Synthetic fuels

as part of a CO_2 neutral energy infrastructure

M. Rothbart

AVL at a Glance

1948
Founded

75
Years of Experience

26
Countries Represented

45
Global Tech and Engineering Centers

11,200
Employees Worldwide

68 %
Engineers and Scientists

11 %
Of Turnover Invested in Inhouse R&D

2,200
Granted Patents in Force

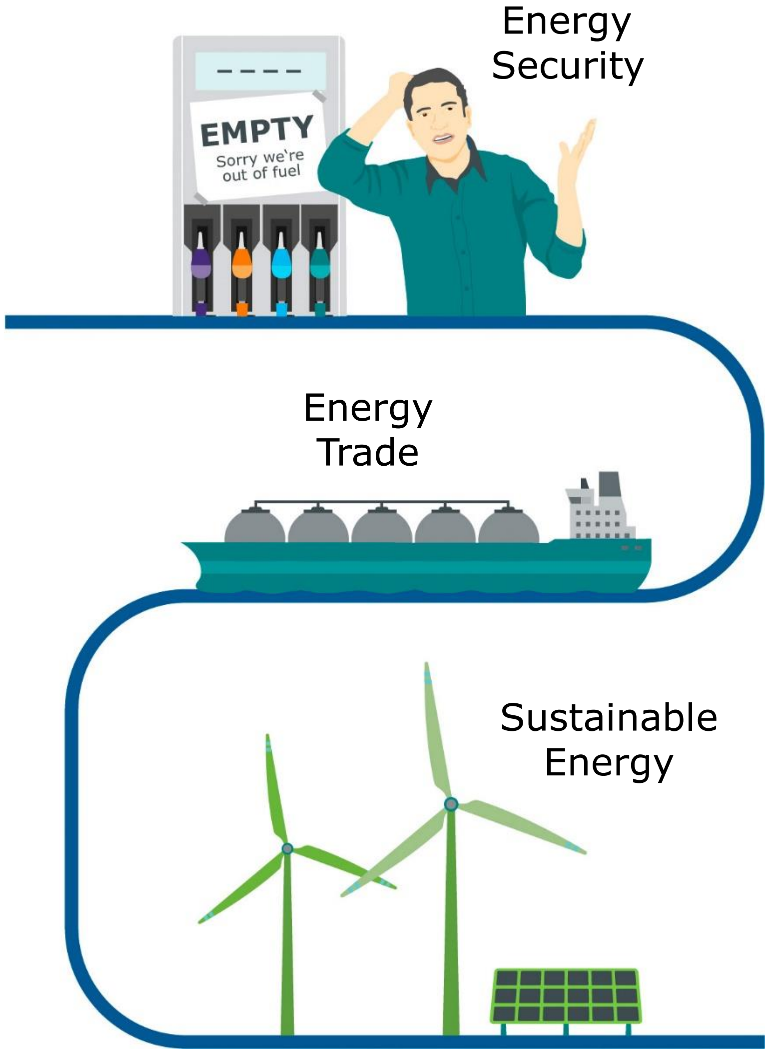
Strive for two goals: Climate-neutrality and energy security

EU wants to become the 1st carbon neutral continent by 2050

United States to achieve a 50-52 percent reduction from 2005 GHG levels in 2030

China will peak emissions before 2030 and aims to achieve carbon neutrality before 2060

Japan aims for zero emissions, carbon neutral society by 2050

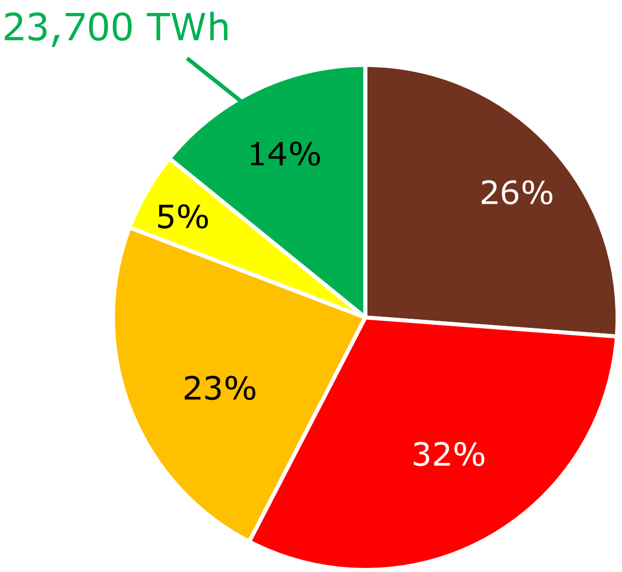


Content

Production

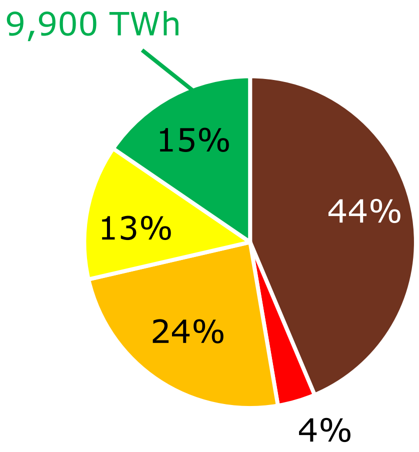
Global Energy Demand 2019

Primary Energy Demand - World



168,000 TWh

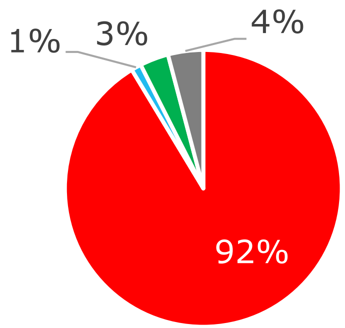
Power Generation - World



64,000 TWh

Coal Oil Gas Nuclear Renewables

Road Transport Sector - World



30,000 TWh

Oil Electricity Other fuels Renewables

Source: IEA WEO 2020

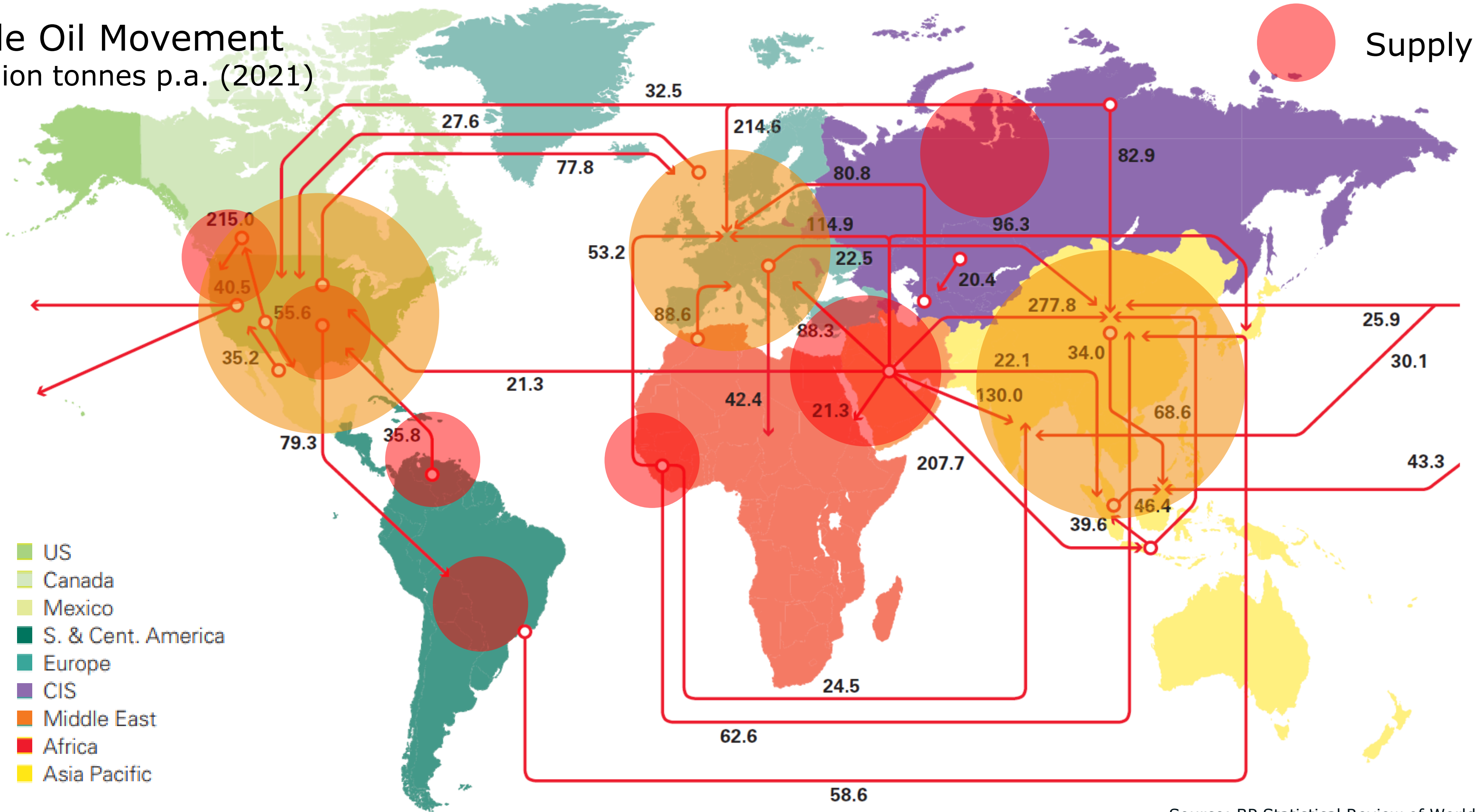
Fossil Energy Trade Today: No Match of Supply & Demand Regions

Demand Centers

Supply Regions

Crude Oil Movement

in Million tonnes p.a. (2021)



Source: BP Statistical Review of World Energy 2022, Page 30, [LINK]

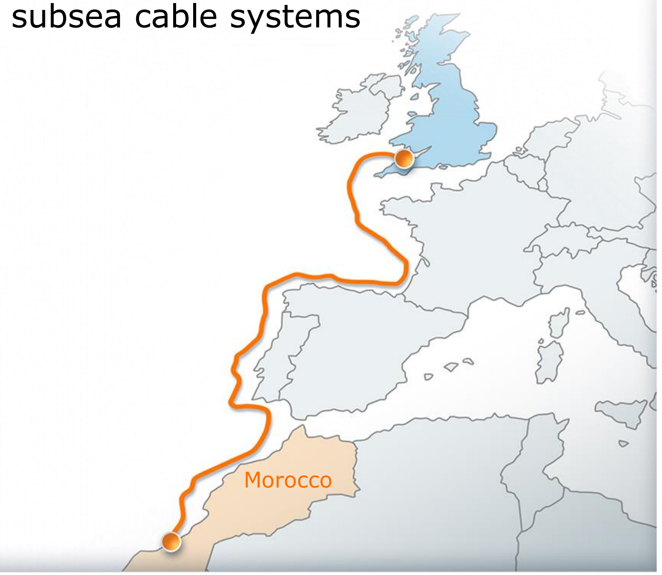
Low Carbon Energy Alternatives for Europe

Extended life of existing power plants

Extending the global nuclear plant fleet's lifetime by 10 years would add 26000 TWh of low carbon electricity generation.

High-voltage DC lines

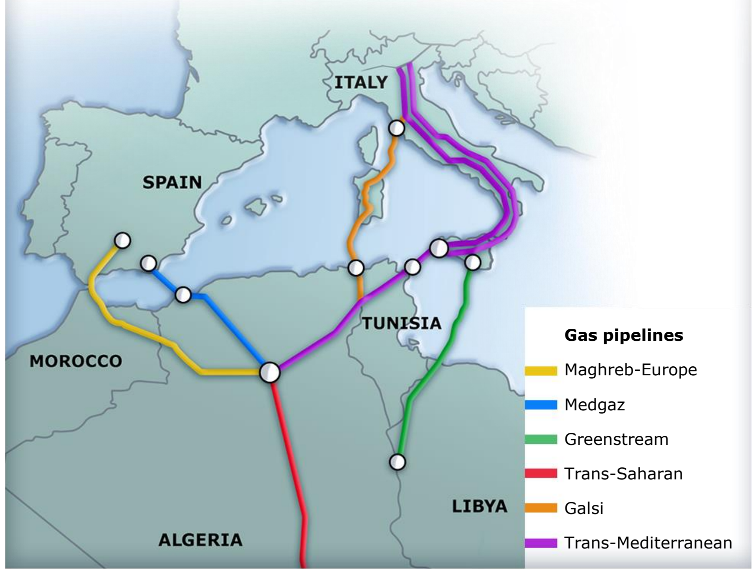
Four cables, each 3800 km long form the twin 1.8 GW High Voltage Direct Current (HVDC) subsea cable systems



Source: https://xlinks.co/

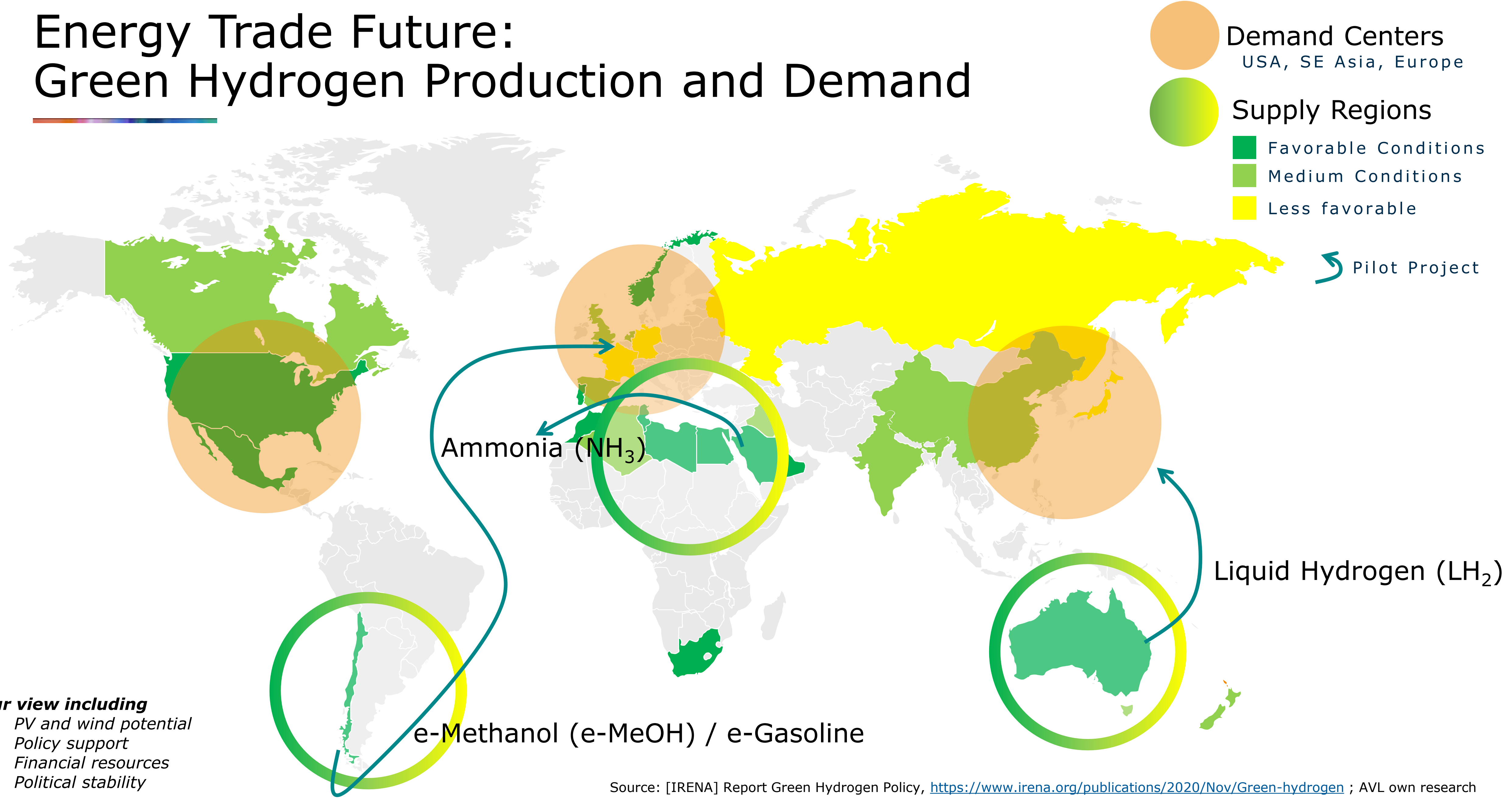
Hydrogen from sun – North Africa to Europe

H_2 generated in North Africa
transport via pipeline to Europe
conversion to electricity



Source: Transmed Pipeline (Algeria-North Italy) 2500 km
https://de.wikipedia.org/wiki/Transmed

Energy Trade Future: Green Hydrogen Production and Demand



Our view including
- *PV and wind potential*
- *Policy support*
- *Financial resources*
- *Political stability*

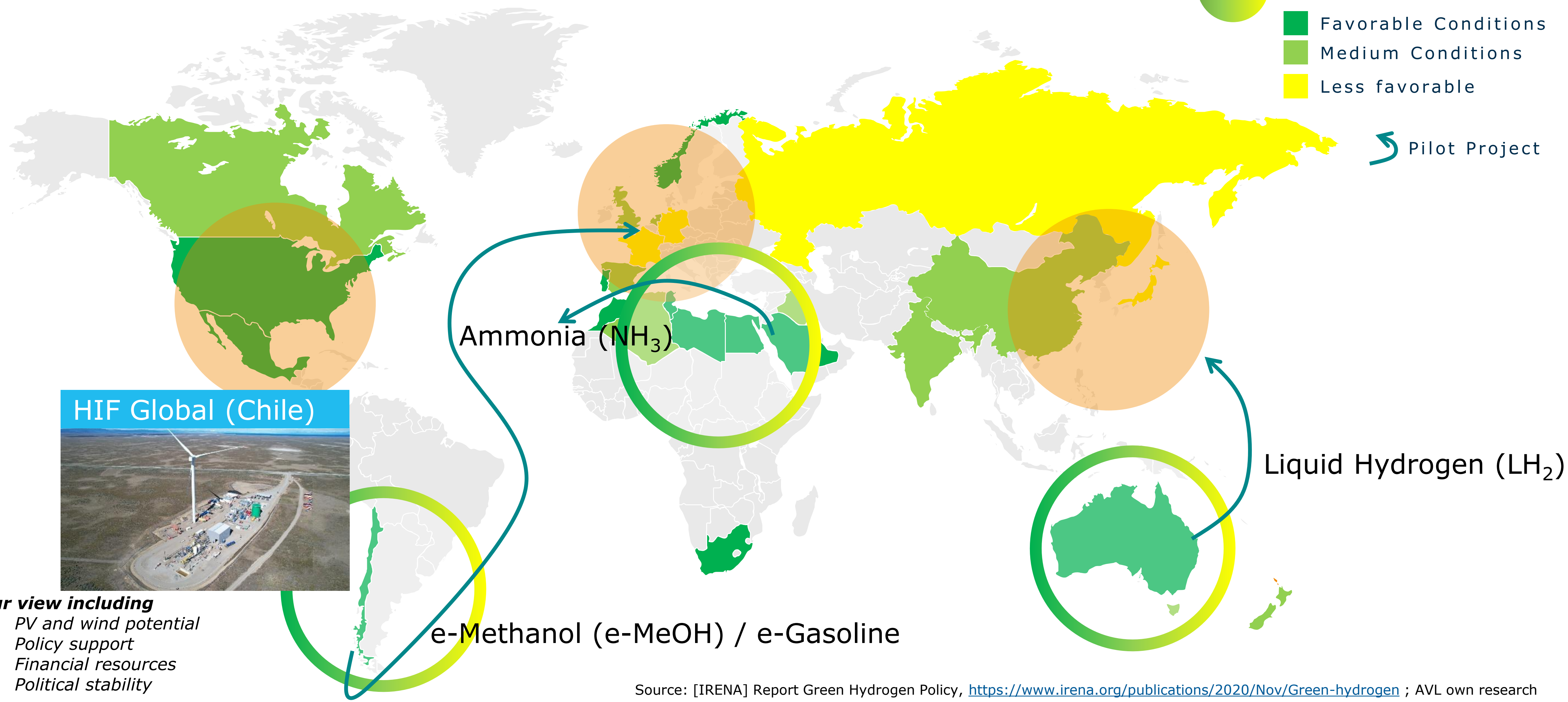
Source: [IRENA] Report Green Hydrogen Policy, https://www.irena.org/publications/2020/Nov/Green-hydrogen ; AVL own research

Energy Trade Future:
Green Hydrogen Production and Demand

Demand Centers
USA, SE Asia, Europe

Supply Regions
- Favorable Conditions
- Medium Conditions
- Less favorable

Pilot Project



HIF Global (Chile)

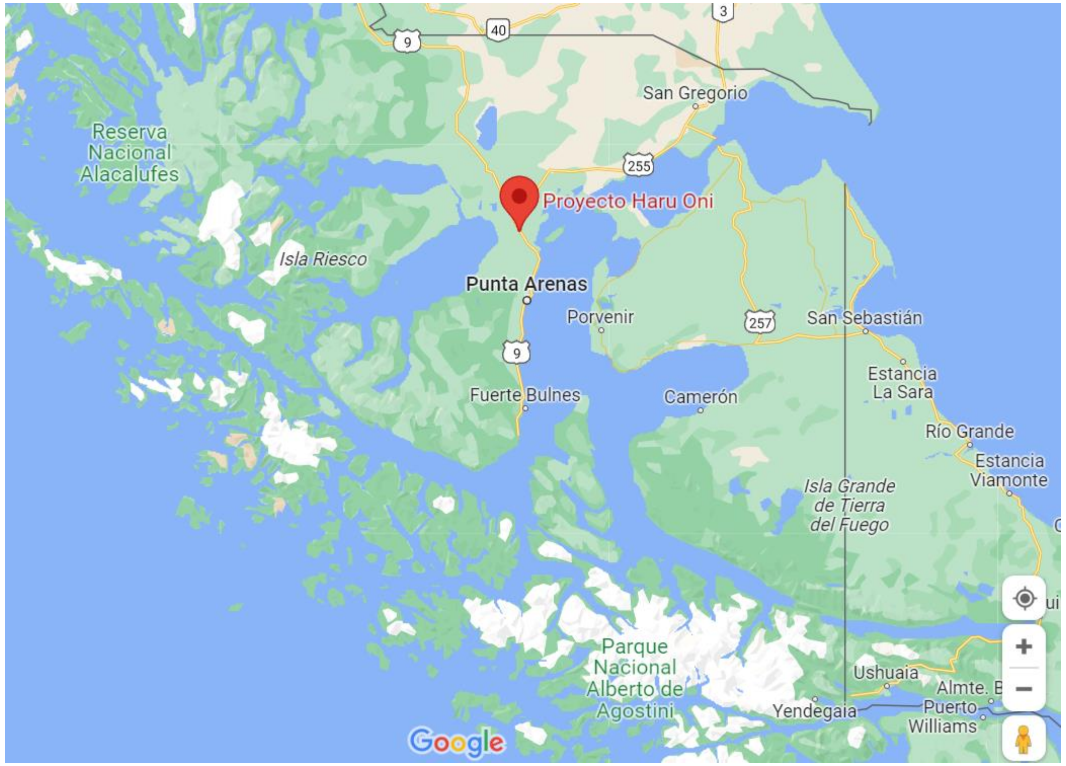
Our view including
- *PV and wind potential*
- *Policy support*
- *Financial resources*
- *Political stability*

Source: [IRENA] Report Green Hydrogen Policy, https://www.irena.org/publications/2020/Nov/Green-hydrogen ; AVL own research

Highly Innovative Fuels - HIF Global - Haru Oni (Chile)

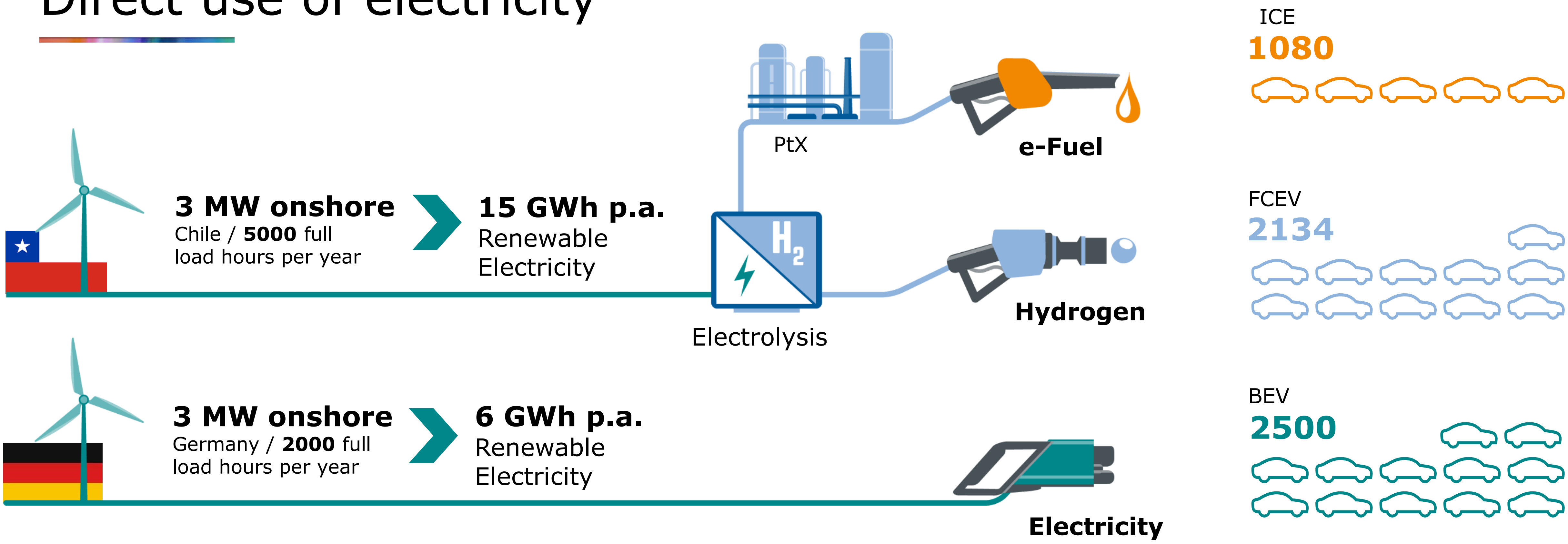
HIF Global and its partners celebrate the first liters of e-fuel from Haru Oni, Chile

Punta Arenas de Chile, December 20, 2022. HIF Global, the world's leading eFuels company, together with its partners, authorities, and community representatives, celebrates the production of the first liters of synthetic gasoline at the Haru Oni Demonstration Plant in southern Chile.



Source: https://www.hifglobal.com/docs/default-source/default-document-library/press-release---first-liters-hif-haru-oni.pdf?sfvrsn=8b9c47f6_9

How many cars can be fueled from one wind turbine?
Direct use of electricity



2000 FLh average number of full-load hours Germany, Source: IG Windkraft, www.igwindkraft.at
5000 FLh average number of full-load hours Chile, Source: Decarbonization of the mobility sector: potential of Power-to-X technologies, https://www.ifkm.kit.edu/downloads/2019_12_17_Seminar_KIT_Audi.pdf
Tank-to-Wheel: C-Segment Car, 12,000 km p.a., 18 kWh/100 km or 5 l/100 km or 1 kg H_2/100 km
Process efficiencies: **Battery electric:** transmission losses 5%, charging losses 8% | **Hydrogen:** 81% H2 electrolyser efficiency, 25% transmission losses liquification H_2, 5% compression losses to 700bar | **e-Fuel:** 43% e-Fuel production efficiency, distribution losses 3%, refueling losses 2%

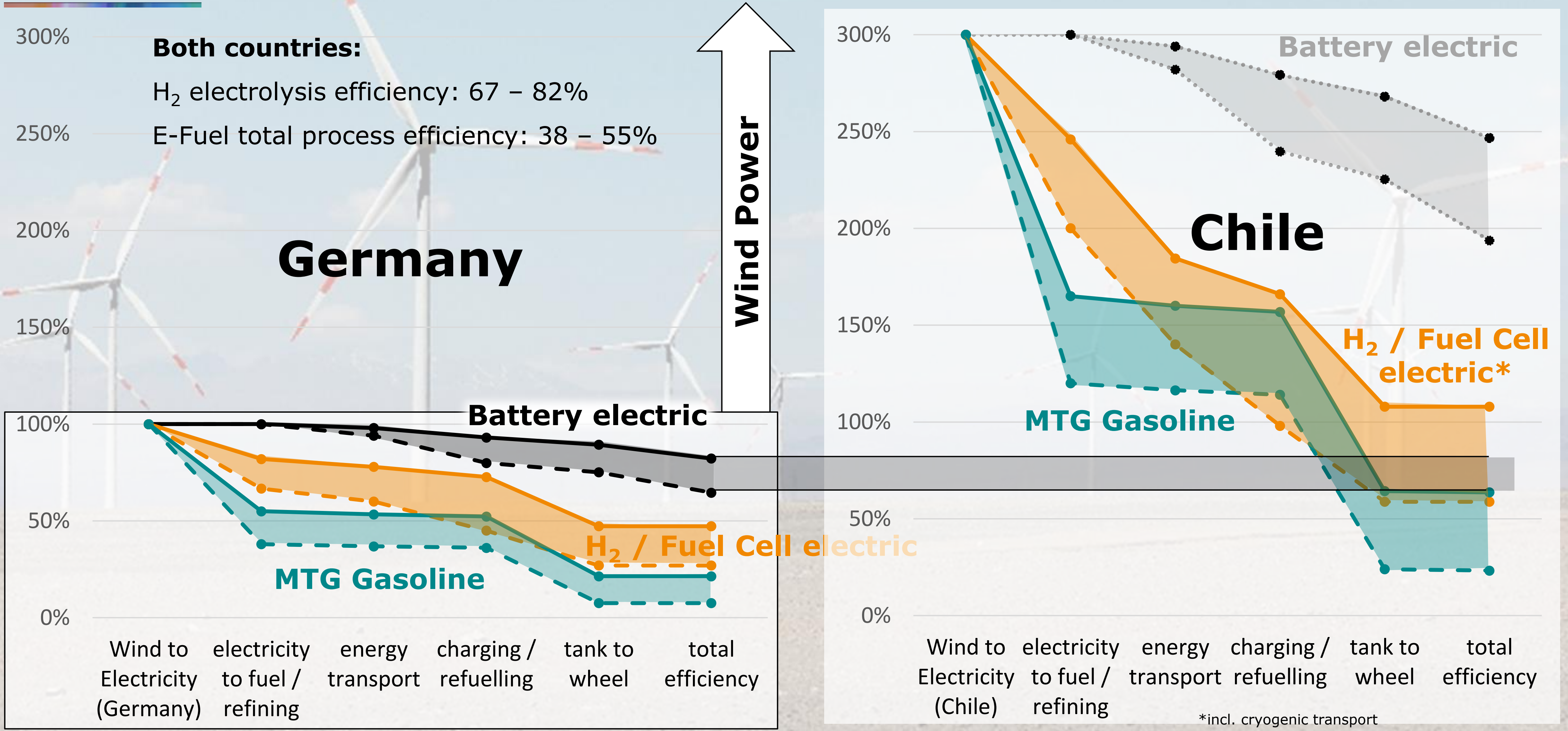
Direct use of electricity shows highest efficiency.
Only true when vehicle charging at same time when electricity is produced.

Efficiency in Energy Conversion of Renewable fuels Germany vs Chile

Both countries:

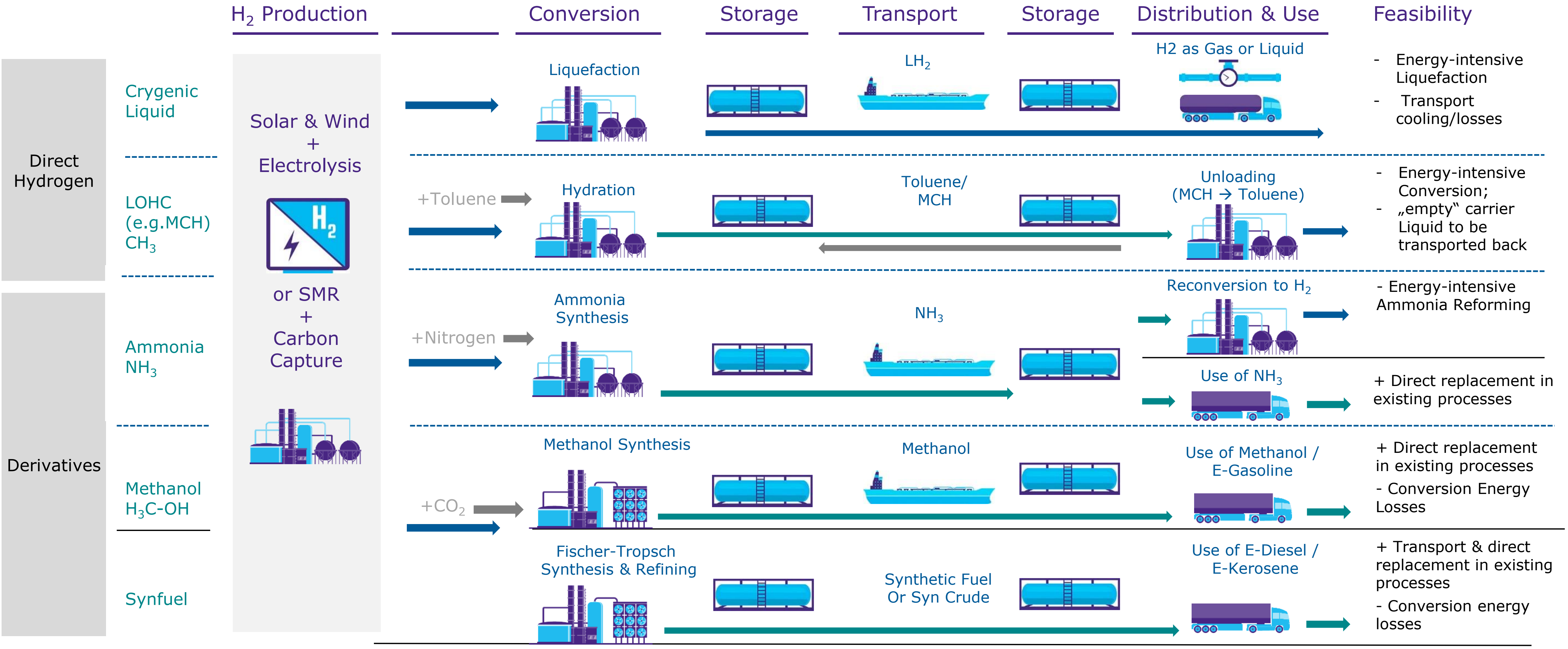
H_2 electrolysis efficiency: 67 – 82%

E-Fuel total process efficiency: 38 – 55%



Transport & Distribution

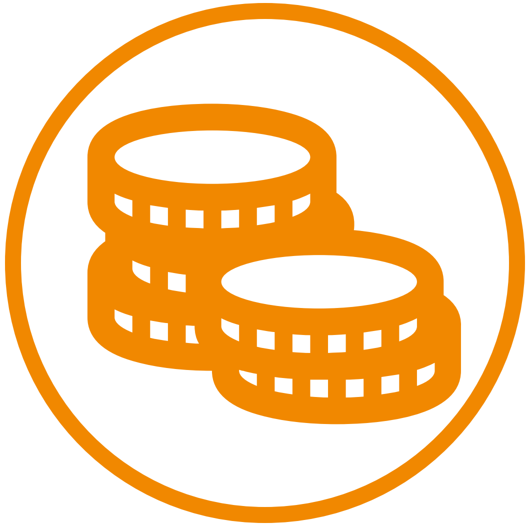
Long-Distance Transport: Different Routes for hydrogen-based energy carriers



(Simplified; several other methods existing)

→ H_2 → N_2, CO_2, LOHC → H_2-based Energy Carrier

Challenges



COSTS

AVAILABILITY

COSTS EXAMPLE

Long-Distance Transport: Different Routes for hydrogen-based energy carriers

(Simplified; several other methods existing)

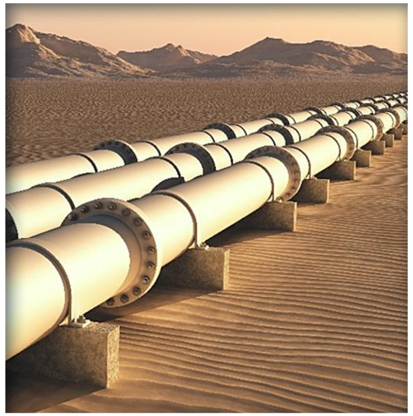
COSTS
EXAMPLE

Hydrogen Transport Cost

Transport costs per kg H_2

Near-term options

	500 km	1000 km	2000 km	3000 km
Vessel, CGH_2 (Inl. waterw., 100 MW)[1]	1.93 €	3.23 €	5.83 €	8.43 €
Truck, CGH_2 (Road, 100 MW)[1]	2.48 €	4.33 €	8.03 €	11.73 €
Vessel, LH_2 (Ocean, 500 MW, 2035+)[2]	0.83 €	0.87 €	0.95 €	1.03 €
36’ Pipeline onshore (15 GW, 2035+)[2]	0.37 €	0.50 €	0.76 €	1.02 €

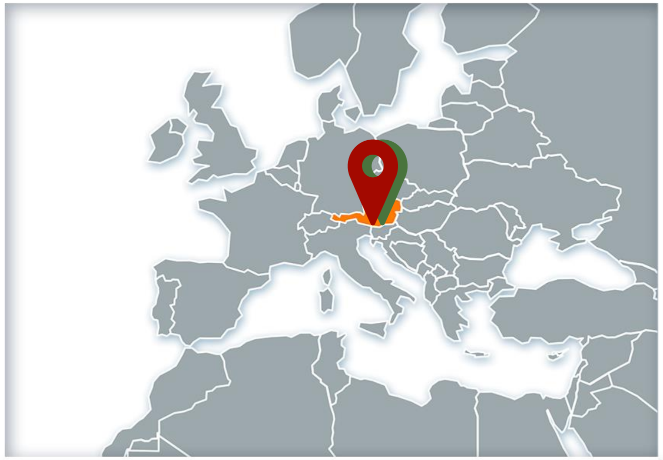


[1] Own Study (Guris/Strategy Engineers, 2022) [2] EU COM/JRC124206 (2021)

Overview of Different Hydrogen Production and Transportation Scenarios: Local vs. Zonal

COSTS EXAMPLE

Local production (today)



	Self-production for a large-scale consumer (**~8,000 h/a**)
	180 €/MWh
	20 MW AEL
	Storage capacity for 1 month production volume
	Production on-site, no transportation kilometers

Local production (future)

	PV buffer (**~1,000 h/a**)
	50 €/MWh
	200 MW PEM
	Storage capacity for 1 month production volume
	Production on-site, no transportation kilometers

Intercontinental supply

	Large-scale PV farm-based production (**~4,000 h/a**)
	15 €/MWh at production site 180 €/MWh at utilization site
	2,000 MW PEM
	Storage capacity for 1 month production volume
	3200 km transportation per vessel 290 km transportation with truck

COSTS
EXAMPLE

Levelized Costs of Hydrogen Supply [€/kg H_2]

Local Hydrogen production

Scenario 1:
Production at fuel station

Today (grid. electricity)

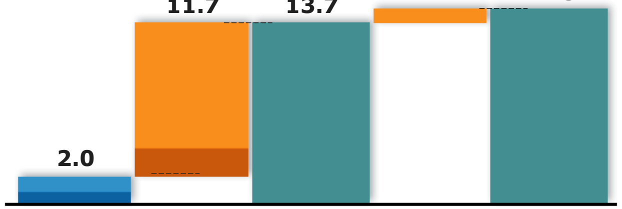
Future (PV buffer)

Hydrogen import

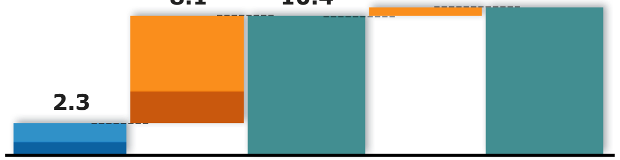
Scenario 2:
Hydrogen from Northern Africa

Comment: Some Studies project transport cost at approx. 1 €/kg

Today (CGH_2)



Future (LH_2)



CAPEX OPEX LCOH LCOH: Levelized costs of hydrogen

Strategy Engineers/AVL simulation, 2022

Long-Distance Transport: Different Routes for hydrogen-based energy carriers

(Simplified; several other methods existing)

H_2 | N_2, CO_2, LOHC | H_2-based Energy Carrier

Upscaling of Solutions for new Fuels

One Fuel Filling Station*:
supplying in avg. 3.7 Mln. Liter fuel per year
(Germany: 14000 stations)

Selected Synthetic Fuel Production Projects

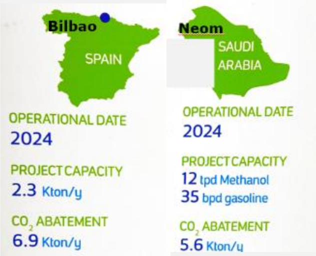
HIF Global (since 2022)

2022 - 130.000 l/year – 1 MW*
2024 – 55 Mln. l/year – 150 MW*
2026 – 550 Mln. l/year - 1.5 GW*

* Plant sizes are own assumptions based on announced e-Fuel volume

Saudi Aramco (2020-2023)

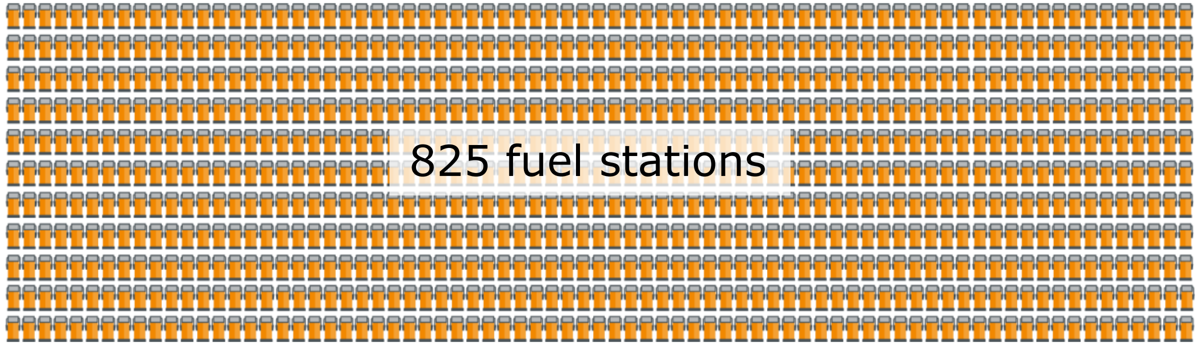
Bilbao: 2.9 Mln. Liter pa (2.3 kton/year)
Neom: 2 Mln. Liter pa. gasoline (35 Barrel/day)

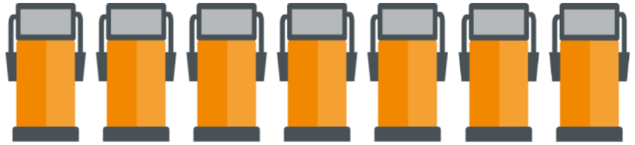


IFE project @ AVL (2024)

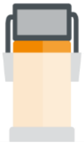
35.000 l/year Diesel – 200 kW_e

Scenario Germany:
20% of each station supply is e-Fuel
→ 1 Mio. Liter e-Fuel per year





7 fuel stations



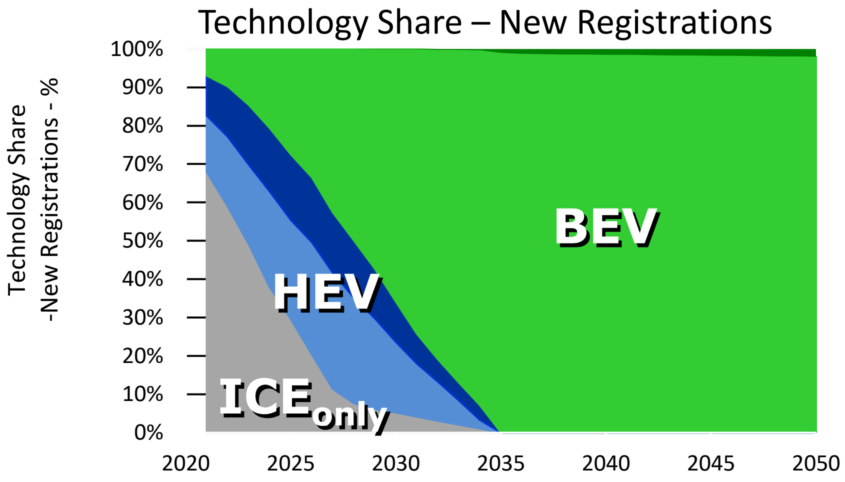
1/10 fuel station

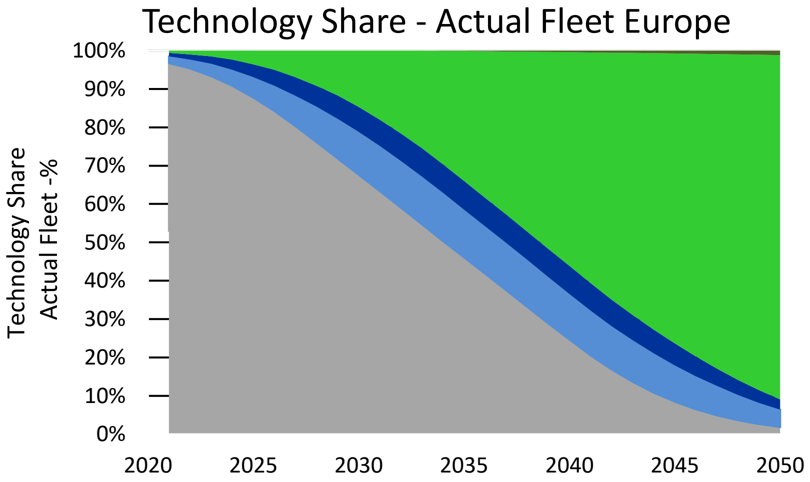
Significant upscaling is required

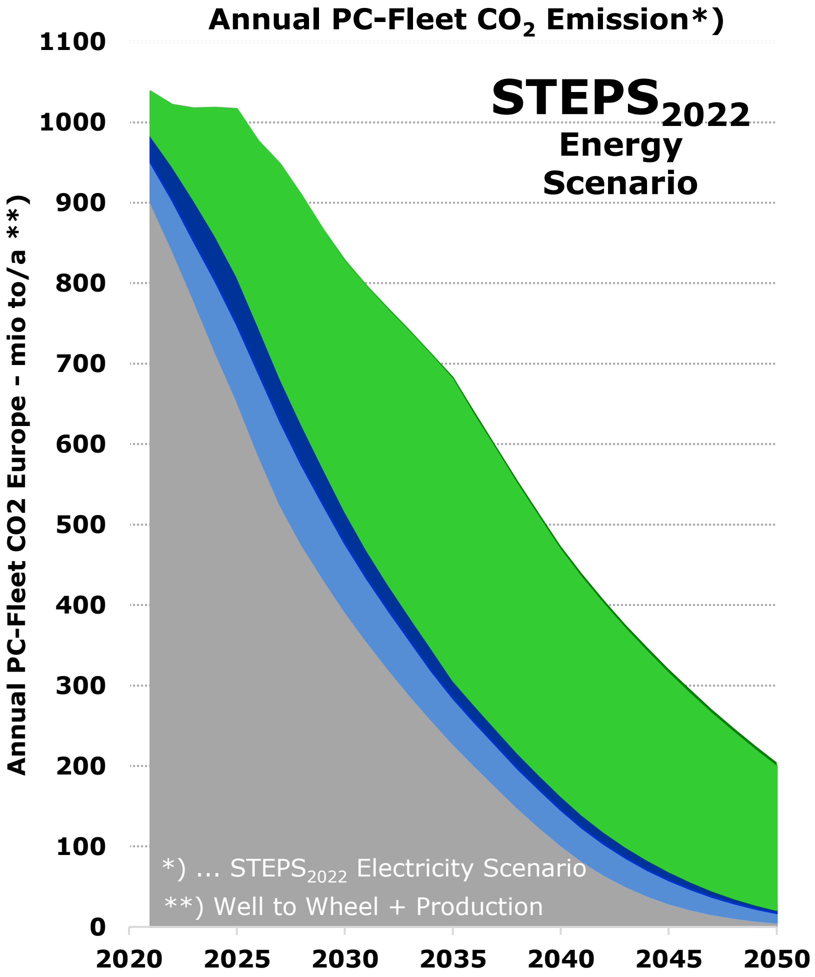
* Fuel Stations turnover, Germany: avg. station 3.7 Mln.l pa, ranging from 300.000 to 10 Mln.l pa, across 14.000 stations countrywide

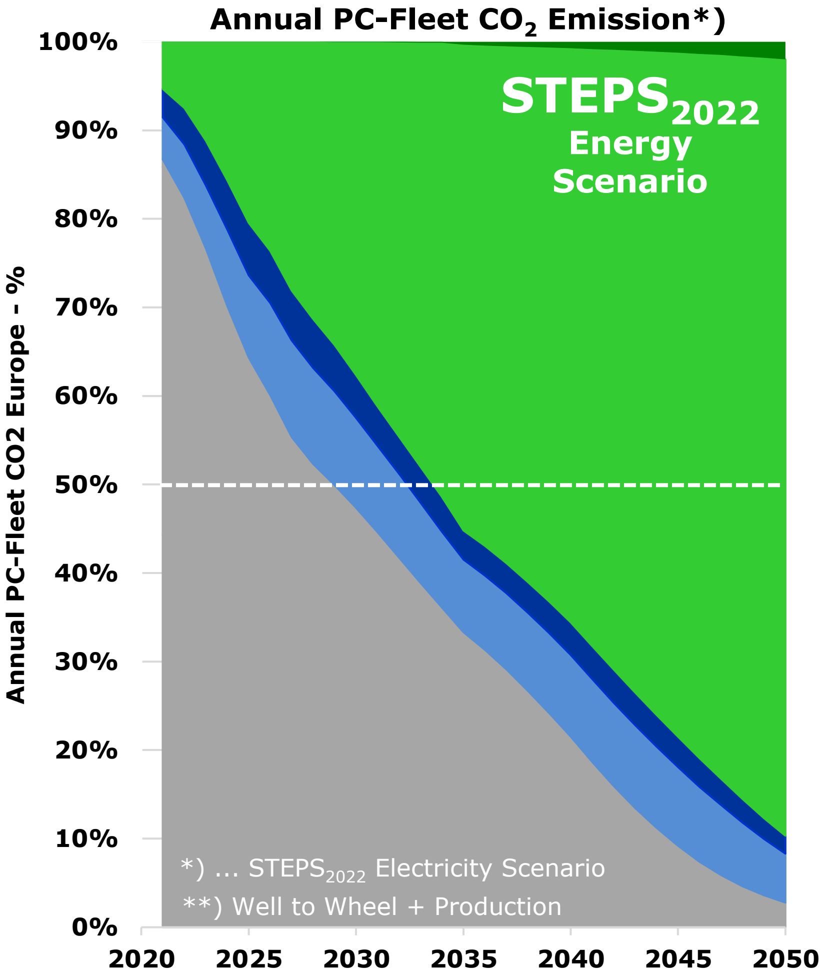
Fleet Application

From Technology Scenario to Fleet CO_2–Europe





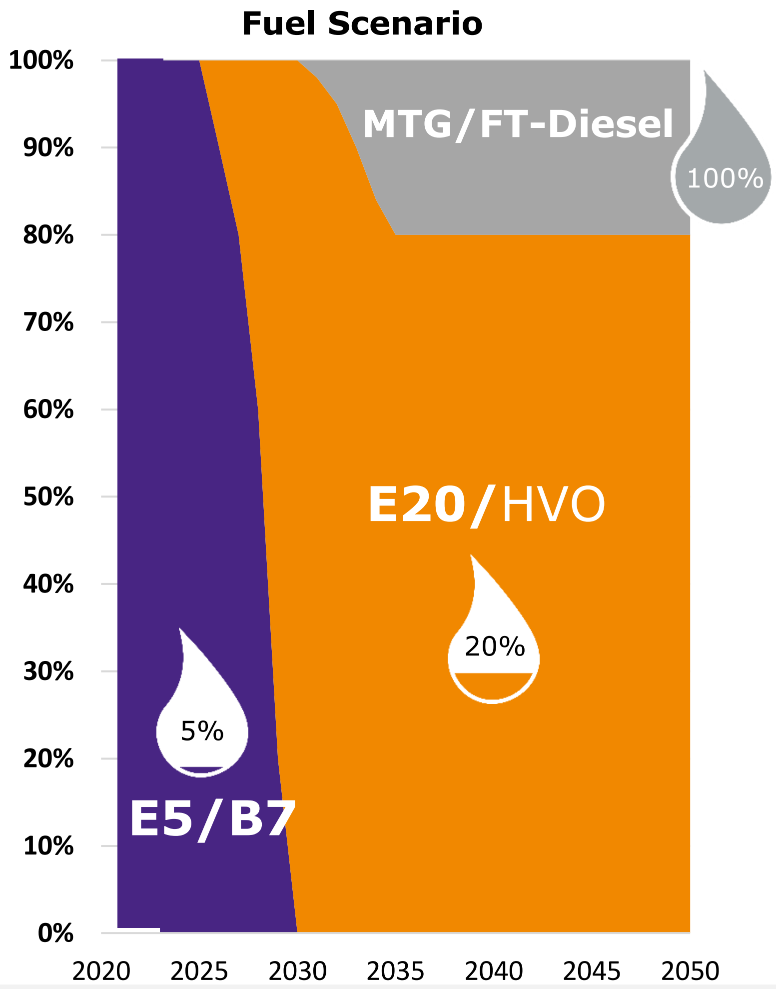


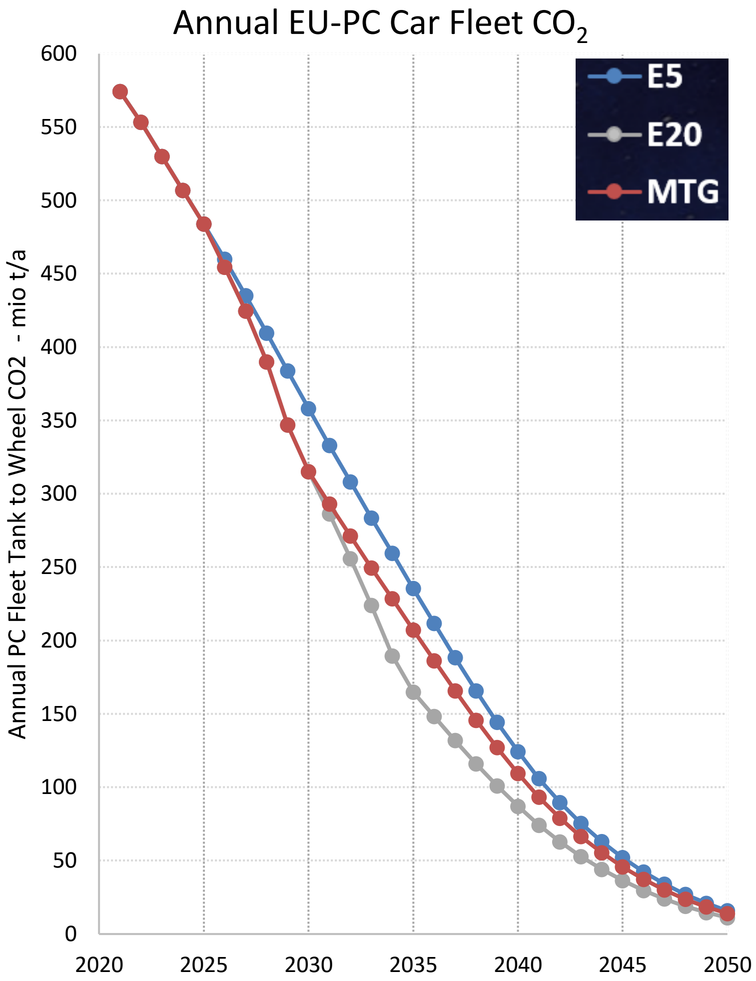


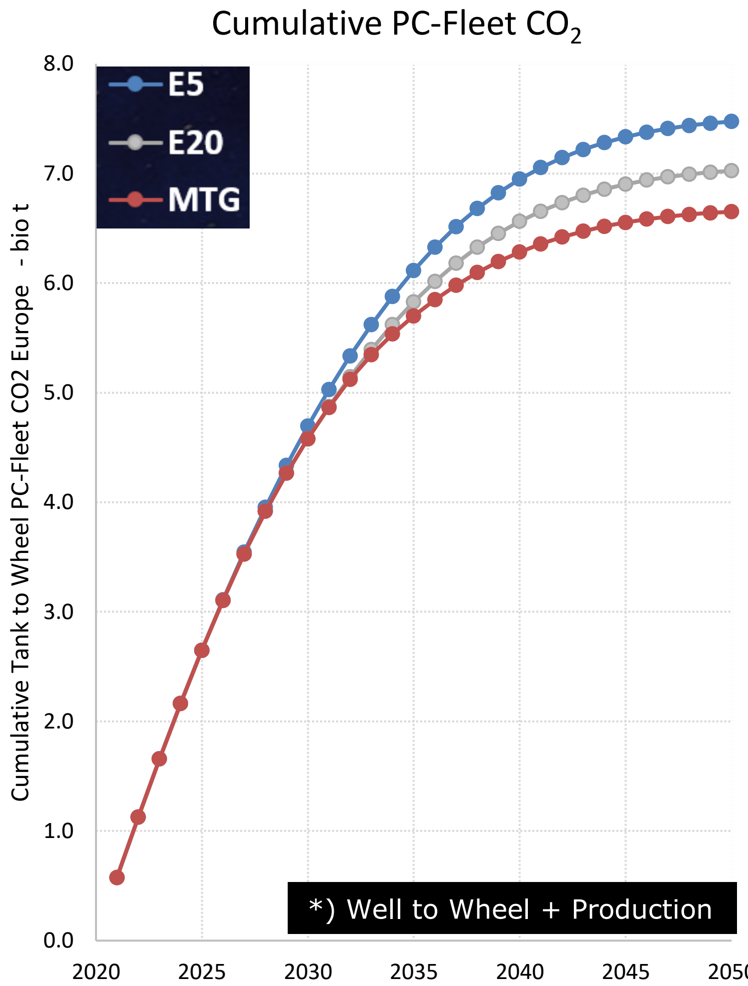
From 2035 onwards, annual fleet CO_2 will be dominated by BEV

Impact of E20(HVO) and 20% e-Fuel on $CO_2e^{*)}$

EUROPE

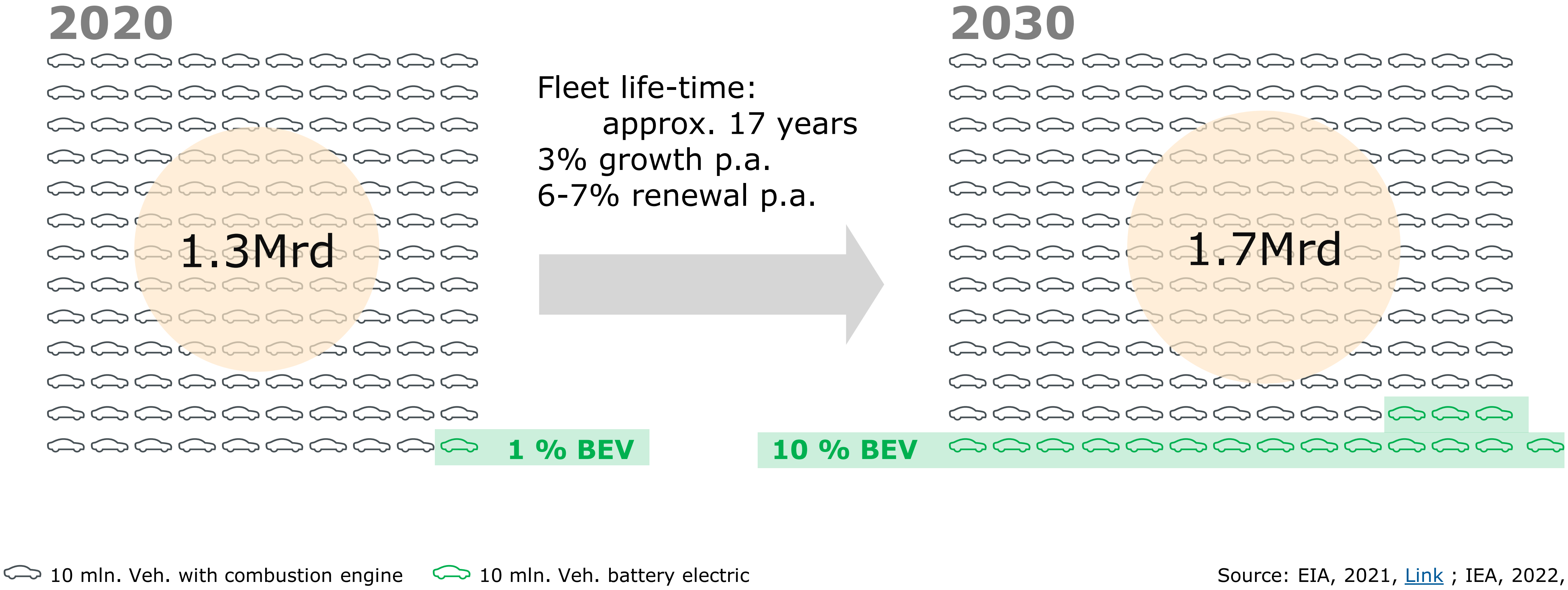






E-Fuel impact in Europe: limited since production late and limited availability.

Global passenger car fleet today and tomorrow

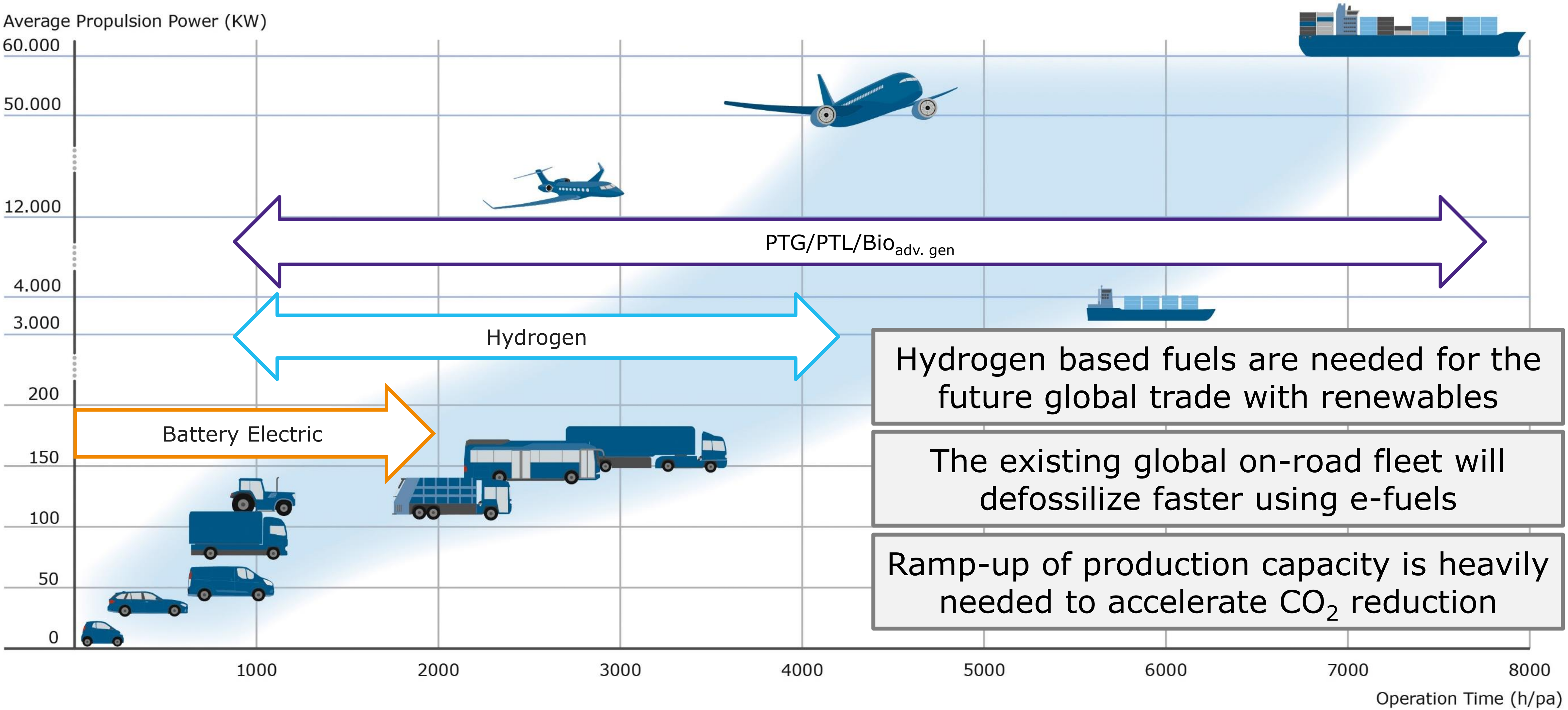


Source: EIA, 2021, Link ; IEA, 2022, Link

Urgent need to de-fossilize the existing fleet.

Conclusion

Does energy availability drive the propulsion portfolio?



Hydrogen based fuels are needed for the future global trade with renewables

The existing global on-road fleet will defossilize faster using e-fuels

Ramp-up of production capacity is heavily needed to accelerate CO_2 reduction

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