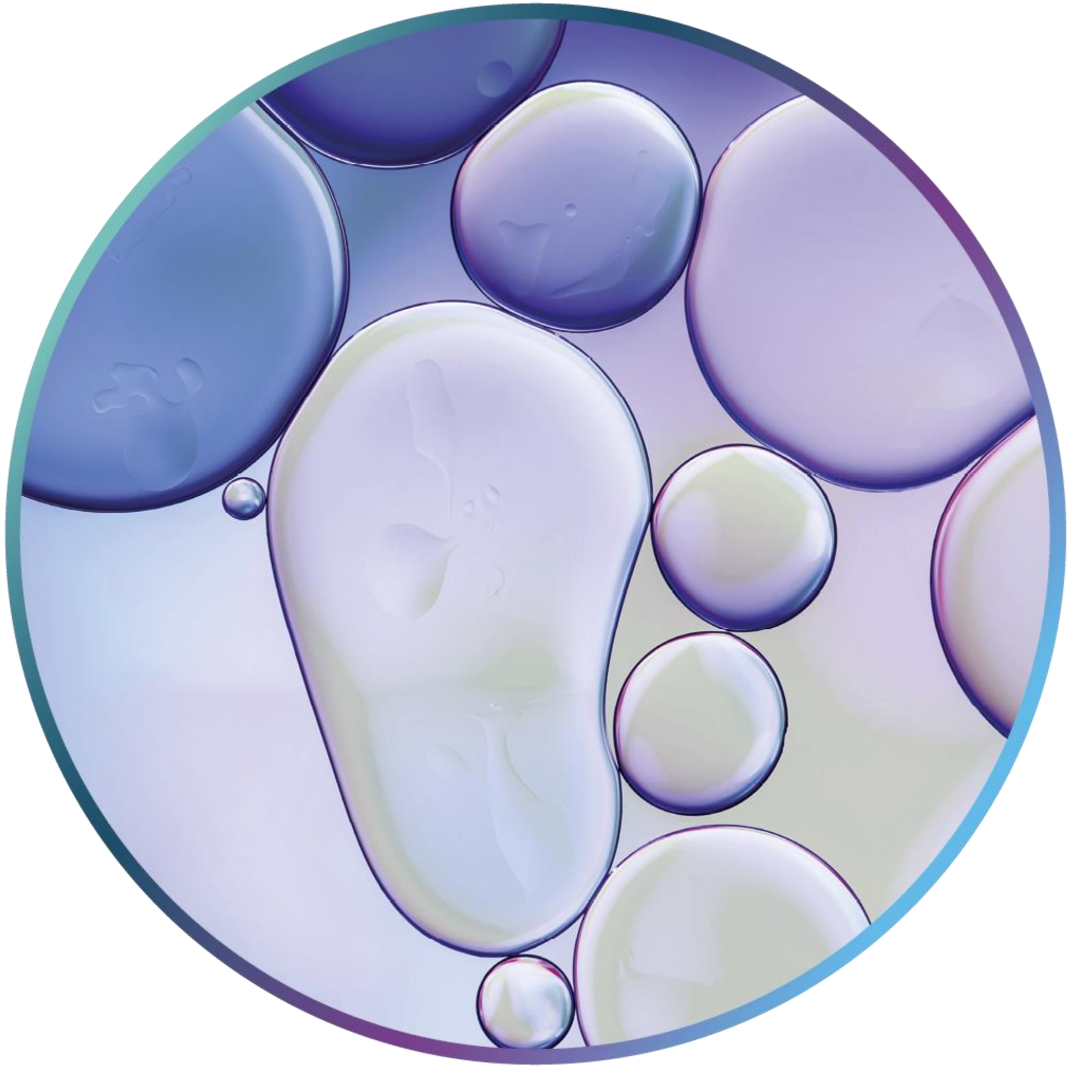


The Future Cost of Electricity-Based Synthetic Fuels:

Conclusions Drawn by Agora Verkehrswende and Agora Energiewende

Urs Maier, Agora Verkehrswende
Matthias Deutsch, Agora Energiewende

Webinar

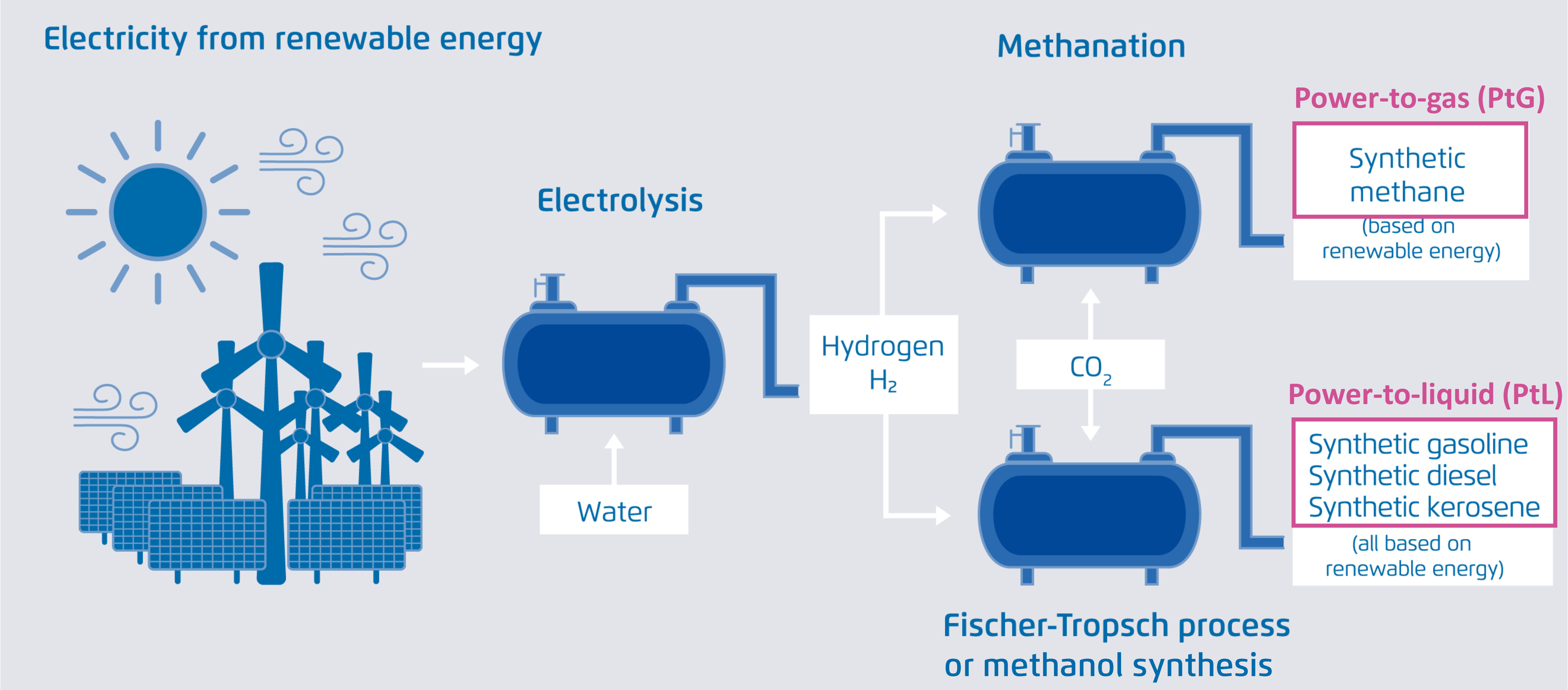
16 May 2018

Agora Verkehrswende and Agora Energiewende

Who we are

- **Two think tanks** with 40 Experts, independent and non-partisan
- **Financed by** Mercator Foundation & European Climate Foundation
- **Project duration**: 2012-2021 (Energiewende) and 2016-2023 (Verkehrswende)
- **Mission**: Develop strategies to decarbonize the energy system in Germany and beyond.
- **Focus**: Power, heating and transport
- **Methods**: Analyzing, discussing, putting forward proposals, Councils of Agoras

Electricity-based synthetic fuels: Power-to-gas and power-to-liquid



Study on the future cost of electricity-based synthetic fuels

Commissioned by: Agora Verkehrswende and Agora Energiewende

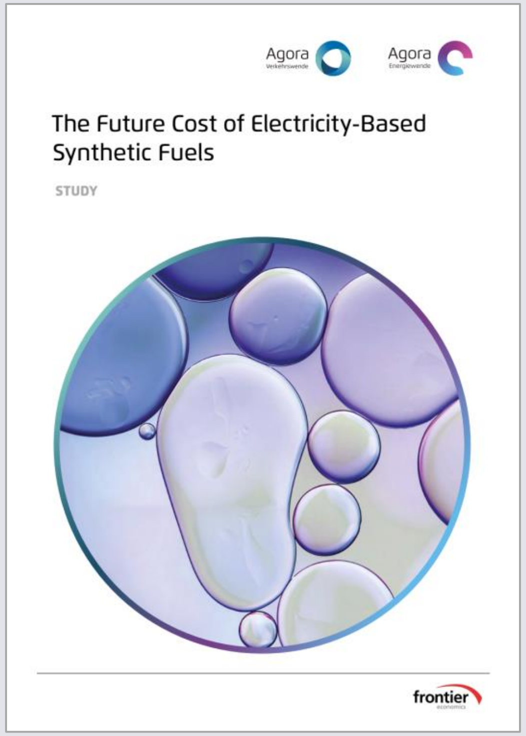
Study by: Frontier Economics

Guiding questions:

- How can the **cost of importing** synthetic fuels – i.e. methane and liquid fuels – develop until 2050? (exemplary analysis for North Africa, Middle East and Iceland)
  What are the cost of producing those fuels on the basis of offshore wind energy in the **North and Baltic Seas**?

Approach:

- Cost estimation along the value chain:
  Power generation, conversion, transport, blending/distribution
- Cost ranges from the literature, expert workshop
- CO_2 neutrality by assuming CO_2 from the air (*Direct Air Capture)*



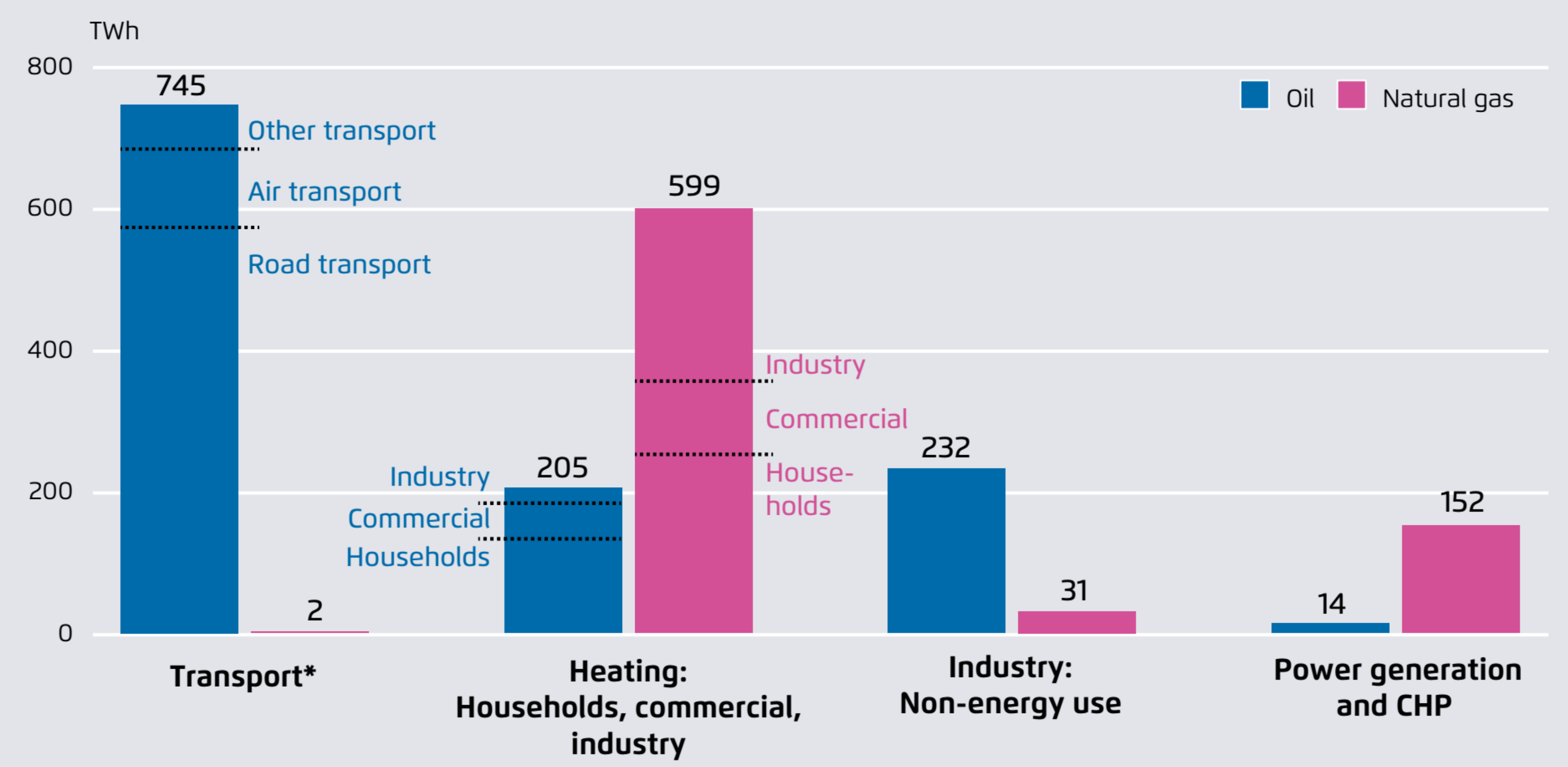
Download:
Study
PtG/PtL-Excel-Tool

1

Synthetic fuels will play an important role in decarbonising the chemicals sector, the industrial sector, and parts of the transport sector.

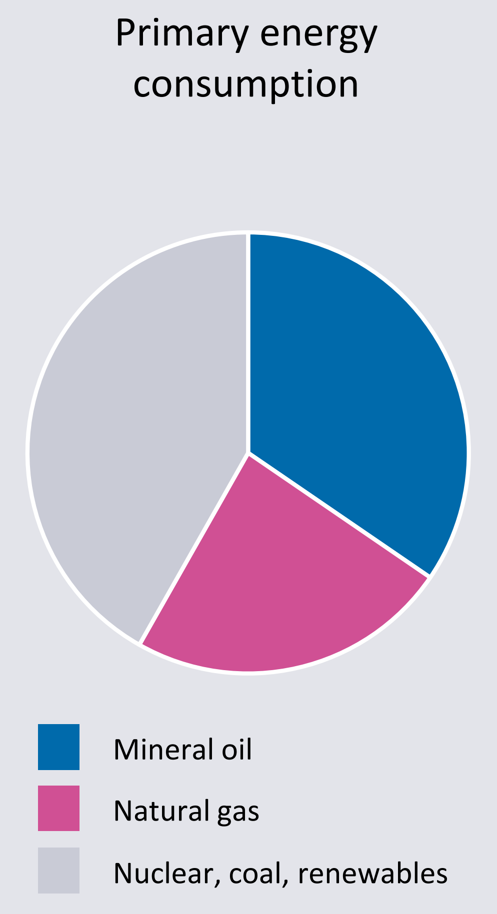
Fossil oil and gas are of crucial importance for Germany today.

Use in Germany in 2015 in TWh



* Includes power uses in commercial and sea transport sectors (bunkering)

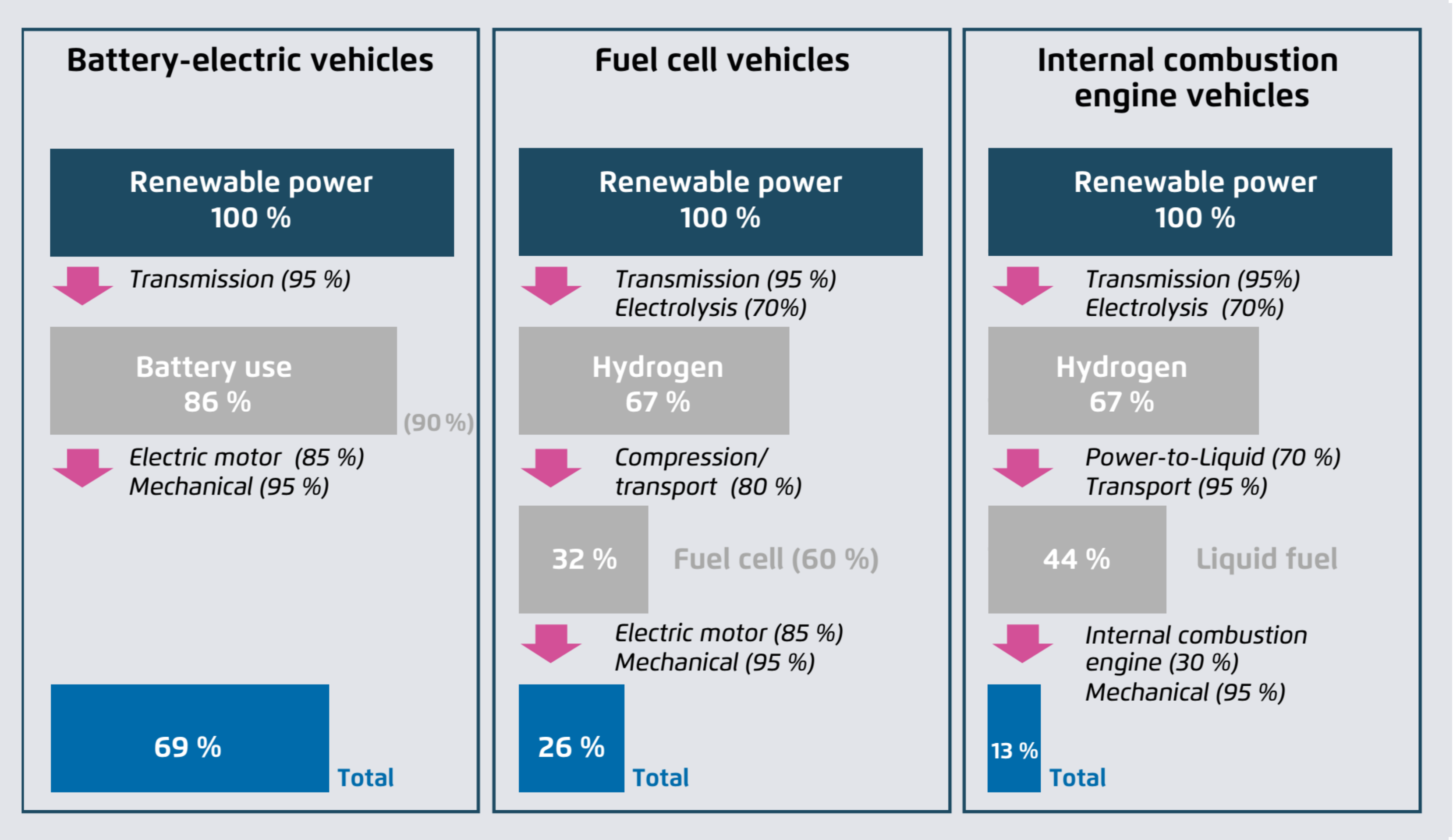
Energy mix 2017



Own illustration based on AGEB (2017)

For passenger cars, battery-driven electric vehicles are the energy efficiency benchmarks.

Individual and overall efficiencies for cars with different vehicle drive technologies



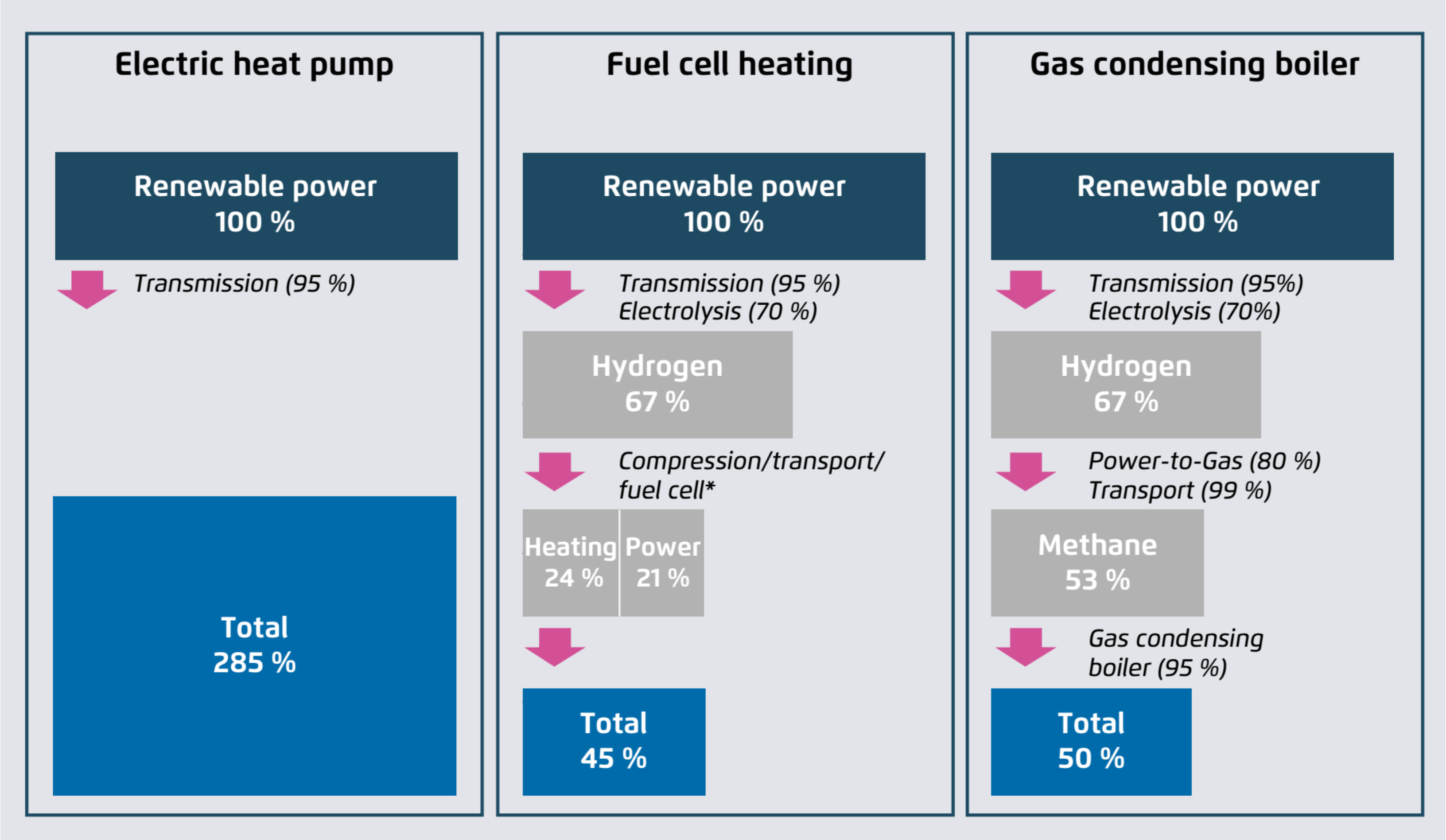
→ To travel the same distance, a **combustion-engine vehicle** would need about **five times** as much renewable electricity as a battery-driven vehicle.

→ A **fuel cell vehicle** needs about **two and a half times** as much electricity.

Own illustration, based on acatech et al. (2017a), Figure 5

Heat pumps have a particular leverage and use renewable electricity especially efficiently.

Individual and overall efficiencies for different heating systems



→ The electric **heat pump** withdraws more energy from the environment (air, soil or water) than required in terms of operational power, which is why it can have an efficiency rating over 100 %.

→ **Open question:** Can the indisputable, physics-based disadvantages of synthetic fuels be more than offset by avoidance of infrastructure costs?

Own calculations based on acatech et al. (2017 a,b), Köppel (2015), FENES et al. (2015)

PtG/PtL should predominantly be used in areas in which the direct use of electricity is not possible.

Decarbonisation options

Decarbonisation options	First priority Direct use of electricity*	Supplemental approaches Synthetic fuels**	
		Hydrogen***	CO_2-based PtG and PtL
Transport	Trains, buses, short-haul trucks, long-haul trolley-trucks and -buses, cars, motorcycles, inland waterway transport (depending on the purpose)	Long-haul trucks and buses without overhead lines, inland waterway transport (depending on the purpose)	Air and sea transport, long-haul trucks and buses without overhead lines, inland waterway transport (depending on the purpose)
Heating	Low-temperature heat with heat pumps in well-insulated buildings and in the industry	Fuel cell CHP in existing buildings with significant insulation restrictions	Existing buildings with significant insulation restrictions and hybrid heating systems with back-up boilers
	High-temperature heat with direct electricity use (resistance heating, plasma, etc.)	High-temperature process heat for hard-to-electrify applications	High-temperature process heat for hard-to-electrify applications

→ For **road transport**, the direct use of electricity should have priority.

→ **Long-haul trucks and buses** will possibly use PtG/PtL.

→ **Hydrogen** is more efficient than CO_2-based PtG/PtL and should therefore have priority.

→ PtG/PtL will indisputably be employed in **air and sea transport**.

Own summary; * or partially direct renewables such as solar thermal power; ** or partially direct renewables by means of biomass; *** mainly used in fuel cells

PtG/PtL should predominantly be used in areas in which the direct use of electricity is not possible.

Agora Verkehrswende

Agora Energiewende

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	High-temperature heat with direct electricity use (resist-ance heating, plasma, etc.)	High-temperature process heat for hard-to-electrify applications	High-temperature process heat for hard-to-electrify applications

→ For **building heat**, the direct use of renewables (deep geothermal, solar thermal) should have priority, as well as heat pumps in sufficiently insulated buildings – where useful also in connection with heat grids.

→ Supplemental in case of **insulation restrictions:** fuel cell CHP with hydrogen and CO_2-based PtG/PtL.

→ For **high-temperature heat**, the direct use of electricity should have priority, supplemented with PtG/PtL.

Own summary; * or partially direct renewables such as solar thermal power; ** or partially direct renewables by means of biomass; *** mainly used in fuel cells

PtG/PtL should predominantly be used in areas in which the direct use of electricity is not possible.

Decarbonisation options

Decarbonisa-tion options	First priority Direct use of electricity*	Supplemental approaches Synthetic fuels**	
		Hydrogen***	CO_2-based PtG and PtL
Industry		Ammonia production; direct reduction of iron ore in steel production	Carbon source for organic basic chemicals
Power	Short-term storage	Long-term storage and reconversion in gas-fired power plants and hydro-gen combustion motors	Long-term storage and reconversion in gas-fired power plants
Commerce, trade, services	Stationary and some mobile power applications in con-struction, agriculture, and logistics	Mobile power applications in construction, agricul-ture, logistics, and military	Mobile power applications in construction, agriculture, logistics, and military

→ **Industry:**
PtG/PtL as carbon source for organic basic chemicals.

→ **Power**:
CO_2-based PtG for long-term storage and reconversion in gas-fired power plants for times when wind and solar power generation are low.

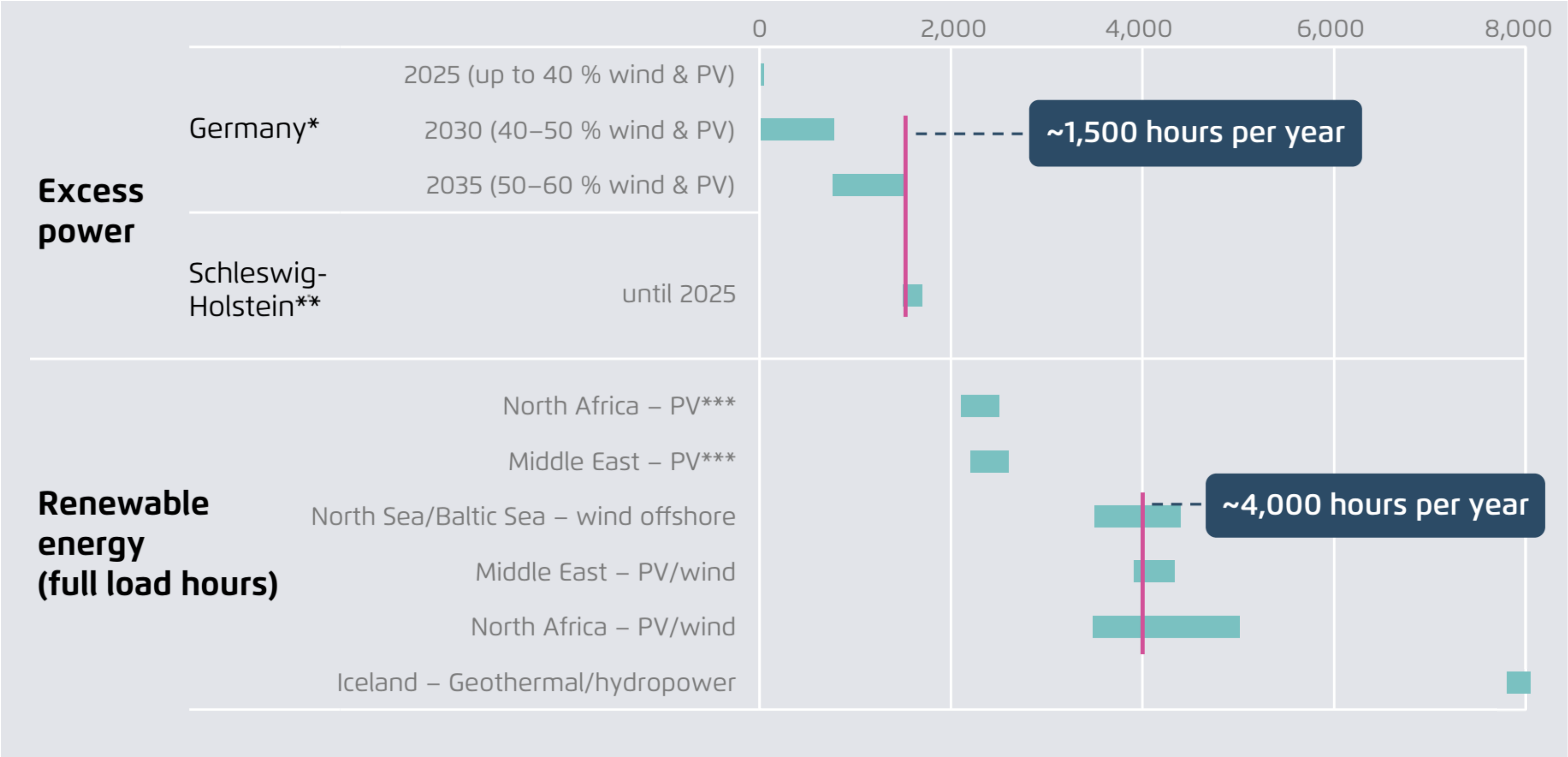
Own summary; * or partially direct renewables such as solar thermal power; ** or partially direct renewables by means of biomass; *** mainly used in fuel cells

2

To be economically efficient, power-to-gas and power-to-liquid facilities require inexpensive renewable electricity and high full load hours. Excess renewable power will not be enough to cover the power demands of synthetic fuel production.

PtG/PtL facilities require high full load hours and inexpensive renewable electricity.

Hours per year



→ **Capacity utilisation of** at least 3,000-4,000 hours/year needed due to high fixed cost.

→ **„Excess power“** with < 2,000 hours/year at low prices is insufficient.

→ **Additional renewable energy plants** needed for PtG-/PtL production: offshore wind, PV & onshore wind ~ 4,000 hrs/year.

→ **Full cost** of renewable energy facilities are relevant.

Own illustration based on acatech et al. (2015), ecofys/IWES (2014), Frontier Economics (2018)

3

In the beginning, synthetic methane and oil will cost between 20 and 30 cents per kilowatt hour in Europe. Costs can fall to 10 cents per kilowatt hour by 2050 if global Power-to-Gas (PtG) and Power-to-Liquid (PtL) capacity reaches around 100 gigawatts.

The cost of synthetic methane and oil can fall from initially 20 to 30 ct/kWh to about 10 ct/kWh by 2050.

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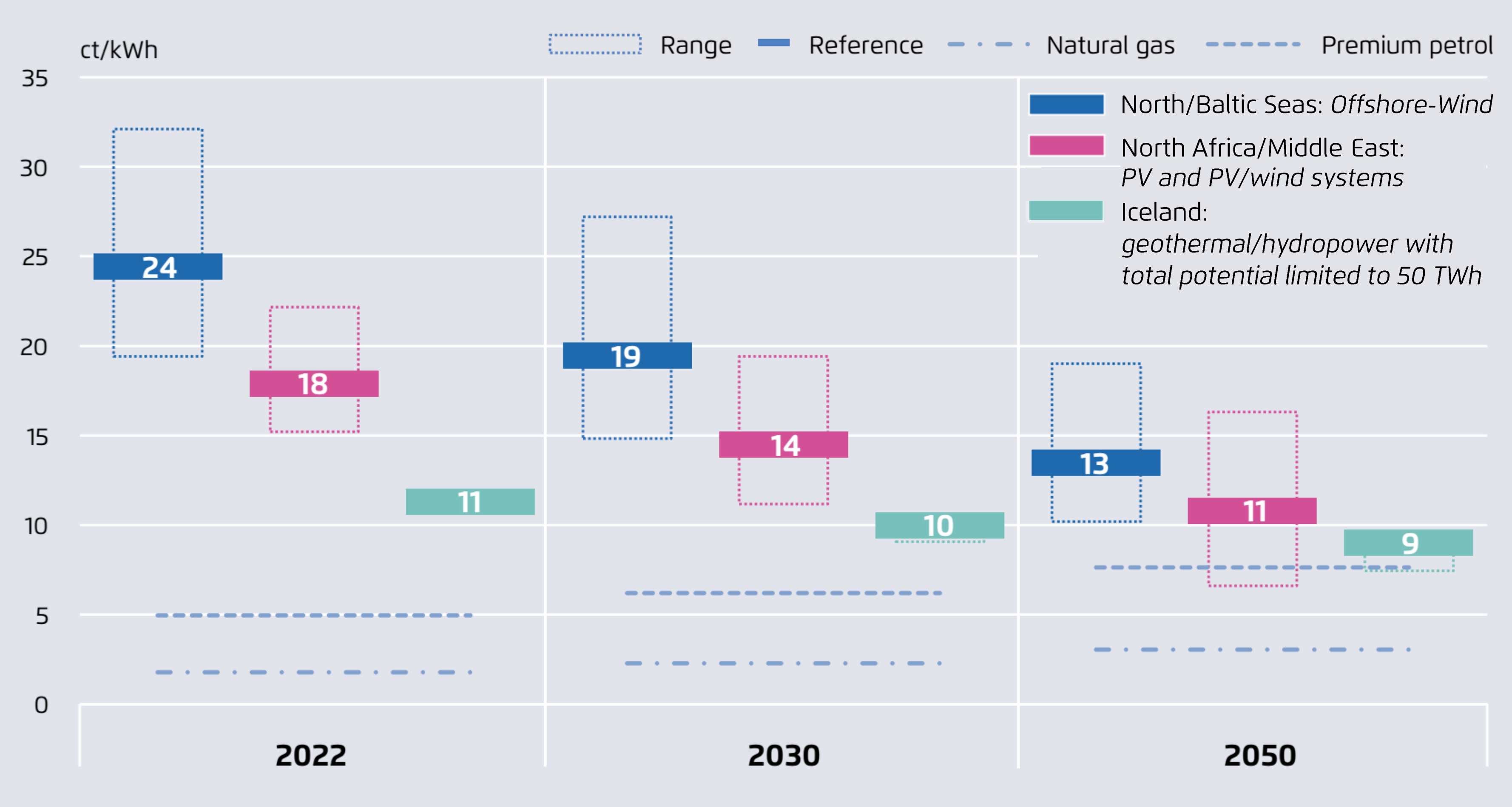
Cost of synthetic methane and liquid fuels fuels in ct_{2017}/kWh *



→ **Prerequisite:** Increase in global electrolysis capacity to 100 GW.

→ **Imports are cheaper**.

→ Further **cost reductions** due to PV, batteries, very large facilities.

→ **Cost increase** due to higher cost of capital in countries with elevated risks; may inverse situation of imports versus domestic production.

→ **Prices**: royalties and global PtG/PtL market.

* without network charges and distribution cost; own calculation based on Frontier Economics (2018) with cost of capital of 6% and CO_2 from *Direct Air Capture*

The sought-after cost decreases require considerable, early and continuous investment in electrolysers.

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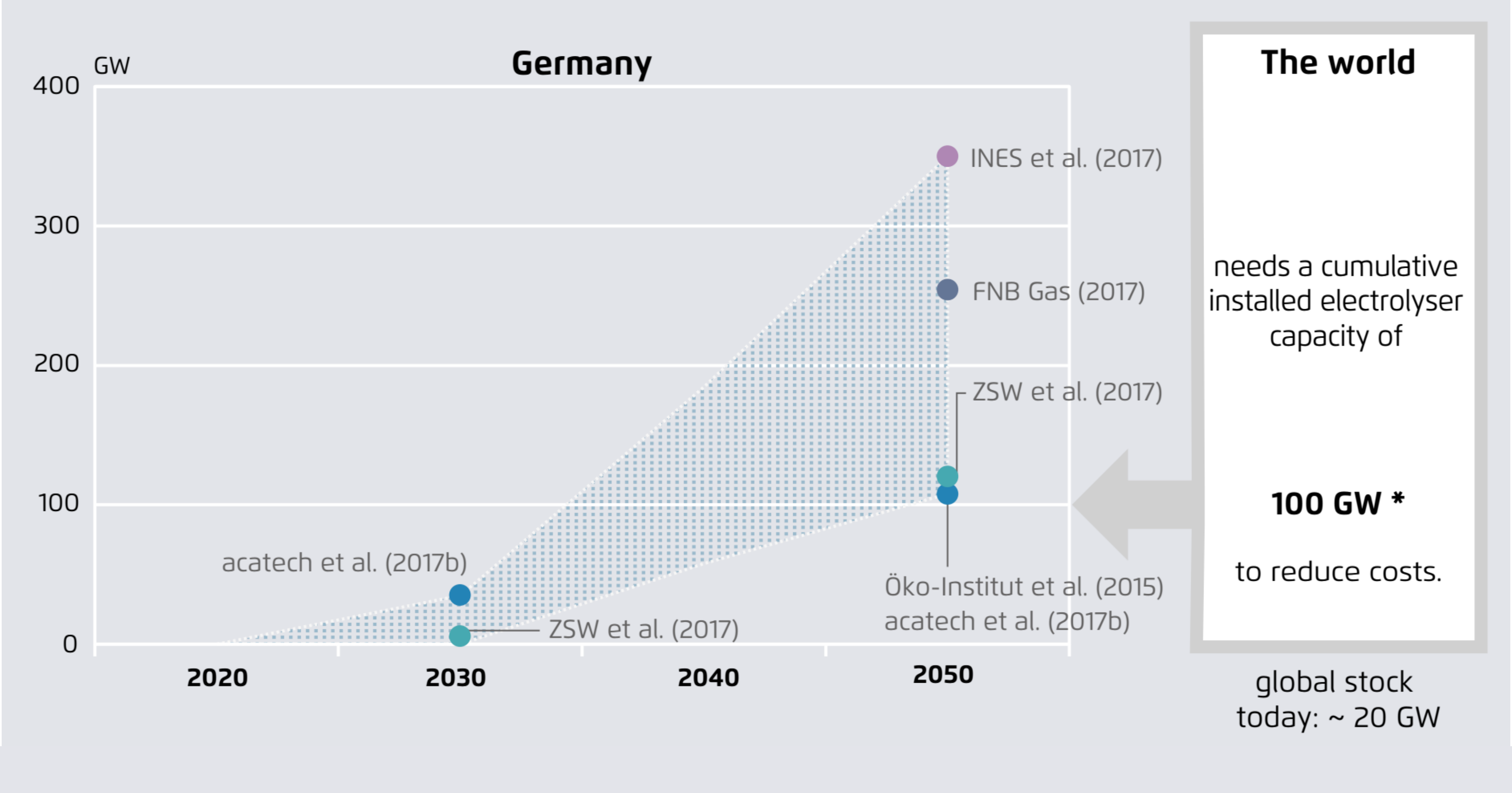
Installed electrolysis capacity for PtG/PtL in scenarios for Germany in GW



→ **Scale and learning effects** are critical for cost reduction, but uncertain (e.g. CO_2 from air).

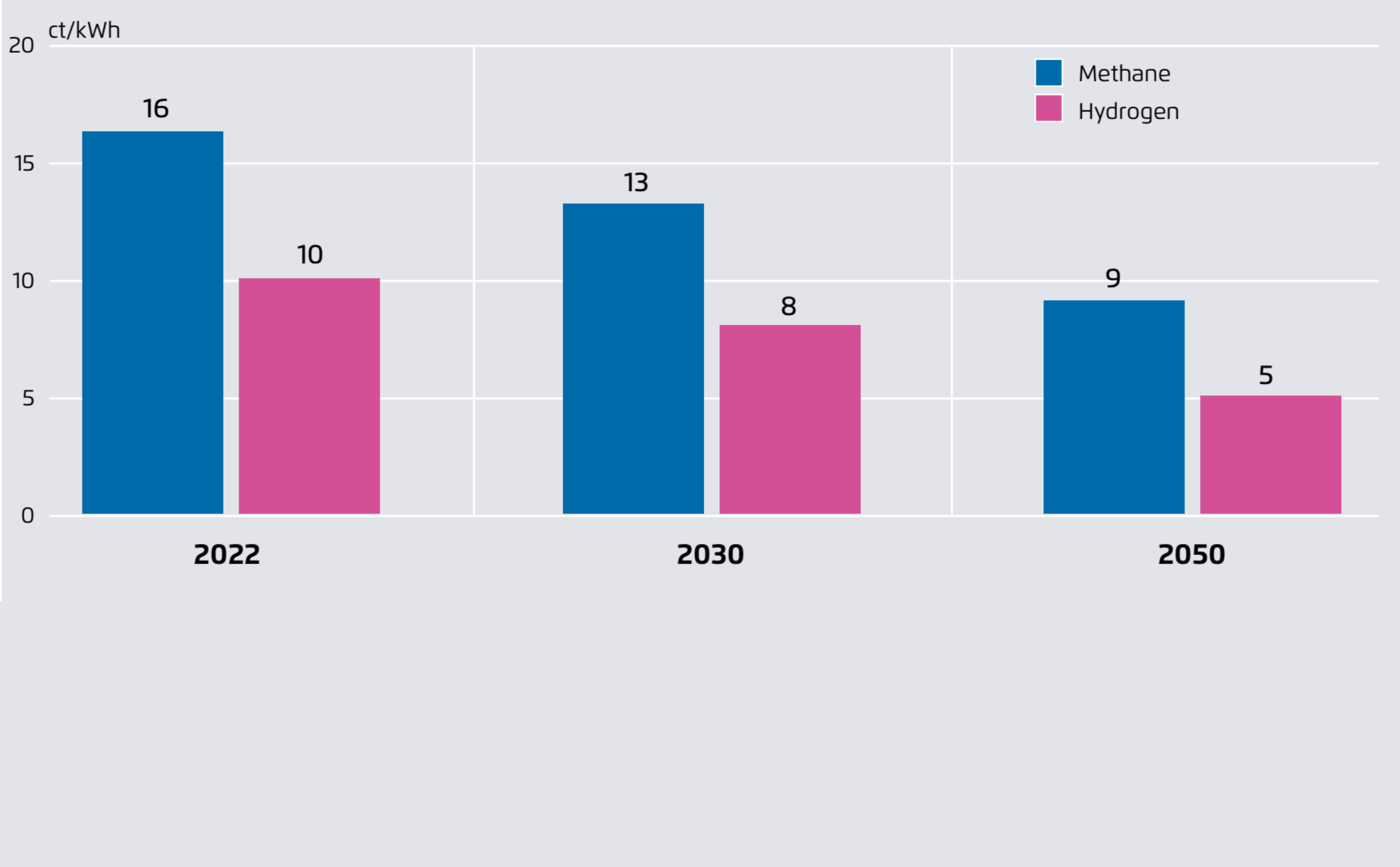
→ International **100-gigawatts-challenge**.

→ Investments are not to be expected without **political intervention or high CO_2 price** due to high cost of synthetic fuels.

Own illustration based on Frontier Economics (2018) and others

Hydrogen production costs less than methane, yet requires new infrastructure and end-use applications.

Cost of synthetic methane and hydrogen production in ct_{2017}/kWh



- → **Hydrogen blending** to natural gas is allowed for small shares of hydrogen in Germany.
- → **Costly retrofitting can be expected** for a share of hydrogen that exceeds 15% by volume.
- → **Local infrastructure** specifically for hydrogen might be an option.
- → **Hydrogen advantage:** no uncertainties of CO_2-capture from air.
- → **Hydrogen disadvantage**: no simple further use of existing infrastructure.

Production with PV in North Africa without cost of transport to Germany; own calculation based on Frontier Economics (2018)

4

We need a political consensus on the future of oil and gas that commits to the phase-out of fossil fuels, prioritises efficient replacement technologies, introduces sustainability regulations, and creates incentives for synthetic fuel production.

Building blocks for an oil and gas consensus

Greenhouse gas emission reduction goals

→

Agreement on an oil and gas consensus

between politics, economy and civil society

Phase out of fossil oil and gas

Gradual decrease in the total use and associated emissions

→

Priority for effi-cient replacement technologies

for example with battery-electric mobility and electric heat pumps

→

Incentives for synthetic fuel production

on the basis of sustainability standards for PtG/PtL and application-specific targets*

* (1.) Minimum greenhouse gas reduction by 70% relative to fossil reference fuels; (2.) Additionality of renewable electricity generation; (3.) CO_2 from the air or from sustainable biogenic sources; (4.) Sustainable use of water and land; (5.) Social sustainability of fuel production

Sustainability standards also need to be established for the raw materials and production of electric batteries.

We need to develop sustainability standards for the production of electricity-based fuels.

Minimum greenhouse gas reduction	Entire production chain of synthetic fuels must emit 70% less greenhouse gas than conventional fossil fuels.
Additional renewable electricity generation	Power for the entire production process (including water processing, etc.) must come from additional renewable energy power stations. If this cannot be achieved, the emissions of each power mix must be balanced.
CO_2 from sustainable atmospheric sources	Only CO_2 capture from the air or sustainable biogenic sources create a closed carbon-neutral CO_2 cycle. If this cannot be achieved, all CO_2 emissions are to be counted.
Sustainable use of water and land	Water processing for electrolysis may not negatively impact water supply. Production sites may not be located in nature reserves or in other vulnerable areas (such as habitats with high levels of biodiversity).
Social sustainability of fuel production	Synthetic fuel production may not negatively impact local communities. When fuel is produced in developing countries, a portion of the revenues must go towards sustainable local development.

Agora Verkehrswende & Agora Energiewende (2018)

Conclusions drawn at a glance

1	Synthetic fuels will play an important role in decarbonising the chemicals sector, the industrial sector, and parts of the transport sector.
2	To be economically efficient, power-to-gas and power-to-liquid facilities require inexpensive renewable electricity and high full load hours. Excess renewable power will not be enough to cover the power demands of synthetic fuel production.
3	In the beginning, synthetic methane and oil will cost between 20 and 30 cents per kilowatt hour in Europe. Costs can fall to 10 cents per kilowatt hour by 2050 if global Power-to-Gas (PtG) and Power-to-Liquid (PtL) capacity reaches around 100 gigawatts.
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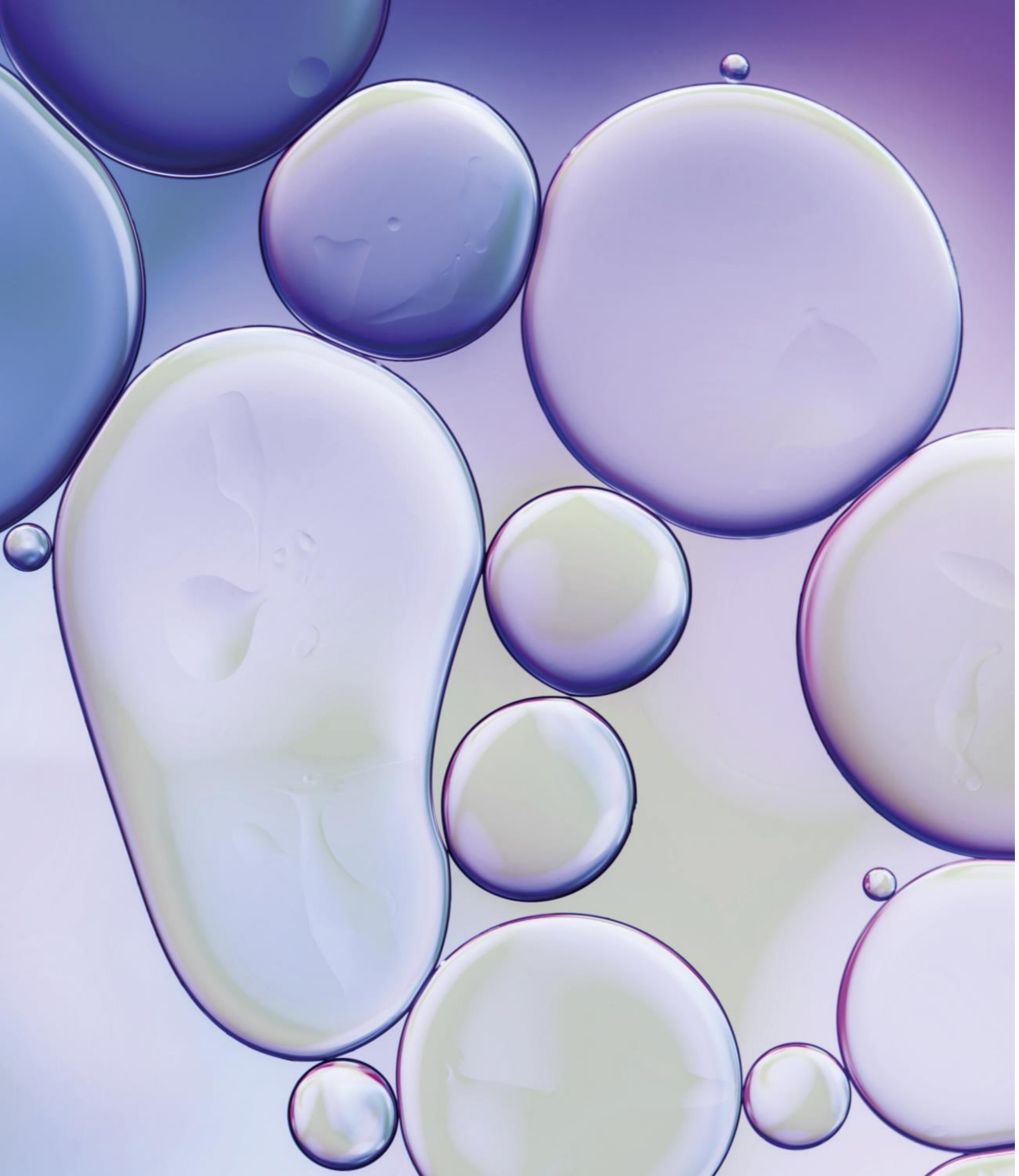

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Agora Verkehrswende and Agora Energiewende are joint initiatives of the Mercator Foundation and the European Climate Foundation.