Competition for Low Carbon Energy Carriers – and the resulting mobility technology options

Waseda Symposium
November 11, 2021

Prof. Dr. Uwe D. Grebe

AVL List GmbH (Headquarters)

Towards a Sustainable Mobility

- Reducing CO_2 Emissions
- Reducing Fossils

- Less Waste
- Less Contamination
- Towards a Circular Economy

- Keep Mobility affordable & simple

Pictures: Shutterstock

The Climate Goal driving the World !

Ursula von der Leyen, President of the European Commission

"We want to become the 1st carbon neutral continent by 2050."

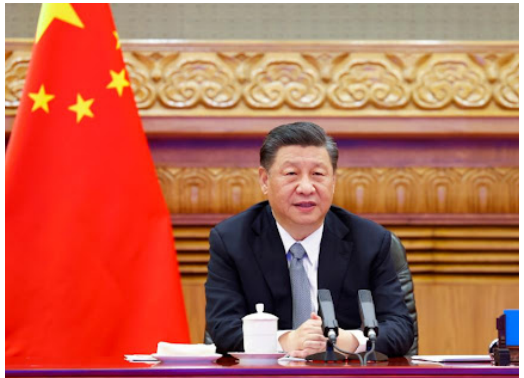
President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target.

United States to achieve a 50-52 percent reduction from 2005 levels in economy-wide net greenhouse gas pollution in 2030.

"Japan aims for zero emissions, carbon neutral society by 2050.

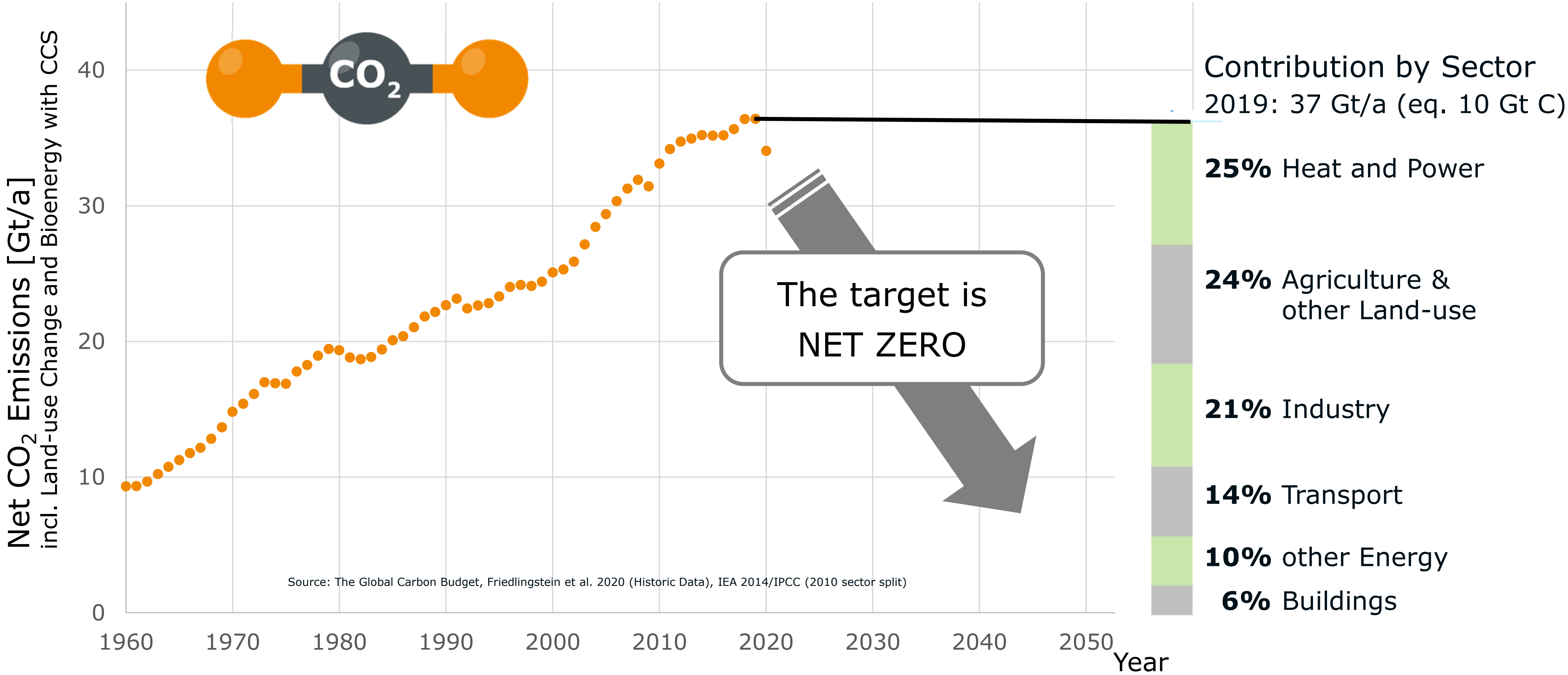
Responding to climate change is no longer a constraint on economic growth."


Former Prime Minister Yoshihide Suga


Xi Jinping

China: Xi Jinping confirms that China will peak emissions before 2030 and aims to achieve carbon neutrality before 2060

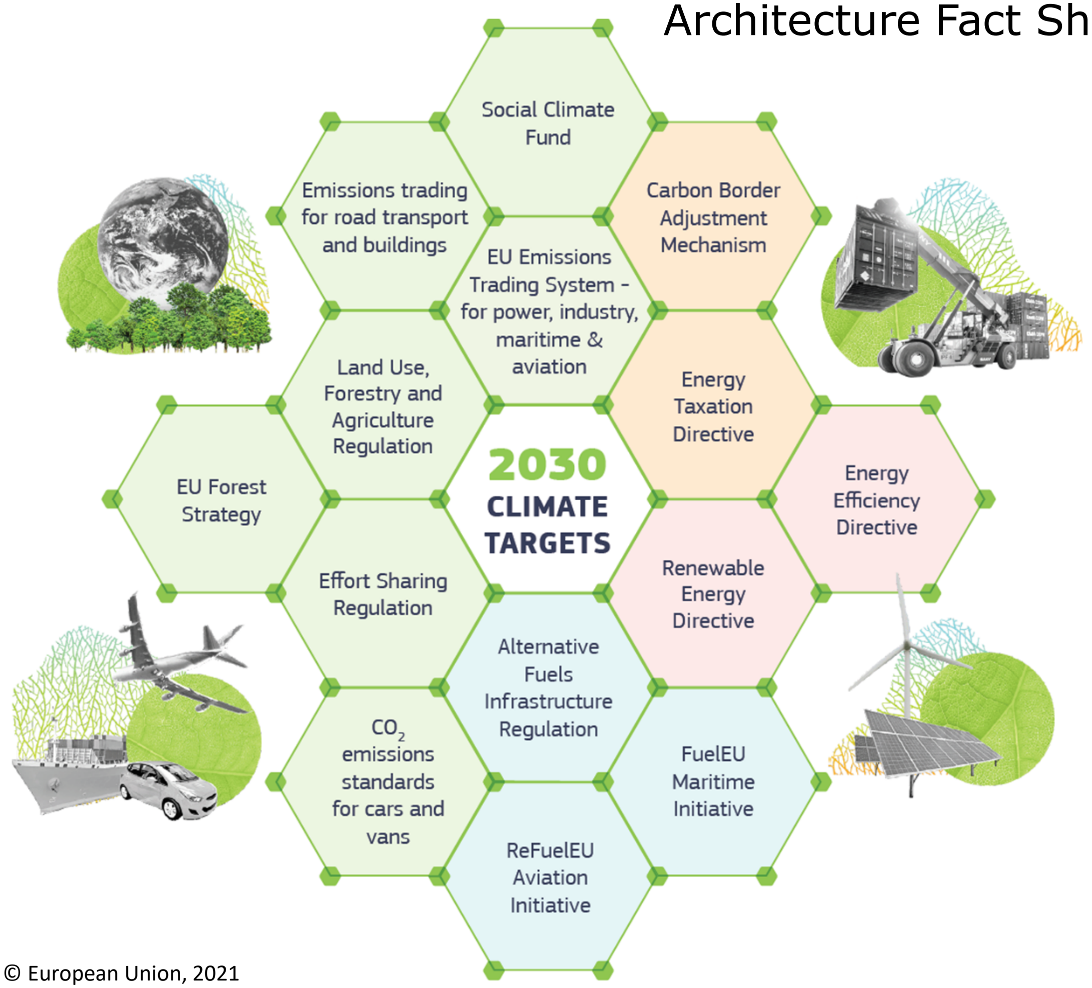
History of Global Human-made CO_2 Emissions



Delivering the European Green Deal - The Decisive Decade

Architecture Fact Sheet

"Fit for 55"
The EU will **reduce its net greenhouse gas emissions by at least 55% by 2030**, compared to 1990 levels.*



*As agreed in the EU Climate Law. On 14 July 2021, the Commission presented proposals to deliver these targets and make the European Green Deal a reality.

Delivering the European Green Deal - The Decisive Deal

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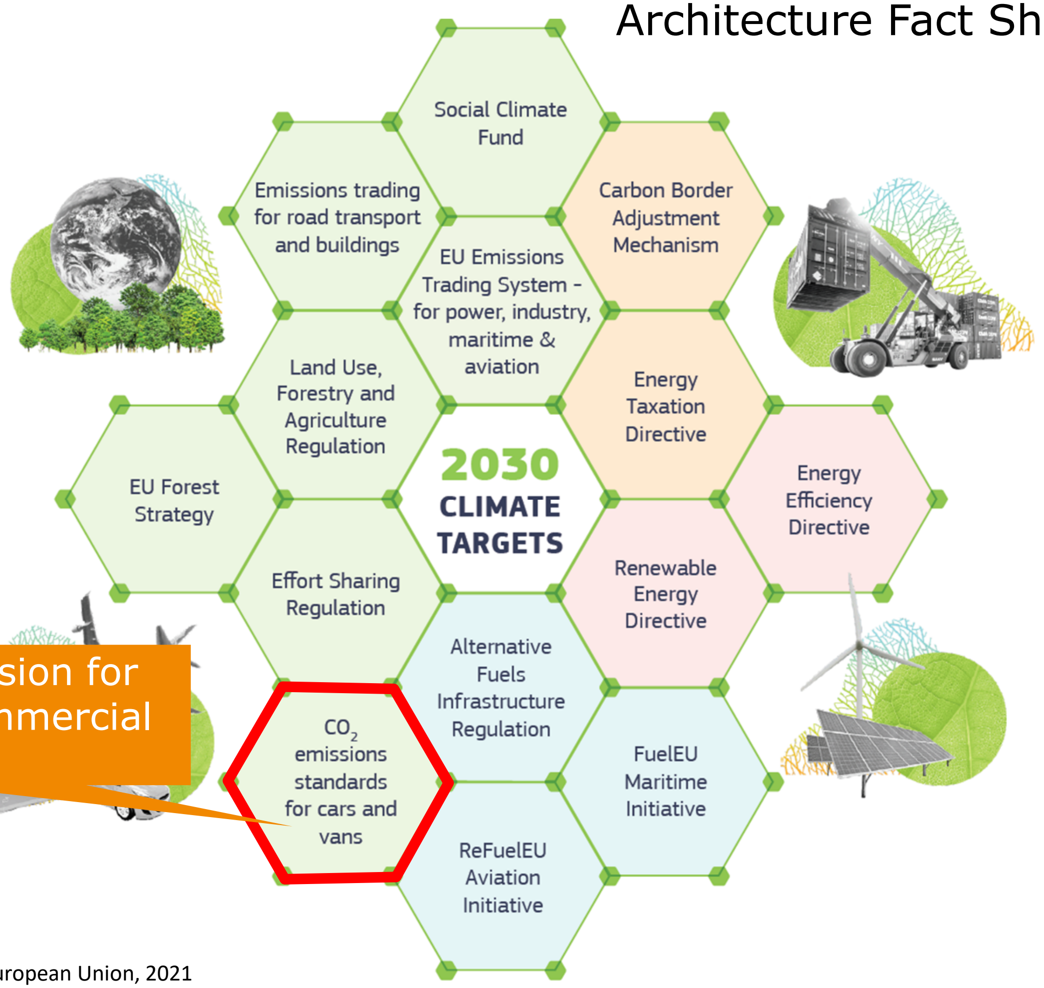
Zero tailpipe CO_2 emission for Passenger & Light Commercial Vehicles after 2035

Architecture Fact Sheet



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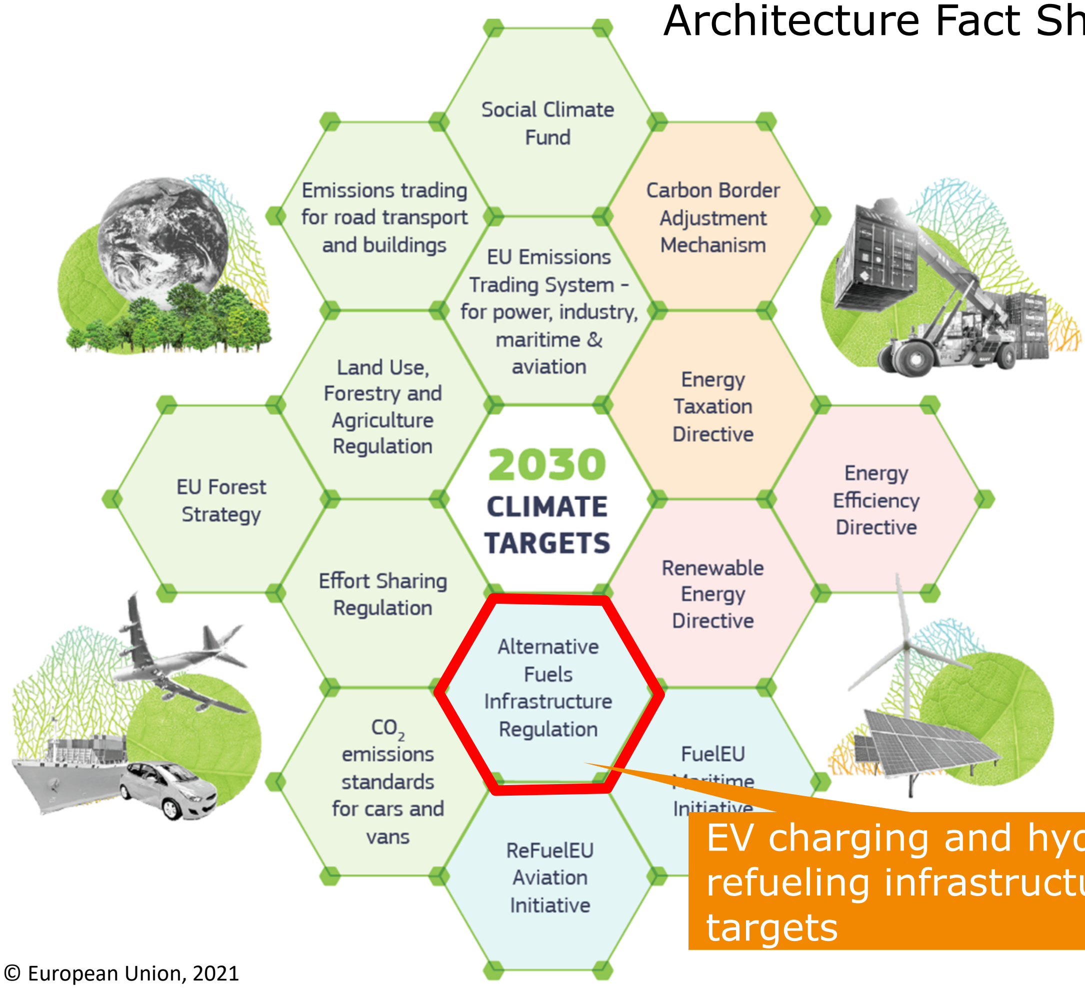

EV charging and hydrogen refueling infrastructure targets

*As agreed in the EU Climate Law. On 14 July 2021, the Commission presented proposals to deliver these targets and make the European Green Deal a reality.

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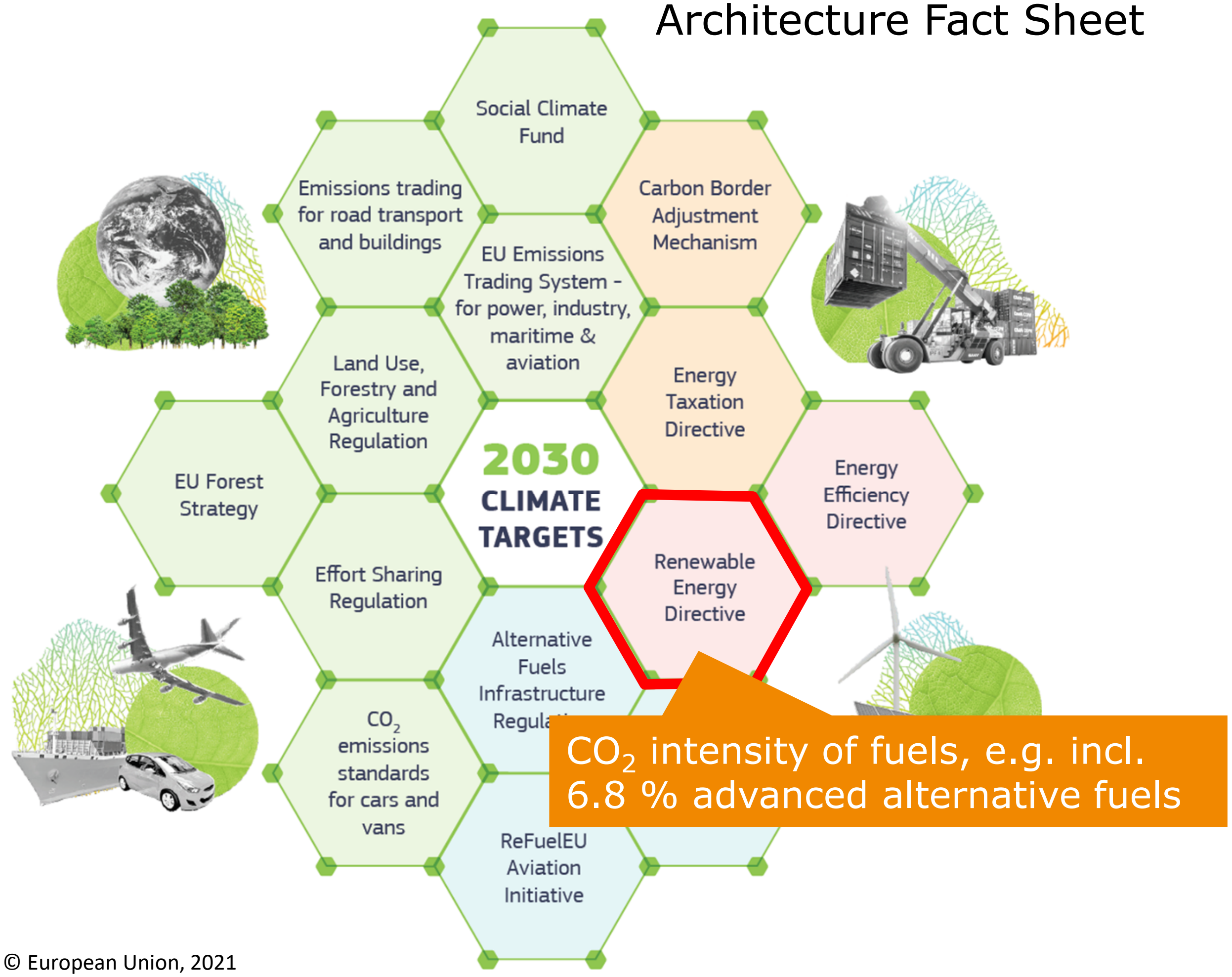

CO_2 intensity of fuels, e.g. incl. 6.8 % advanced alternative fuels

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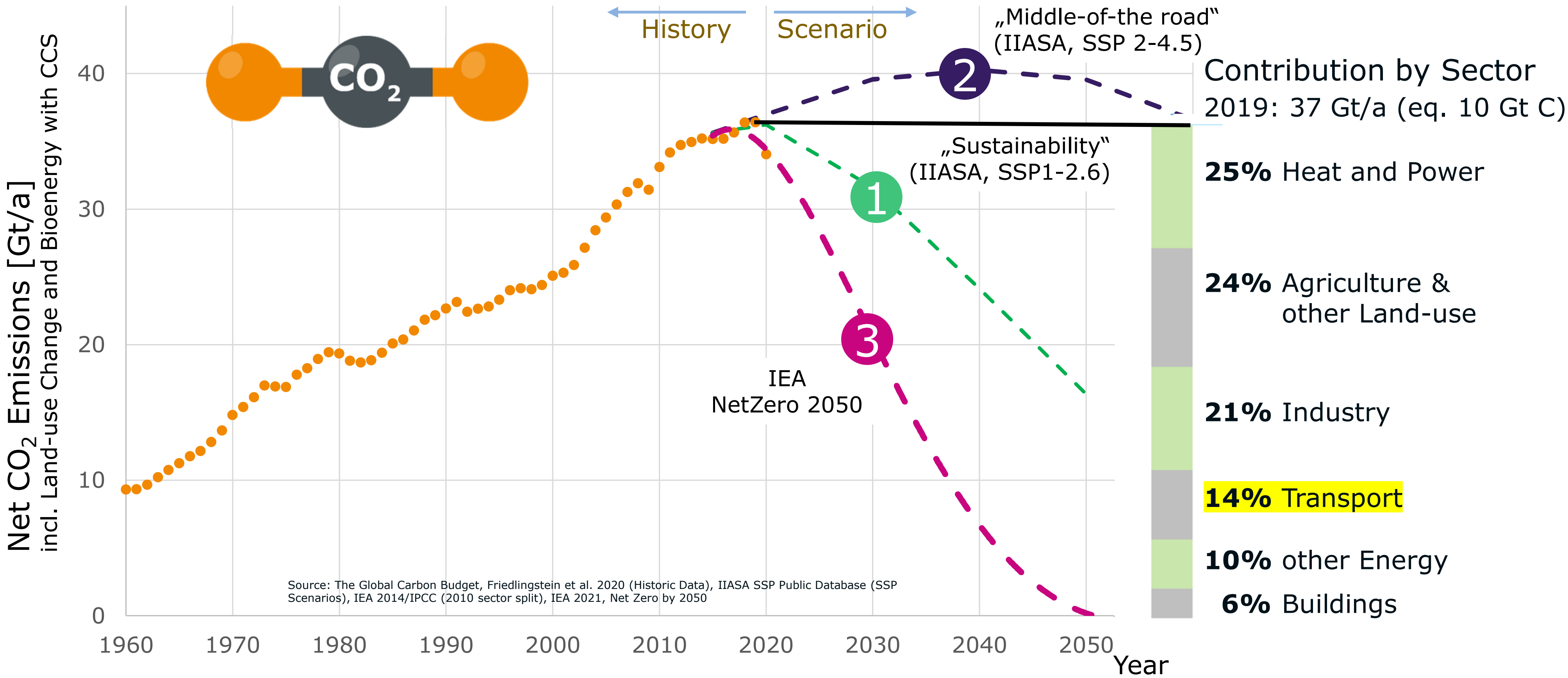
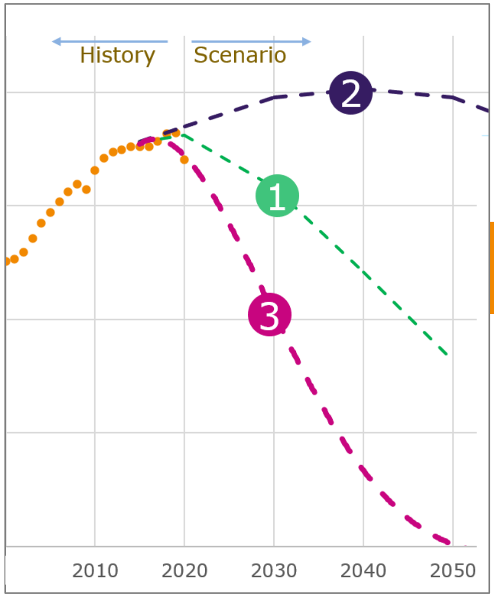
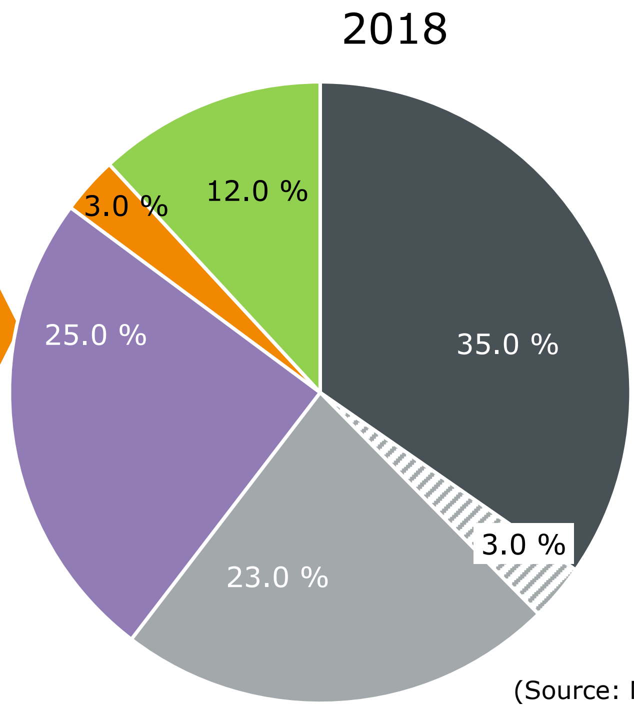
History of Global Human-Made CO_2 Emissions

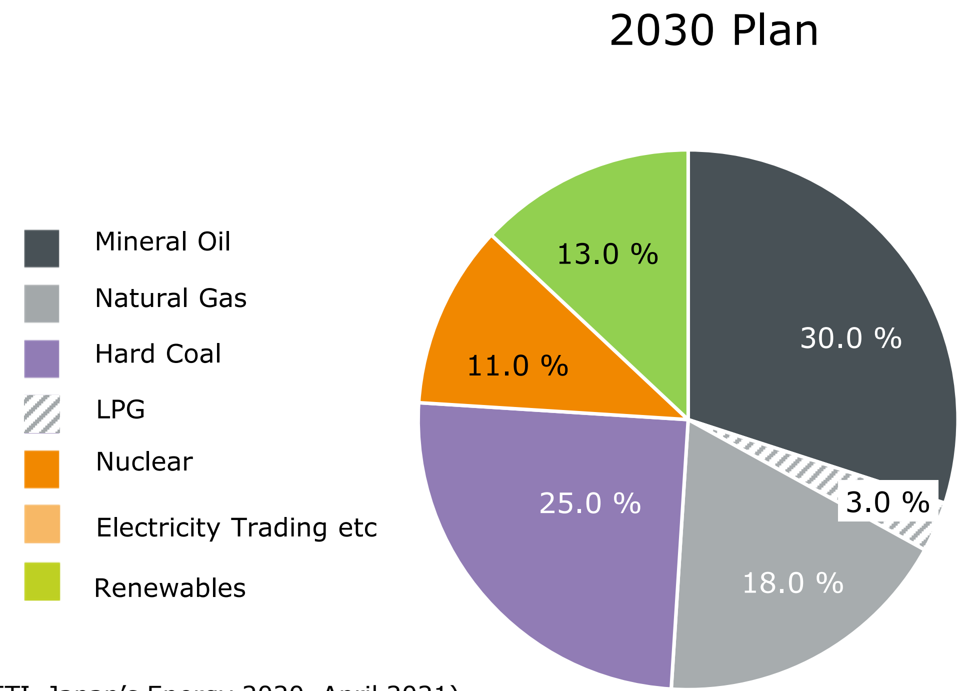


→ Drastic Measures for Emissions reduction required across **all Sectors**

Shift towards Renewable Energy – Example Japan: Primary Energy Supply, Real 2018 and Plan 2030



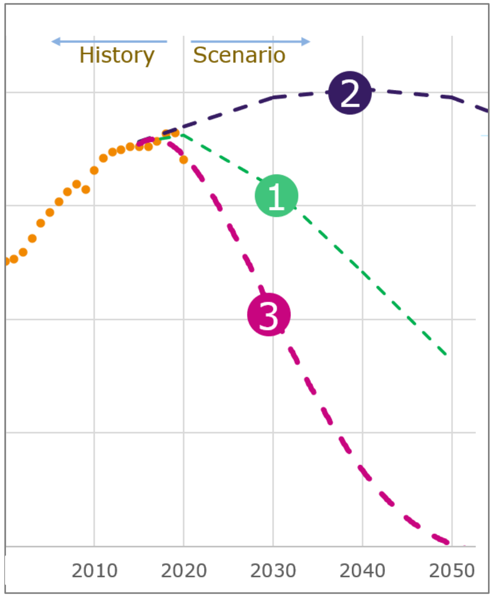




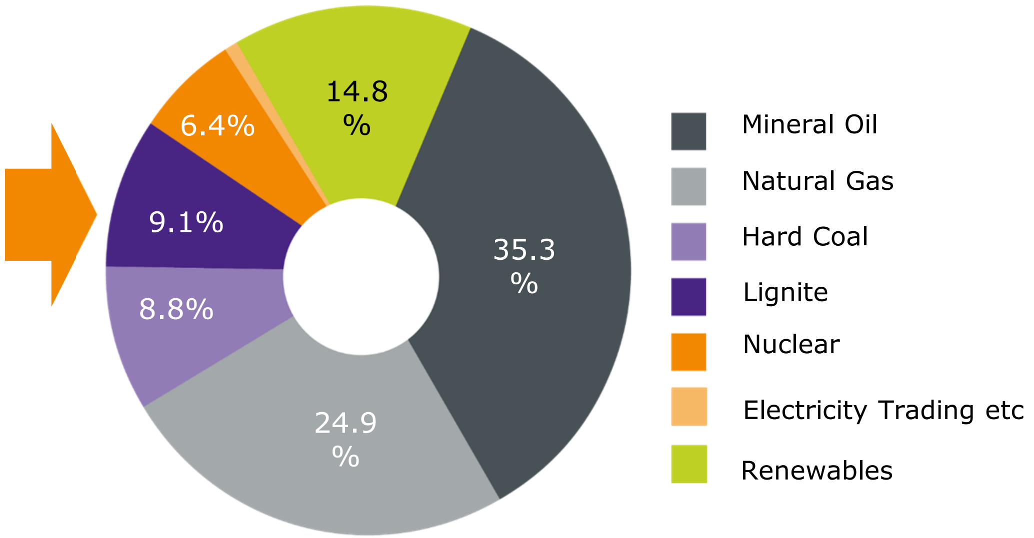
(Source: METI, Japan's Energy 2020, April 2021)

- Energy Mix: Major dependence on Fossil Energy: 85% (in 2018) and 75% (Plan 2030)
- Nuclear Energy will gain importance in coming Decade
- Energy Security a major driver for Japan's Strategy
- To meet CO_2 targets further reduction of fossil fuel required

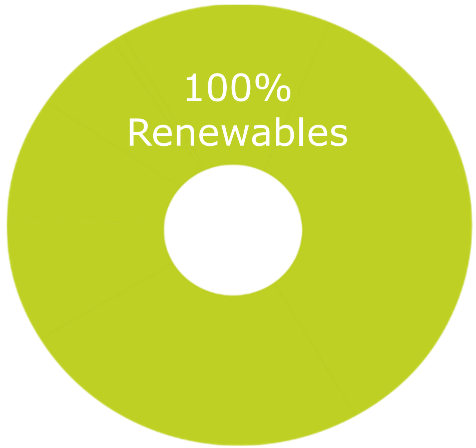
Shift towards Renewable Energy – Example Germany: Primary Energy Supply, Real 2019 and Plan 2045



Primary Energy Consumption, Germany 2019*
Total: 12.832 Petajoule (3564 TWh)



2045 "Plan"
(no details defined yet)

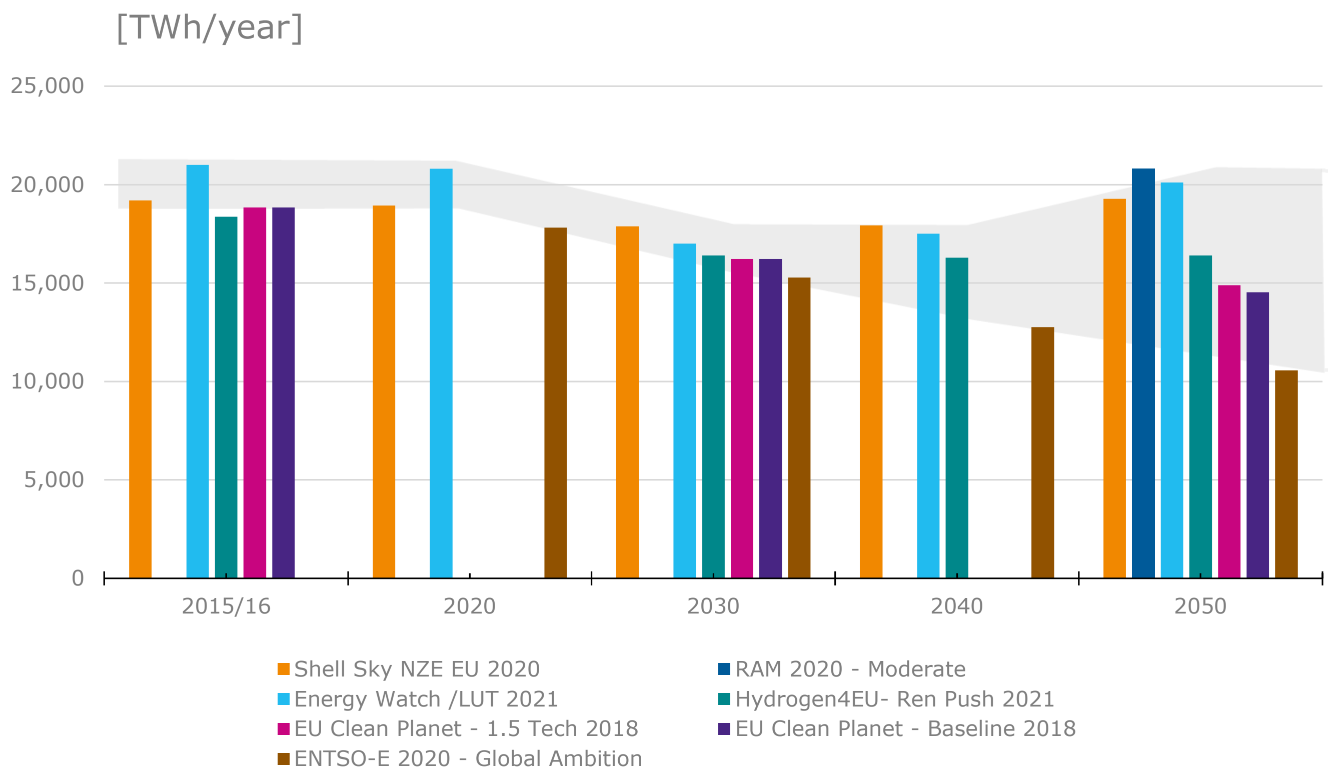


80% to be replaced by renewables – or saved

(*2020 data available but not representative due to COVID)

- Target: Germany to become Carbon neutral by 2045
- Coal, Gas, Oil and Nuclear to be phased out
- >80 % of energy is to be replaced – or saved!

Total EU Primary Energy Demand in EU - Scenario
(based on external studies)

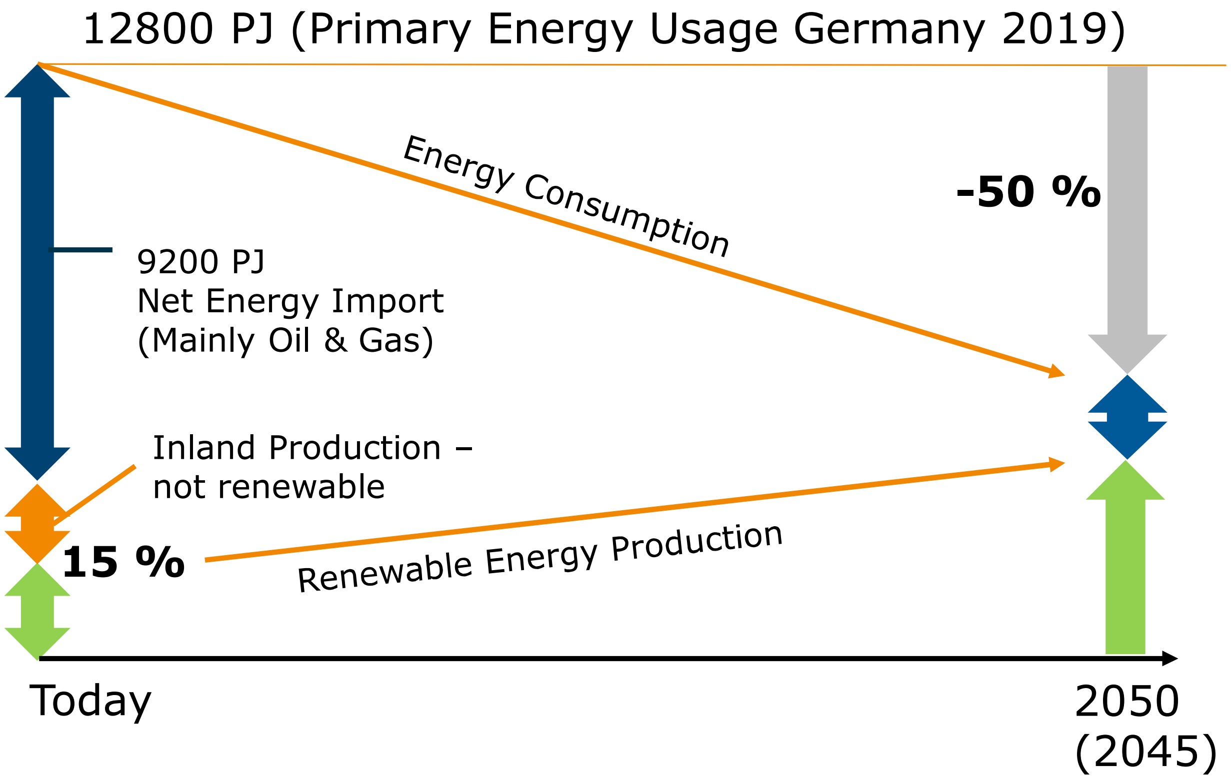


Only small slight decline towards 2030/2040 (due to efficiency gain/ electrification).

No major changes in energy demand is expected until 2050.
However, the transformation to renewables in all sectors will be a challenge.

Source: 2021 09 Shell Study Energy study, based on TUHH Energy carrier model

Towards Climate Neutrality
Example Germany



Efficiency Gains:
Energetic building refurbishment
Electrification of transport
Less cars, less cows
…..

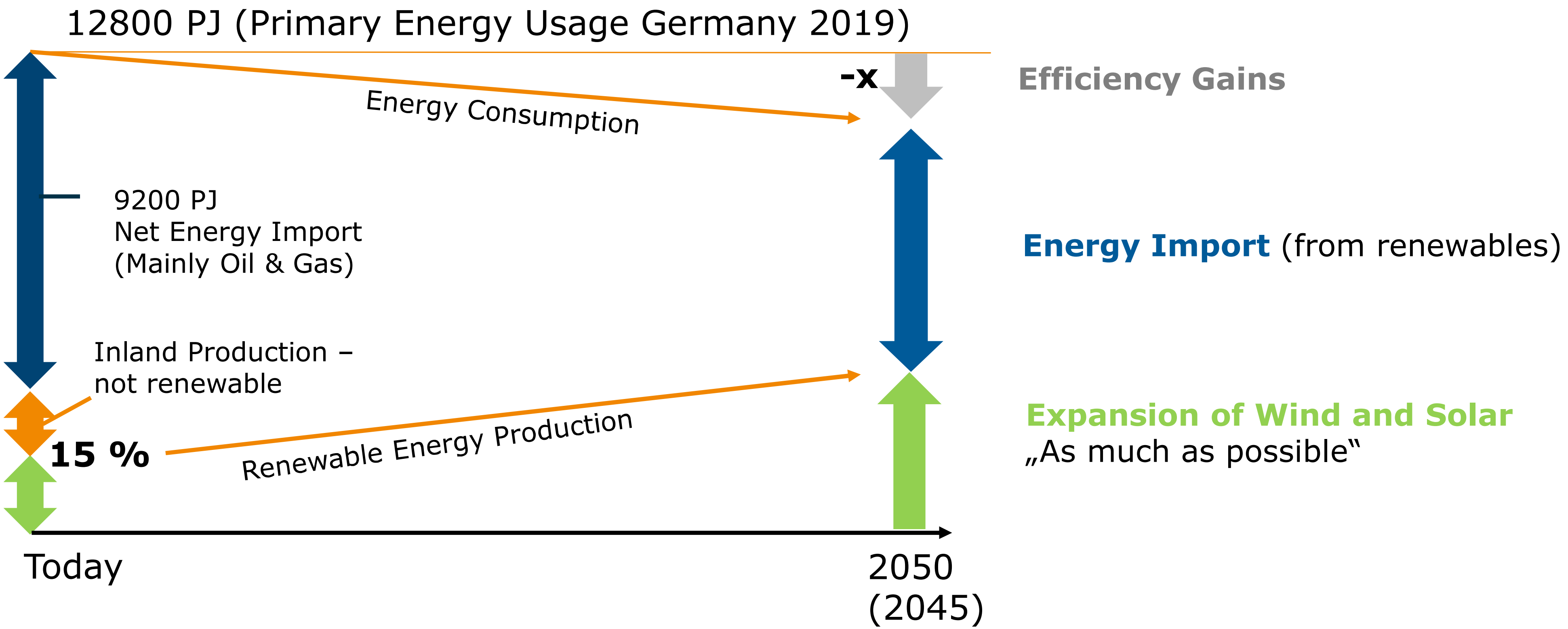
Energy Import (from renewables)

Expansion of Wind and Solar:
>350 GW Solar (7x today)
>200 GW Wind (3.5x today)

Reduction in Primary Energy usage is part of the plan

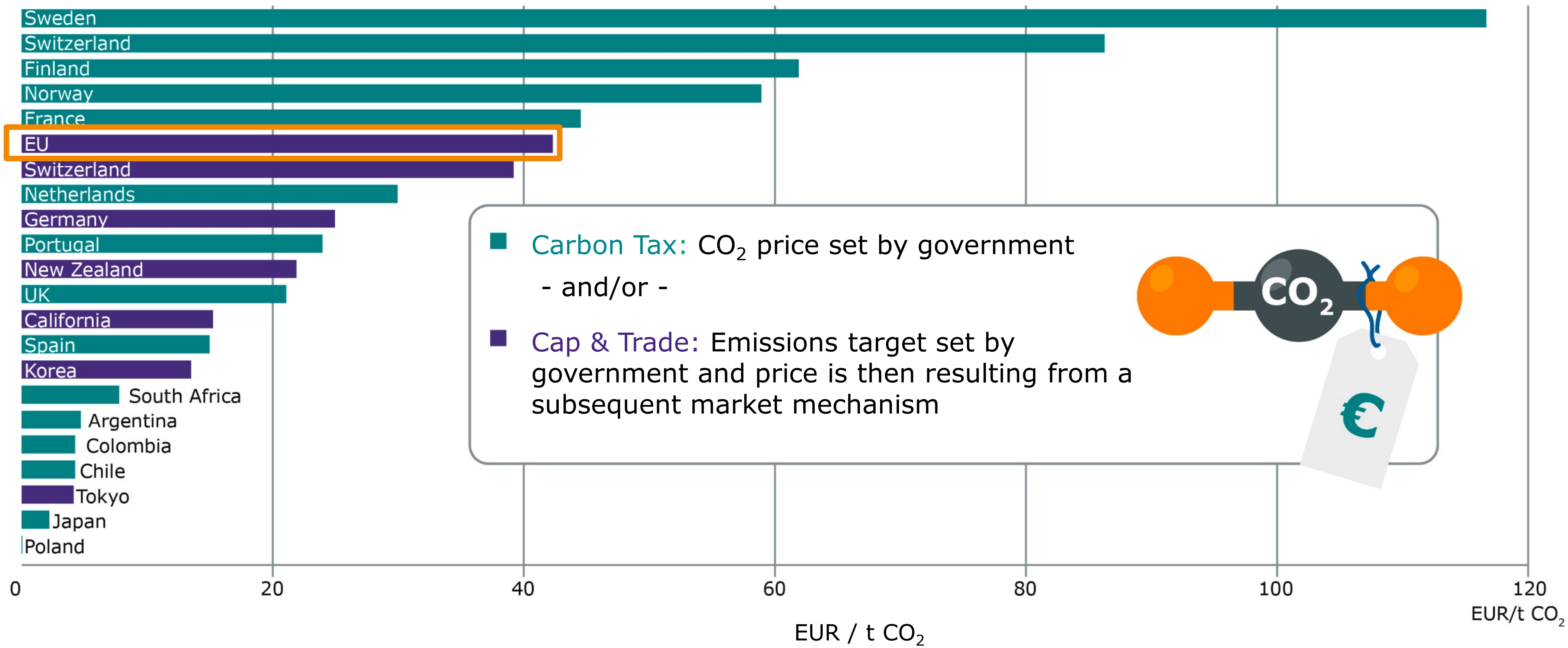
Arbeitsgemeinschaft Energiebilanzen;
2045/2050: Prognos, Öko-Institut, Wuppertal-Institut, for Agora Energiewende (2020/21)

Towards Climate Neutrality
Example Germany



Reduction in Primary Energy usage AND Import of Energy

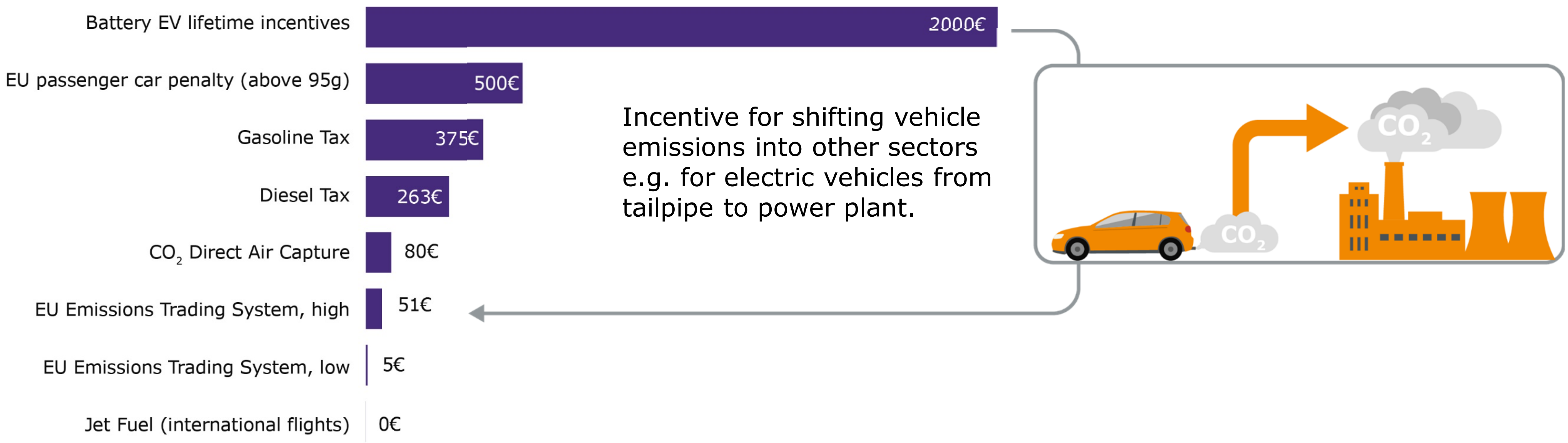
Economic Approach: Assign a Cost to CO_2 Emissions



- Developed countries have started to introduce a **cost burden for CO_2 emissions**
- However, **cost varies greatly**, due to lack of global agreement or trading system

CO_2 „value" highly depends on how and where emissions occur

Price, cost, incentive, penalties or tax [EUR/t CO_2], for Germany in 2021



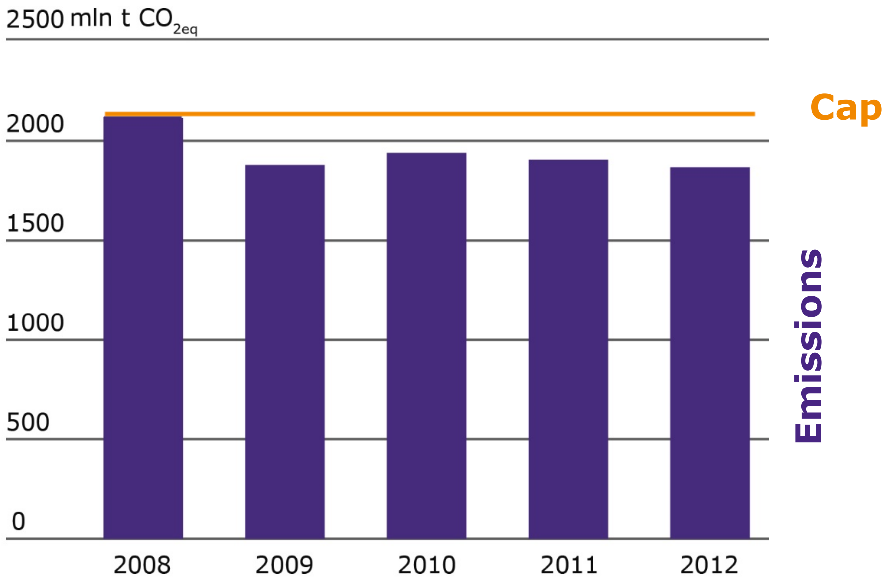
CO_2 is currently far from becoming a good „currency"

Reduction Efforts are greatest in sectors and regions with highest „CO_2 Price" - which is often not where the real cost & effort for CO_2 avoidance is lowest → **Economic Inefficiency**

Beginning of a CO_2 Economy: Cap & Trade System in Europe

Supply is regulated by European Commission (Cap)

Demand is determined by the energy market (Emissions)



„EU ETS" = European Emission Trading Scheme

Trading Period 2008-2012

- Fixed CO_2 Emission Limit (Cap)
- Initially, Emissions Rights have been given out for free - based on previous emissions
- Later, Emission rights have been offered via auctions

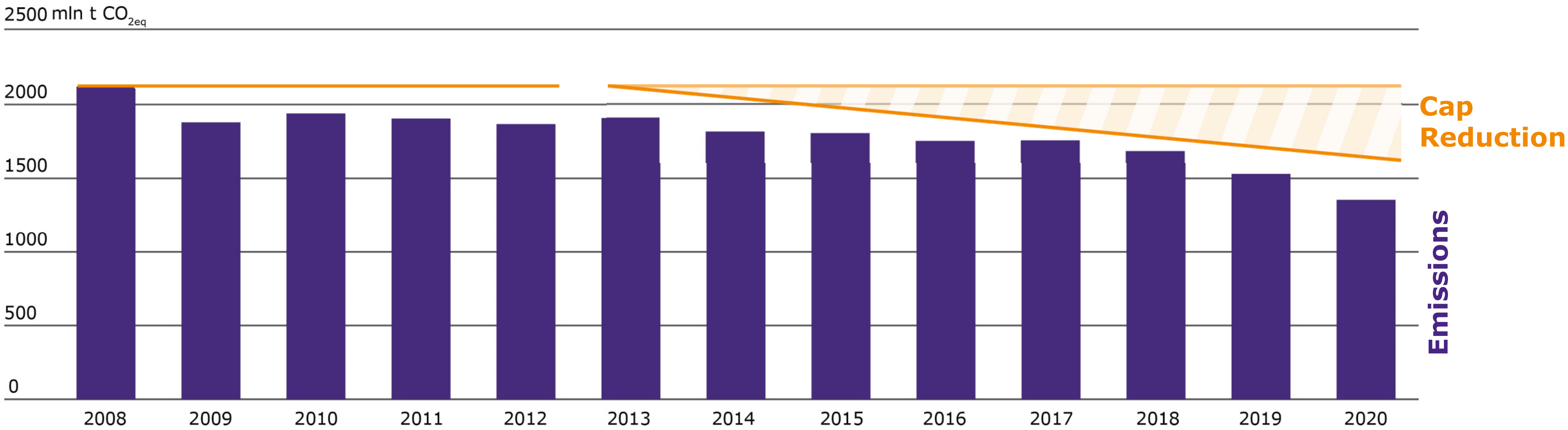
Beginning of a CO_2 Economy: Cap & Trade System in Europe

Supply is regulated by European Commission (Cap)

Demand is determined by the energy market

Trading Period 2013-2030

- Cap Reduced (-1.75% p.a.)
- Additional sectors included

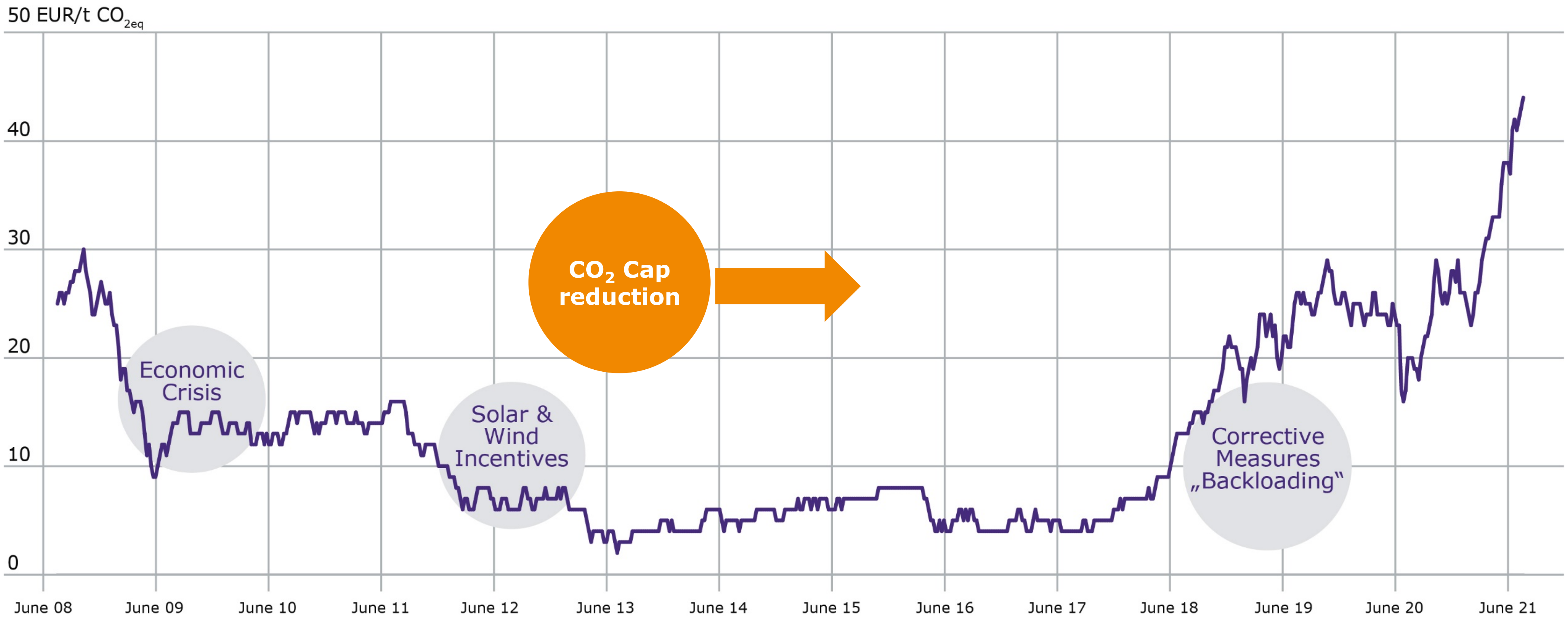


„EU ETS" = European Emission Trading Scheme

- EU ETS is successfully implemented and reduction target (40% vs. 1990) was achieved 10 years early
- **CO_2 Price** was assumed to continuously increase by reducing the Cap each year

CO_2 price dependent on many factors, not just Emission Cap

(EEX data, retrieved from Sandbag Carbon Price Viewer)



In principle, Cap-and-Trade is a powerful policy measure for efficient CO_2 reduction

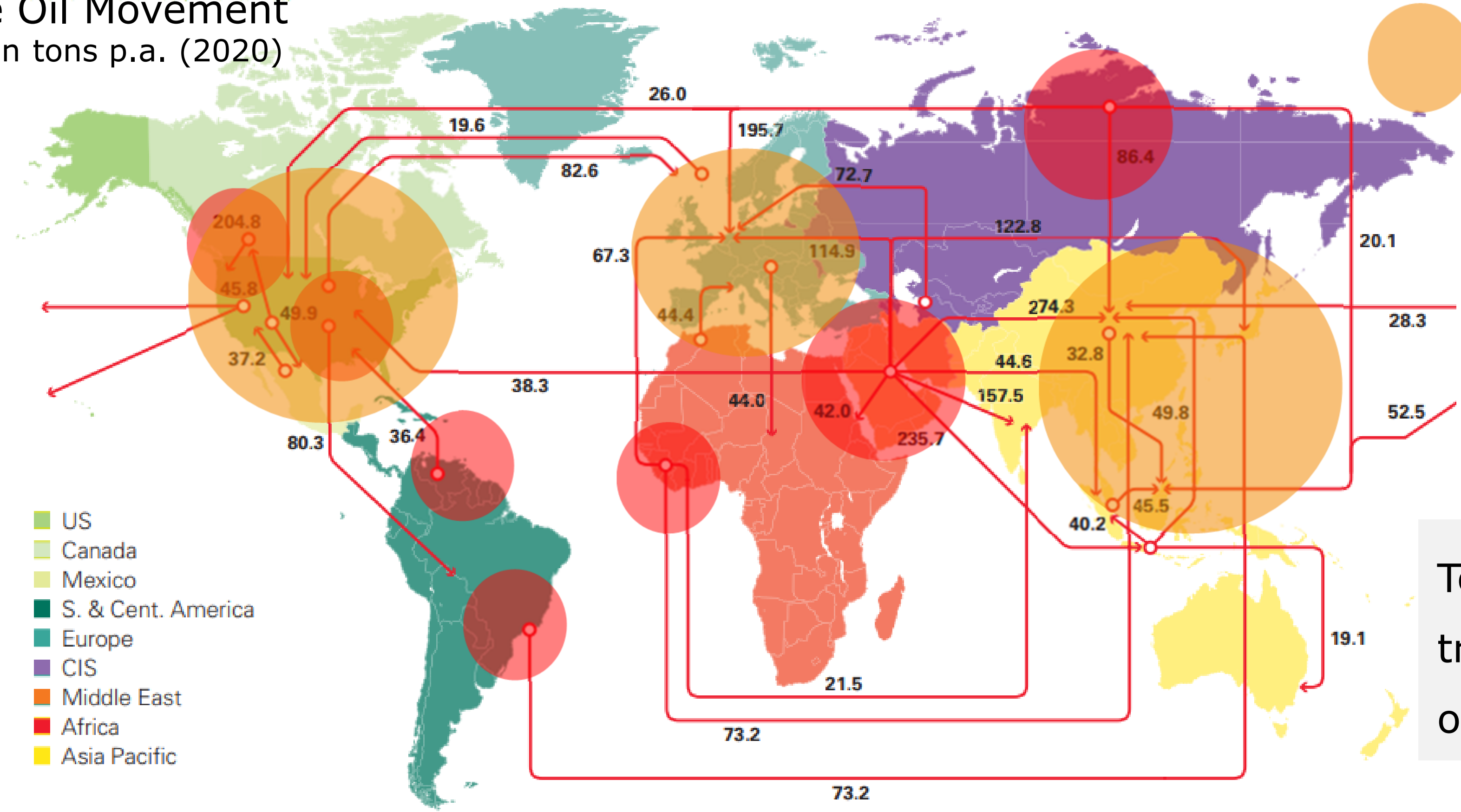
- In future, CO_2 needs to become a more stable „currency" so that industry can plan with

Energy Trade Today

Crude Oil Movement
in Million tons p.a. (2020)

„Supply Regions"

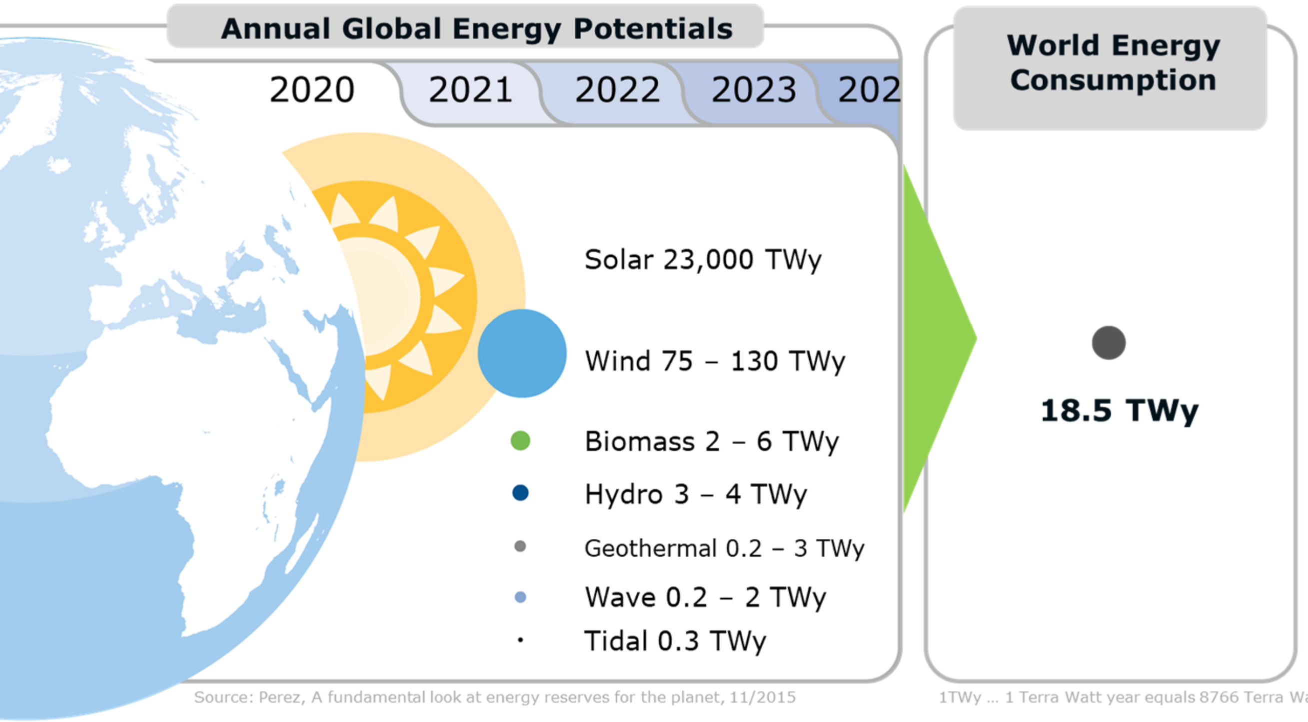
„Demand Centers"



Today's global energy trade is fully based on fossil fuels

Source: Source: BP Statistical Review of World Energy 2021
Page 35: https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

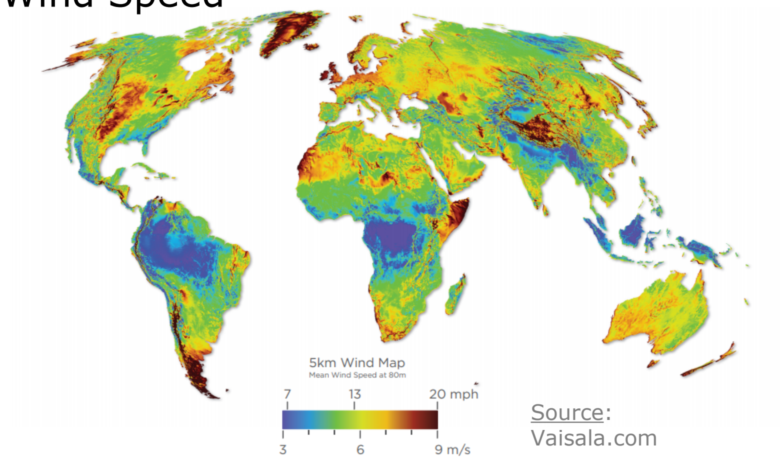
Renewable Energy:
Sufficient, but usually wrong place & time…



Source: Perez, A fundamental look at energy reserves for the planet, 11/2015

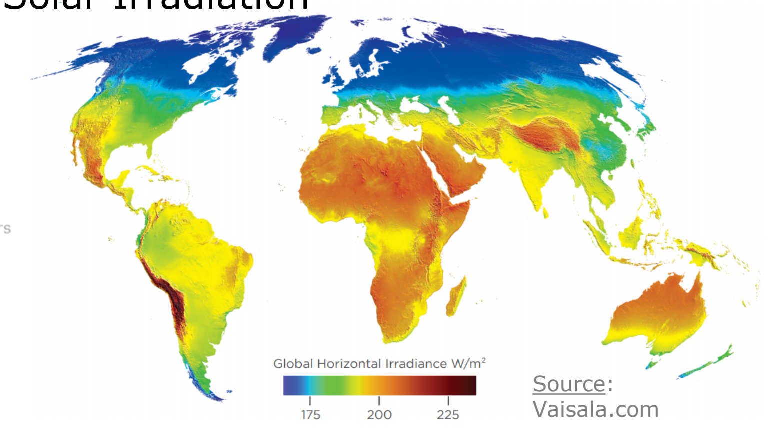
1TWy … 1 Terra Watt year equals 8766 Terra Watt hours

Wind Speed



Source: Vaisala.com

Solar Irradiation

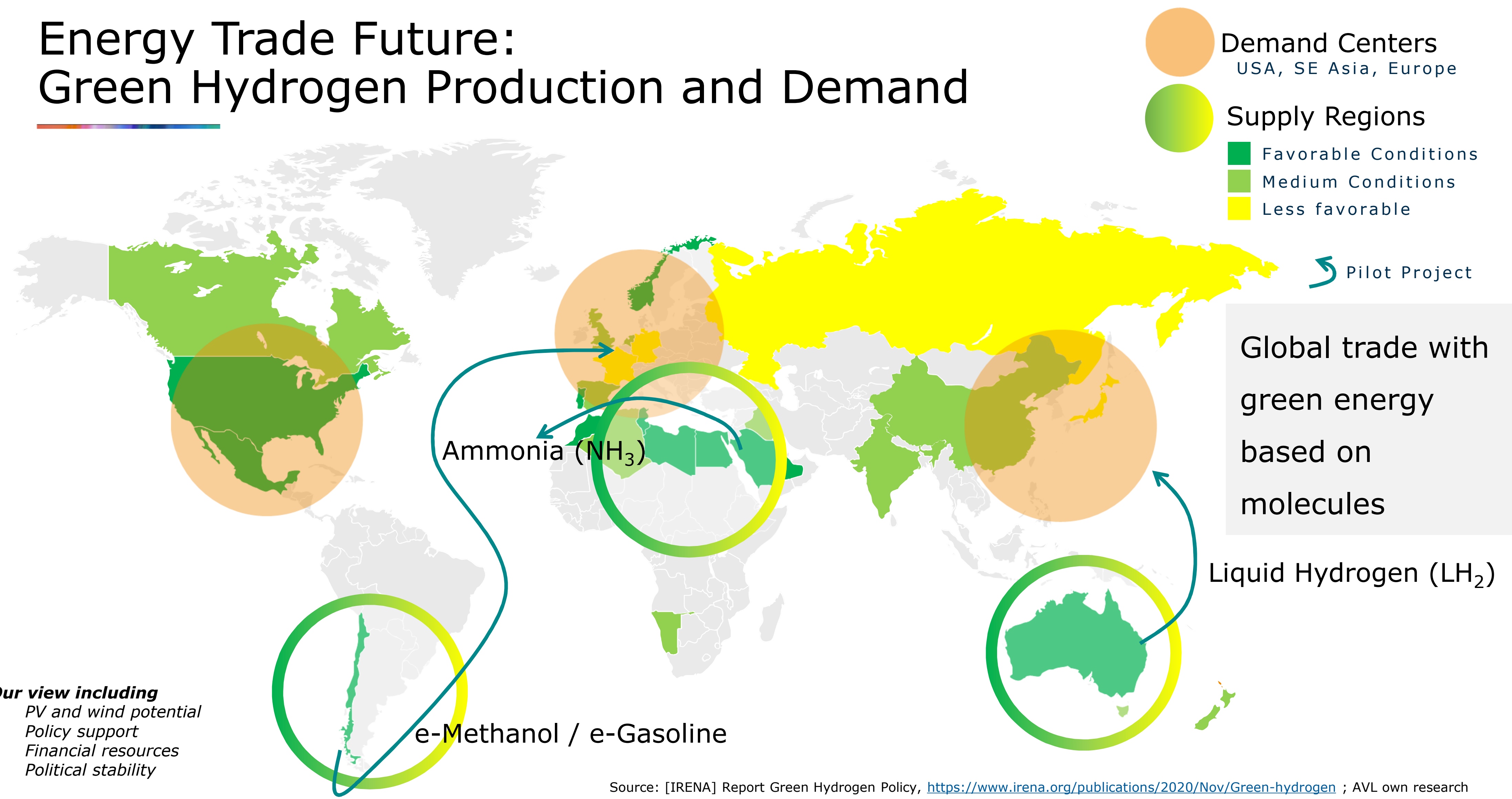


Source: Vaisala.com

Need for Storage and Long-Distance Transport

Source:
https://www.vaisala.com/sites/default/files/documents/Vaisala_global_wind_map.pdf?utm_content=Wind-Map
https://www.vaisala.com/sites/default/files/documents/Vaisala_global_solar_map.pdf?utm_content=Solar-Map

Energy Trade Future:
Green Hydrogen Production and Demand



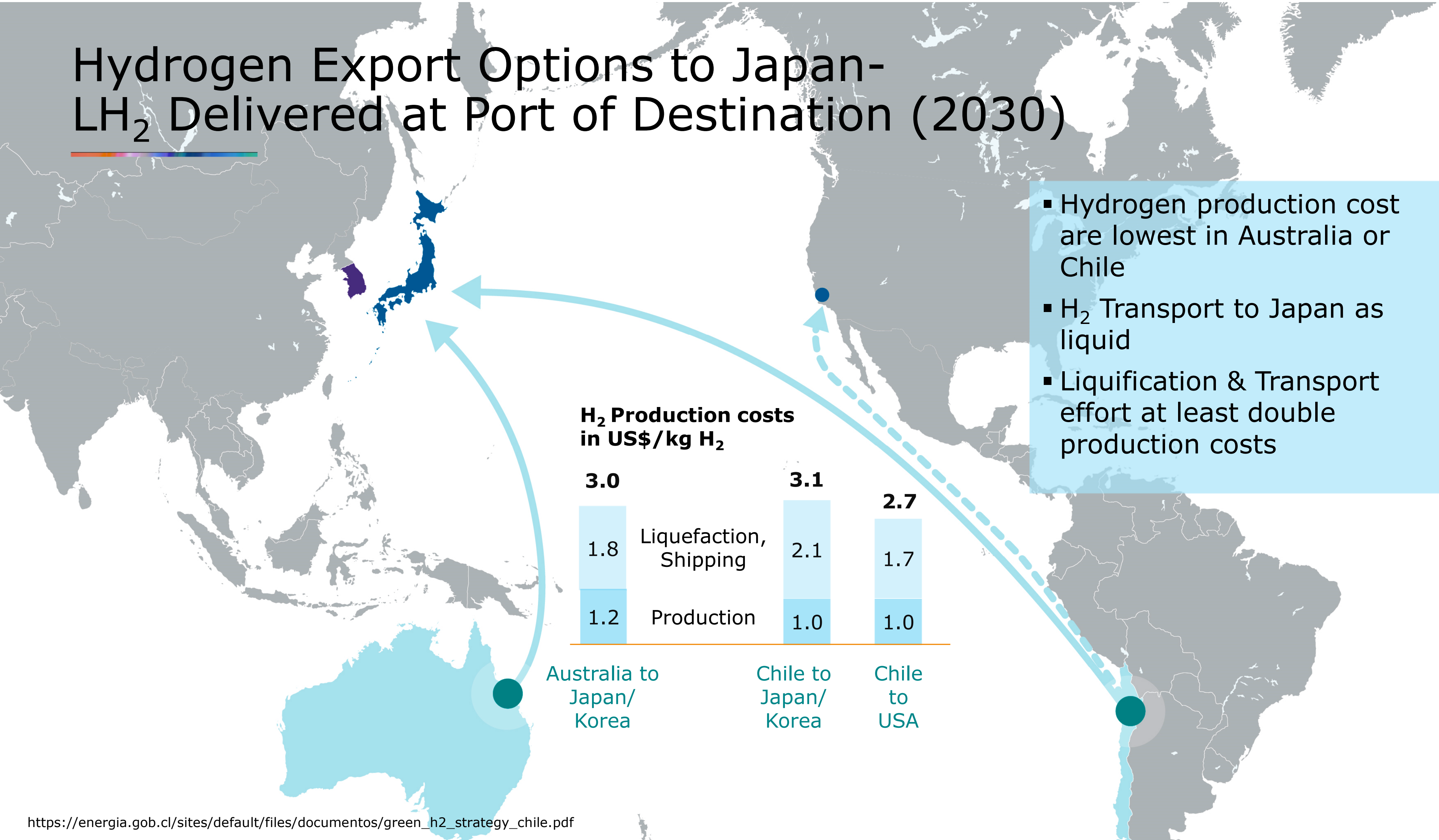
Global trade with green energy based on molecules

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

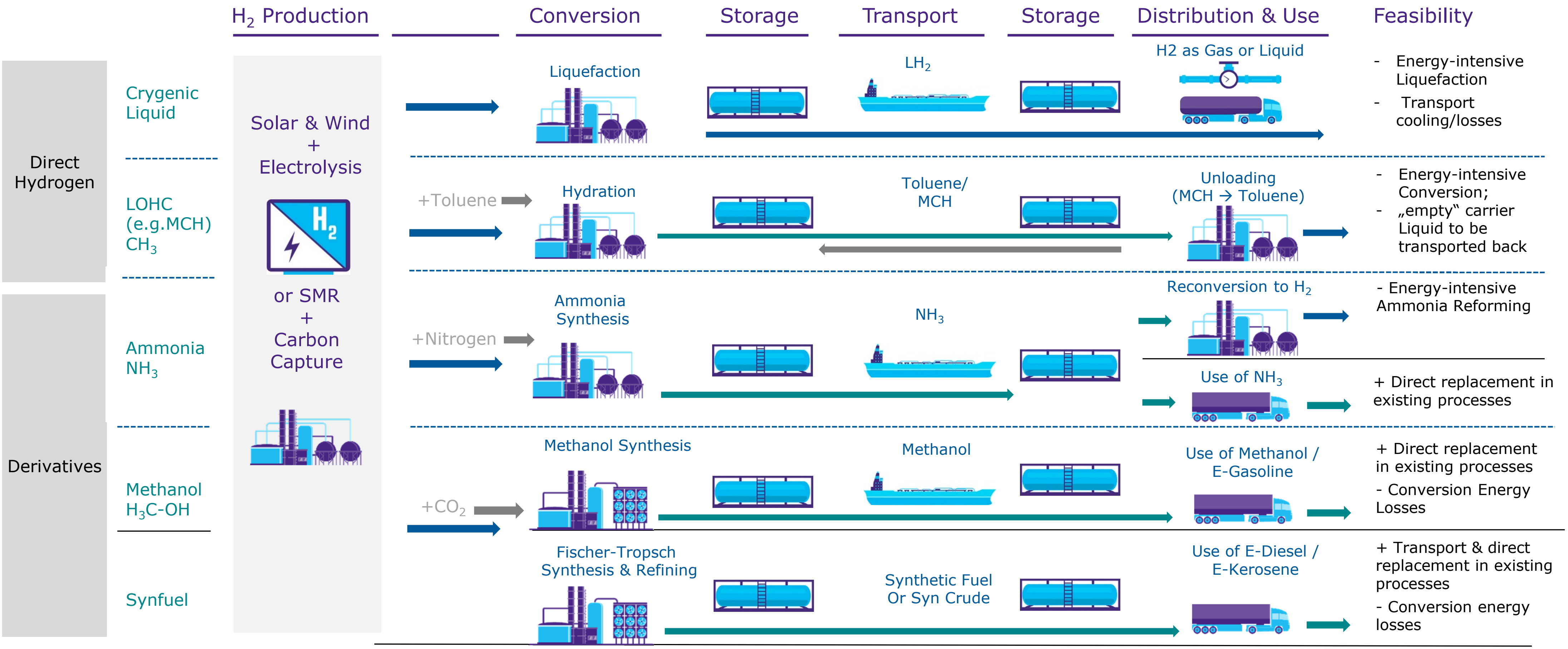
Hydrogen Export Options to Japan- LH_2 Delivered at Port of Destination (2030)

- Hydrogen production cost are lowest in Australia or Chile
- H_2 Transport to Japan as liquid
- Liquification & Transport effort at least double production costs



https://energia.gob.cl/sites/default/files/documentos/green_h2_strategy_chile.pdf

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

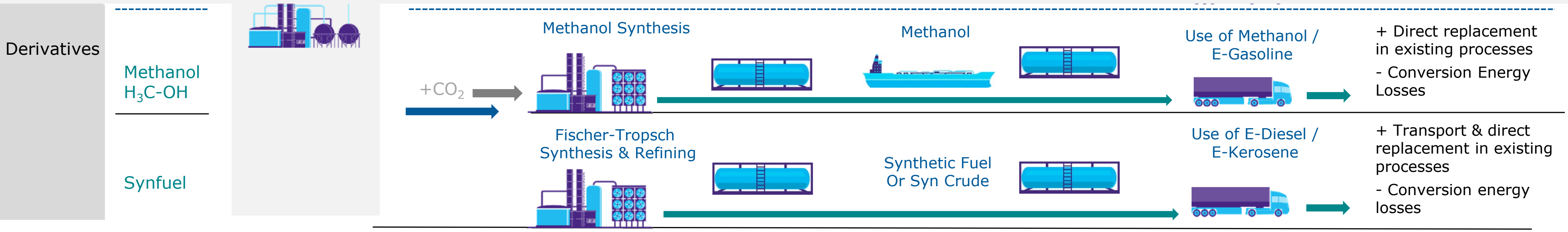


(Simplified; several other methods existing)

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

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

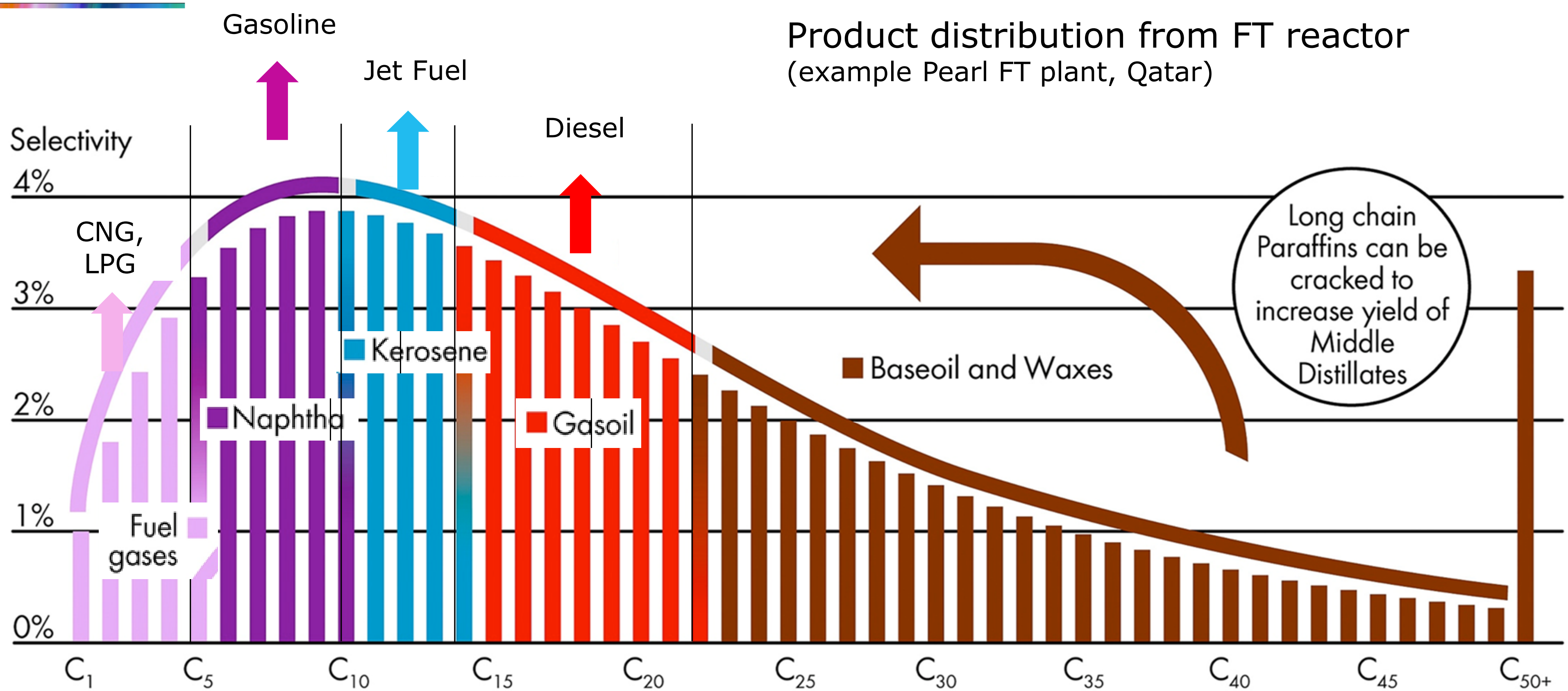
Focus on e-fuels pathways



(Simplified; several other methods existing)

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

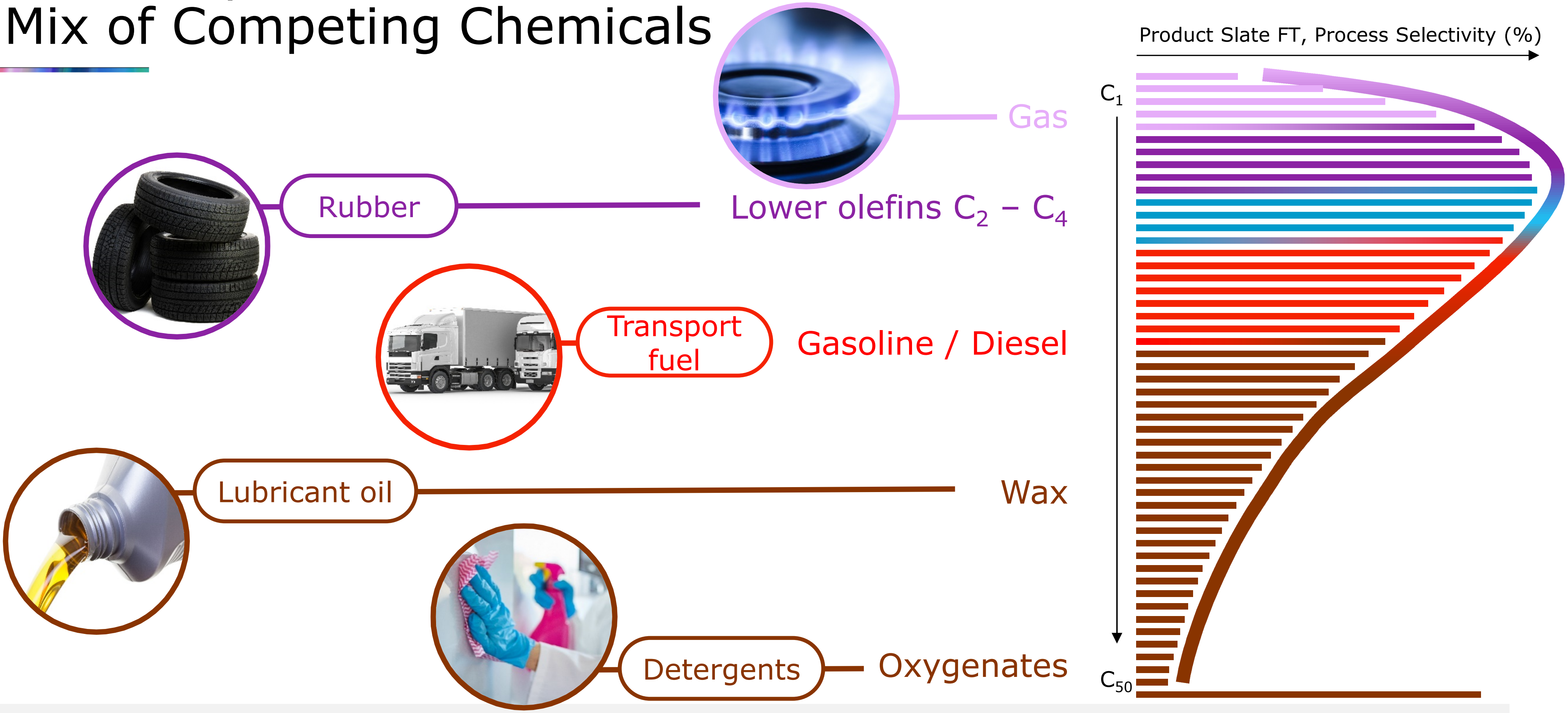
FUEL COMPONENTS FROM E-FUEL PROCESSING: HYDROCARBON PRODUCT SLATE (EXAMPLE: FISCHER-TROPSCH)



PtX processes will always deliver a wide Diversity of HydroCarbons – depending on plant layout

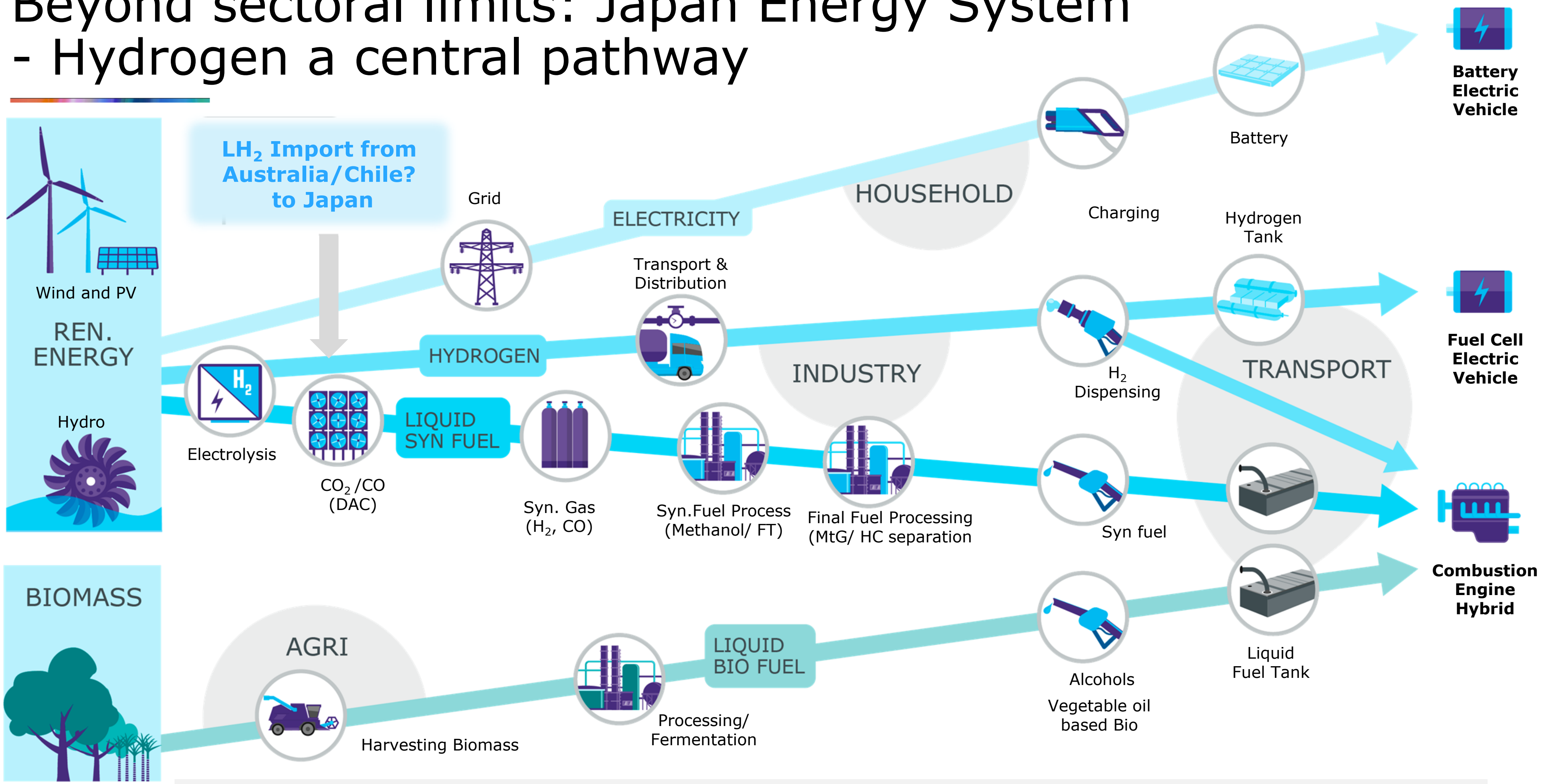
Source: SHELL, https://www.shell.com/about-us/major-projects/pearl-gtl/the-world-s-largest-gas-to-liquids-plant.html

Fischer Tropsch Process Product slate – A Mix of Competing Chemicals



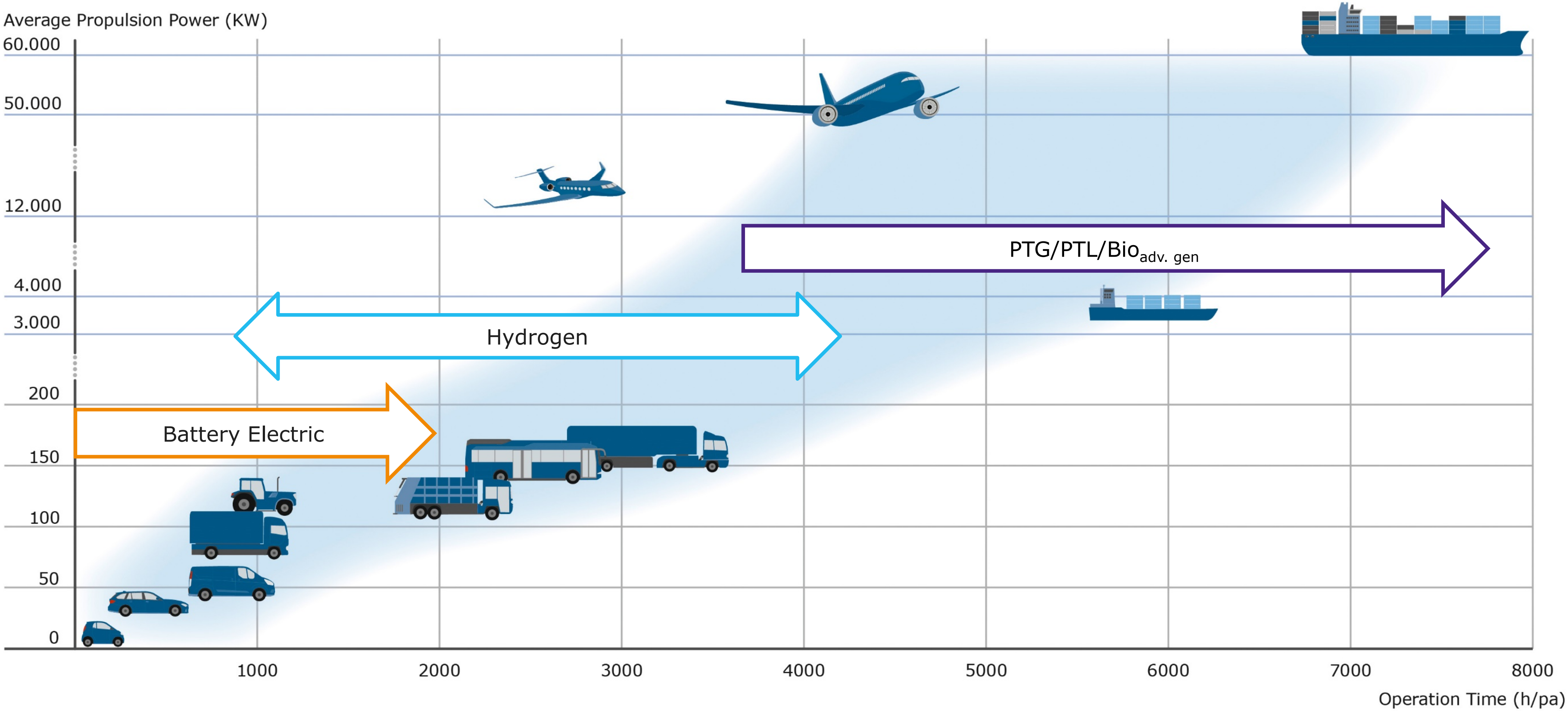
In future a variety of finished products require Renewable Hydrocarbons

Beyond sectoral limits: Japan Energy System - Hydrogen a central pathway

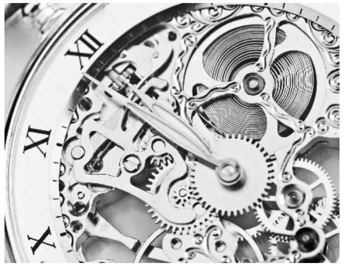


→ In theory, optimizing of CO_2 **across sectors** would be possible by trading emission certificates

“Sustainable Fuel Map” for Transport Applications



A Global Trading System for renewable Energy is mandatory – regional focus will not lead to a net zero world



A Century-long Task. Reducing CO_2 Emissions towards a climate-neutral level is an unprecedented challenge.

Electricity from wind and solar is a vital element of every scenario.

The right framework. Emissions trading is a powerful instrument if effectively implemented.

An accompanying Hydrogen Strategy is important – for Energy Transport and Storage

The Energy Vectors. Energy pathways consist in the entire chain – Conversion from Wind & Solar, storage, transportation routes, distribution networks, and final use case.

The Powertrain. The most advantageous fuel options – Hydrogen, Liquid Fuels, direct electricity – is driving the corresponding best choice of powertrain.

Thank you

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Public

Towards a Sustainable Mobility
(Main Topics where we can contribute)

Backup UDG
UN: zu allgemein

European Union Fit for 55

- All sectors are affected by the EU CO_2 reduction targets towards 2030
- Measures of relevance for automotive are CO2 fleet targets, Infrastructure deployment and green fuels
- CO_2 reduction is a global issue addressed by most major economies

Strategies for CO_2 reduction Japan & Germany

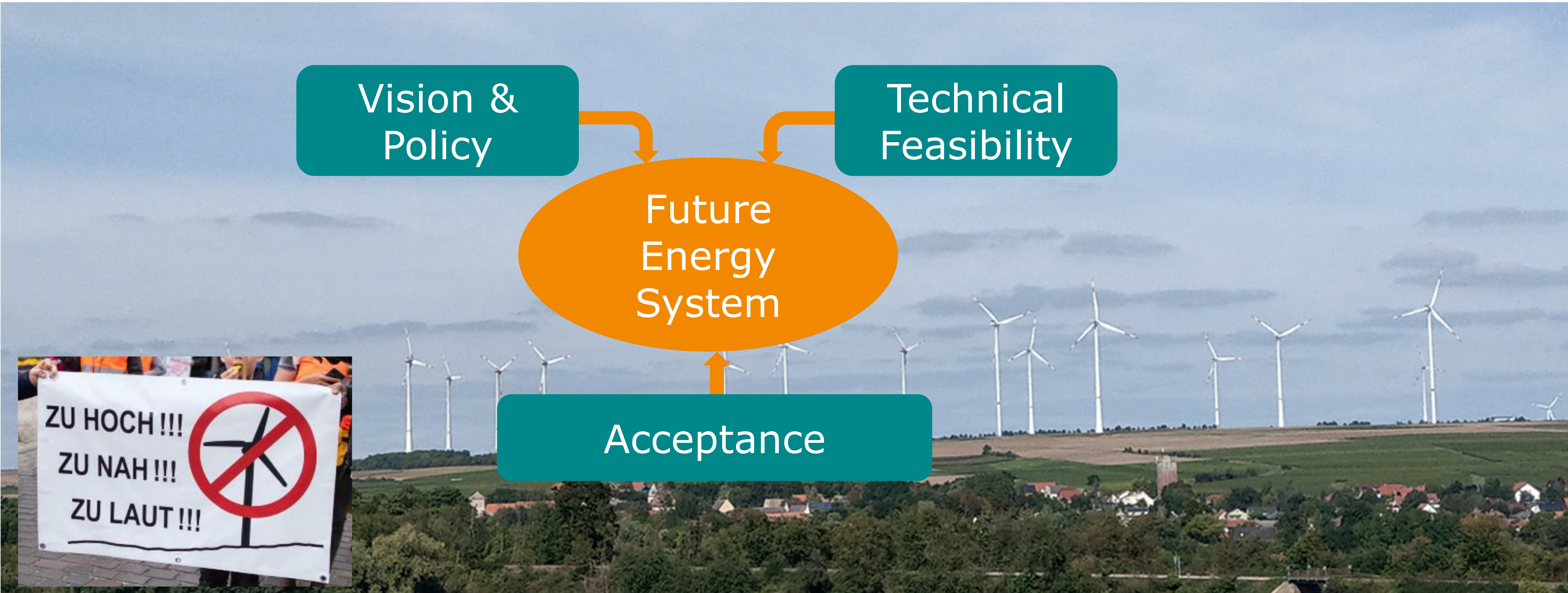
Japan:

- Energy supply security dominant driver in energy plan for 2050 zero CO_2
- Realistic (too small?) reduction planned for fossil energy for 2030
- Recognition that Nuclear has to be a as major contributor to support CO_2 reduction - despite recent past history
- Major renewable energy imports required (e.g. green LH_2)

Germany:

- Challenging targets to achieve CO_2 free reduction plan for 2045
- Reducing fossil + nuclear energy share down from 85% (2019) will depend on:
  - Drastic upgrade of inland wind & solar ren. energy production
  - Major ren. Energy imports required
  - Fast step out of coal power generation
  - Re-Consider Nuclear power generation ?

Creation of tomorrow’s Energy System:
Acceptance is as important as policy and technical feasibility

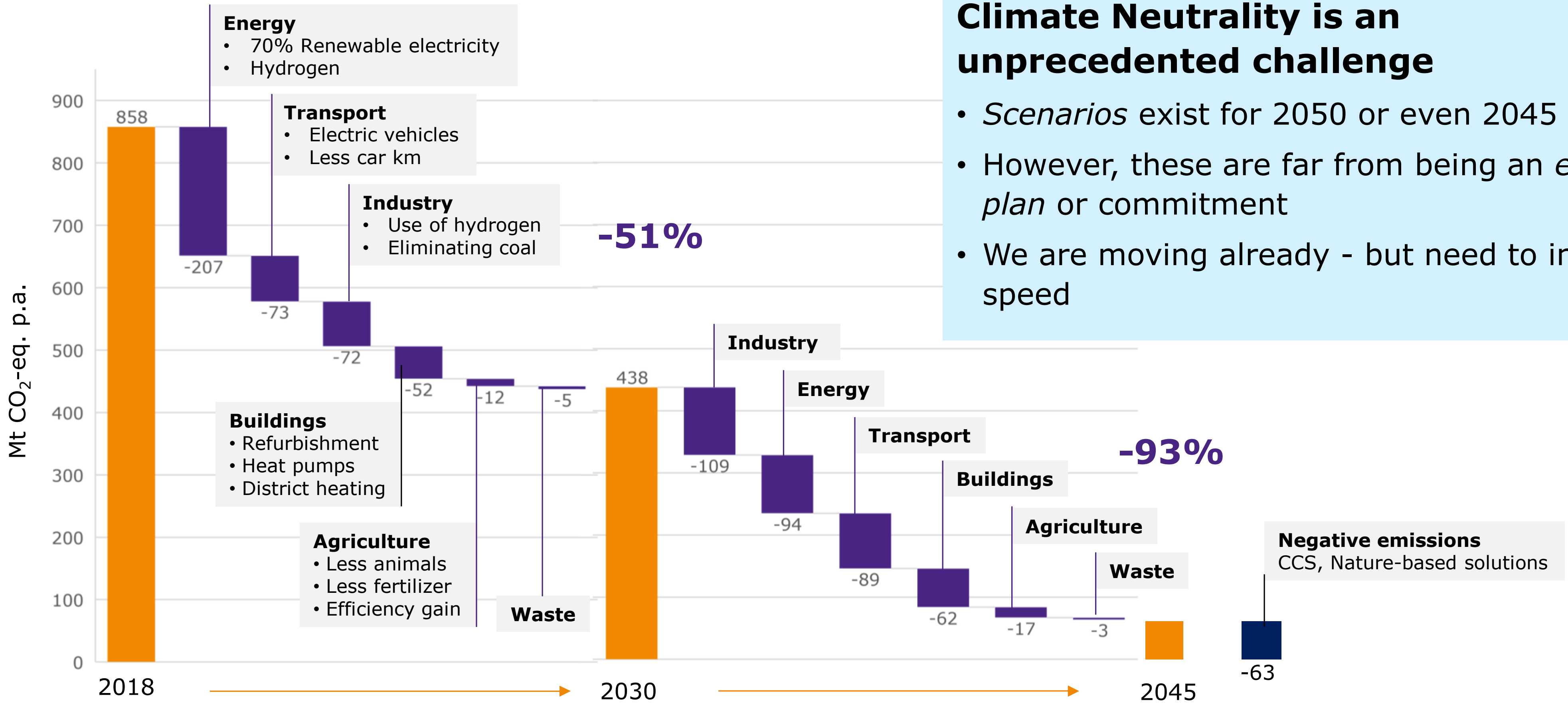


→ Wind and solar installed capacity will probably remain significantly below what is theoretically possible

Pledges & Measures

- Carbon neutrality target will require major changes not only in energy system
- Reduction of energy consumption required
- Efficiency increase and behavioural changes in all sectors – in contrast to several studies which don’t forecast a major reduction of consumption.
- Import of renewable energy is important part of the scenarios

Scenario towards Climate Neutrality - Example Germany



Climate Neutrality is an unprecedented challenge

- *Scenarios* exist for 2050 or even 2045
- However, these are far from being an *executable plan* or commitment
- We are moving already - but need to increase speed

2045/2050: Modified from Prognos, Öko-Institut, Wuppertal-Institut, for Agora Energiewende (2020/21)

CO_2 Economy - summary

- CO_2 Emissions need to get a price tag to activate market forces for CO_2 reduction
- We might see a CO_2-Economy in future, with CO_2-lean products and services to become more competitive

- **Two systems exist: Cap-and-Trade vs. direct taxation of emissions**

Cap-and Trade can be more powerful instrument than simple taxation

- ➢ The achievement of emission target is guaranteed by the Cap
- ➢ The right CO_2 price is determined by trading instead of “arbitrary” setting by government
- ➢ However, Cap-and-Trade has to be implemented correctly
  - A Trading Scheme has to be established
  - Complexity: Many factors are influencing real emissions and thus the CO_2 price

- Climate impact of a CO_2-molecule is independent on its origin - but today, prices are different for each region and sector, and they are volatile

We are far from having established a consistent framework today, but we are learning and will become better over time

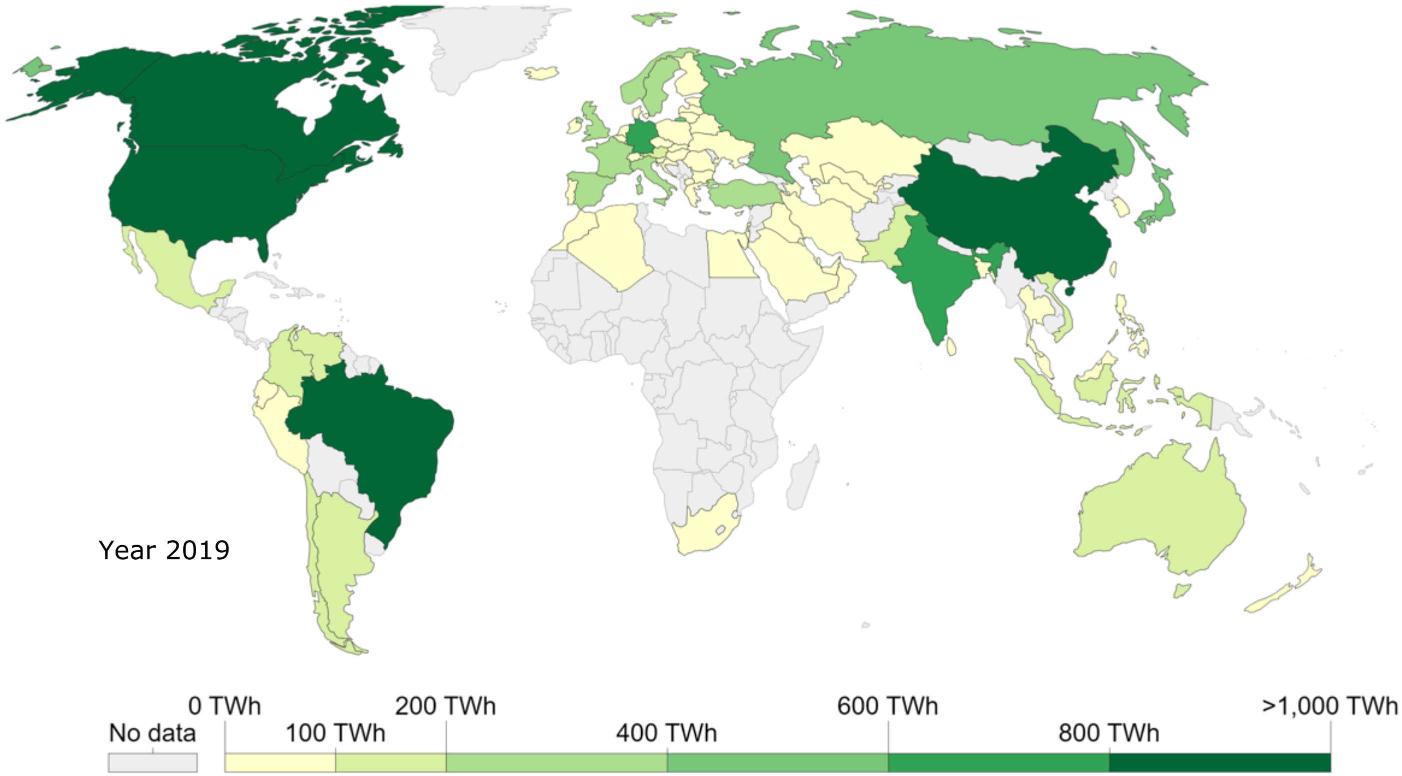
Primary Energy from Renewables Today

Renewable energy Consumption includes hydropower, solar, wind, geothermal, wave and tidal and bioenergy.

Renewable Energy Consumption (TWh) pa)

Year	1965	2019
China	61	4985
US	590	2290
India	53	736
F	130	315
UK	13	315

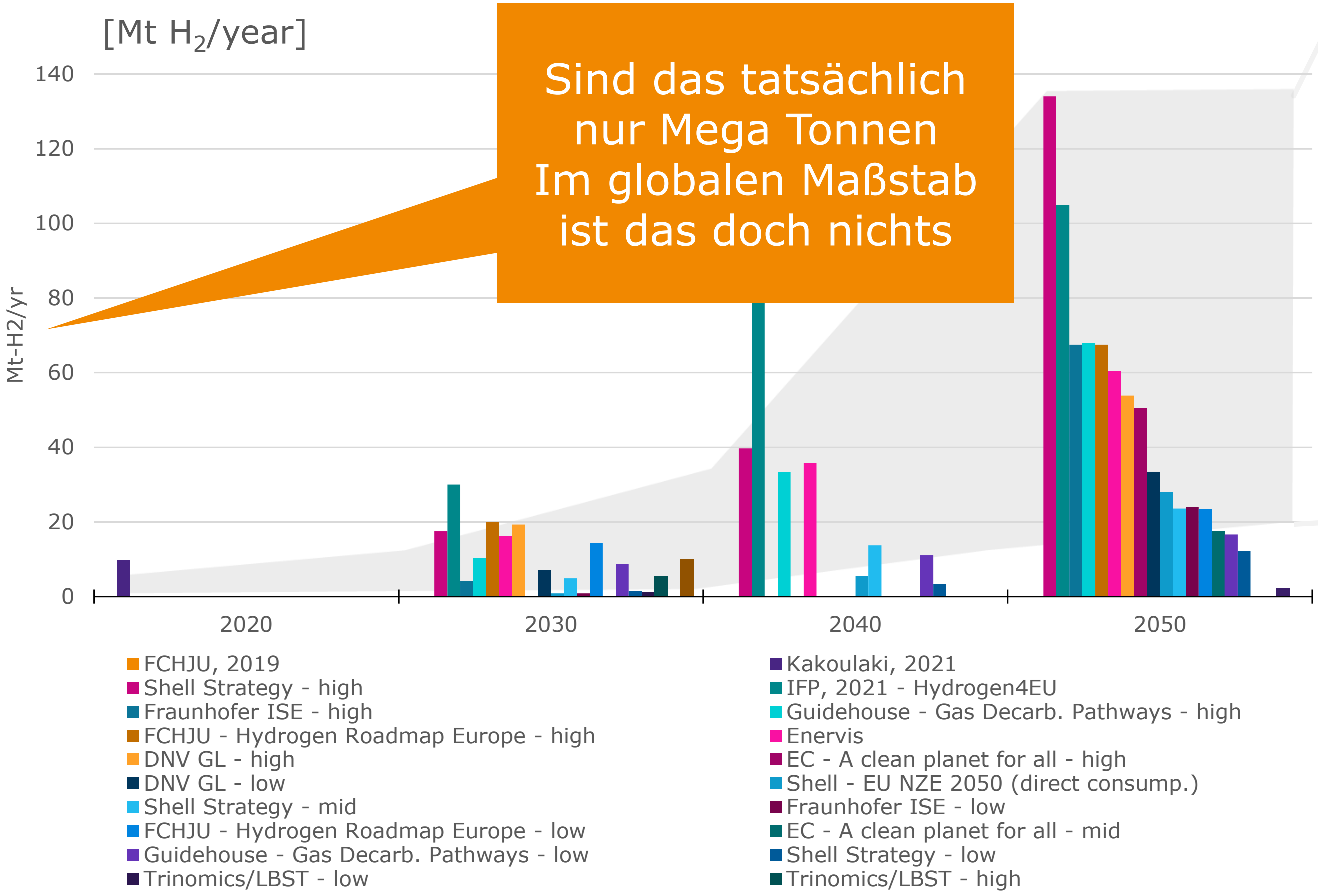
Traditional biofuels are not included.
Energy consumption is based on primary energy equivalents, rather than final electricity use.
Source:
https://ourworldindata.org/renewable-energy
https://http://www.bp.com/statisticalreview



Today: Mostly regionally produced and transport via electric grid
Tomorrow: Storage and Long-Range Transport in Molecules

Total Hydrogen Demand in EU - Scenario

(based on external studies)



Hydrogen demand EU 2021 ~9Mt/p.a.

- ~34% going towards refining,
- ~ 38% ammonia,
- ~ 8% methanol production

Future Hydrogen demand EU:

- may grow slowly towards 2030
- more significantly towards 2040/50

Hydrogen will play an increasingly important role as Energy Vector in transport, power, heating

Key 'Hydrogen' Questions:

- H_2 competitive production pathways for low-carbon hydrogen
- H_2 import/ transport/sector-coupling potential

Renewable Global Energy Trade

- Global trade with fossil fuels will be replaced by renewables
- For long distances, hydrogen-based fuels are the main energy carrier

Synthetic Fuels – and their Future

- **Conversion from renewable Electricity into liquid fuels a most attractive option – esp. for transport**
- **BUT:**
  - Poor efficiency,
  - non existing commercial manufacturing plants
  - and high production costs a major challenge
- **Important to note that industry and chemical sectors also have major Demand for ren. Energy components**
  - Conversion from 'green electrons' into synthetic Hydrocarbons deliver valuable HC-molecules outside the transport fuel product molecule range
  - Market demand from non transport sectors (especially chemical ind.) will drive volumes and price for synth. Transport Fuels
  - Within Transport sector: any available synth.Fuels will be used where replacement of fossil fuels is most difficult: especially long range Aviation