frontier economics

Automatic convenience translation

Green, blue hydrogen - Potentials and security of supply

DVGW Congress Perspectives for H2 Module #1

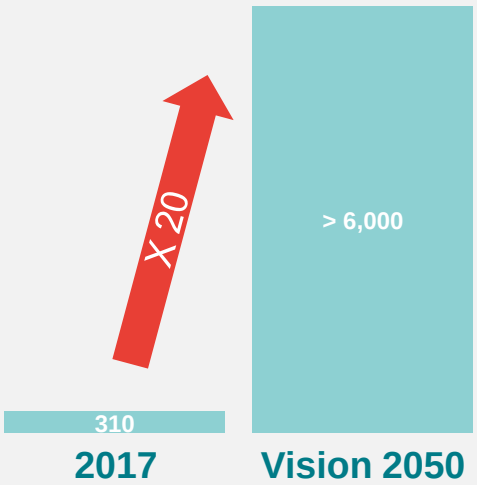
7. Oktober 2020

There is no way around hydrogen / chemical energy carriers, for a **secure** renewable energy supply

The three central challenges for a 100% renewable energy supply ...

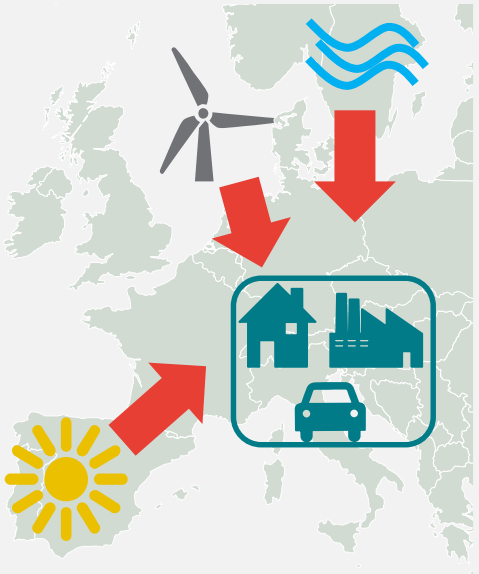
... develop sufficient sources ...

Final energy demand to be met by electricity from wind and solar power (TWh/a) in EU28*



The **demand for renewable energy sources** will increase massively **-** with the challenge of finding **sufficient and acceptable production regions** in Europe.

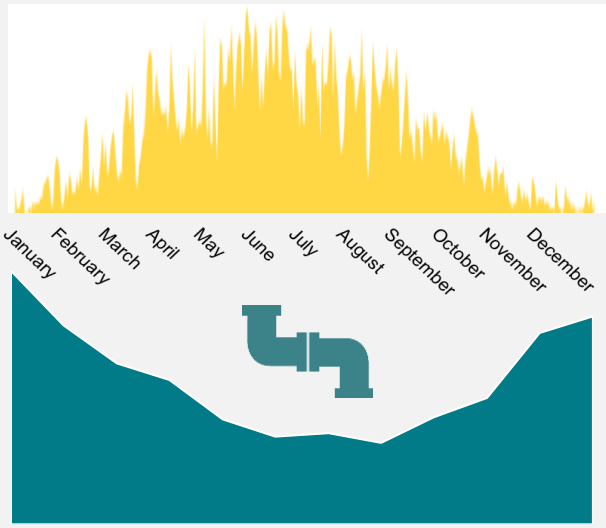
... transport energy ...



Effective **energy transport and -distribution** are the key to a secure renewable energy supply.

... and save seasonally!

Schematic annual profile PV production

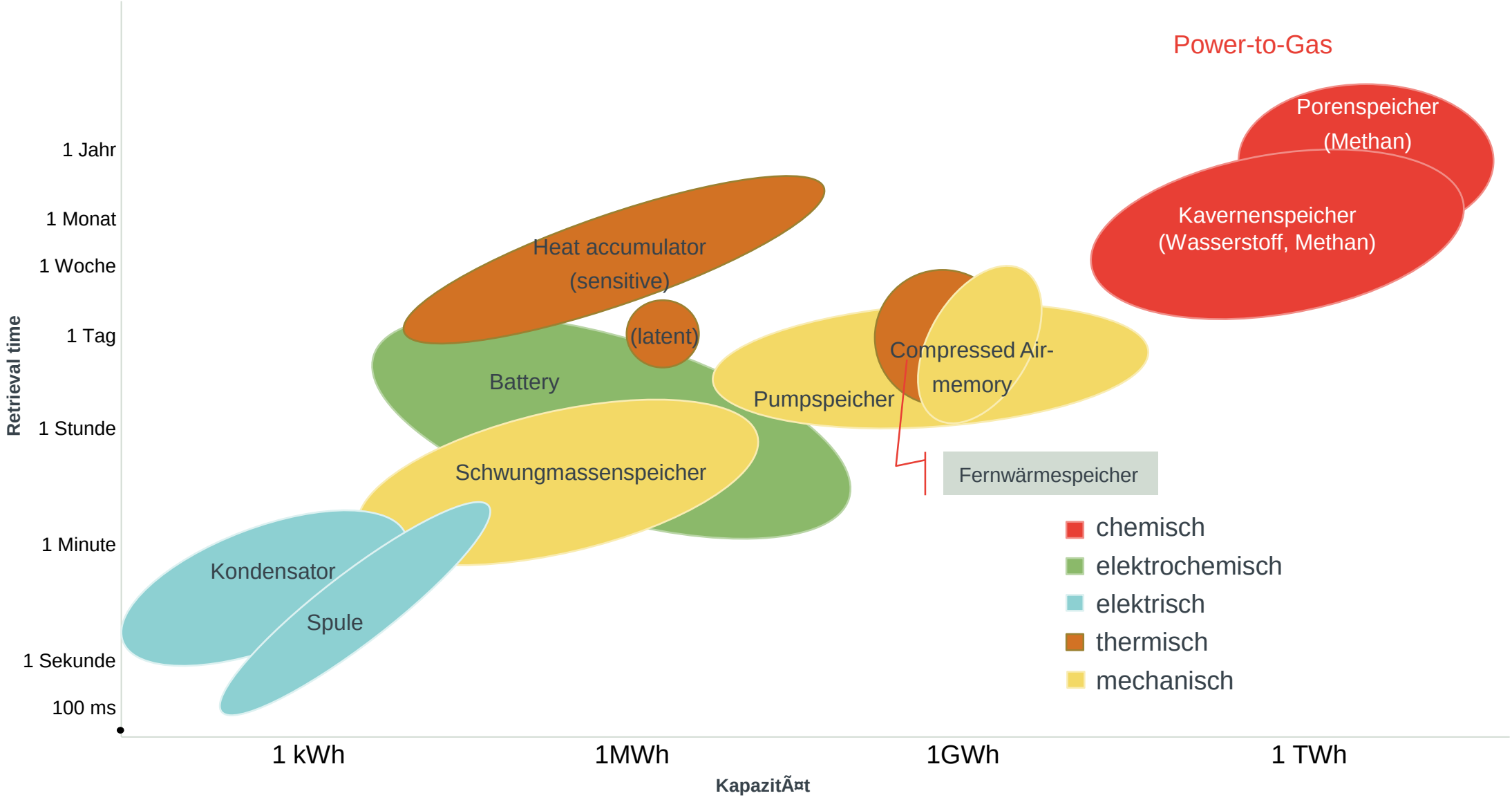


Average monthly gas consumption in 8 analysed countries

Supply-dependent renewable energy sources and fluctuating energy demand (e.g. for heat) require **large seasonal energy storage facilities**.

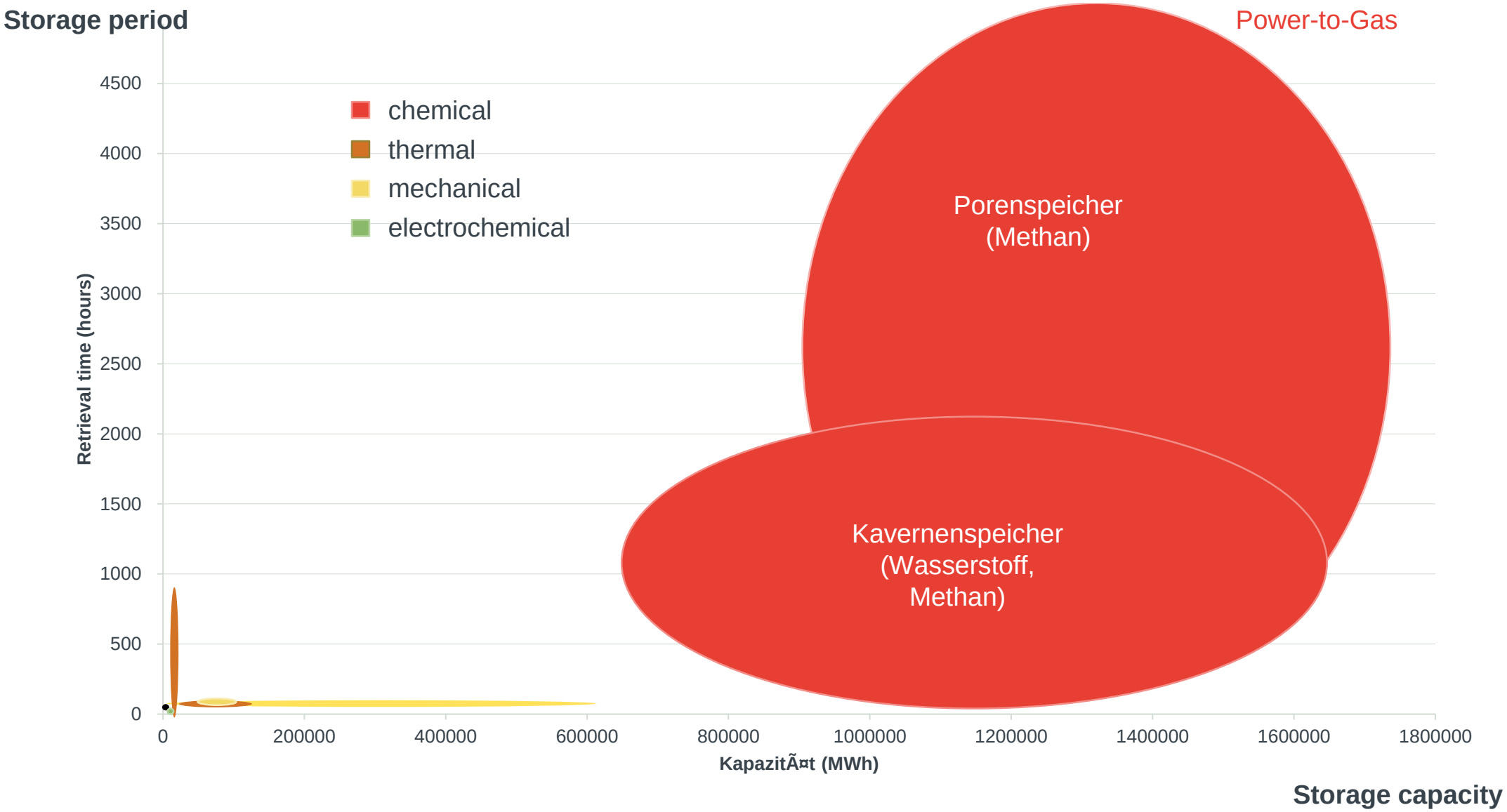
Source: Frontier 2019: "The Value of Gas Infrastructure in a climate neutral Europe
http://www.frontier-economics.com/media/3113/value-of-gas-infrastructure-report.pdf
*) Scenario "100% renewables" is based on the assumption of a 40% reduction in final energy consumption and constant water and biomass potential

Storage: Alternatives to hydrogen/PtX not foreseeable for storing large amounts of electricity directly over a long period of time ...



Source: Sterner et al., Energy Storage (2014)

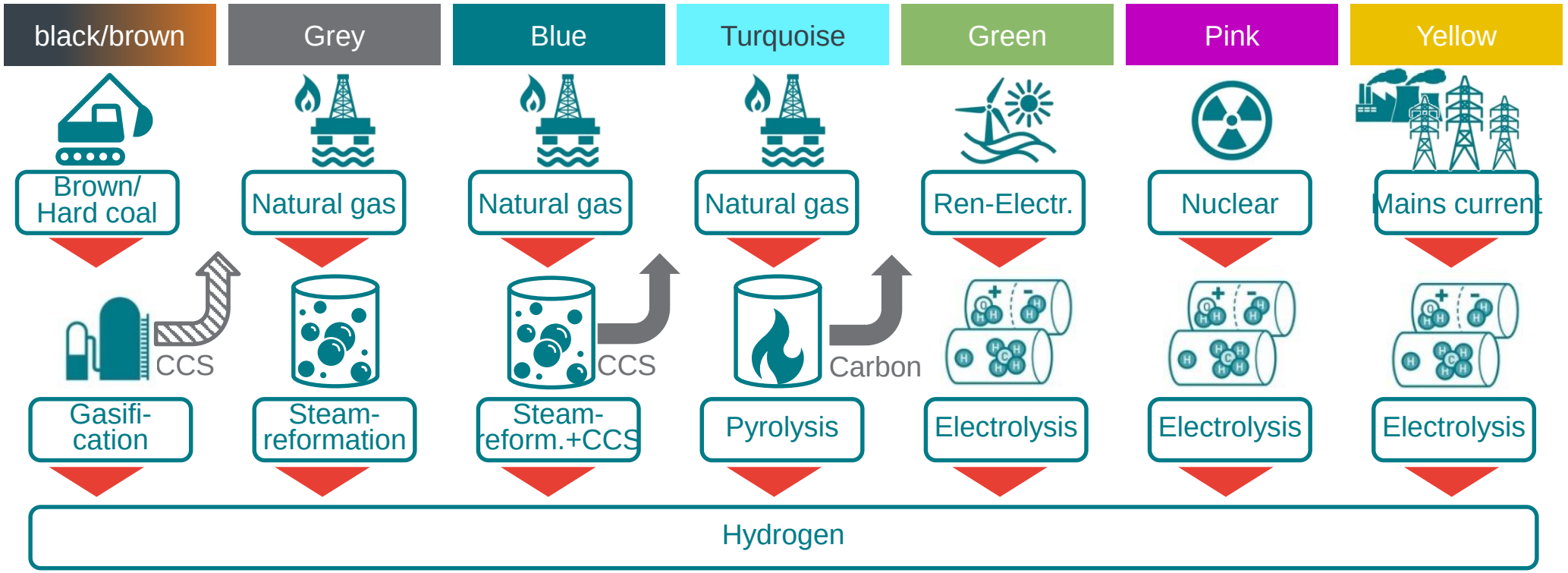
... and on a linear scale the whole challenge!

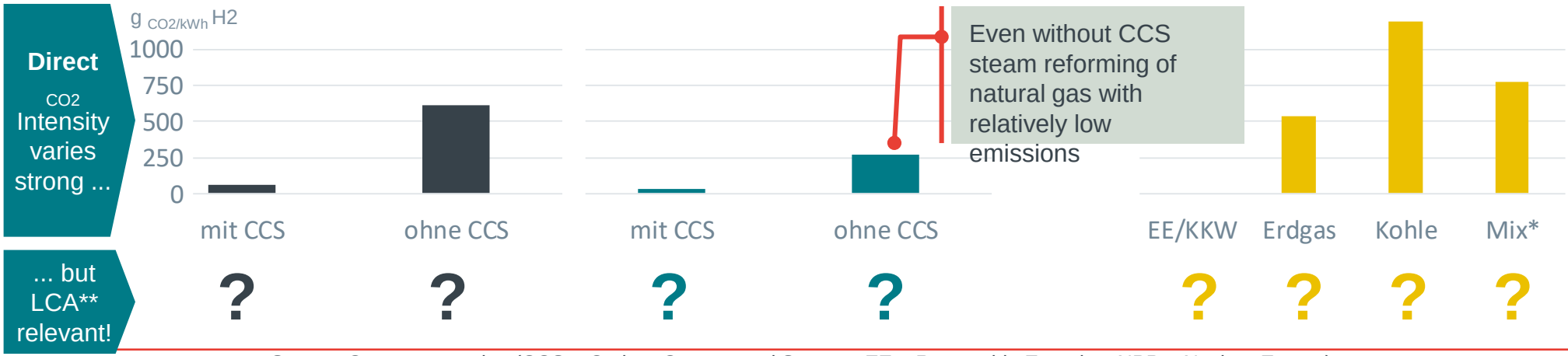


Source: Illustration adapted from Sterner et al., Energy Storage (2014)

Sources: Hydrogen is a versatile energy carrier ...

Selection



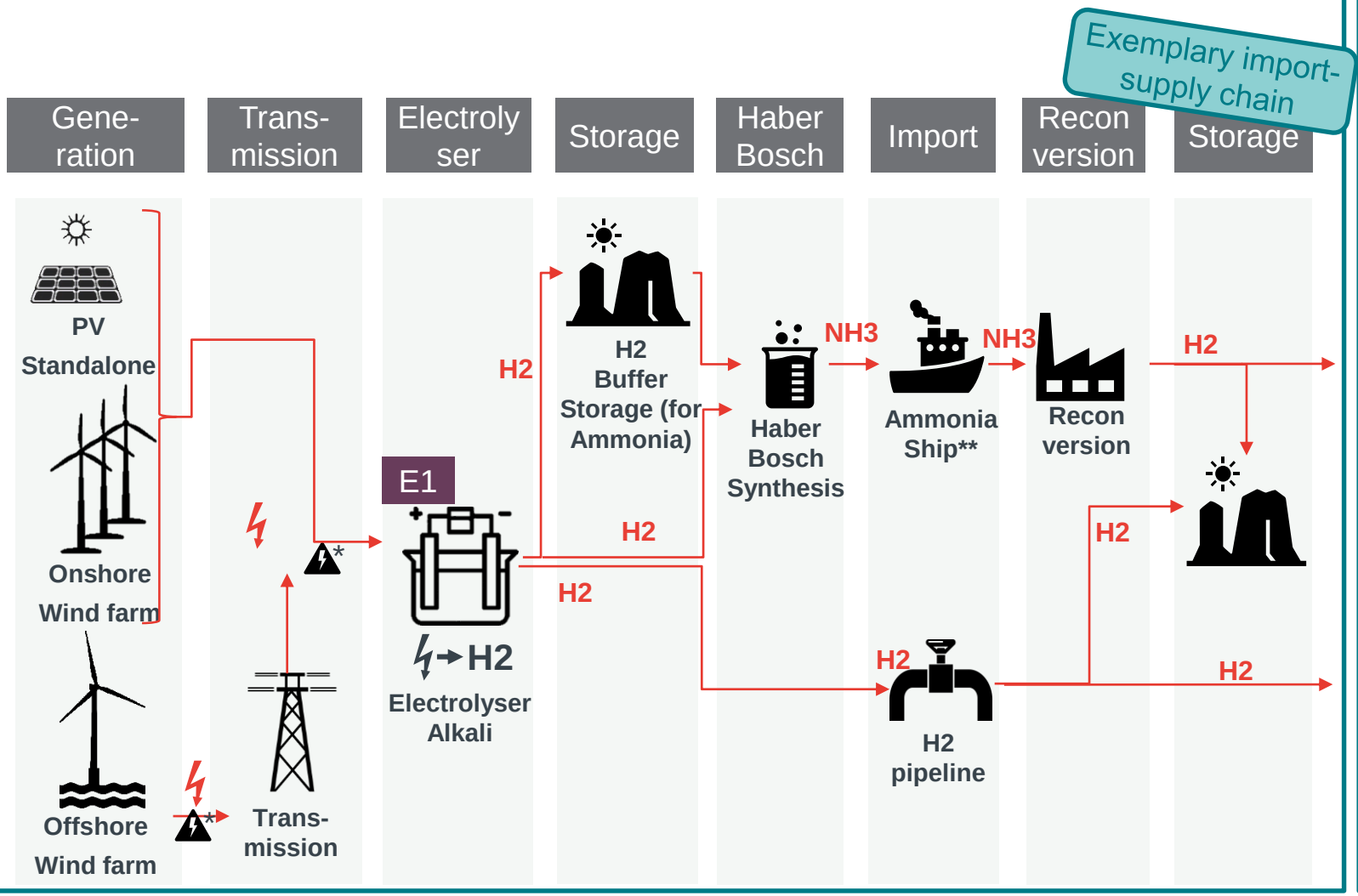


Source: Own presentation (CCS = Carbon Capture and Storage, EE = Renewable Energies, NPP = Nuclear Energy)
Source direct CO2 intensity: IEA 2019 "The Future of Hydrogen", conversion based on calorific value 33.33kWh/kgH2
*) Global electricity mix 491g $_{CO2/kWhel}$
**) Life Cycle Analysis

Background: Without life cycle analysis meaningful technology comparisons not possible!

Work in progress

Hydrogen supply chains contain numerous infrastructure elements ...



... whose CO2 emissions during construction and operation must also be part of the consideration!

Therefore, **meaningful technology comparisons** require a **life cycle analysis!**

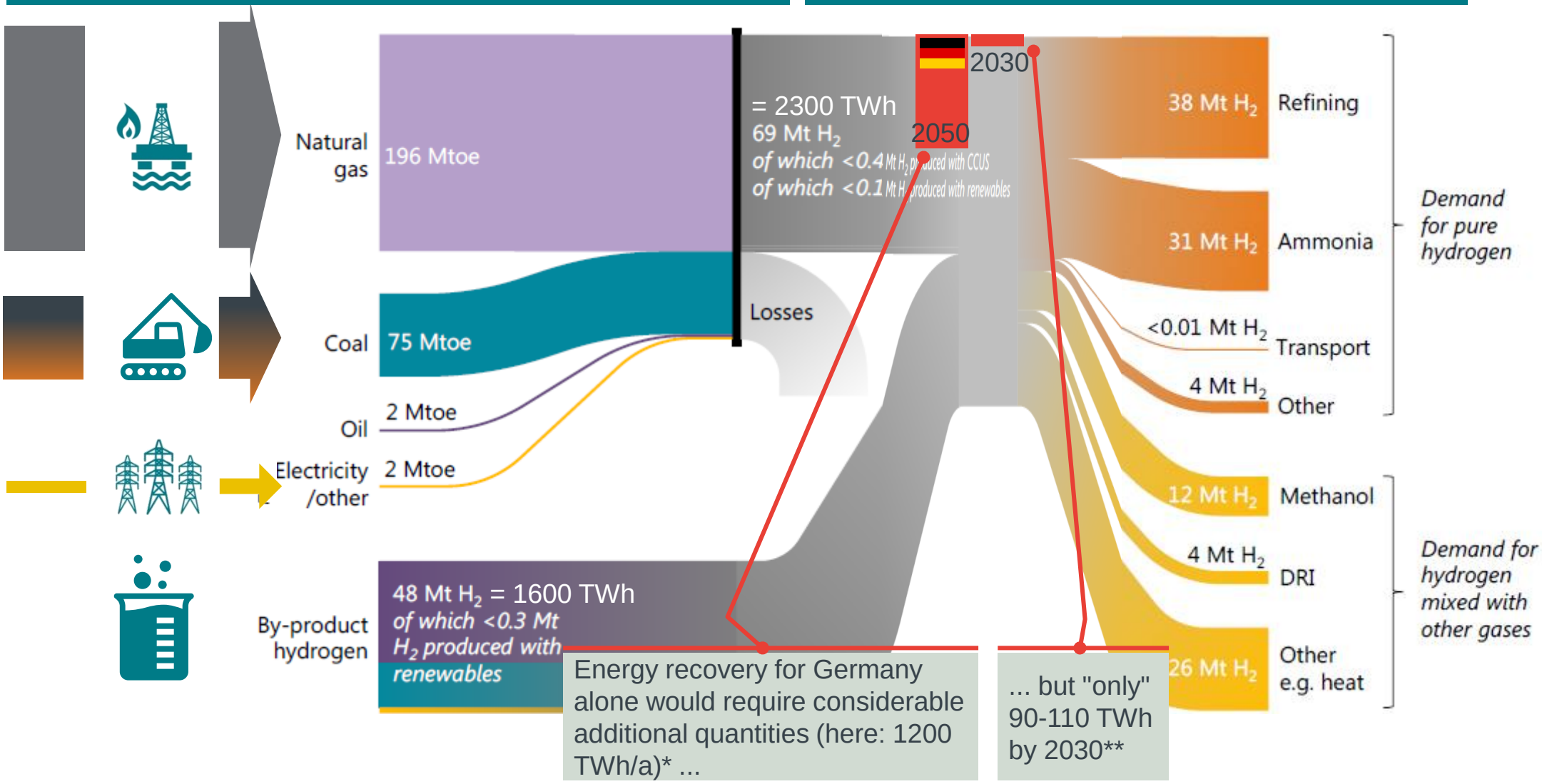
* converter stations & transformers
**including import and export terminals

Source: Own presentation based on current work for the Fuel Study FVV (work in progress)

Volume: The world market for H2 is quite significant, but future quantities require multiplication!

Fossil H2 production dominates worldwide ...

... and the material use!



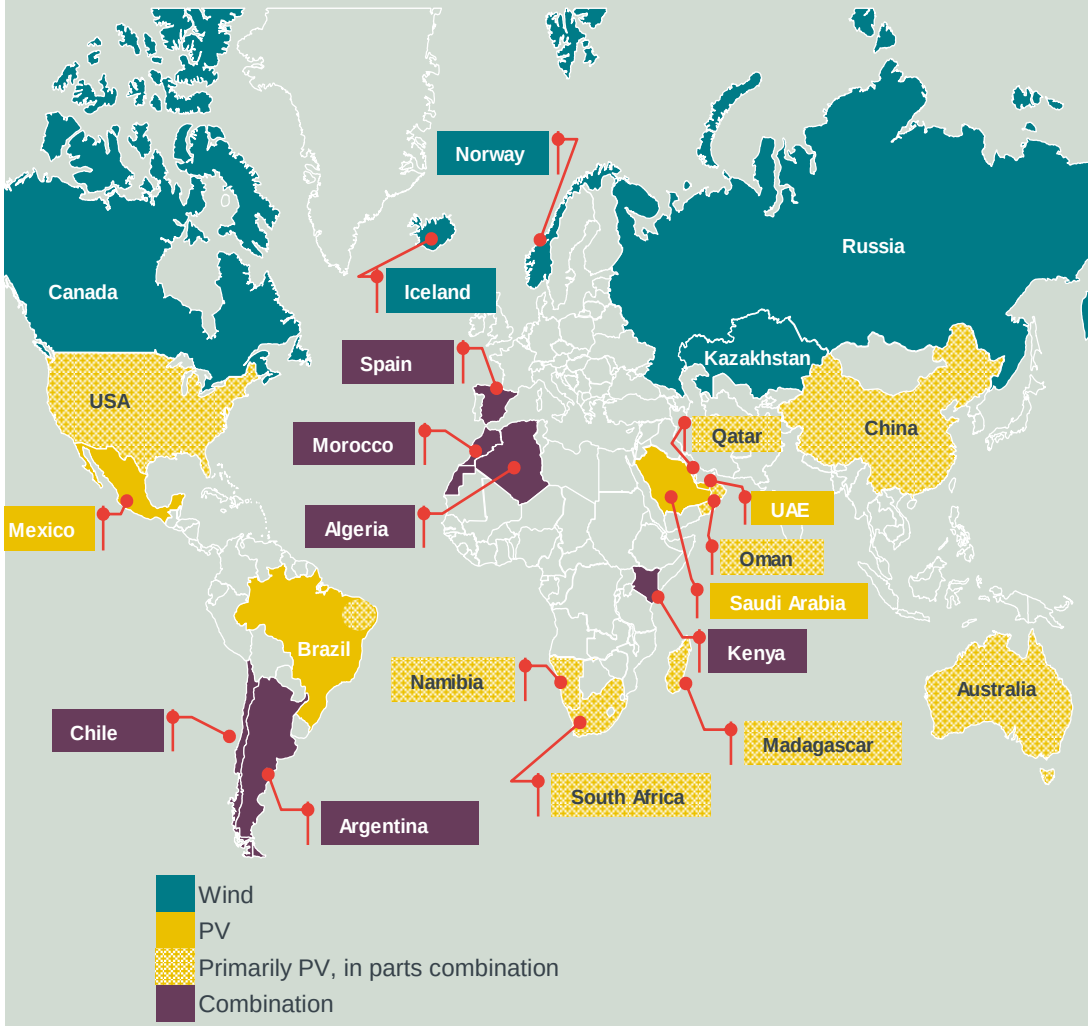
Source: Own adapted representation based on IEA 2019 "The Future of Hydrogen" Figure 6

*) Assumption Germany on the basis of Frontier 2018: "The value of gas infrastructure for the energy turnaround in Germany". http://www.frontier-economics.com/de/de/news-und-veroeffentlichungen/veroeffentlichungen/article-i4363

**) Source: Hydrogen Strategy Germany (of which 14 TWh by 5GW electrolysis)

But worldwide numerous potential exporters for PtX available!

Screening of possible exporting countries
(costs/potential/framework conditions)



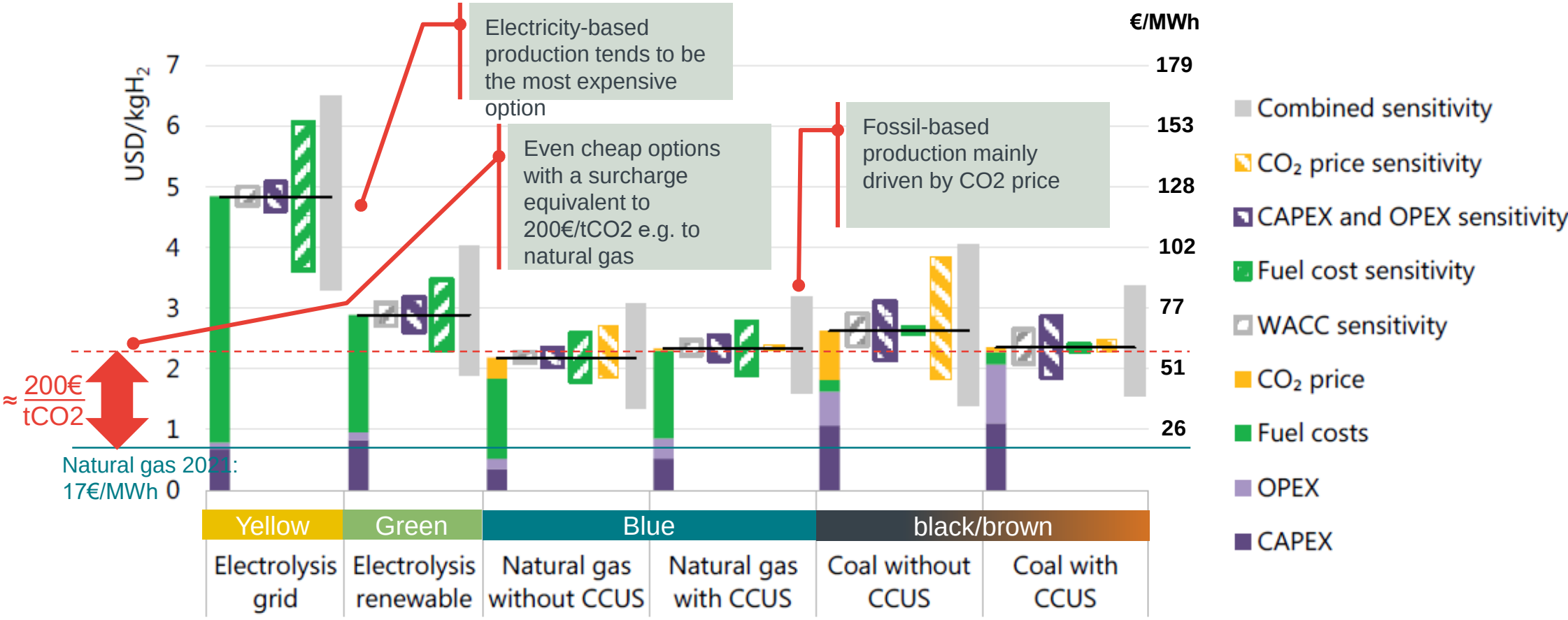
Cluster of potential exporting countries

Type	PtX Motivation and Readiness	Exam-ples
Front-runners	➢ Especially favourable in early stages of market penetration	Norway
Hidden Champions	➢ PtX could readily become a serious topic if facilitated appropriately	Chile
Giants	➢ Provide order of PtX magnitudes demanded in mature market	Australia
Hyped Potentials	➢ Potential to lead technology development; may depend on solid political facilitation	Morocco
Converters	➢ Strong motivation for PtX export technology; may require political facilitation	Saudi Arabia
Uncertain Candidates	➢ May drive PtX technology development, export uncertain	China

Quelle: Frontier 2018 "International Aspects of a Power-to-X Roadmap"
http://www.frontier-economics.com/media/2642/frontier-int-ptx-roadmap-stc-12-10-18-final-report.pdf

Costs: Analyses suggest intense competition between different production routes in Europe ...

IEA estimate for Europe: hydrogen production costs for different technology options 2030



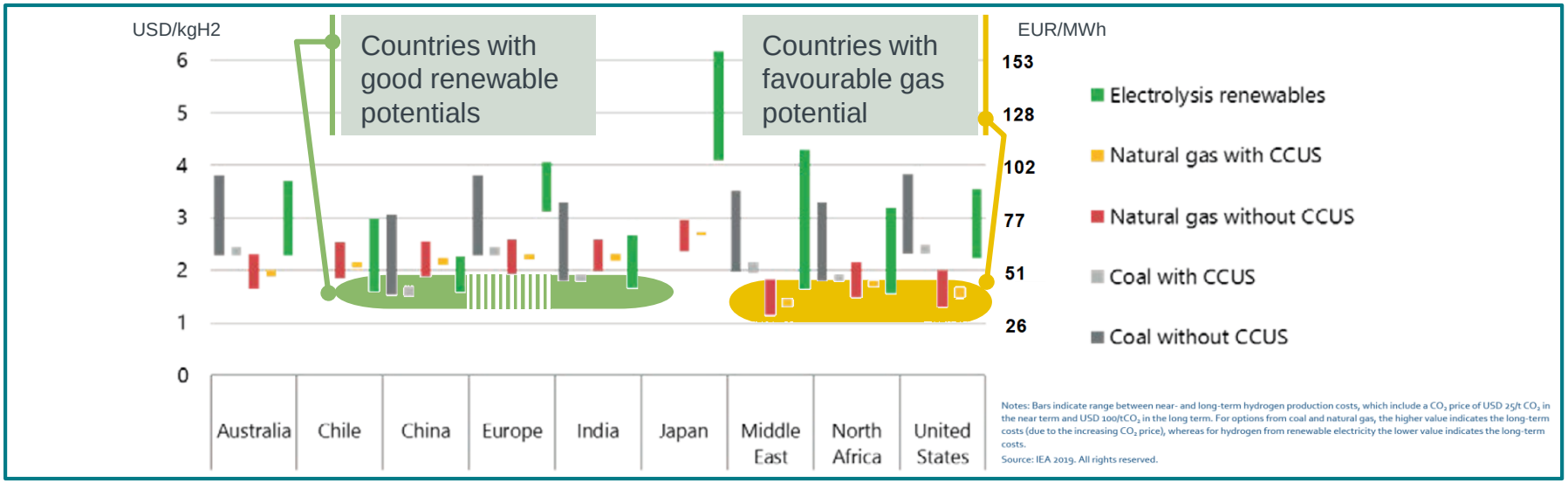
Notes: WACC = weighted average cost of capital. Assumptions refer to Europe in 2030. Renewable electricity price = USD 40/MWh at 4 000 full load hours at best locations; sensitivity analysis based on +/-30% variation in CAPEX, OPEX and fuel costs; +/-3% change in default WACC of 8% and a variation in default CO_2 price of USD 40/tCO_2 to USD 0/tCO_2 and USD 100/tCO_2. More information on the underlying assumptions is available at www.iea.org/hydrogen2019.

... with a considerable long-term premium over fossil fuels.

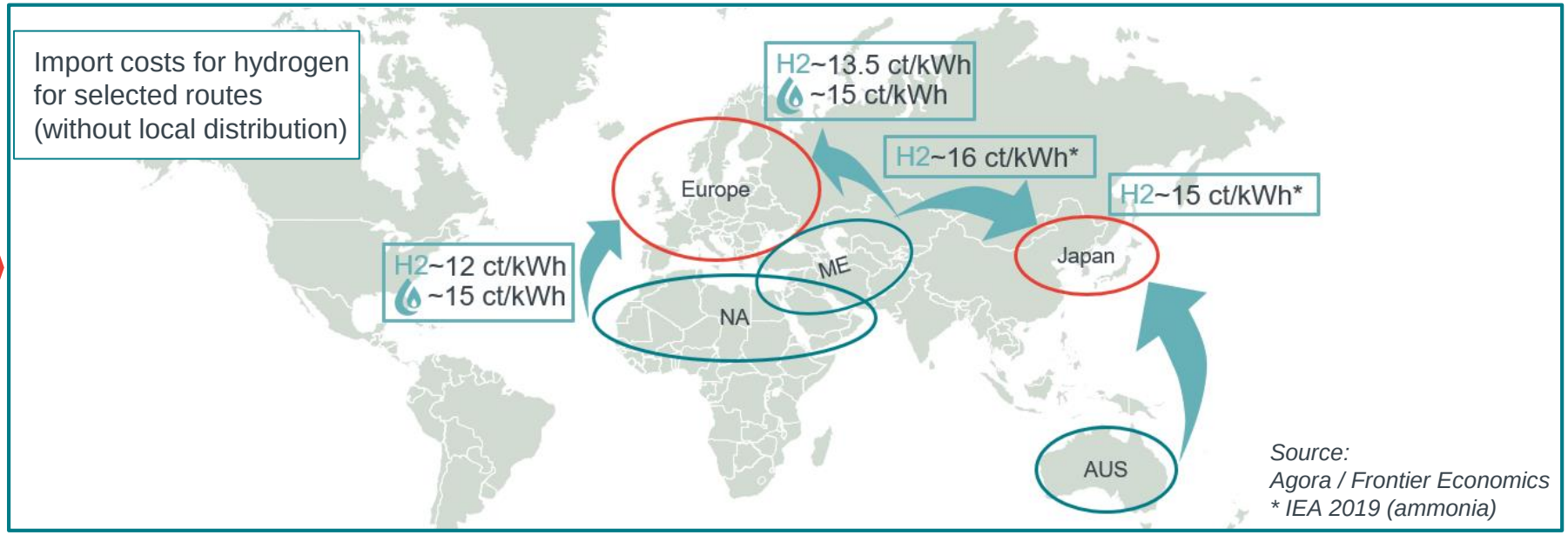
Source: Own presentation based on IEA 2019 "The Future of Hydrogen", Figure 16

A uniform world market price level is emerging, but it is fed by different sources in different regions.

Globally, costs differ mainly due to the availability of resources ...



... but with quite uniform import costs!



Source above: Own presentation based on IEA 2019 "The Future of Hydrogen", Figure 19
Source below: Own representation

Conclusion: We need a market for "colourful" hydrogen

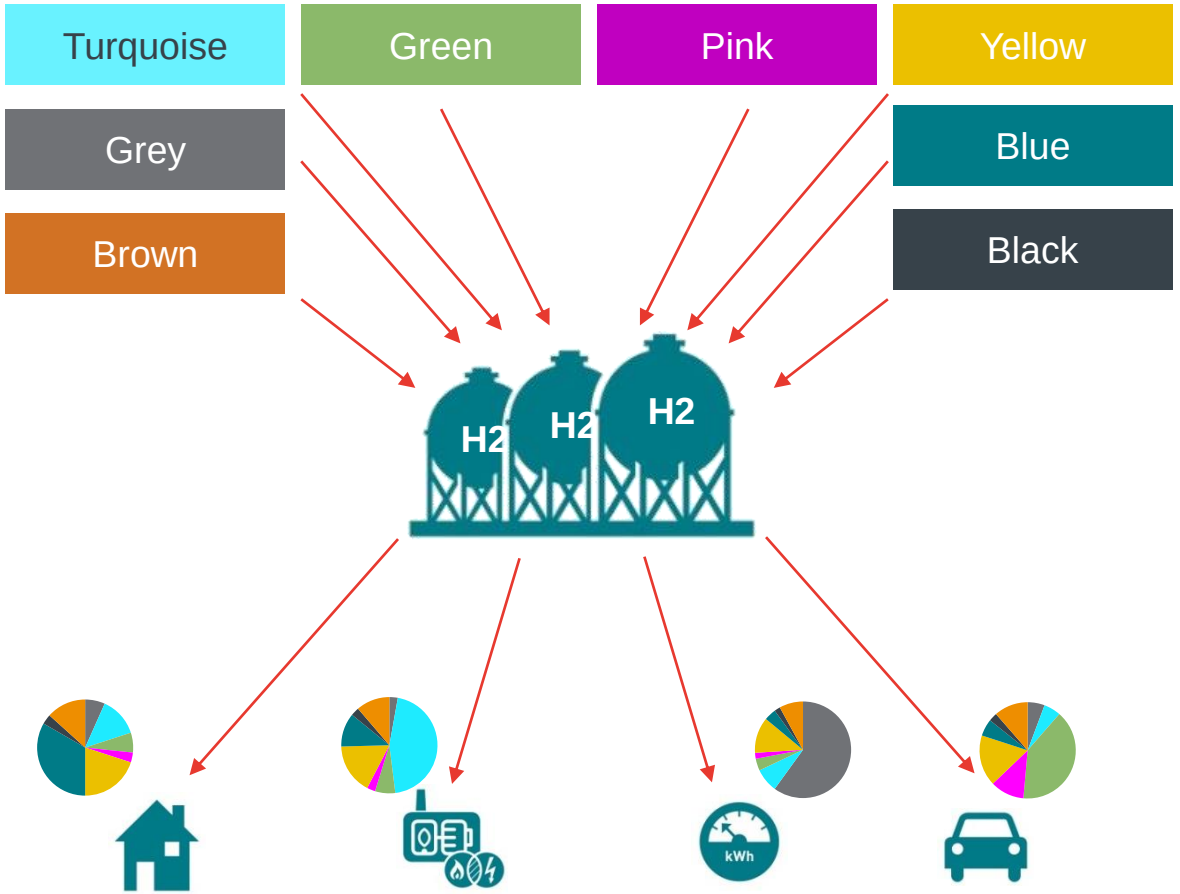
There is no way around hydrogen and chemical energy carriers!

There is a multitude of production routes

The CO2 advantages/disadvantages of the various routes must be weighed up in a life cycle analysis!

The magnitude of potential demand requires the use of many / all production channels

Cost structures speak for international competition



We need a regulatory framework that ensures fair competition for all production routes made possible - a successful hydrogen market will be "colourful"!

Individual climate advantages must pay off!

Thanks a lot!

Dr. David Bothe

+49 221 337 13 106

+49 176 641 00 11 3

david.bothe@frontier-economics.com