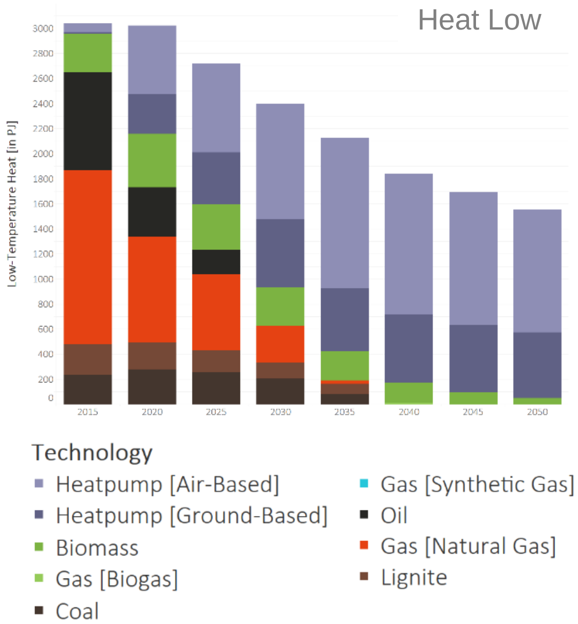

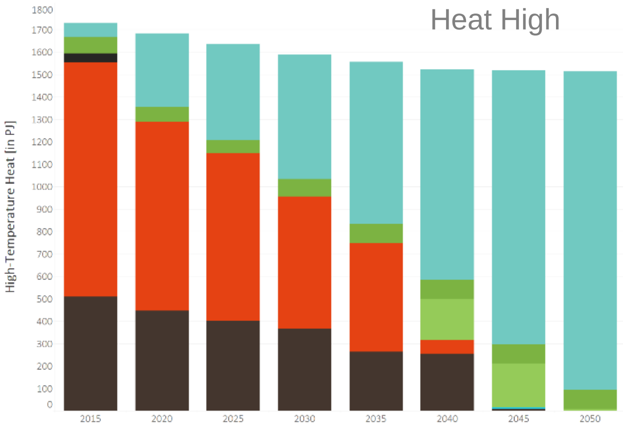

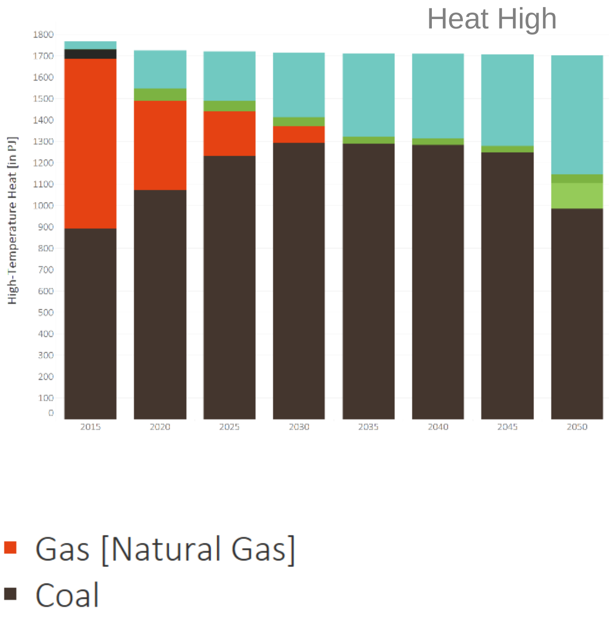

Comparing the Emissions of the three Scenarios

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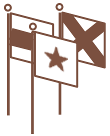

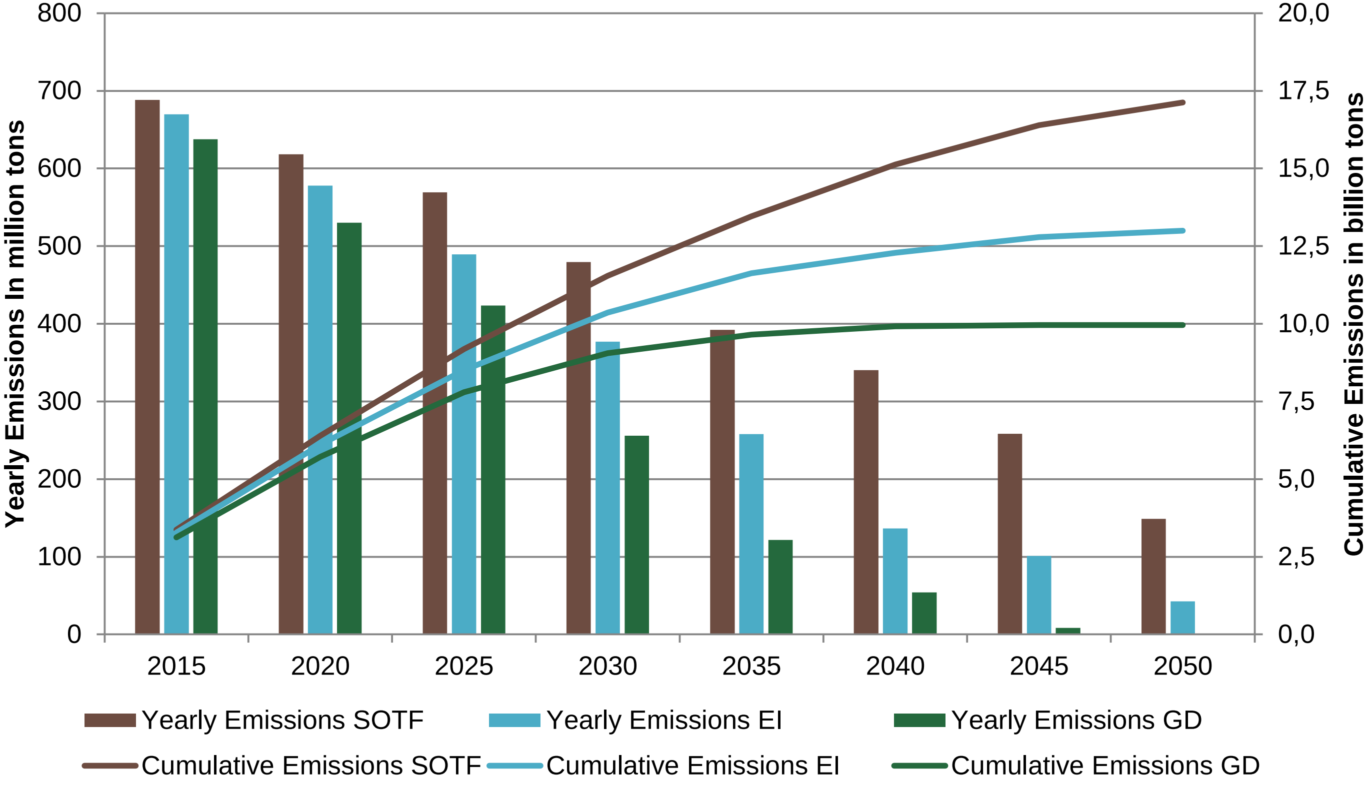

Key Findings

- Governmental induced technology-phase-outs have a great impact
- CO_2 Pricing is a strong market based tool to effectively promote renewable technologies
- NDCs' reduction goals are overachieved due to model limitations
- To decarbonize space heating and hot water supply, existing buildings must be retrofitted rapidly
- Industrially demanded high heat is highly dependent from economical aspects
- Passenger transport has to rely on BEV's, only in later years synthetic gas plays a role
- Freight transport can be decarbonized with biofuels. Marginal costs of rail transport are lower

Thank you for your attention.

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References

IEA 2016. World Energy Outlook 2016. Paris: International Energy Agency.

Löffler, Konstantin, Karlo Hainsch, Thorsten Burandt, Pao-Yu Oei, and Christian von Hirschhausen. 2017. "Decarbonizing the Indian Energy System until 2050: An Application of the Open Source Energy Modeling System OSeMOSYS." IAEE Energy Forum, Energy Forum, , no. Singapore Issue 2017 (July): 51–52.

Löffler, Konstantin, Karlo Hainsch, Thorsten Burandt, Pao-Yu Oei, Claudia Kemfert, and Christian von Hirschhausen. 2017. "Designing a Model for the Global Energy System—GENeSYS-MOD: An Application of the Open-Source Energy Modeling System (OSeMOSYS)." Energies 10 (10): 1468. https://doi.org/10.3390/en10101468.

Oei, Pao-Yu, Hanna Brauers, Claudia Kemfert, Martin Kittel, Leonard Göke, Christian von Hirschhausen, and Paula Walk. 2018. "Kohleausstieg in NRW Im Deutschen Und Europäischen Kontext - Energiewirtschaft, Klimaziele Und Wirtschaftliche Entwicklung." https://www.diw.de/documents/publikationen/73/diw_01.c.598424.de/diwkompakt_2018-129.pdf.

Öko-Institut ed. 2015 "Klimaschutzszenario 2050 2. Endbericht." 2. Berlin, Karlsruhe: Öko-Institut e.V. https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccx/2015/Bericht_Runde_2.pdf.

UBA ed. 2013 „Politikszenarien für den Klimaschutz VI" Berlin. https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4412.pdf

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Appendix

Capital Costs in M€/GW for new capacities

	2020	2030	2040	2050	Source
Onshore Wind	1150	1000	940	900	Breyer/Gulagi
Offshore Wind	2636.667	1936	1710	1592,352	Dynelmod
Photovoltaic	580	390	300	246	Ram / Breyer 2017
Hydro large (>10MW)	2200	2200	2200	2200	ETRI 2014
Heat pump Ground based	1650	1550	1460	1370	ETRI 2014
Heat pump Air based	780	730	690	650	ETRI 2014

Capital Costs in M€/GW for new capacities

	2020	2030	2040	2050	Source
Hardcoal	1600	1600	1600	1600	ETRI 2014
Lignite	1900	1900	1900	1900	ETRI 2014
Gas	636	607	579	550	ETRI 2014
Biomass	2620	2370	2150	1950	ETRI 2014
Geothermal	4970	4470	4020	3610	Breyer/Gulagi
Nuclear	4350	4100	3800	3750	ETRI 2014

Variable Costs in M€/PJ

	2020	2030	2040	2050	Source
Residual Lignite	1.09	1.07	0.88	0.57	Gerbaulet
Import Hardcoal GD	1.52	1.45	1.26	1.08	WEO 2016
Import Hardcoal EI	1.54	1.52	1.36	1.20	WEO 2016
Import Hardcoal SOTF	1.65	1.84	1.84	1.80	WEO 2016
Import Gas GD	6.45	8.53	8.71	8.87	WEO 2016
Import Gas EI	6.54	8.91	9.38	9.86	WEO 2016
Import Gas SOTF	7.01	10.82	12.73	14.79	WEO 2016
Import Oil GD	10.04	11.35	10.11	8.92	WEO 2016
Import Oil EI	10.18	11.86	10.88	9.91	WEO 2016
Import Oil SOTF	10.91	14.40	14.77	14.86	WEO 2016

Energy Mix on Federal State Level – EI Scenario

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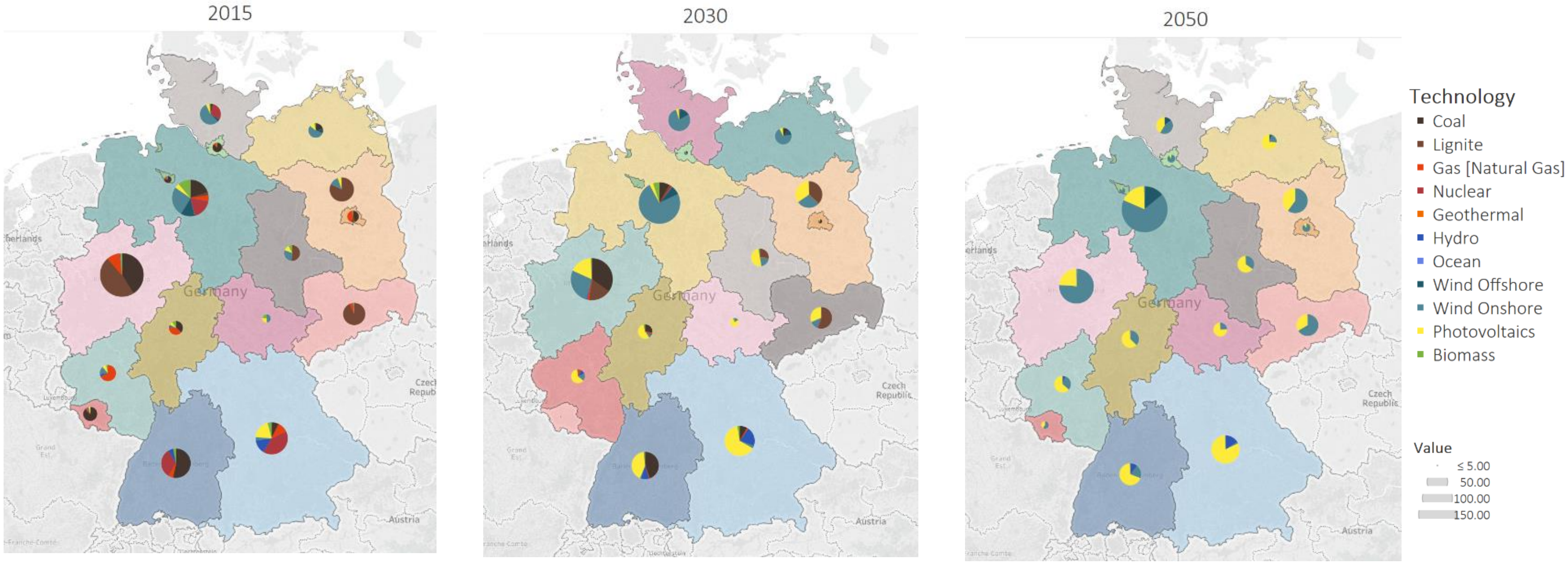

Energy Mix on Federal State Level – SOTF Scenario

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SURVIVAL OF THE FITTEST