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Energiewende
Switch to the Future

Welcome to the

Australian-German Energy Symposium

18-19 September 2019

adelphi

ENERGY TRANSITION HUB
an Australian-German innovation partnership

AHK
Deutsch-Australische Industrie- und Handelskammer
German-Australian Chamber of Industry and Commerce

Diving into joint energy visions: Scenarios for the Australian-German energy transition - two energy super powers, hydrogen/efuel and technology export

Moderator: **A/Prof. Malte Meinshausen** *(no slides)*
Co-Director of the Energy Transition Hub, Deputy Academic Convenor, Australian-German Climate and Energy College, University of Melbourne

Prof. Gunnar Luderer
Co-Director of the Energy Transition Hub, Deputy Chair, Research Domain III - Transformation Pathways, Potsdam Institute for Climate Impact Research (PIK)

Dr. Carsten Rolle
Head of the Department of Energy and Climate Policy, Federation of German Industries (BDI)

Prof. Karen Pittel
Director, ifo Center for Energy, Climate and Resources, ifo Institute for Economic Research

Dylan McConnell
Research Fellow - Energy Systems, Energy Transition Hub

Dr. Falko Ueckerdt
Managing Director – Germany, Energy Transition Hub and Co-Head, National Energy Transitions Team, Potsdam Institute for Climate Impact Research (PIK)

Dr. Daniel Roberts *(no slides)*
Director, Hydrogen Energy Systems Future Science Platform, CSIRO Energy

Attilio Pigneri *(no slides)*
CEO, H2U and President, Australian Association for Hydrogen Energy

The global energy transition for limiting global warming to below 2°C

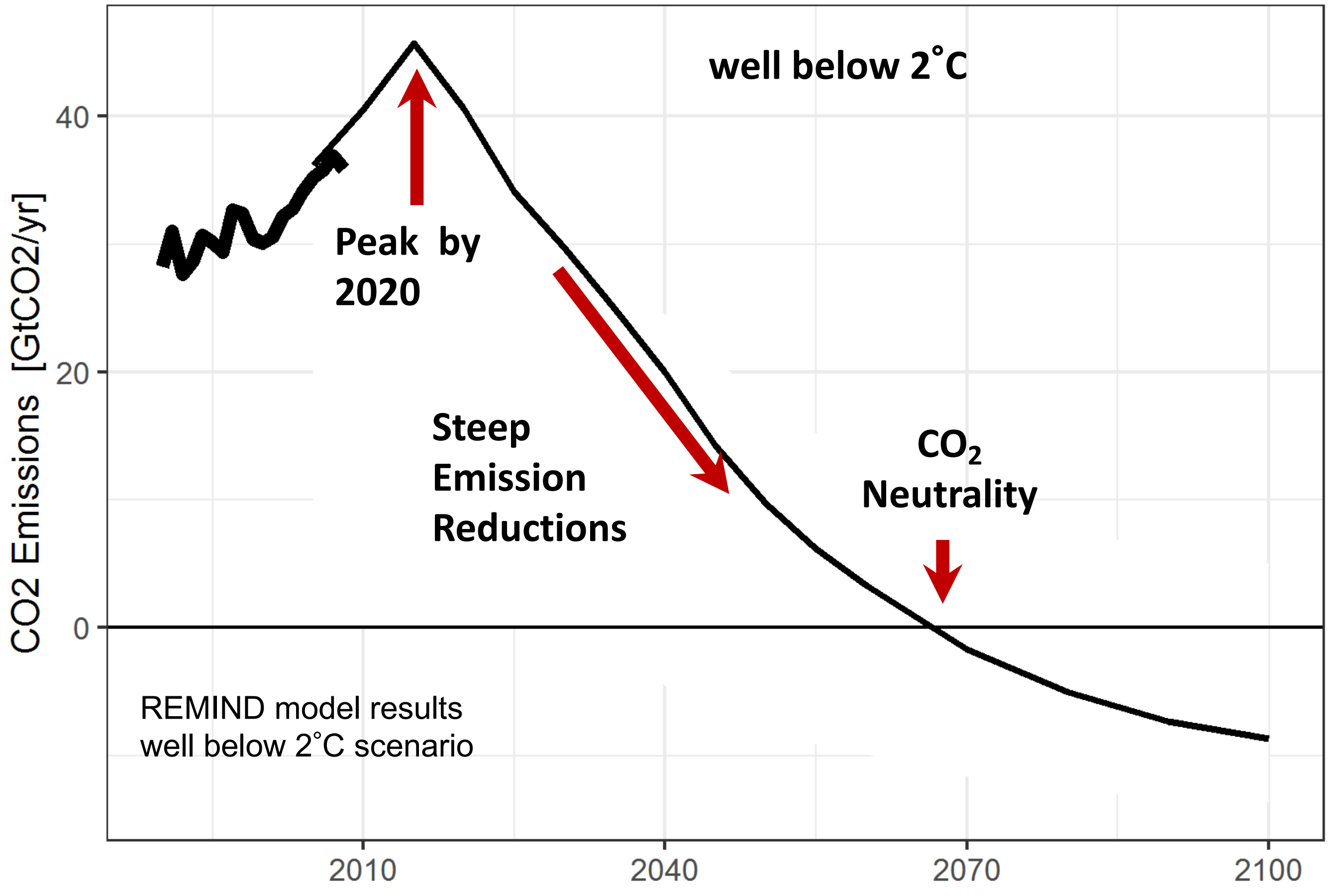
Gunnar Luderer

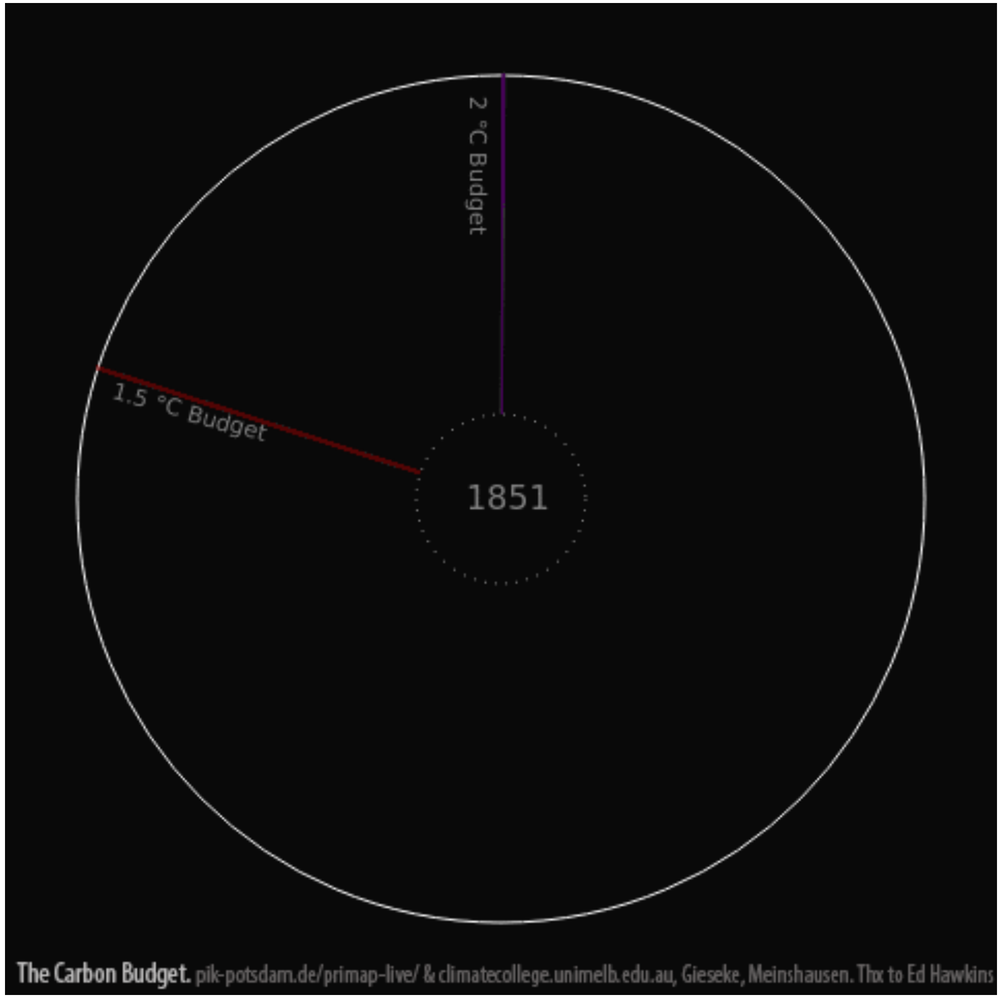
Australian-German Energy Symposium
September 19th, 2019

ENERGY TRANSITION HUB

P I K
Potsdam Institute for Climate Impact Research

The net zero emissions challenge

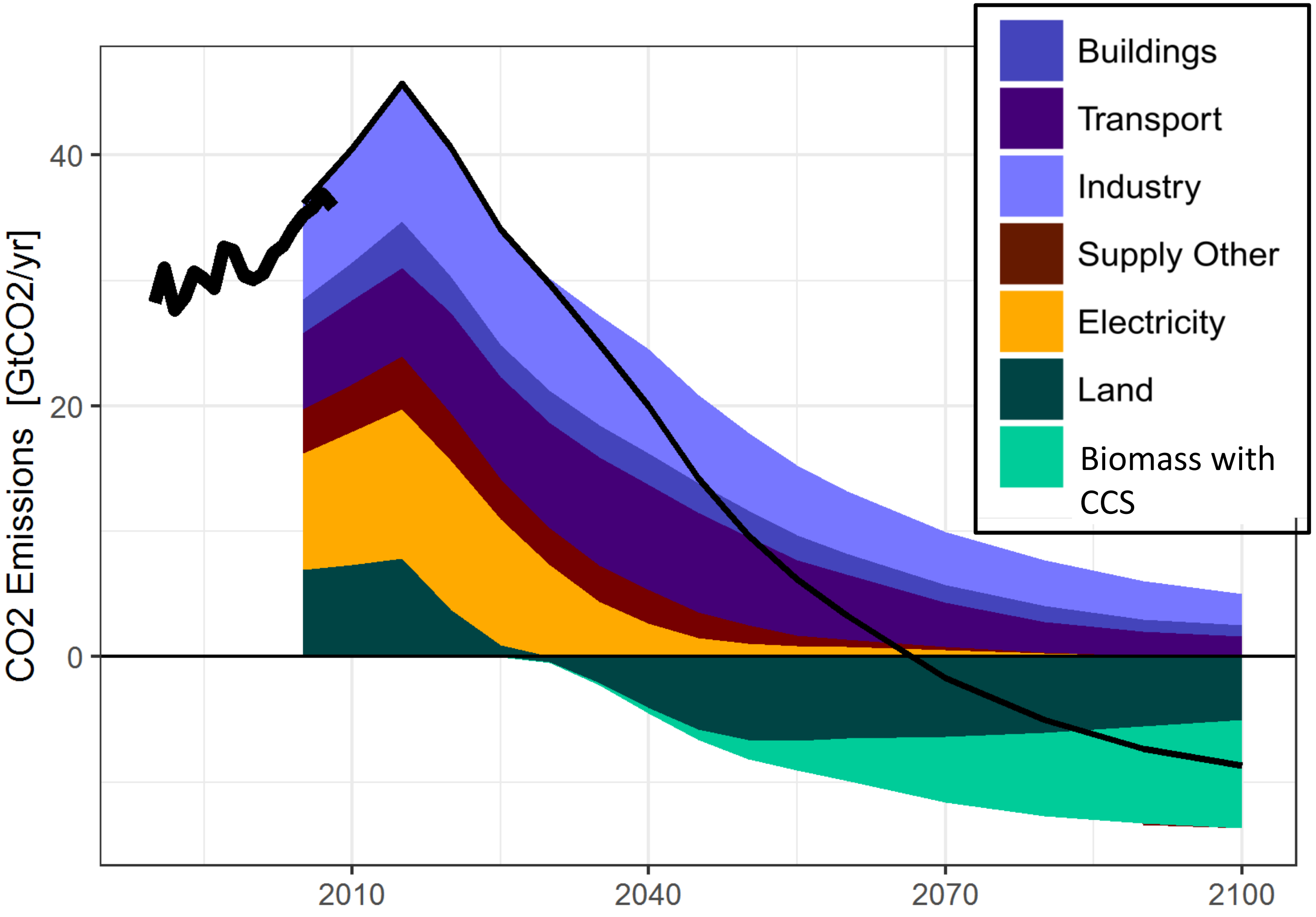




Gieseke and Meinshausen (2016)

Based on
Luderer et al. (2018), *Nature Clim. Chnage*
Bertram et al. (2018), ERL

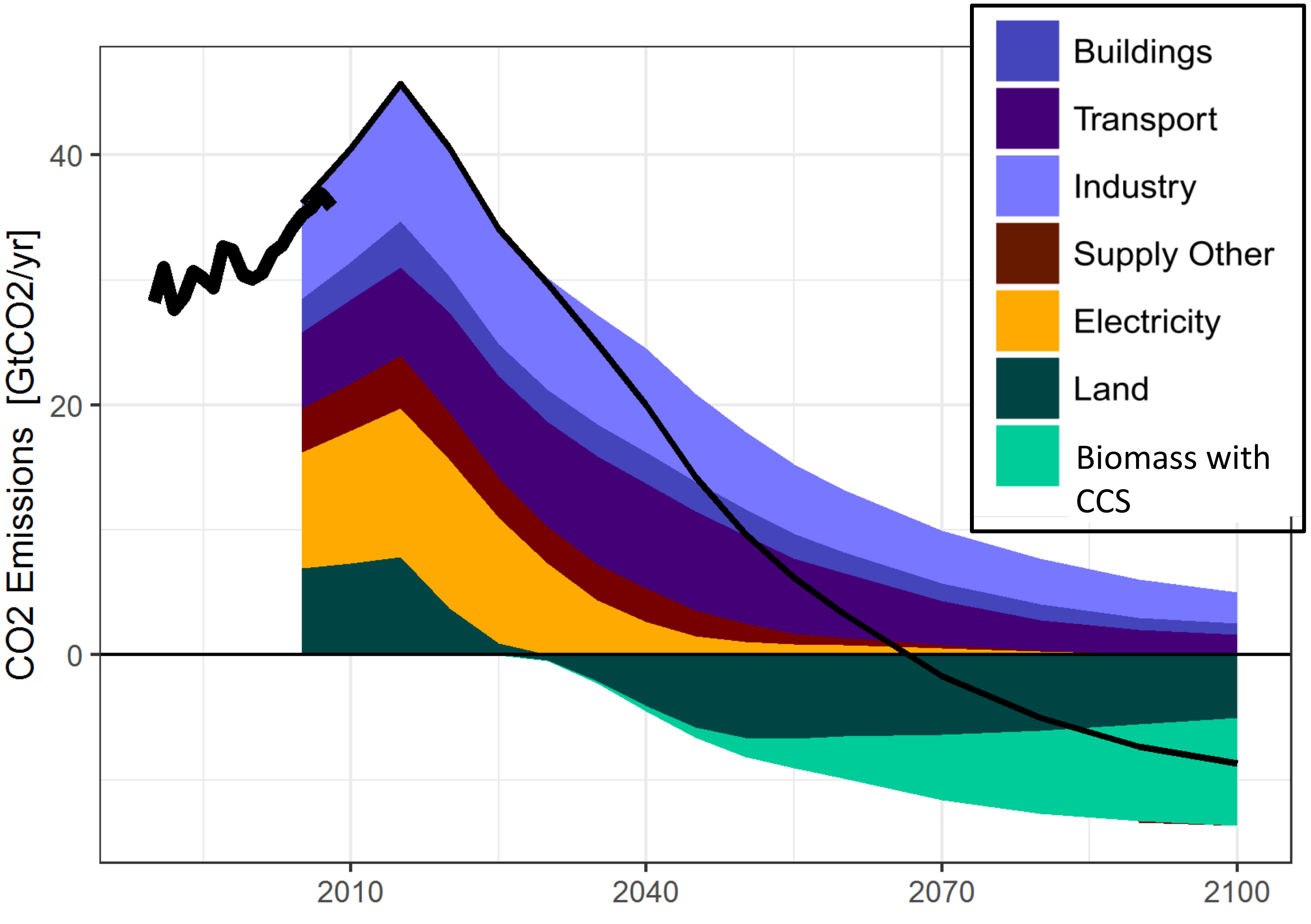
The net zero emissions challenge

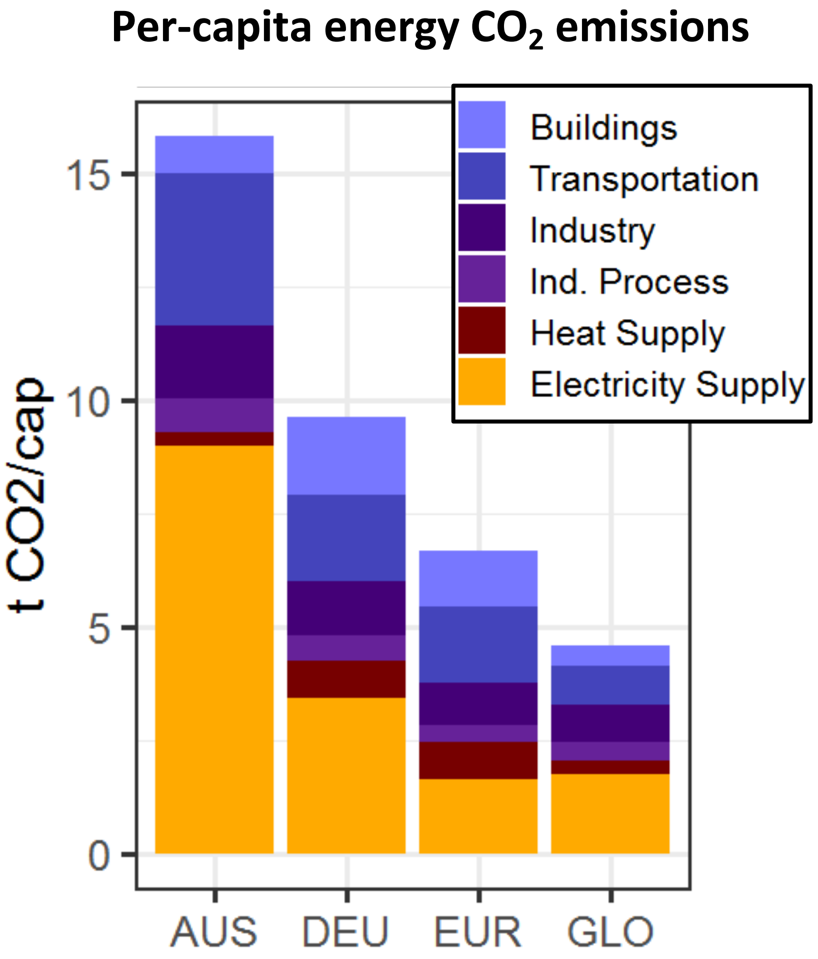


- Rapid emissions reductions in the **power sector**: phasing out coal and ramping up renewables
- Remaining fossil CO_2 emissions are dominated by **decarbonization bottlenecks** in **transport** (freight, aviation) and **industry** (steel, cement, chemicals)
- These residual fossil emissions are the key determinant of the feasibility of Paris targets and the scale of **carbon dioxide removal** (CDR)

Based on
Luderer et al. (2018), *Nature Clim. Chnage*
Bertram et al. (2018), ERL

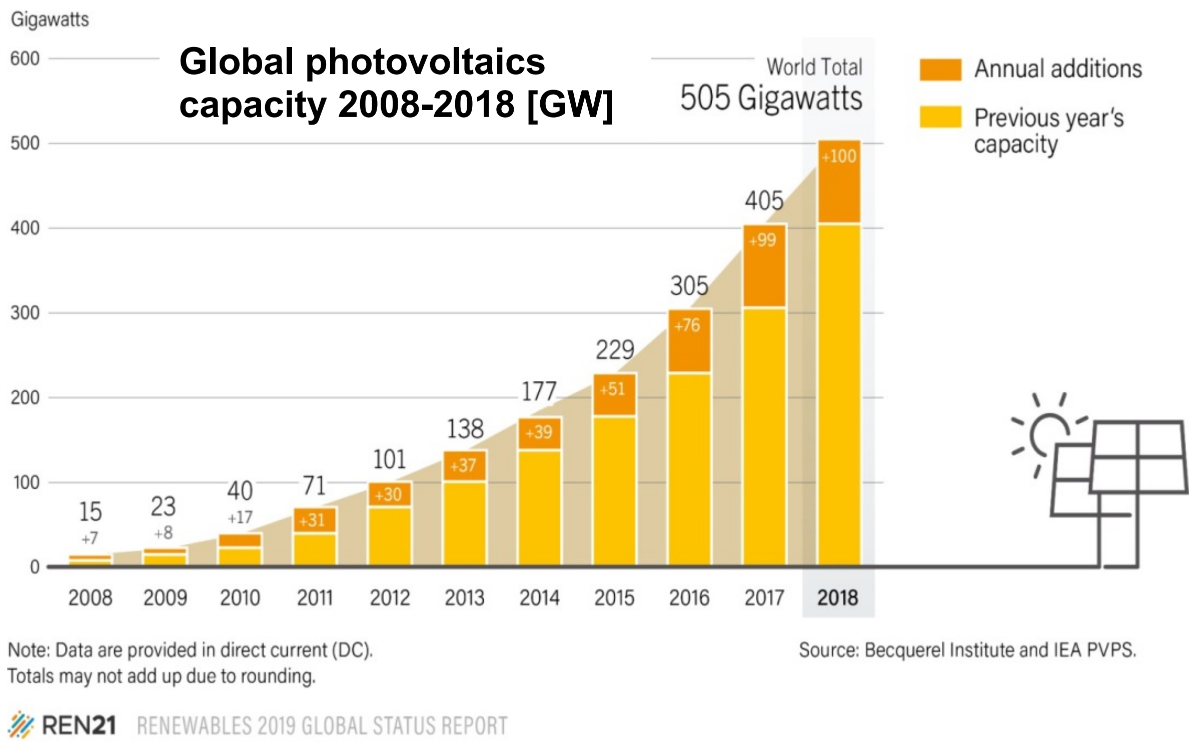
The net zero emissions challenge

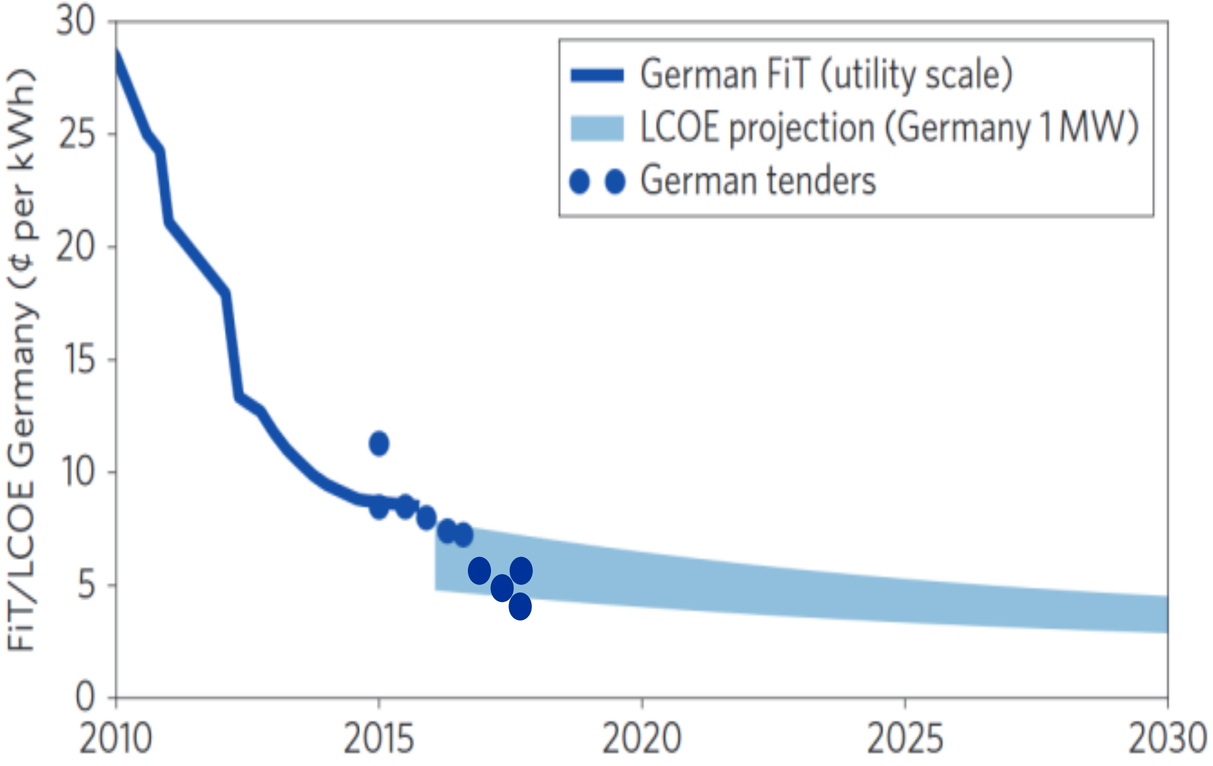




Based on
Luderer et al. (2018), *Nature Clim. Chnage*
Bertram et al. (2018), ERL

Opportunity (1): Renewable electricity





Creutzig et al. 2017, Nature Energy

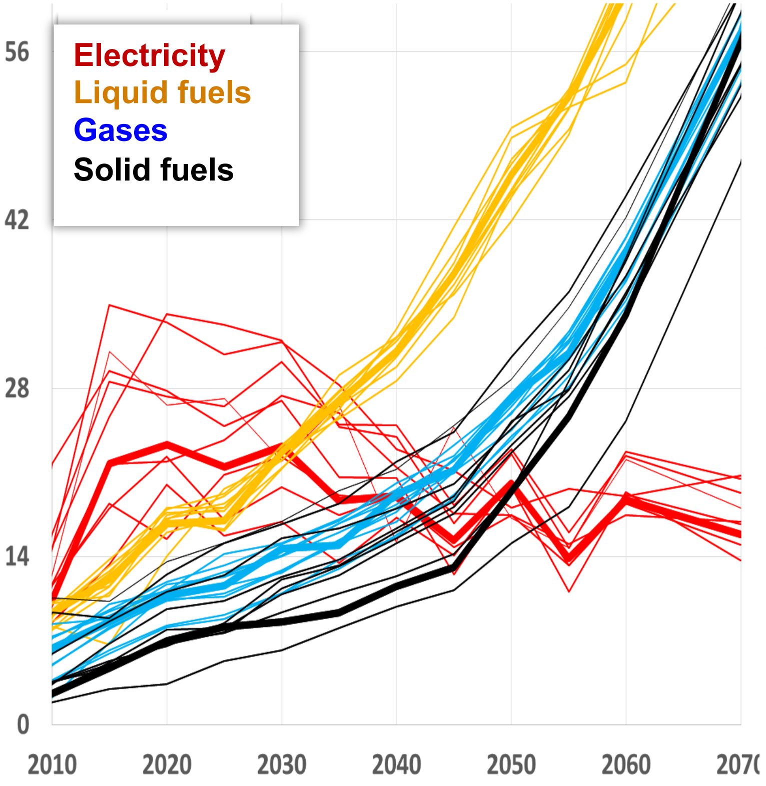
Distrib

Opportunity (2): Deep electrification

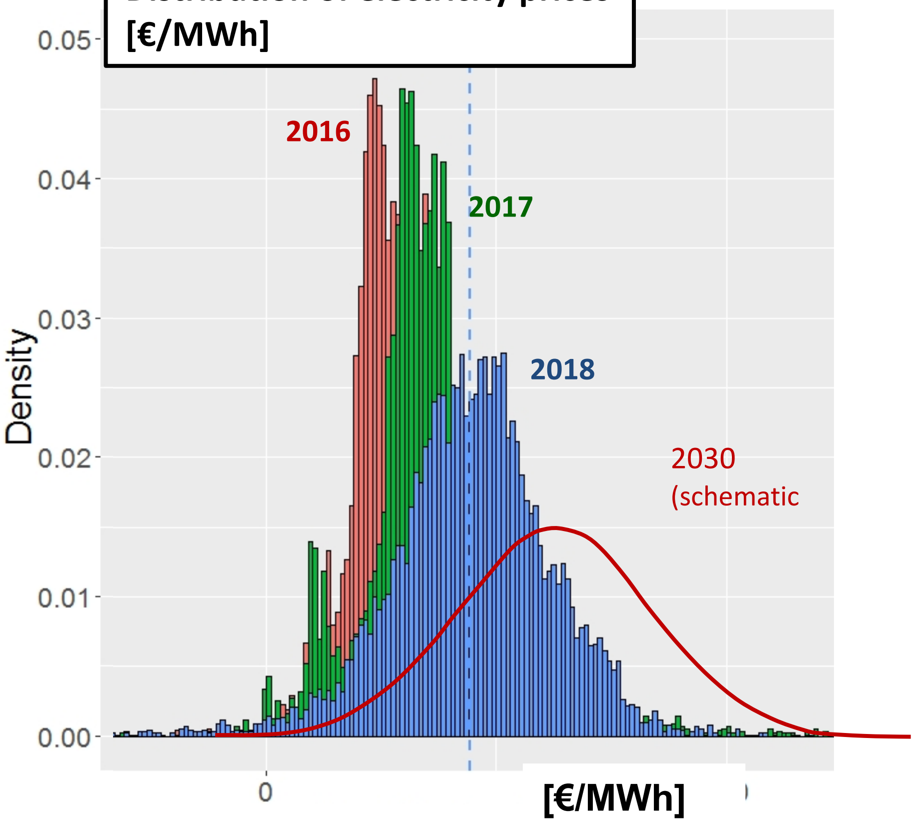
Electricity is set to become cheapest energy carrier…

…but also more variable…

Energy prices [$/MWh]



Distribution of electricity prices [€/MWh]



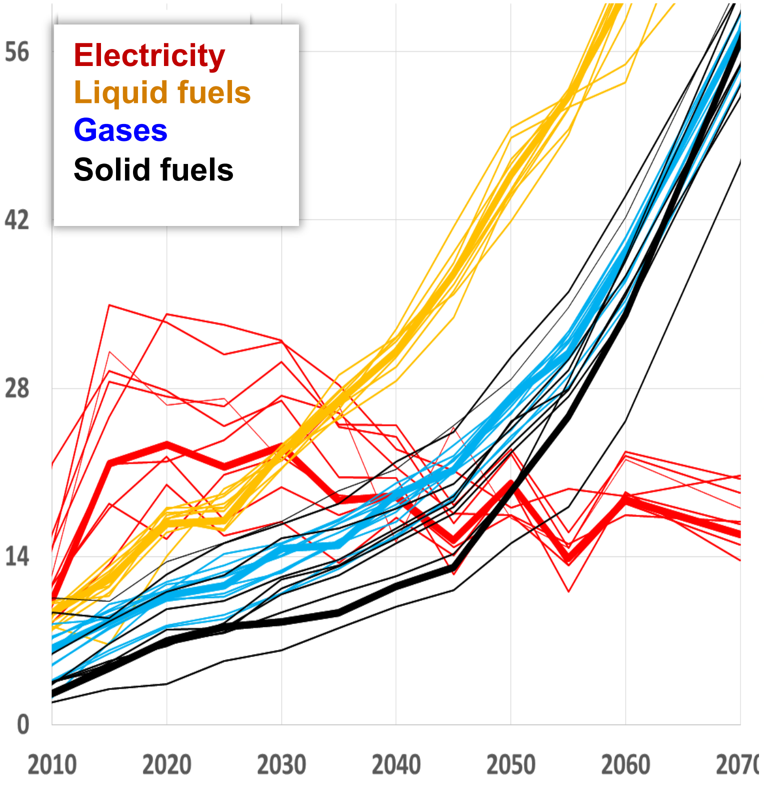
Opportunity (2): Deep electrification

Electricity is set to become cheapest energy carrier…

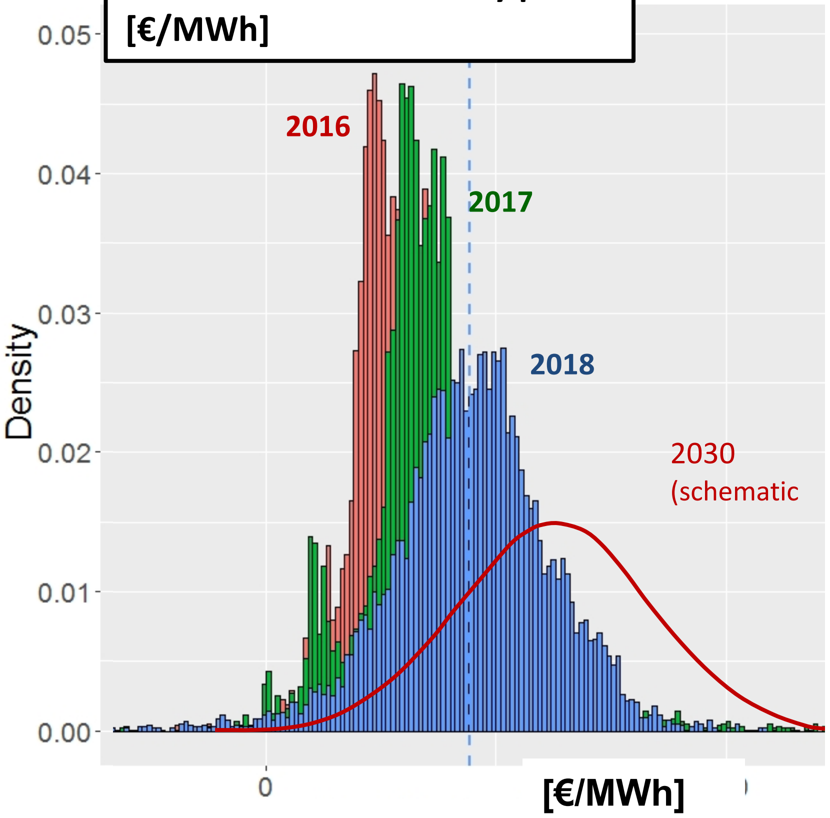
…but also more variable…

…making electrification increasingly attractive.

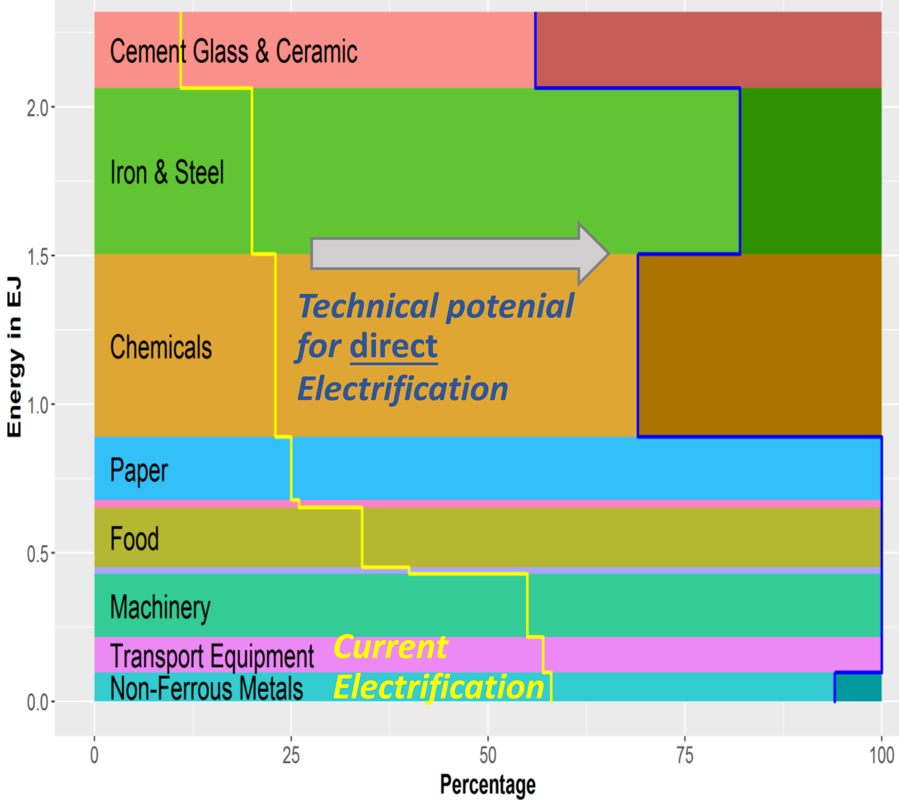
Energy prices [$/MWh]



Distribution of electricity prices [€/MWh]

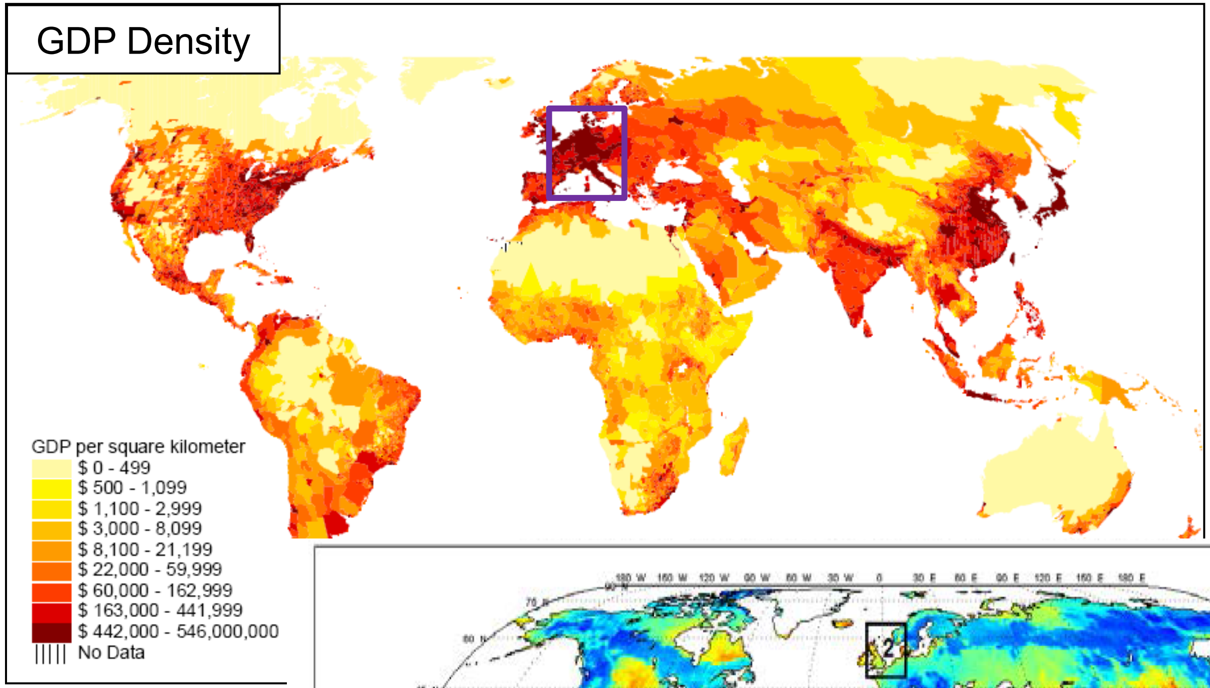


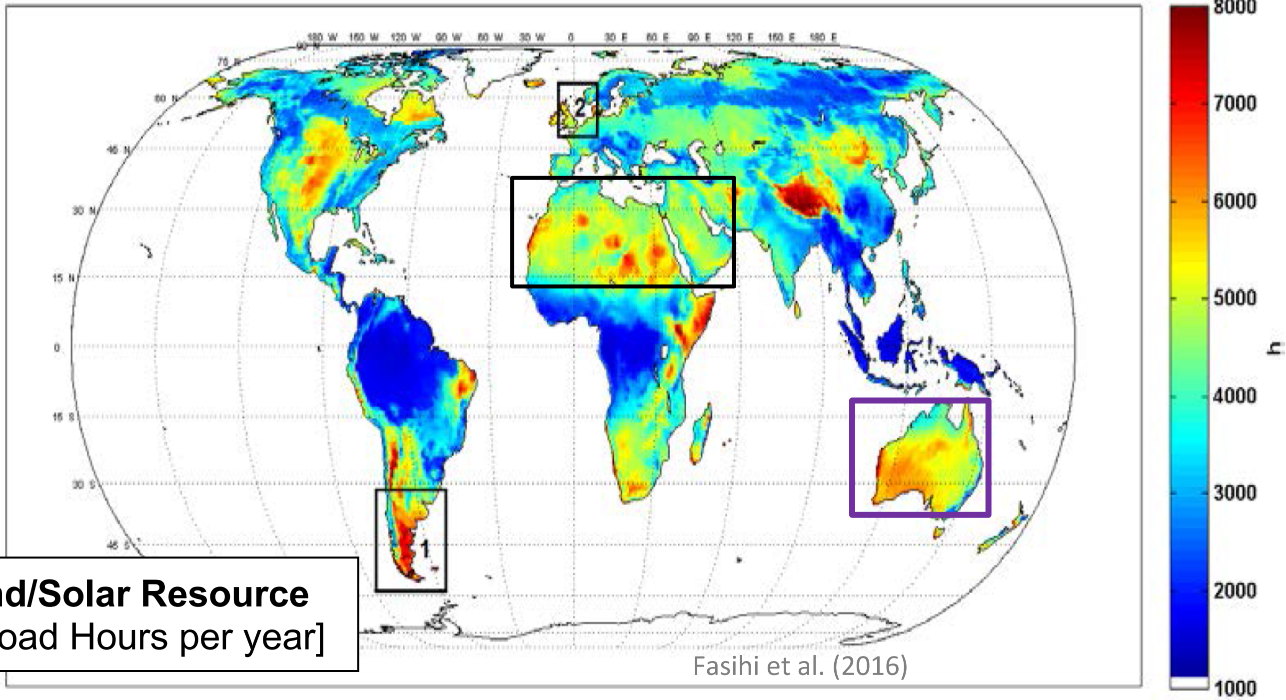
Electrification potentials in industry



Madeddu et al., in preparation

Opportunity (3): Shipping the sun





Combined Wind/Solar Resource Potential [Full Load Hours per year]

Fasihi et al. (2016)

How can renewable energy be traded?

- **Electricity** via ultra high voltage grid grid
- **Synthetic fuels** (hydrogen, methane, methanol,…)
- **Energy intensive materials** (steel, aluminum, ammonia,…)

Thank you!

Contact:

Gunnar Luderer

Energy Systems Group

luderer@pik-potsdam.de

acatech
DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN

BDI
The Voice of German Industry

Transition Scenarios for Germany

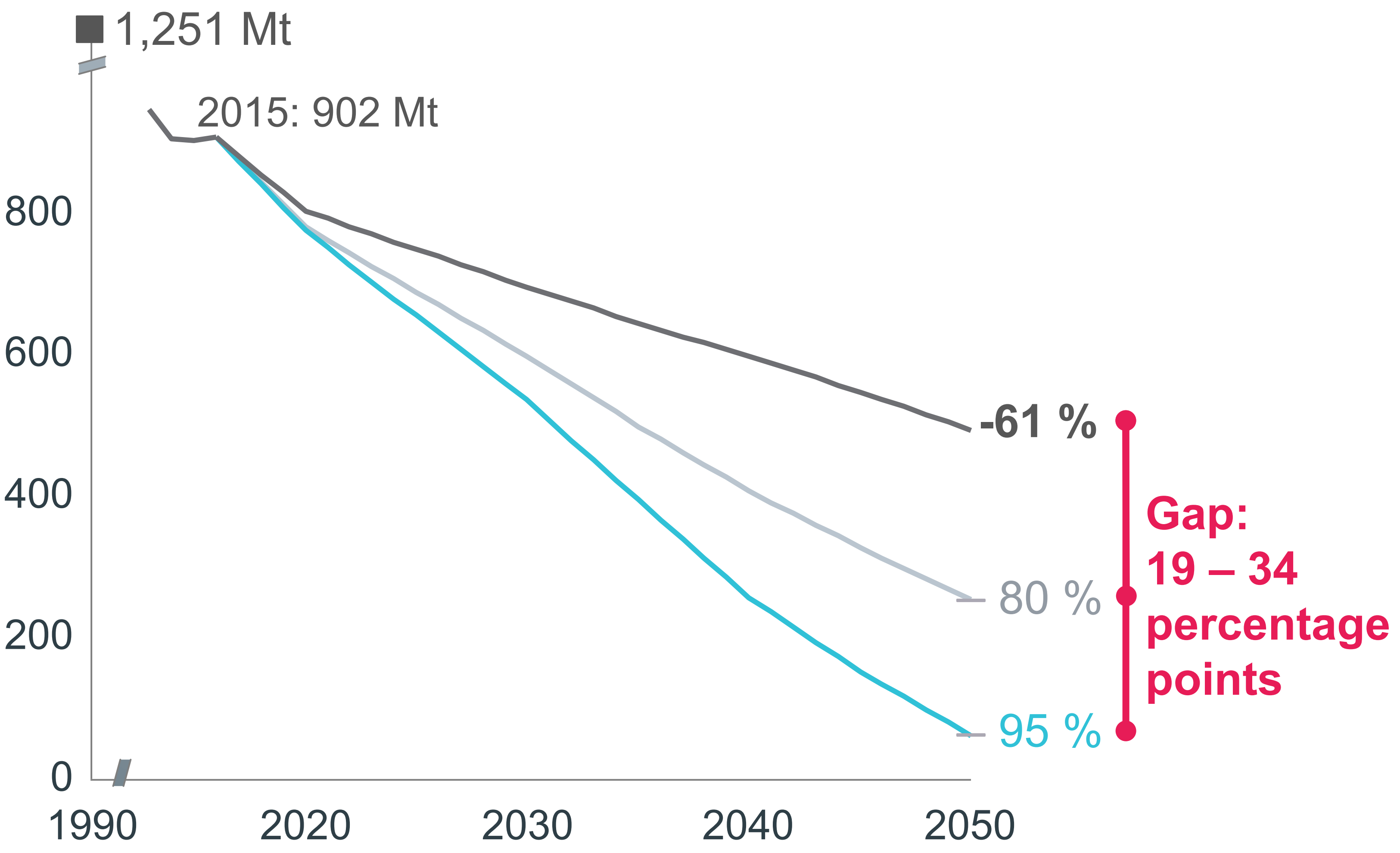
Dr. Carsten Rolle
Prof. Dr. Karen Pittel

Australian-German Energy Symposium 2019

Key Results from
BDI-Study „Climate Paths for Germany“

There are huge gaps to be filled in order to reach political goals

Greenhouse gas (GHG) emissions in Germany
Million Tons CO_2 equivalents



Sources: The Boston Consulting Group, Prognos 2017

Altering assumptions would directly affect modeling outcome.

We modelled according to the following assumptions:

Perfect carbon leakage protection

Energy and emmissions-intensive industries will not have to face direct or indirect costs resulting from the ETS that exceed the current level

Electricity grid/infrastructure

Changed demand and supply structures, overhauled power grid without structural bottlenecks, no cut-off of renewable energies due to insufficient grid infrastructure

Economic abatement costs

2050 climate goal is reached with priority to most cost-efficient (abatement costs) measures first across the different sectors

Perfect regulation

Right policy decisions are taken at the right point in time. Cross-sector measures are implemented in an ideal way

Demand Side Management

All new consumers of power/energy (electric vehicles, heat pumps, PtX) are assumed to be able to contribute to overall system integrity/stability

Technological Progress

Expert roundtables estimated future technology costs and benefits. Results tested against current scientific estimates

80 % path achievable with technologies known to us today

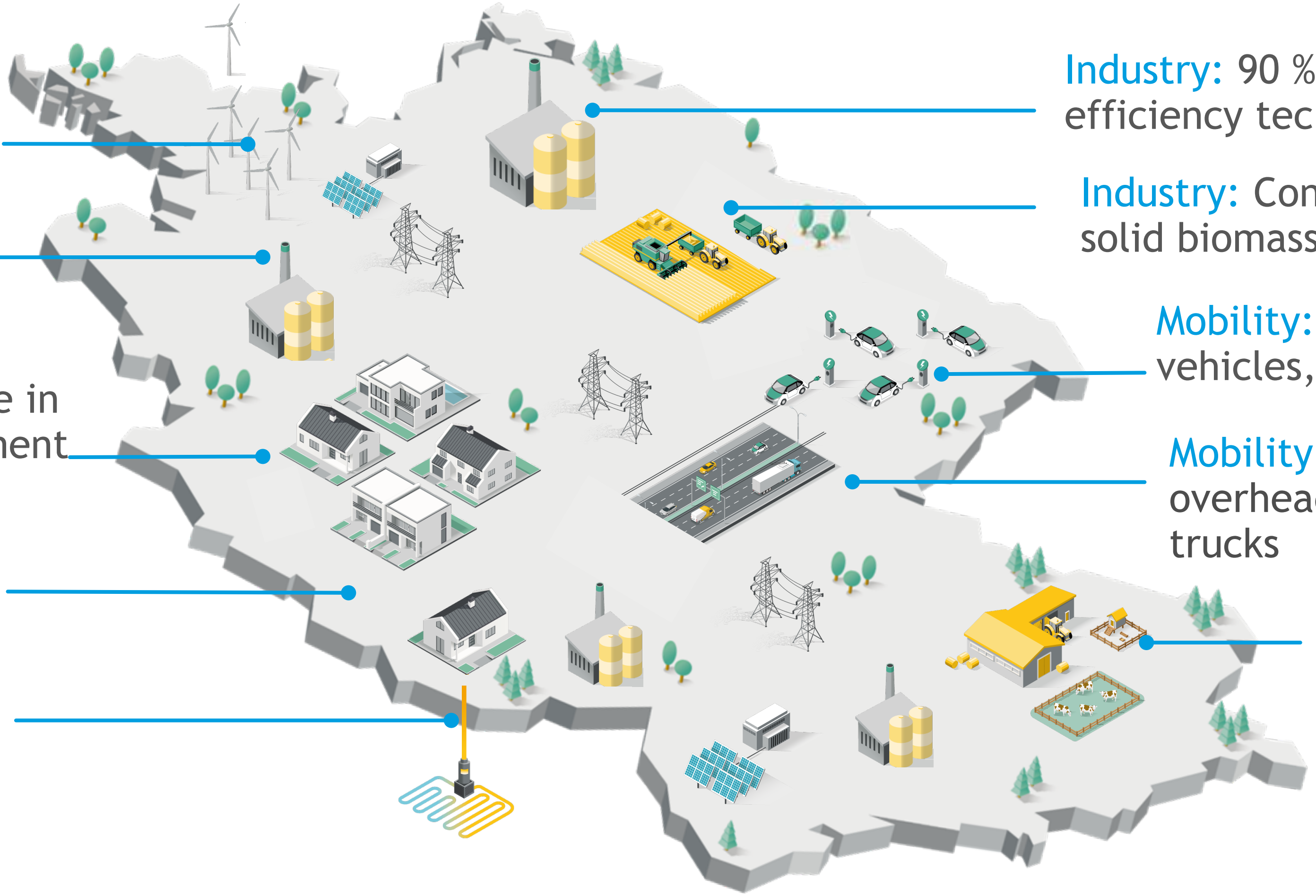
Energy: 240 GW wind and PV, grid extension

Energy: Gas gradually replaces coal in backup generation

Buildings: 50 % increase in the building refurbishment rate (1.7 % p. a.)

Buildings: Expanded urban district heating

Buildings: 14 mn. heat pumps, mainly in residential building stock (1 – 2 families)



Industry: 90 % penetration of efficiency technologies

Industry: Concentration of national solid biomass for heat < 500°C

Mobility: 26 mn. electric vehicles, 2/3 of passenger cars

Mobility: 4.000 km of electric overhead lines for highway trucks

Farming: More efficient use of fertilizers

PV = Photovoltaik
All figures refer to 2050

80 % path: sectors deliver diverse reductions

Bubbles: Mt CO_2e % change vs. 1990	1990 (dark) vs. 2015 (bright)	2050 current policies	2050 80 % climate path
Power sector	-22 %	-71 %	-89 %
Industrial processes	-36 %	-41 %	-51 %
Industrial heat/steam	-32 %	-52 %	-72 %
Mobility	-2 %	-44 %	-73 %
Buildings	-39 %	-70 %	-92 %
Agriculture, other	-46 %	58 %	-70 %
Σ	1990: 1,251 2015: 902 (-28 %)	493 -61 %	254 -80 %

95 % path requires zero emissions in most sectors

Bubbles: Mt CO_2e % change vs. 1990	1990 (dark) vs. 2015 (bright)	2050 current policies	2050 80 % climate path	2050 95 % climate path
Power sector	-22 %	-71 %	-89 %	-100 %
Industrial processes	-36 %	-41 %	-51 %	-87 %
Industrial heat/steam	-32 %	-52 %	-72 %	-99 %
Mobility	-2 %	-44 %	-73 %	-100 %
Buildings	-39 %	-70 %	-92 %	- 100 %
Agriculture, other	-46 %	58 %	-70 %	-74 %
∑	1990: 1,251 2015: 902 (-28 %)	493 -61 %	254 -80 %	62 -95 %

95 % path to breach technical feasibility, social acceptance

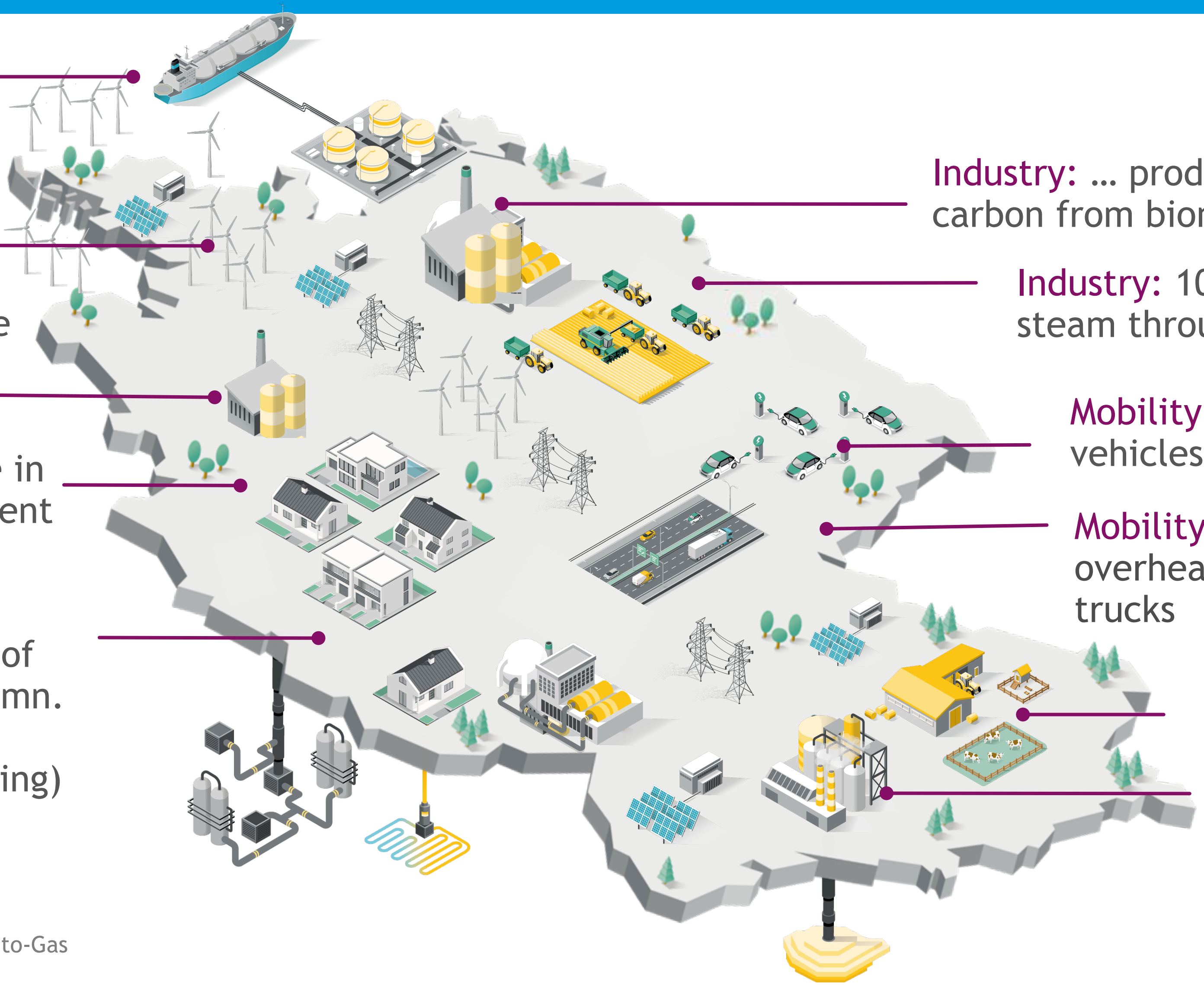
340 TWh Imports „renewable fuels“ (PtL, PtG)

Energy: 295 GW wind and PV, grid extension

Energy: 100 % renewable with PtG, gas-grid as seasonal storage

Buildings: 70 % increase in the building refurbishment rate (1.9 % p. a.)

Buildings: Heating free of fossil fuels (through 16 mn. heat pumps and 100 % renewable district heating)



Industry: … produces with recycled carbon from biomass incineration

Industry: 100 % renewable heat / steam through biogas and PtG …

Mobility: 33 mn. electric vehicles, 4/5 of passenger cars

Mobility: 8.000 km of electric overhead lines for highway trucks

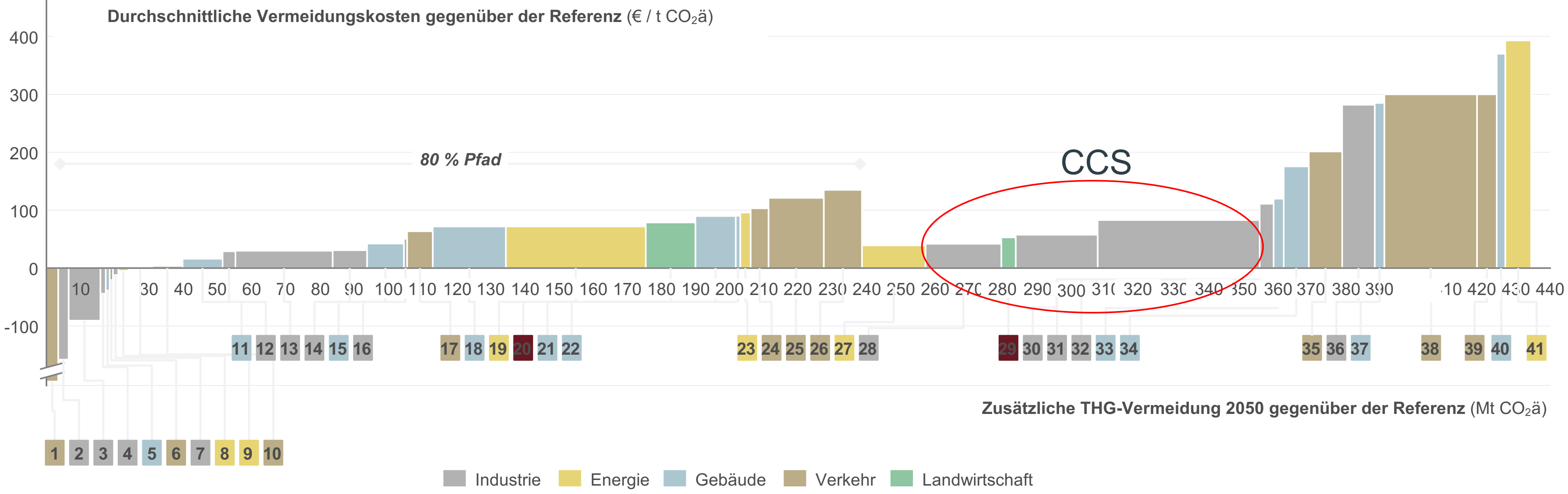
Farming: „methane pill“ for cattle population

Carbon Capture and Storage for steal, cement, ammonia, refineries, waste combustion

PtL = Power-to-Liquid, PtG = Power-to-Gas
All figures refer to 2050

Nur direkte Kosten, volkswirtschaftliche Perspektive, kumuliert, diskontiert auf 2015

Marginal cost of avoiding GHG up to 400 € / t CO_2 to reach 95 % target

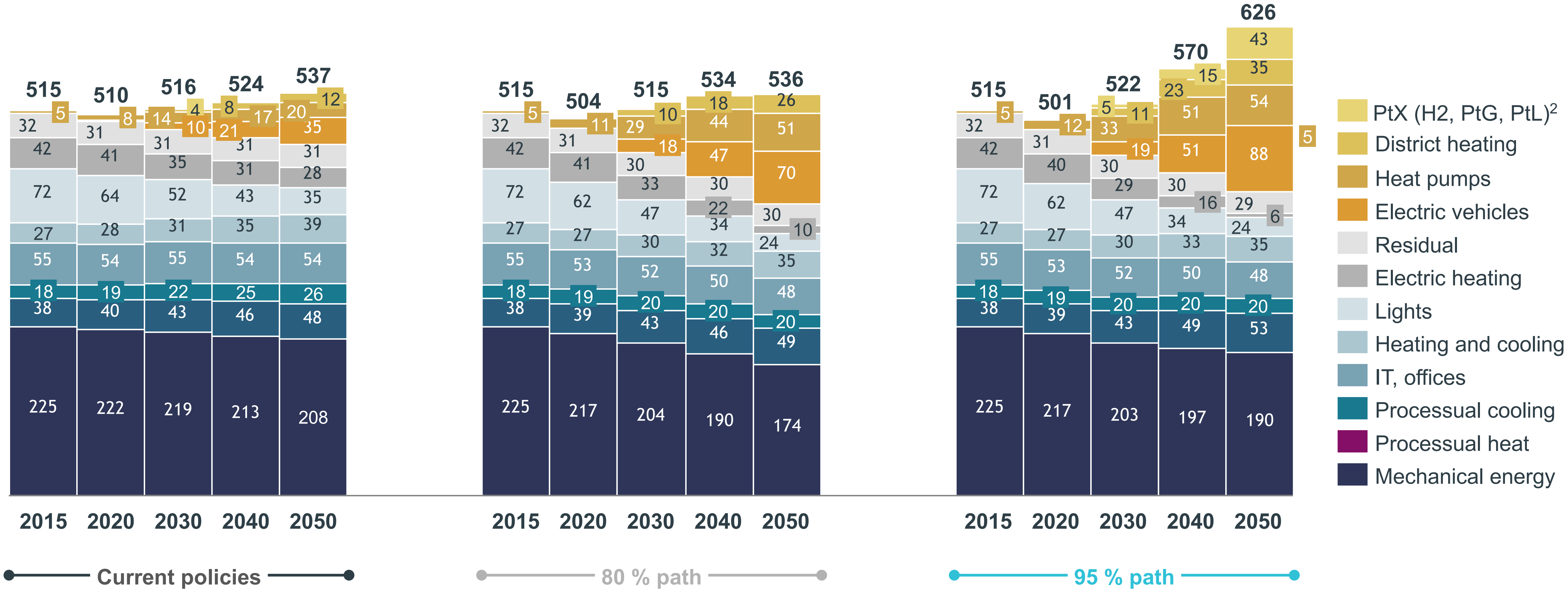


1 Verkehrsträgerverlagerung (Schiene, Schiff, Bus)
2 Energieeffizienz durch Einsatz von IE3-/IE4-Motoren und Frequenzumrichtern
3 Energieeffizienz bei Querschnittstechnologien
4 Ausbau der Solarthermie zur Wärmebereitstellung in der Industrie
5 Ausbau der Solarthermie in der Raumwärme und Warmwasservers. in Haushalten und GHD
6 Sonstige Effekte im Verkehrssektor
7 Anlagenmodernisierung in der Methanol-, Ammoniakherstellung und von Steam-Crackern
8 Ausbau von Wind Onshore
9 Ausbau von Wind Offshore
10 Straßen-Güterverkehr: Effizientere Antriebe
11 Geräte und Prozesse in Haushalten und GHD: Effizienz und Energieträgersubstitution
12 Energieeffizienz bei der Hochofen-Route, Prozessoptimierung Lichtbogenofen
13 Substitution von Erdgas durch Biomasse in Nieder-/Mitteltemperaturwärme (<500 °C)
14 Substitution von HFKWs / FKWs, u.a. bei Kühlung und Klimatisierung
15 Ausbau der Fernwärme
16 Neue bzw. modernere Öfen und Mahlanlagen bei Zement- und Kalkproduktion
17 Antriebswechsel Schwere Nutzfahrzeuge (Oberleitung, Gas, FC, BEV)
18 Ausbau von Wärmepumpen
19 Ausbau von Gaskraftwerken
20 Vergärung von Gülle in Biogasanlagen
21 Gebäudebestand: Erhöhung der Sanierungsrate auf 1,7 % p.a.
22 Gebäude Neubau: KfW 40 Niveau in Wohngebäuden ab 2030
23 Ausbau Photovoltaik
24 Antriebswechsel Leichte Nutzfahrzeuge (BEV, Gas, FC)
25 Antriebswechsel Personen-Straßenverkehr (BEV,PHEV, FC, Gas)
26 Niedrigerer Verbrauch von Straßenfahrzeugen
27 Weiterer Ausbau Erneuerbarer Energien
28 "Oxyfuel"-CCS bei der Zementproduktion
29 "Methanpille" und weitere Maßnahmen Landwirtschaft
30 "Post-Combustion"-CCS bei Raffinerien und Gichtgas-Verstromung
31 "Post-combustion"-CCS bei der Stahlproduktion
32 "Post-combustion"-CCS bei der Ammoniakproduktion
33 PHH/GHD Geräte und Prozesse: Effizienz und Energieträgerwechsel
34 Weiterer Ausbau Wärmepumpen, Fernwärme, Solarthermie
35 Antriebswechsel Personen-Straßenverkehr (BEV, PHEV, FC, Gas)
36 Biogas und PtG in der Industrie
37 1,9% San.rate im Gebäudebestand, annähernd Passivhausniveau in Neubauten
38 Synthetische Kraftstoffe im Verkehr
39 Antriebswechsel Straßen-Güterverkehr (Oberleitung, Gas, Batterie, FC, BEV)
40 Synthetische Kraftstoffe Raumwärme und Warmwasser
41 Ausbau Gaskraftwerke mit PtG

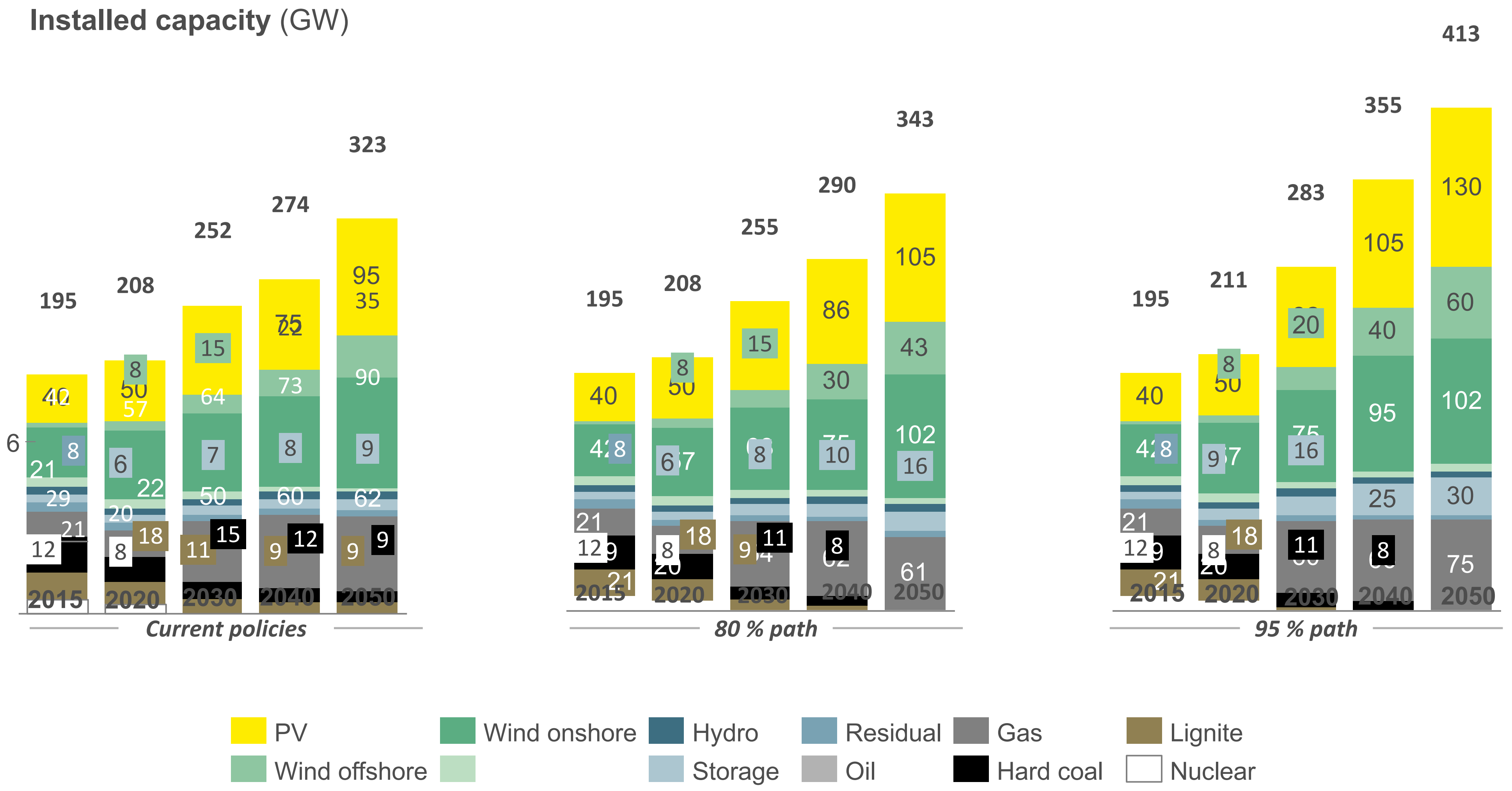
THG-Vermeidung bezieht sich auf verursachte Emissionen 2050 und stellt die Abweichung gegenüber den THG-Emissionen der Referenz in 2050 dar.
Vermeidungskosten zeigen direkte volkswirtschaftliche Vermeidungskosten. Sie ergeben sich aus kumulierter THG-Vermeidung 2016-2050, kumulierten Kosten und Einsparungen 2016-2050 und sind auf das Jahr 2015 diskontiert. Investitionen sind mit volkswirtschaftlichem Realzinssatz von 2 % annuisiert. Stromkosten wurden in allen Sektoren mit Systemkosten, Importe mit Grenzübergangspreisen bewertet.
Quelle: BCG

Net power demand significantly rises in 95 % path

Net power demand, applications (TWh)



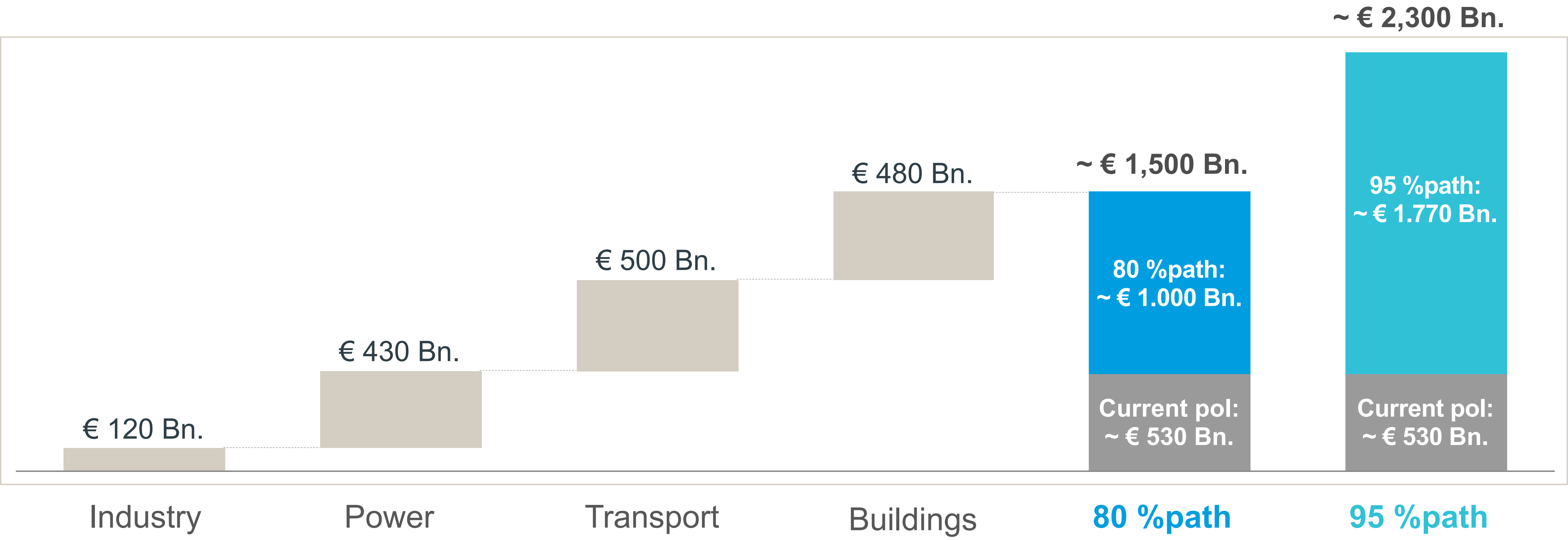
Strong growth of installed capacity, especially in renewables



Source: Prognos, BCG

Additional investments of € 1,500 to € 2,300 bn. until 2050

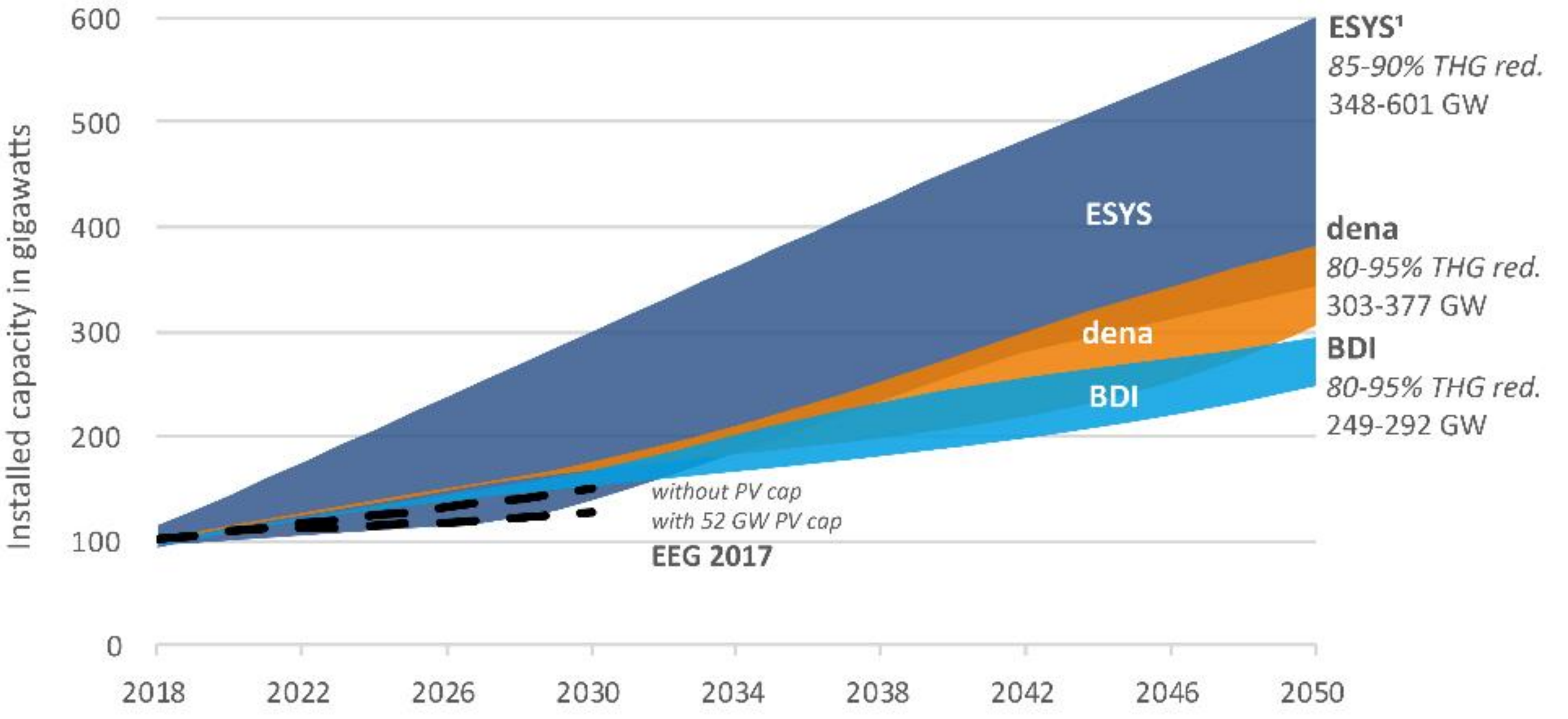
Cumulative marginal investments until 2050 (vs. scenario without GHG reduction efforts)



Key Results from a Comparison of Three Studies on Transition Scenarios

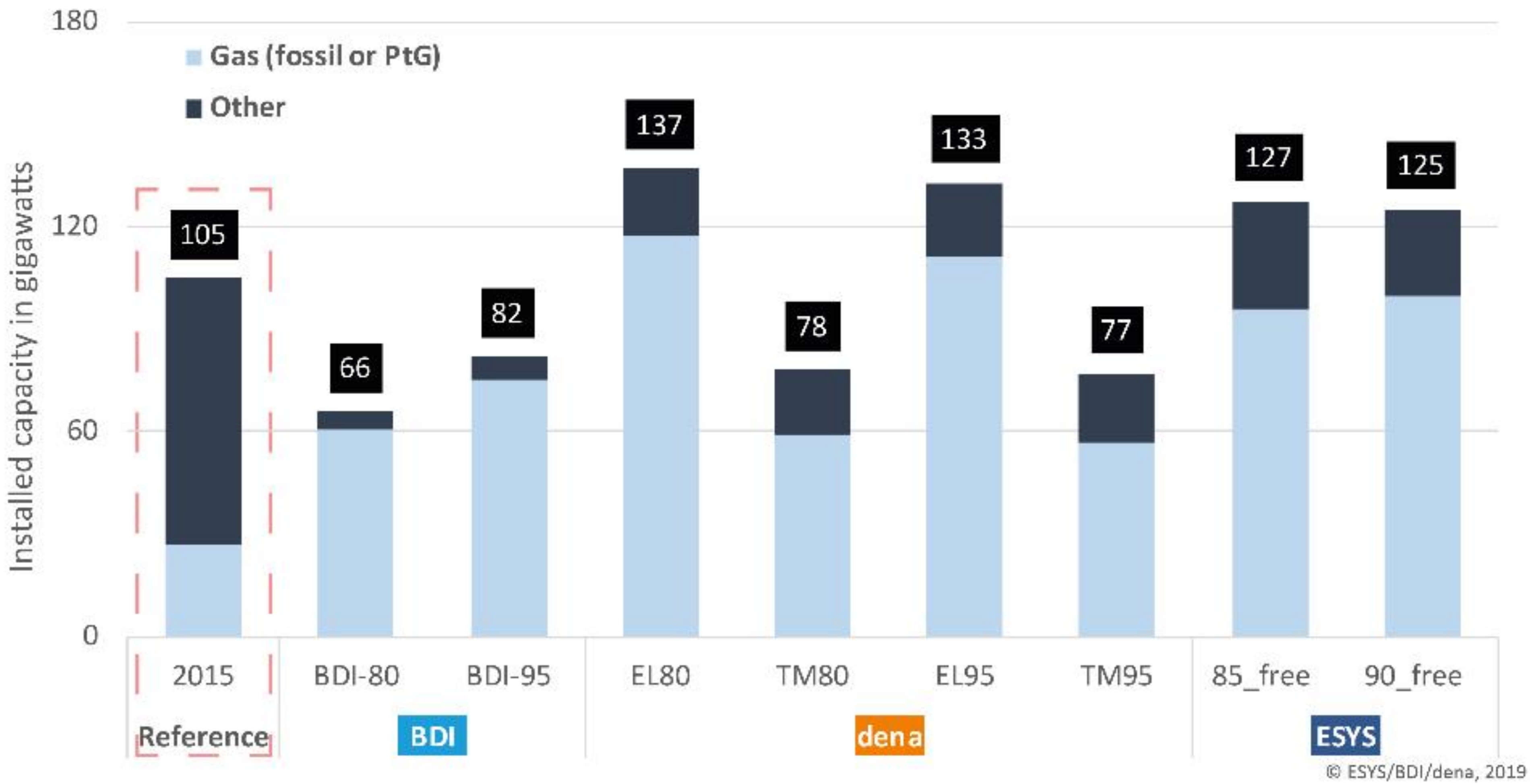
Energy Systems of the Future	Coupling the different energy sectors – options for the next phase of the energy transition
Federation of German Industries	Climate Paths for Germany
Deutsche Energie-Agentur	dena Study Integrated Energy Transition

Expansion of wind and PV systems in Germany

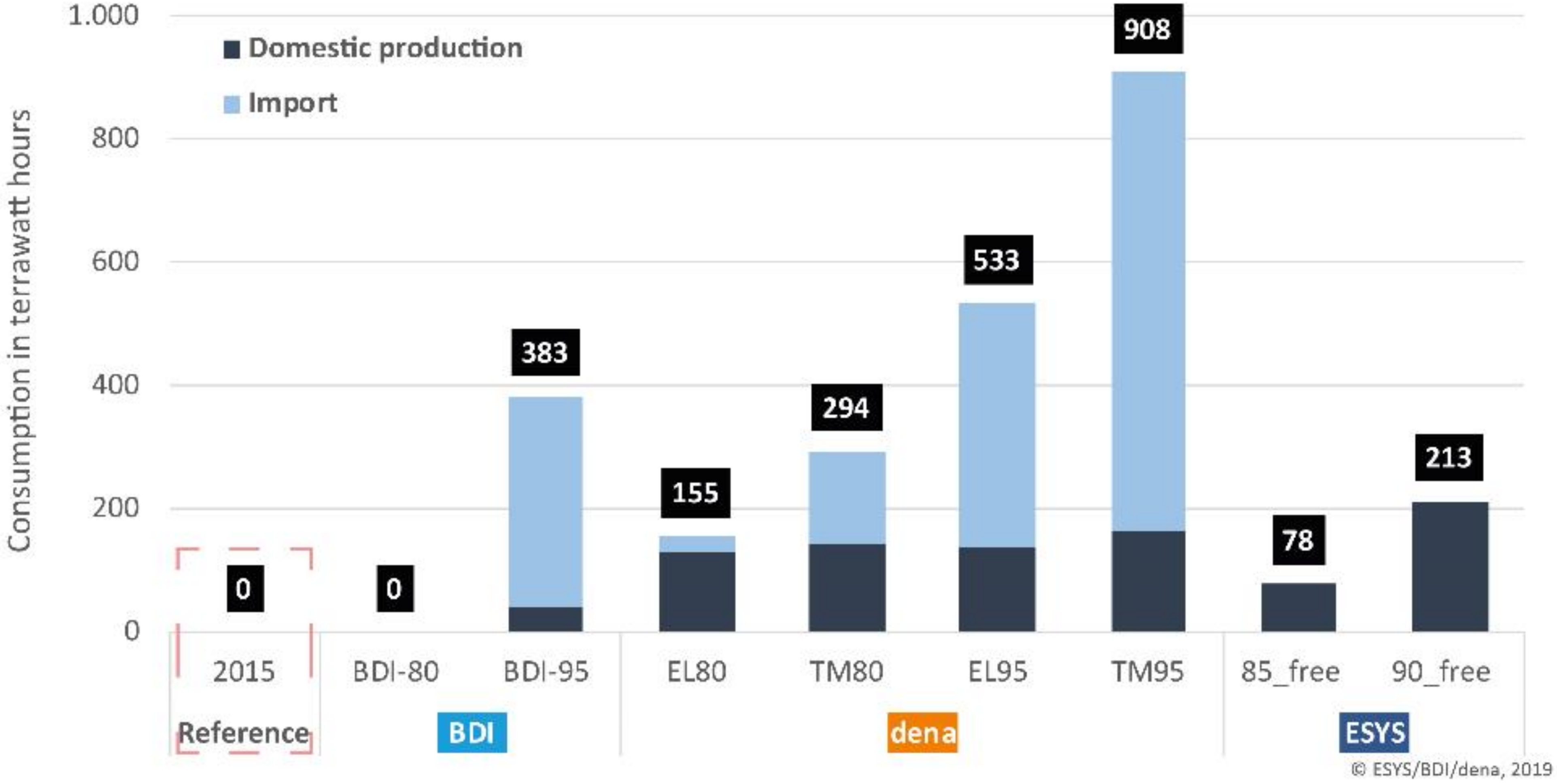


¹In the ESYS study, the GHG reduction only related to the energy system, including the 85_active scenario.

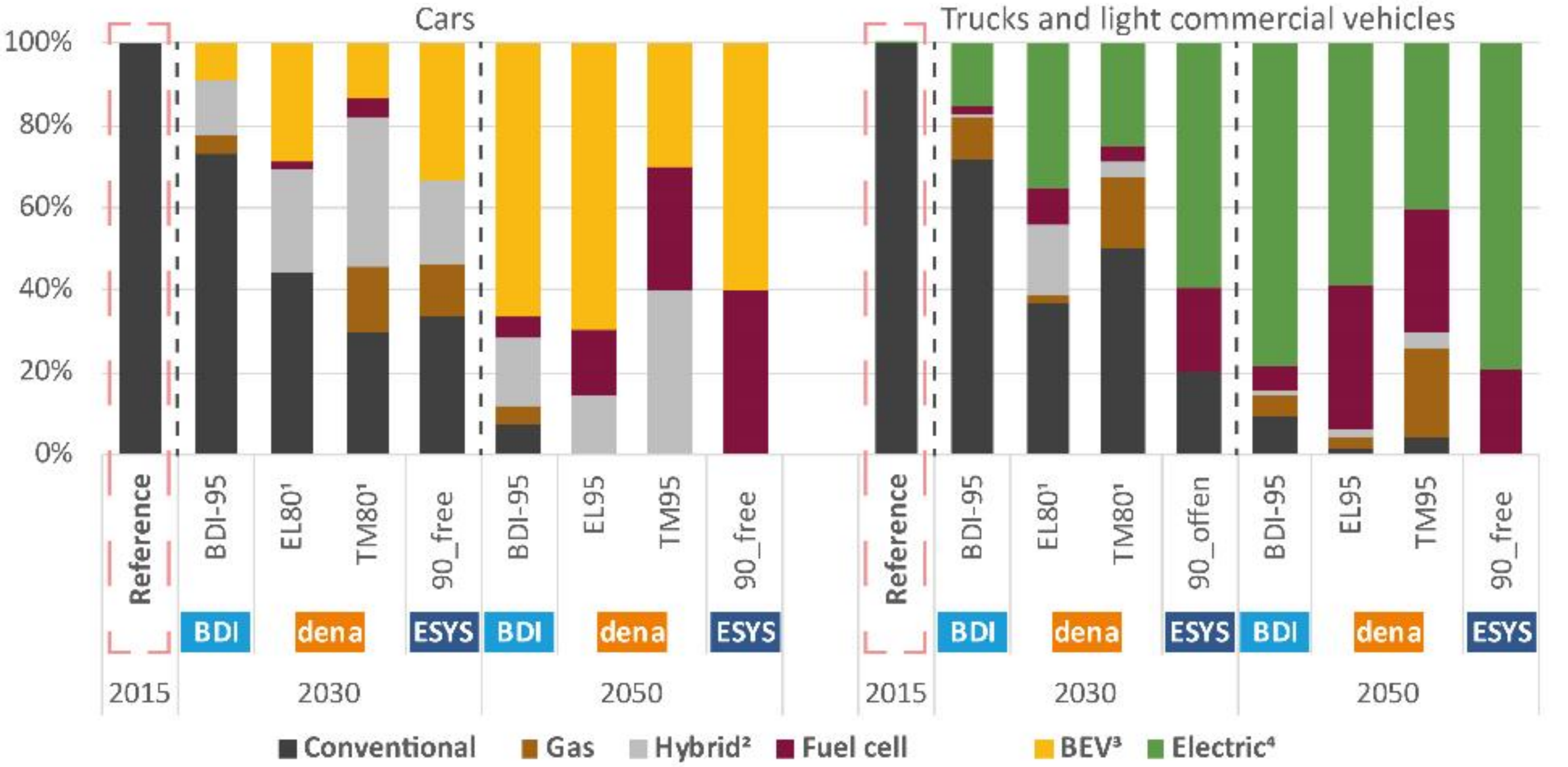
Dispatchable power generation capacity in Germany 2050



Use of synthetic energy carriers in Germany 2050

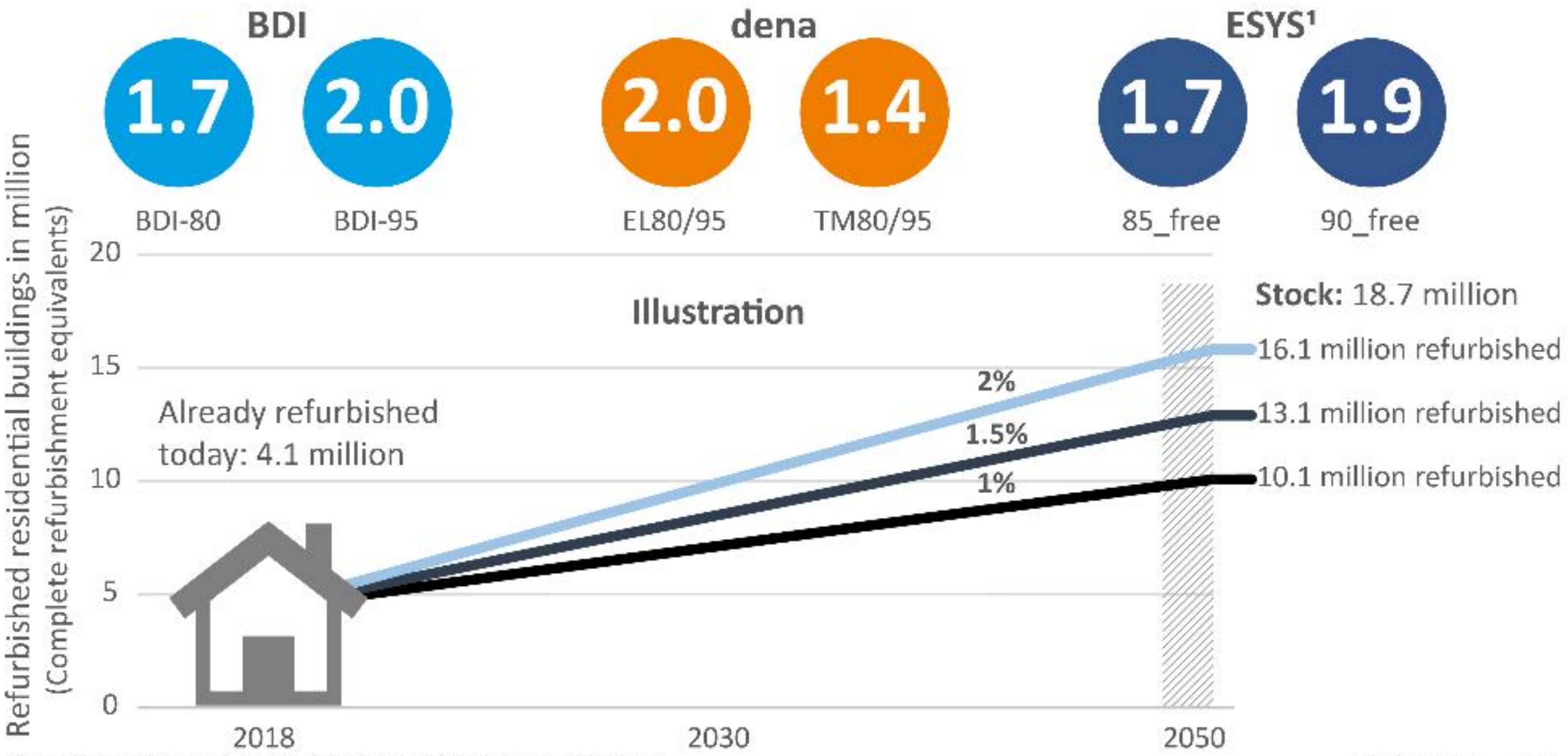


Proportion of drive types in road-based transport to 2050



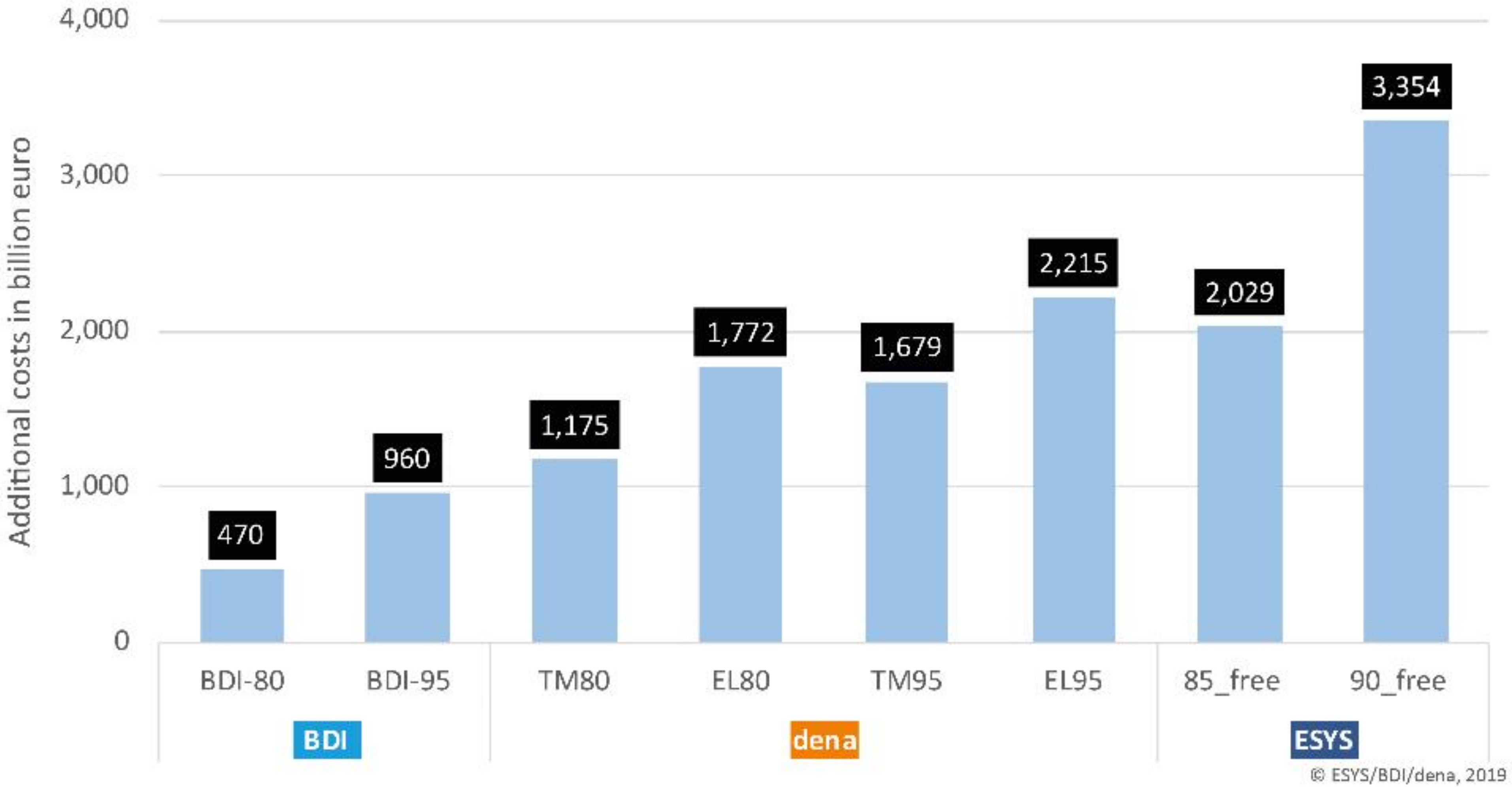
[1] Up until 2030, the dena study does not differentiate between the 80% and the 95% path. [2] Plug-in hybrids (conventional and gas). [3] Battery electric vehicles. [4] BEV and overhead line.

Necessary refurbishment for residential buildings to 2050



[1] The refurbishment rates in the two ESYS scenarios relate to Germany's entire building stock.

Additional costs over reference scenario to 2050



Key Take Aways

Investment requirements are high but not insurmountable

High investment costs but also high potential benefits
→ additional incentives needed to bridge the investment gap

Policy mix required: Carbon pricing as backbone of climate policies needs to be complemented by especially infrastructure and innovation policy

Don‘t think of 2030 (only), **think of 2050**!

Uncertainty vs commitment: Avoid infrastructure lock-in but also costs of procrastination

95% (or net zero) requires **global efforts!**

Electrical storage systems and flexible loads in Germany 2050

Electrical storage systems and flexible loads in Germany 2050

Heat pumps, millions

80 to 95% GHG reduction:

BDI	14-16
dena	7-17
ESYS[1]	11-15

Battery storage systems, GW

80 to 95% GHG reduction:

BDI	10-23
dena	15-18
ESYS[1]	75-191

Power-to-X capacity, GW_{el}

80 to 95% GHG reduction:

BDI	0-11
dena	53-63
ESYS[1]	77-112

BEV cars, millions

80 to 95% GHG reduction:

BDI	21-28
dena	12-30
ESYS[1]	27-42

[1] In the ESYS study: 85-90% GHG reduction in the energy system.

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RMIT University

Monash University

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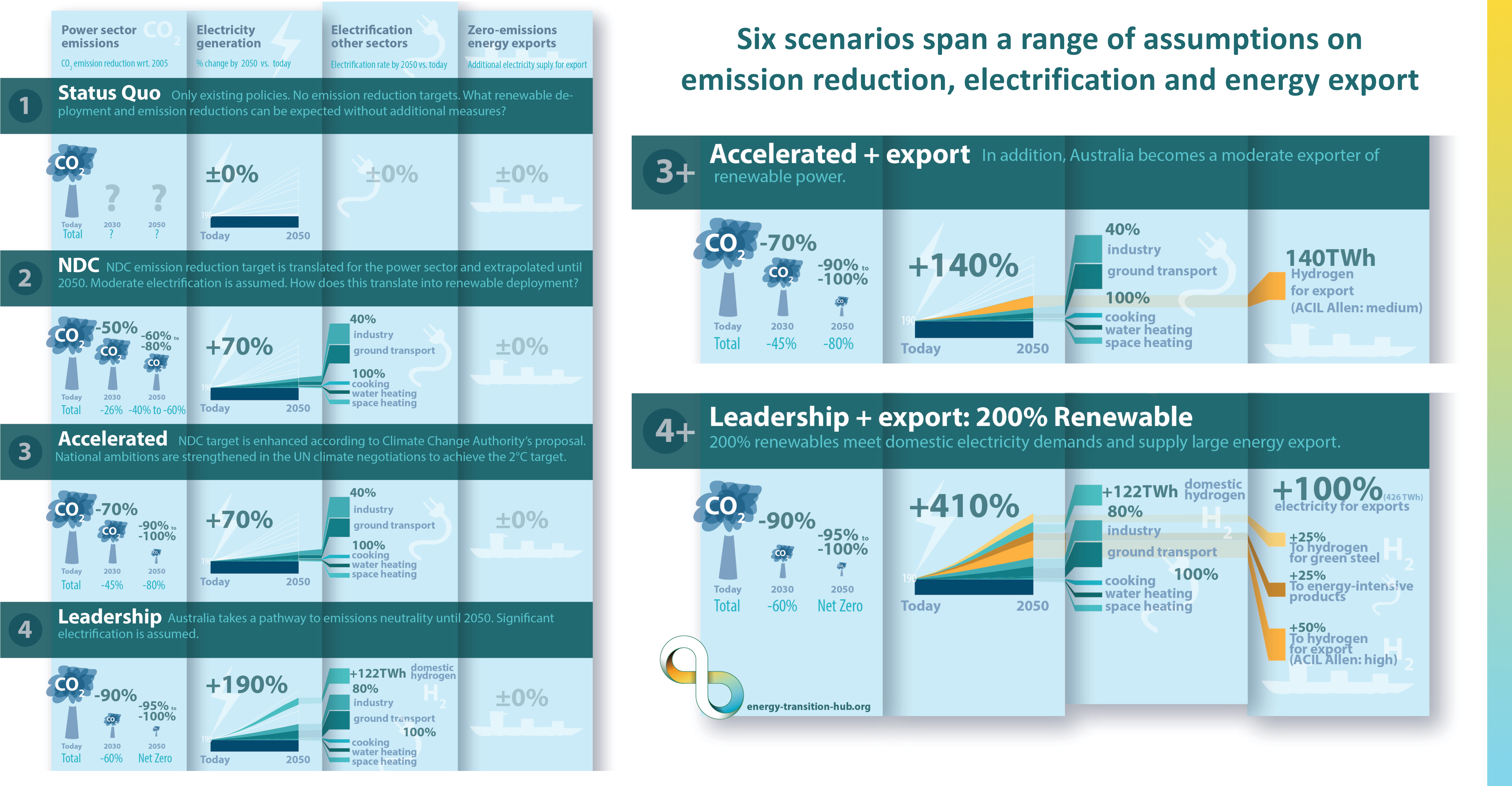
Multi-model Energy Transition and Export Scenarios for Australia

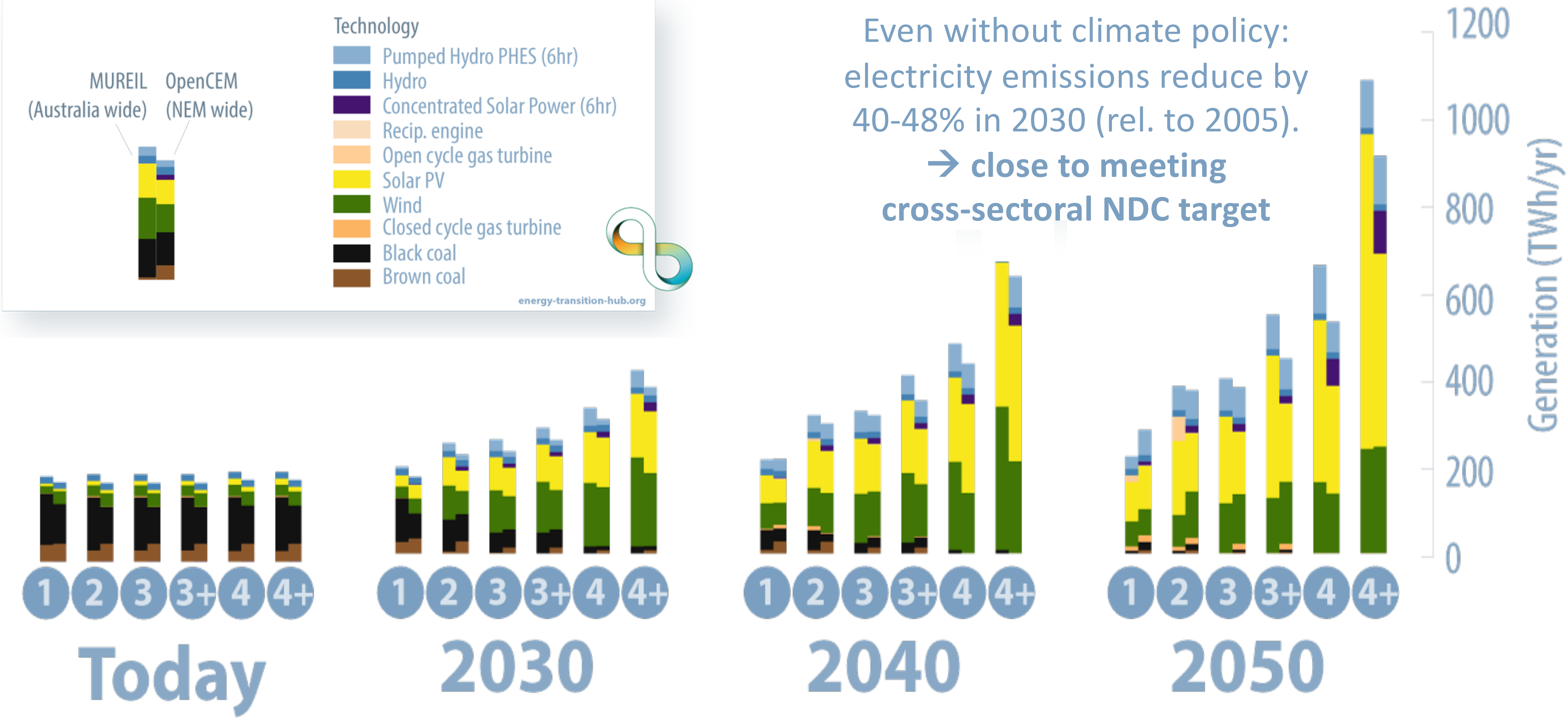
Dylan McConnell, Falko Ueckerdt (on behalf of the scenario group of the hub)

ENERGY TRANSITION HUB an Australian-German innovation partnership

Four models derive cost-optimal transition scenarios of Australia's electricity supply until 2050



Main result 1: Solar PV and wind power dominate Australia's electricity future



Even without climate policy: electricity emissions reduce by 40-48% in 2030 (rel. to 2005).

→ **close to meeting cross-sectoral NDC target**

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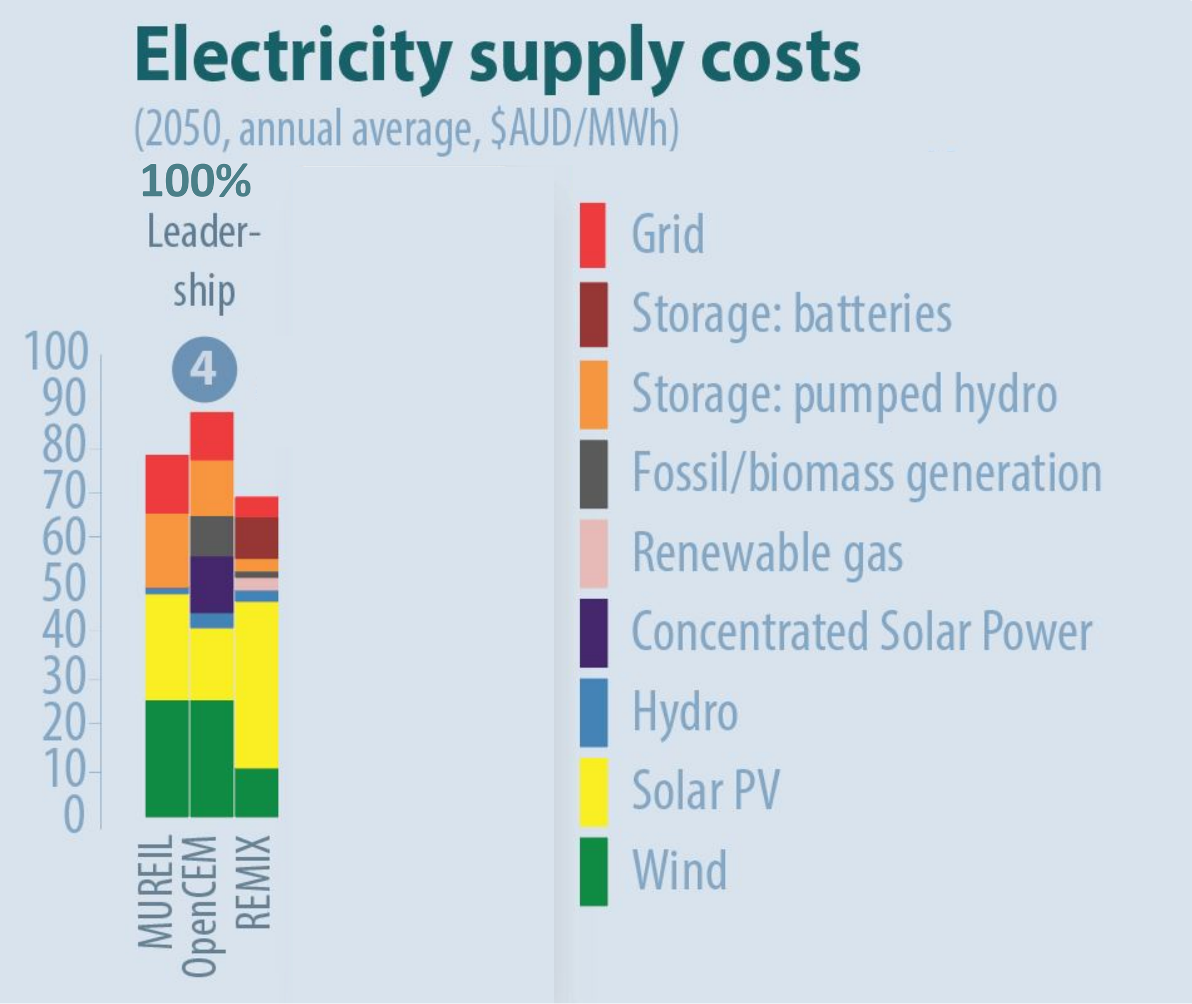
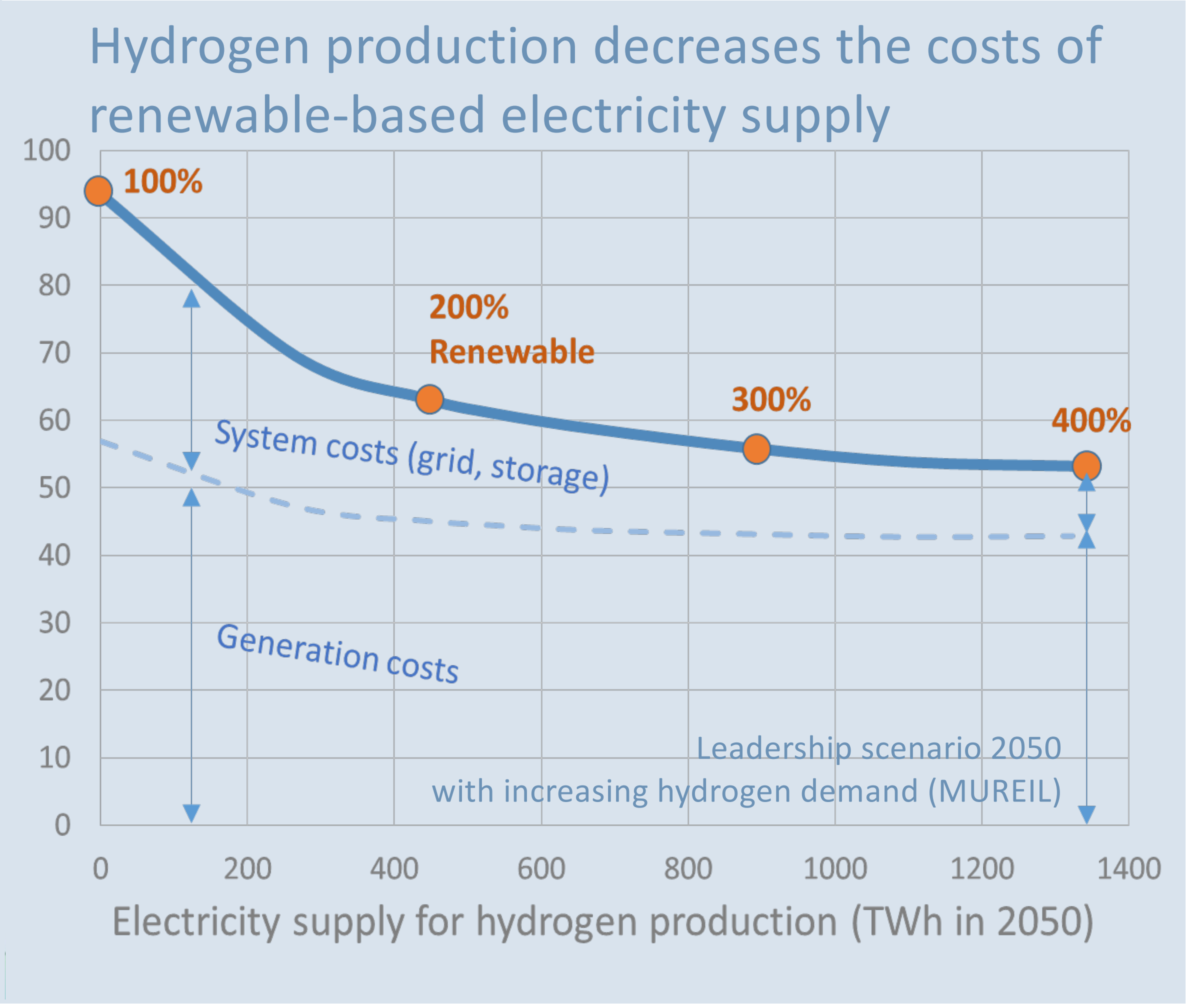
Main result 2: Renewable-based system costs are similar or lower than today





Average 2050 costs (total and by source) of supply per unit of electricity demand (domestic and export) across the scenarios and models. These long-term marginal costs comprise all costs (variable and fixed as annuities) for a 2050 equilibrium power system, while costs for hydrogen production and related infrastructure are not included. In perfect markets, these long-term marginal costs translate into average wholesale electricity prices. While average costs results are similar across models, the remaining differences are due to model-specific parameter assumptions, scope, detail and structure.

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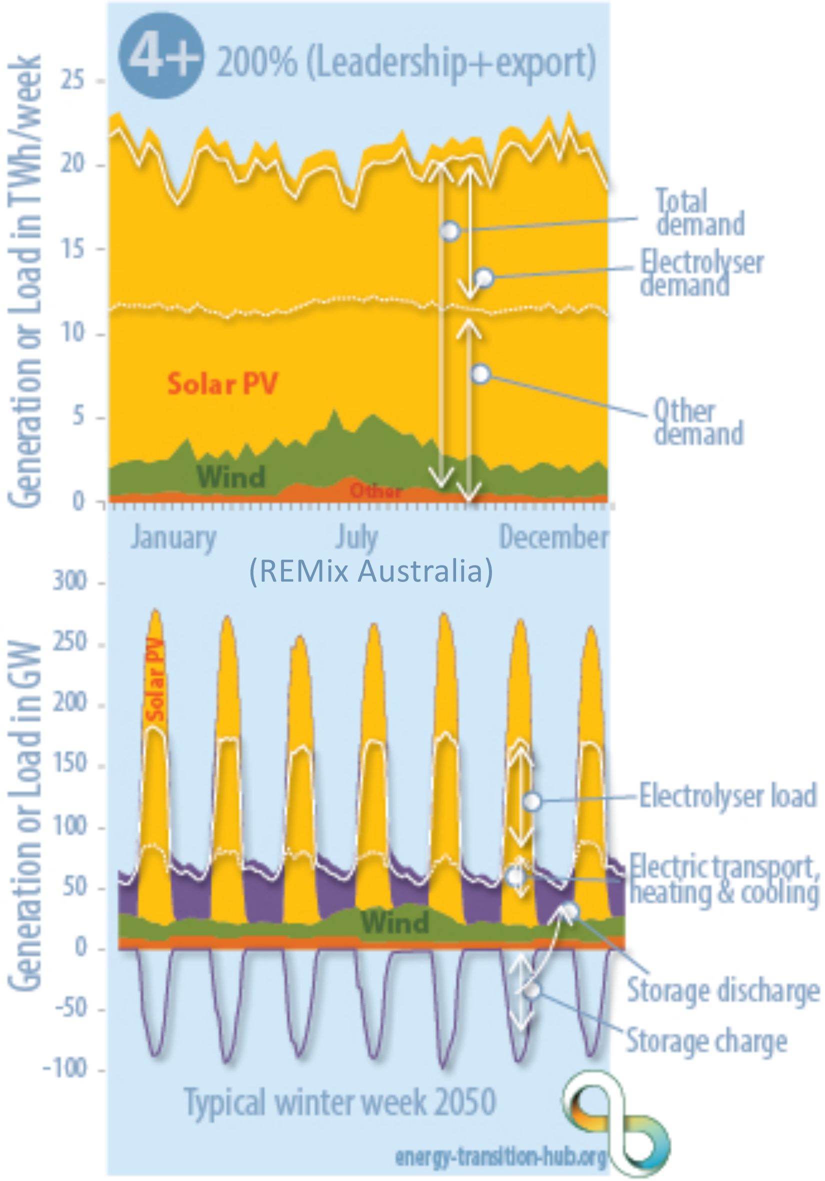
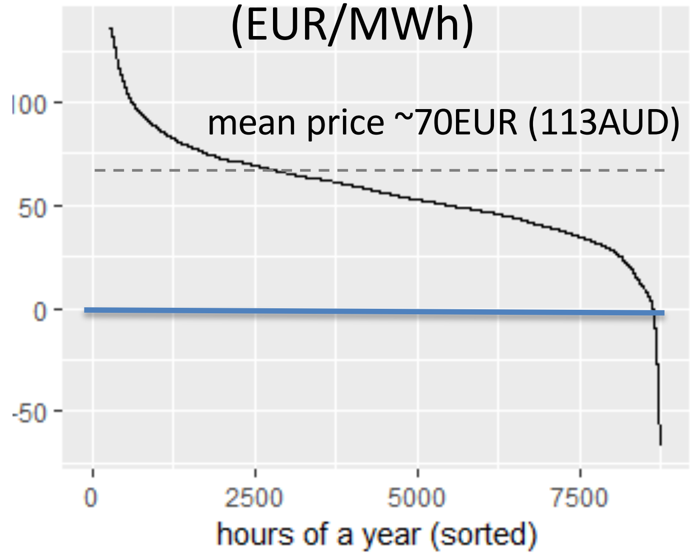
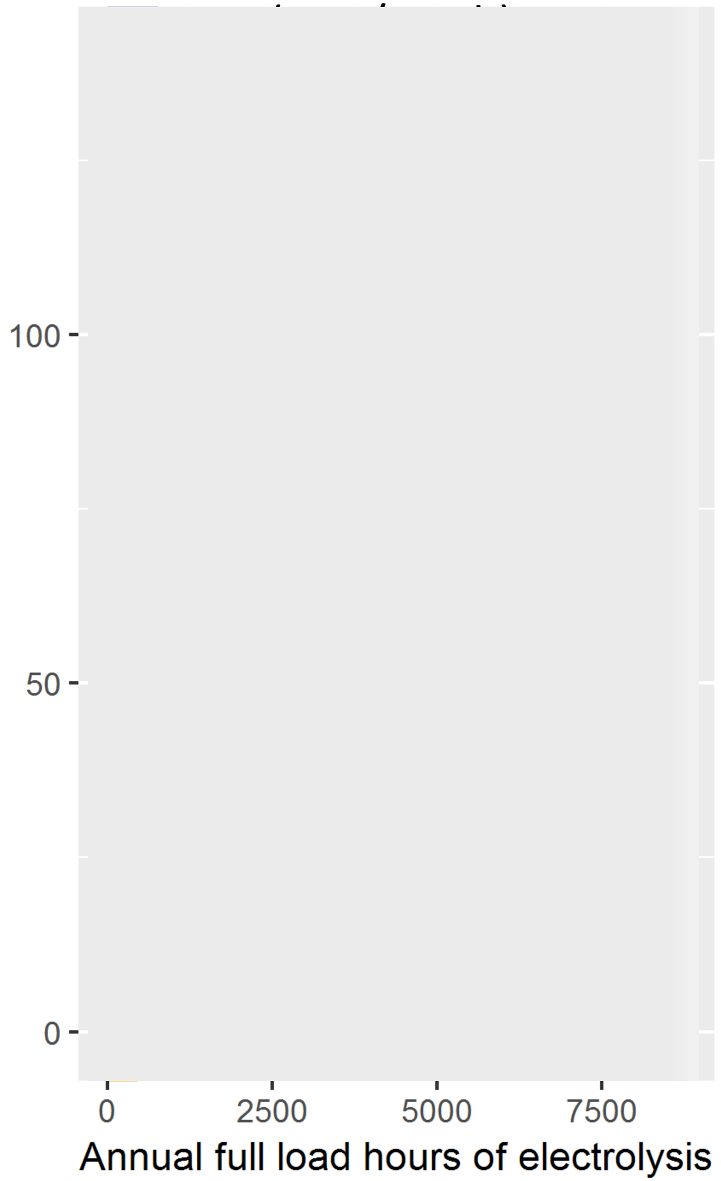
Main result 3: hydrogen costs can be reduced with "NEM electrolysis"



2018/19 South Australia price duration curve (EUR/MWh)



Hydrogen costs as function of annual full-load hours



Assumptions

- electrolysis: efficiency 75%, 1000 EUR/kW (1600AUD/kW)
- methanation: efficiency 80%, 200 EUR/kW (320AUD/kW)
- Lifetimes: 20 years, WACC: 5%
- Future investement costs highly uncertain
- For this figure: no hydrogen transport/storage losses and costs

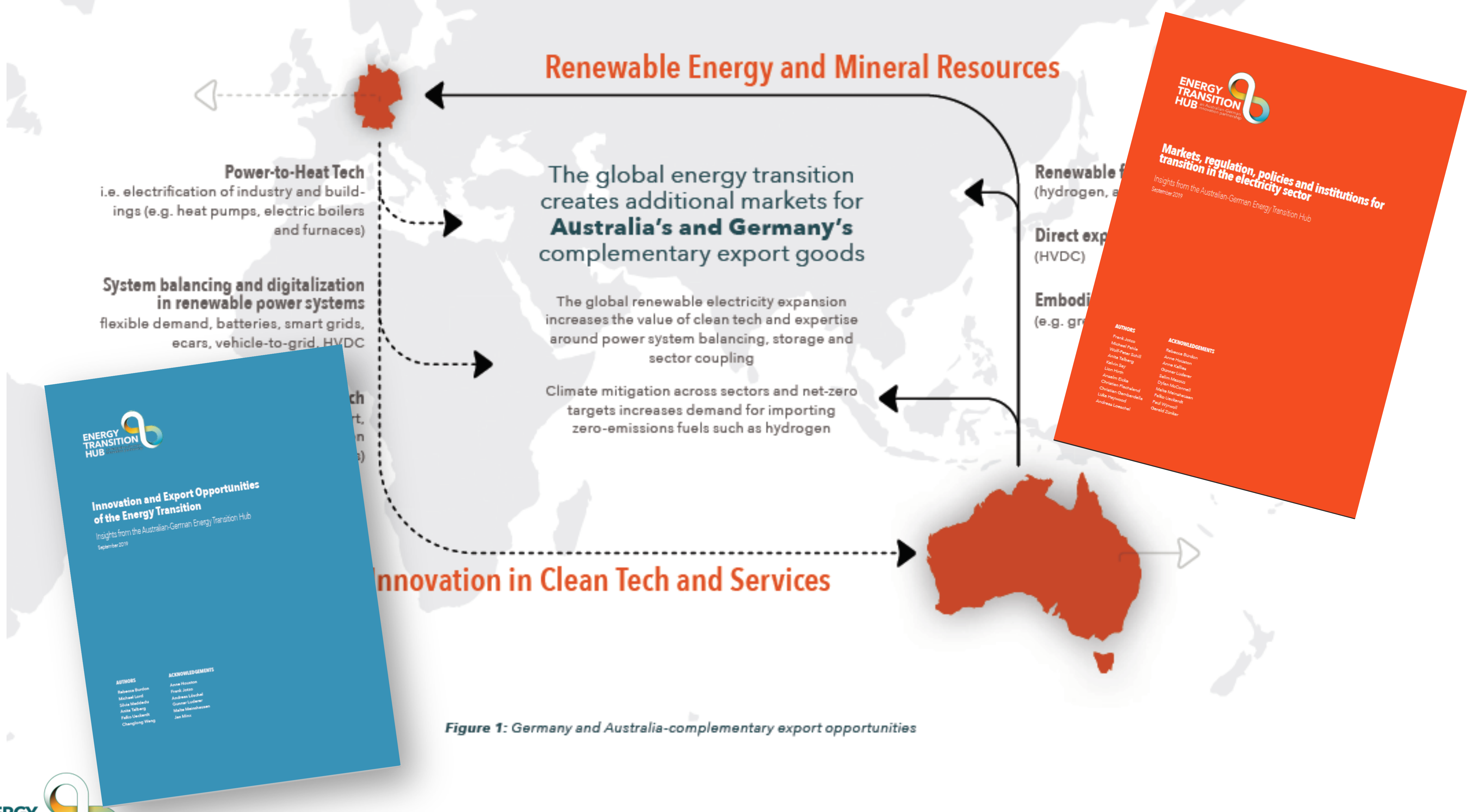
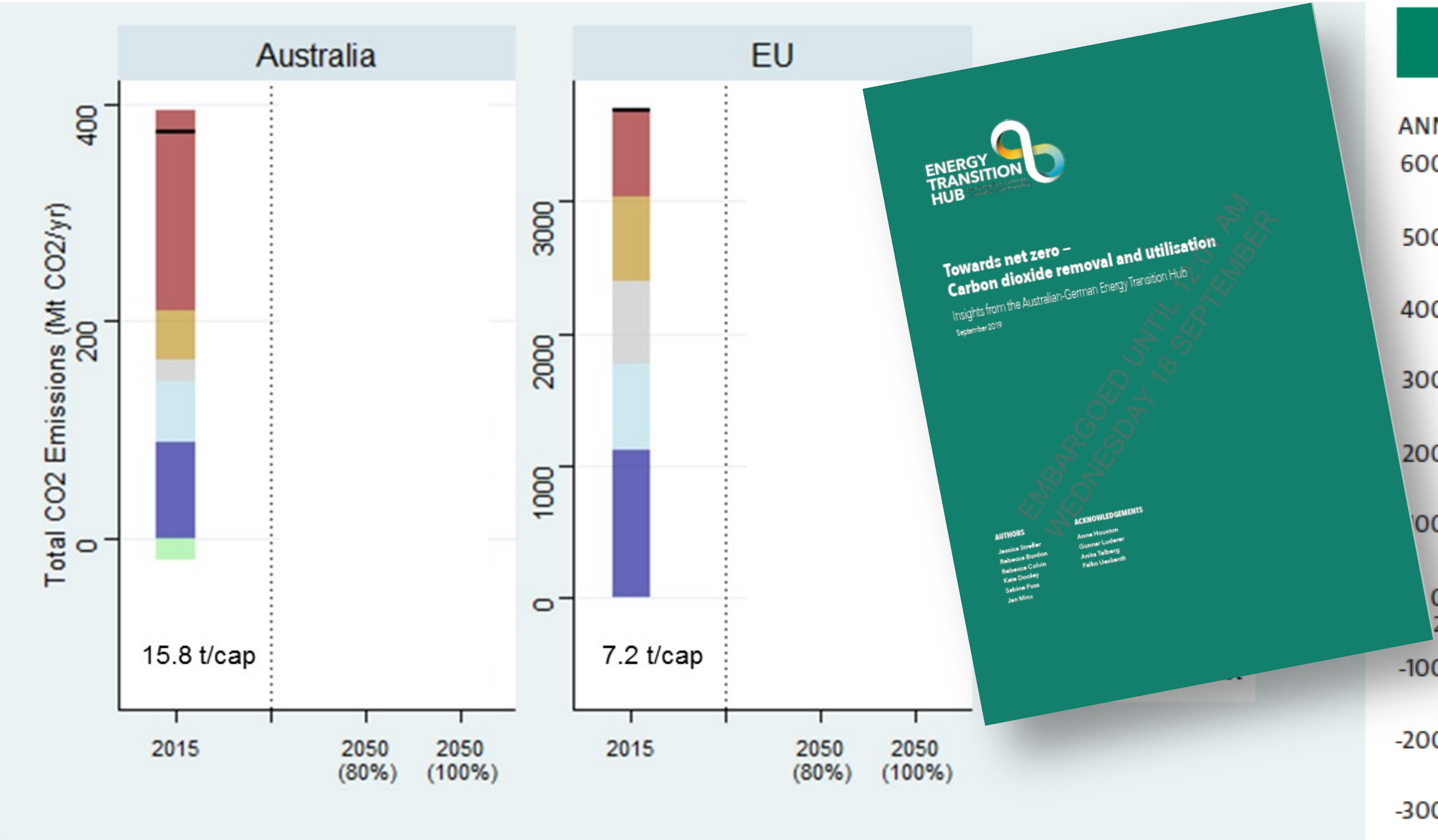
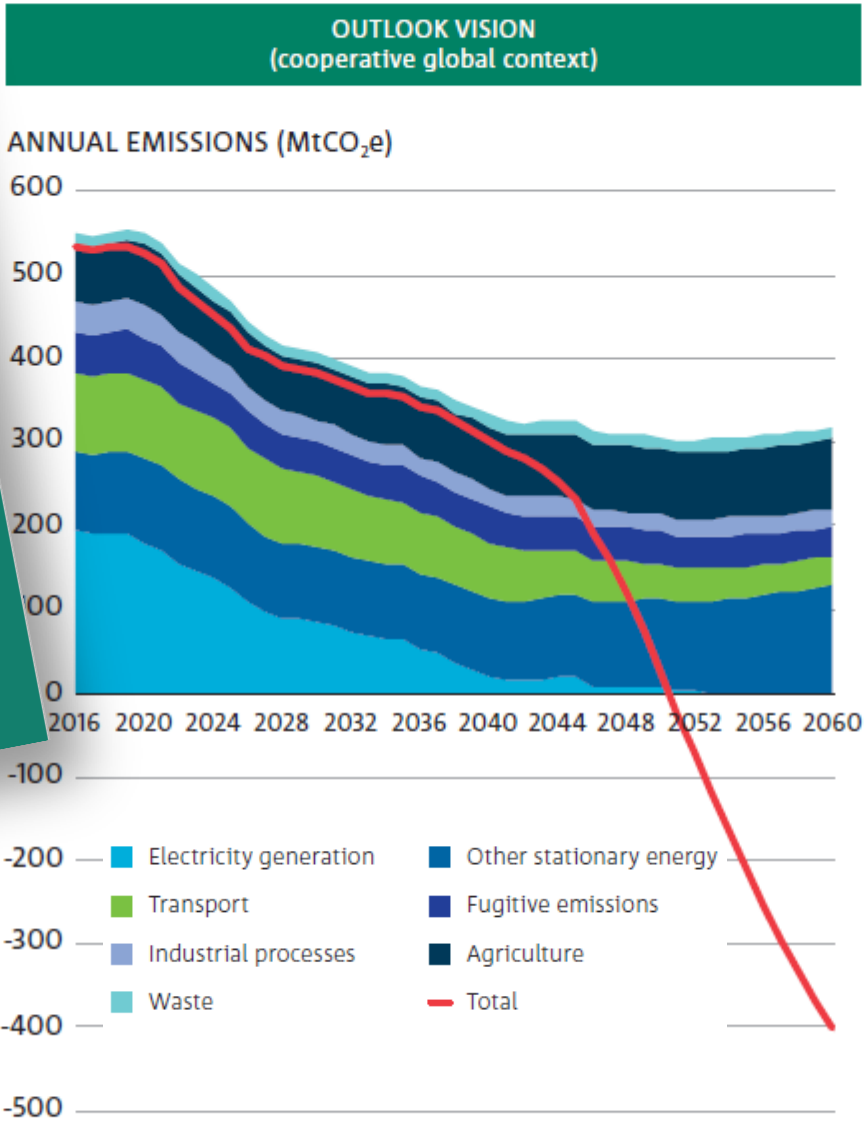


Figure 1: Germany and Australia-complementary export opportunities

Outlook: Carbon dioxide removal could become a 2nd key advantage for Australia



Global REMIND model



ANO 2019