Volvos transition towards sustainable transports with hydrogen as one of the pathways

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Agenda

- Volvo Group and our sustainability targets
- Hydrogen as one of our transition path
- Hydrogen in our vehicles
  - FC
  - Storage
  - Refueling
- Summary

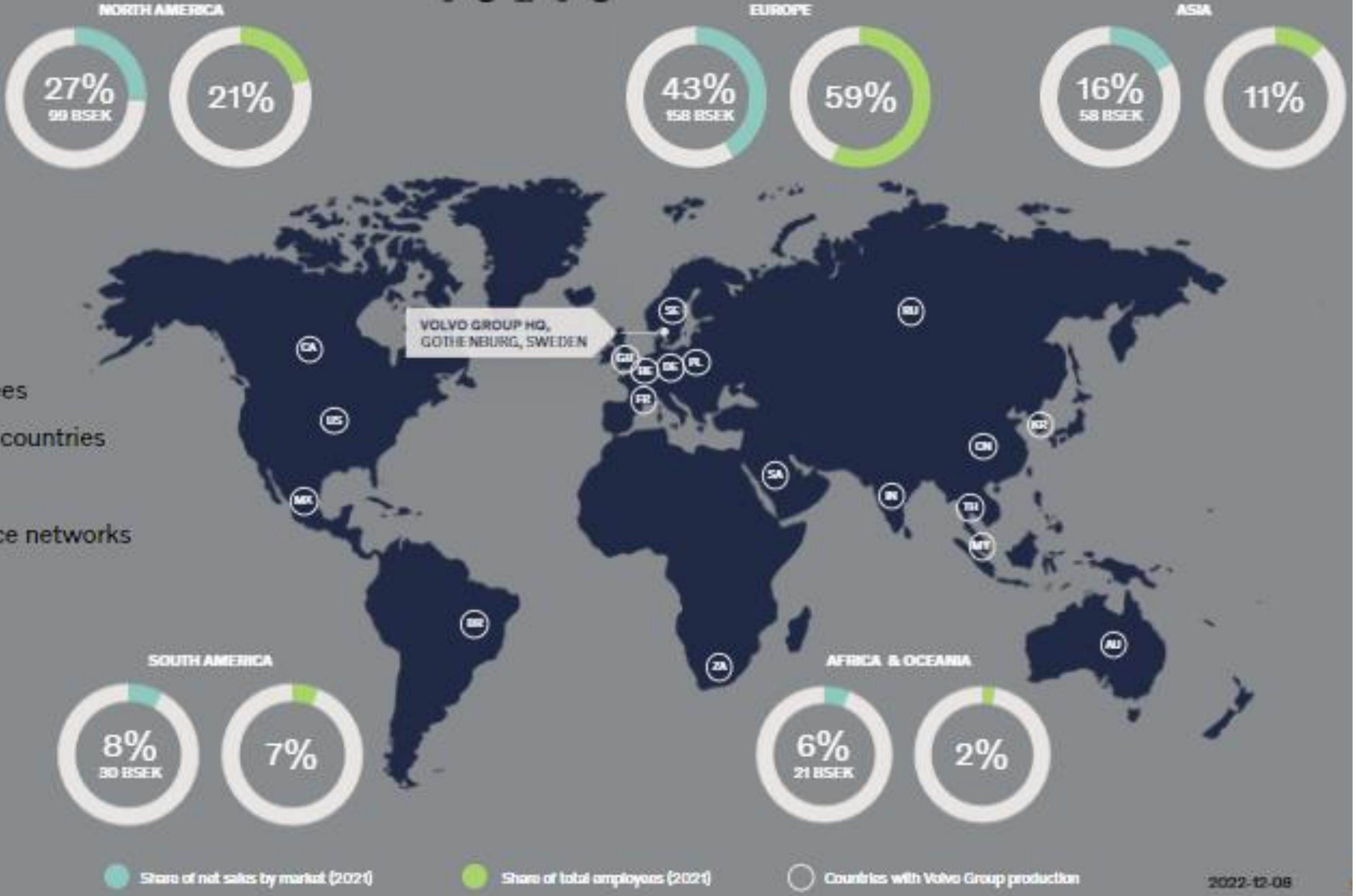
What we do

Volvo Group offers trucks, buses, construction equipment, power solutions for marine and industrial applications, financing and services that increase our customers' uptime and productivity.

We contribute to the development of electrified and autonomous solutions for the benefit of customers, society and for the environment.

Global presence

- 95,000 employees
- Production in 19 countries
- 190 markets
- Worldwide service networks and dealerships

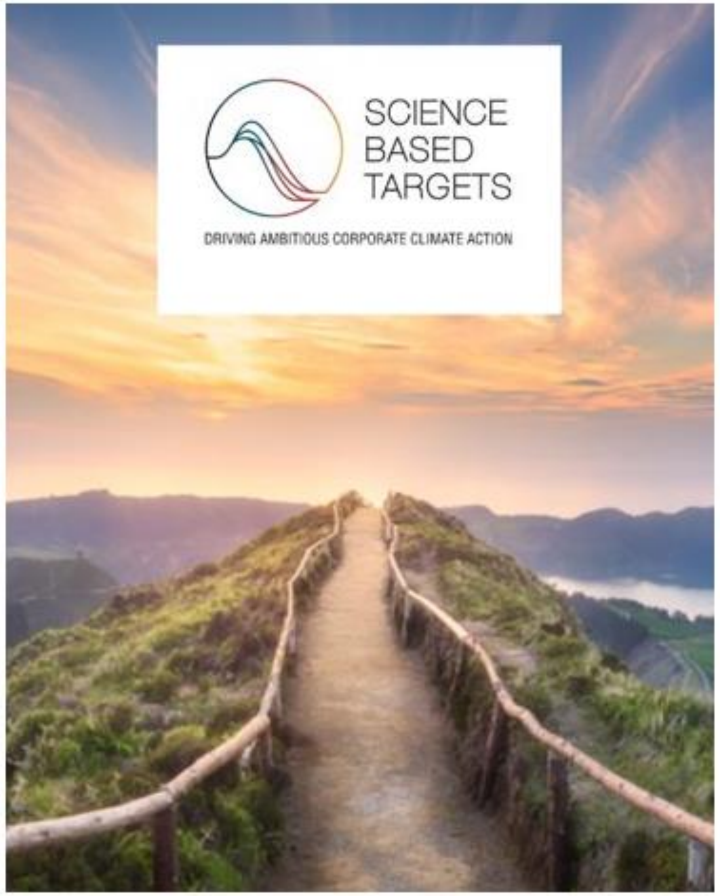


Volvo and Paris Agreement

- Volvo has committed to the Paris agreement (to limit global warming to a maximum of 1.5^{o}C above pre-industrial levels)
- Science based target (SBT) helps organizations to set target in line with Paris agreement
- Lower the CO_2 emissions with 40% by 2030
- Lower the CO_2 emissions with 100% by 2040

Science Based Targets initiative (SBTi)

- Initiative designed for organizations to set targets aligned with UN Paris agreement on Climate Change
- Volvo is committed to target Net-zero value chain greenhouse gas emissions by no later than 2050
- Volvo has now set ambitious interim science-based targets to reach this objective.



Science Based Targets is based on Reporting in accordance with Greenhouse Gas Protocol

Scope 1 - Direct emissions from operations

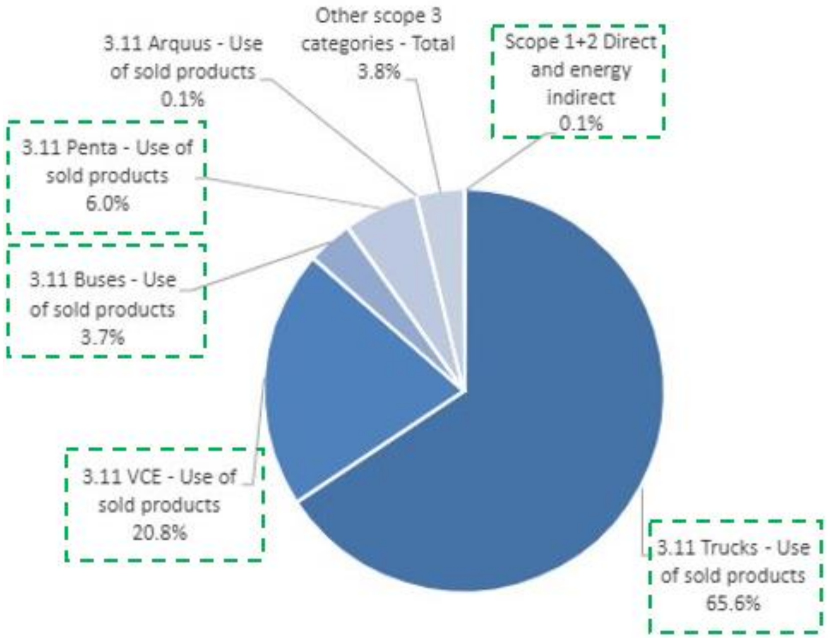
Scope 2 - Indirect emissions from purchased energy to operations

Scope 3 - All other indirect emissions in value chain, incl. use of sold products

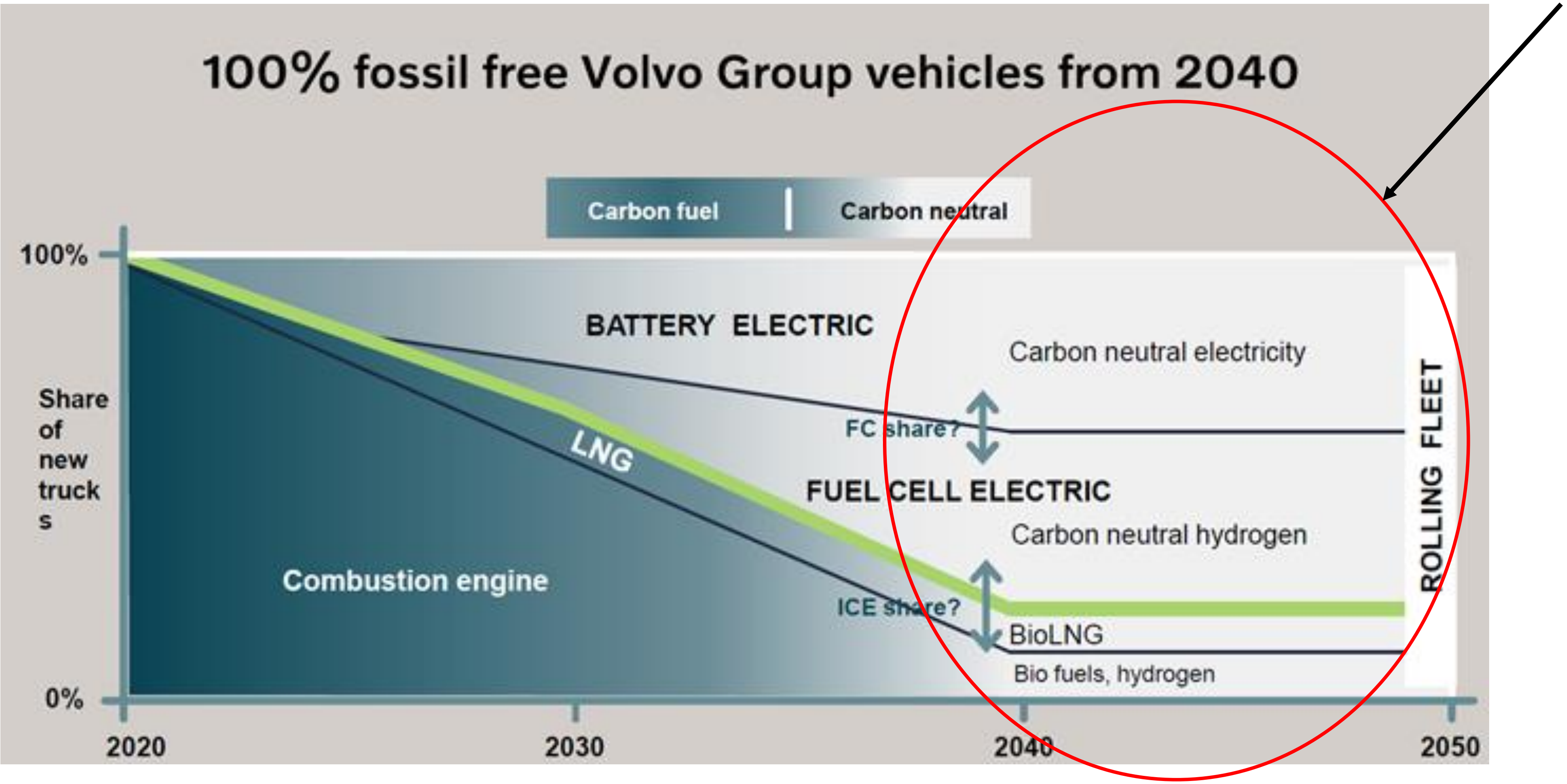
Energy carrieers

More than 95% of Group emissions coming from use of sold products

Scope 1+2+3, 2019 baseline



Emission factors needed

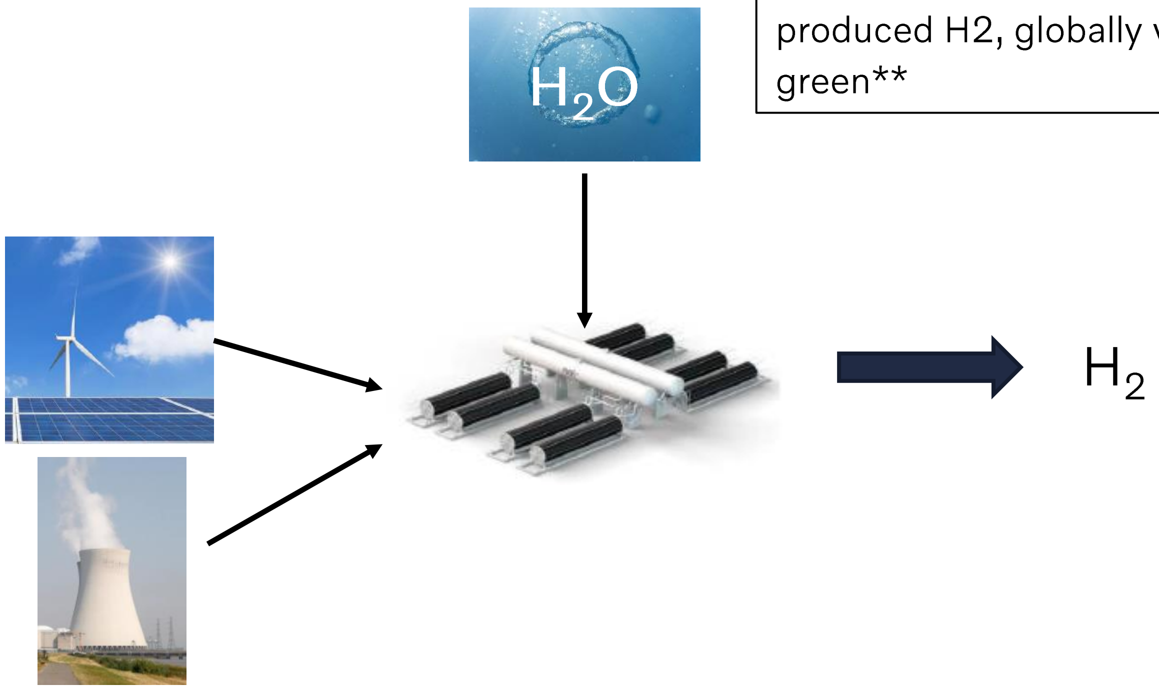


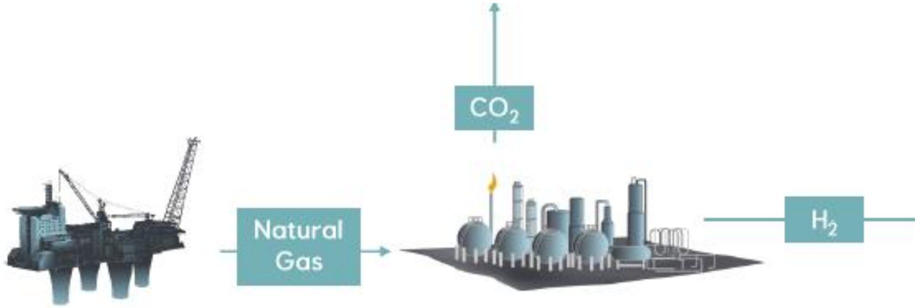
- How much CO_2 do the vehicles emits (well to wheel)?
- Emission factors for each fuel and each market are needed

2020 less than 1% of produced H2, globally was green**

Green/Pink/Blue/Grey H_2

H_2	• Electrolysis (PEM or Alkaline) • From water and power • Renewable energy • 100% CO_2 emissions reduction
H_2	• Electrolysis (PEM or Alkaline) • From water and power • Nuclear energy • 100% CO_2 emissions reduction
H_2	• Steam methane reforming • From natural gas • With CCS/CCU • 70% CO_2 emissions reduction*
H_2	• Steam methane reforming • From natural gas • Without CCS/CCU • 1 ton H_2 => 8 ton CO_2 emissions



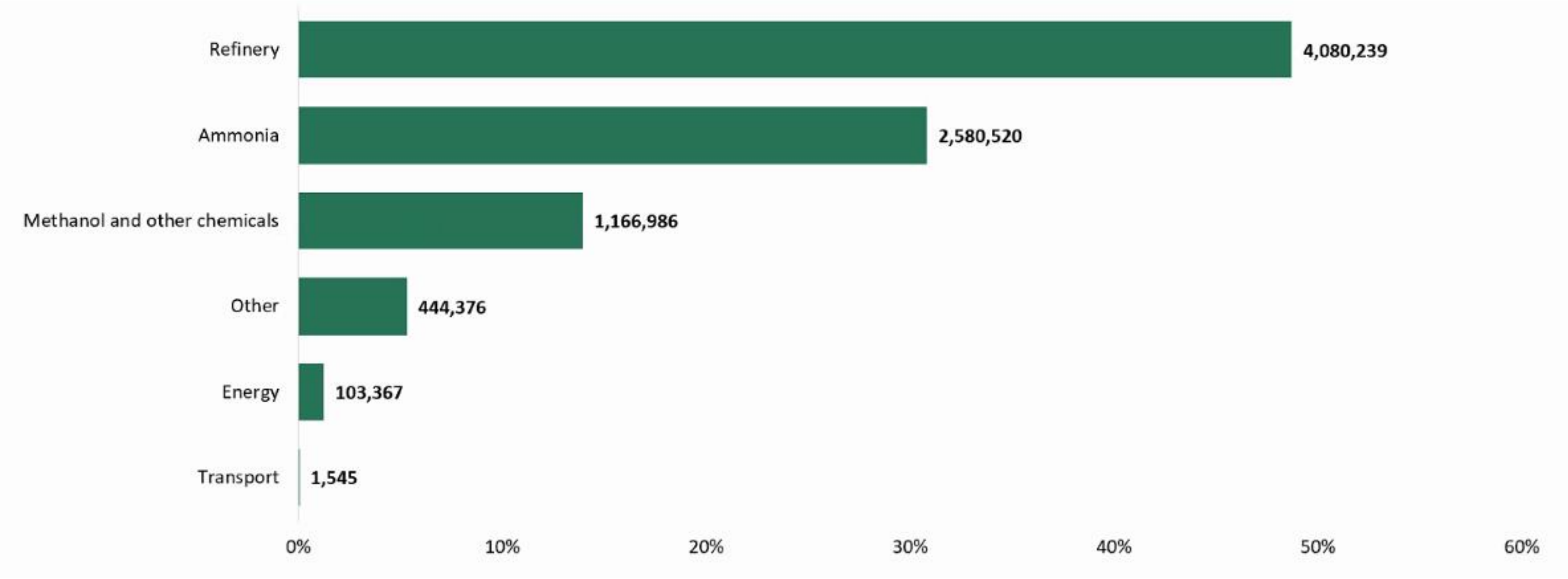


*JEC well to wheel study 2020
** Irena Global energy outlook 2020

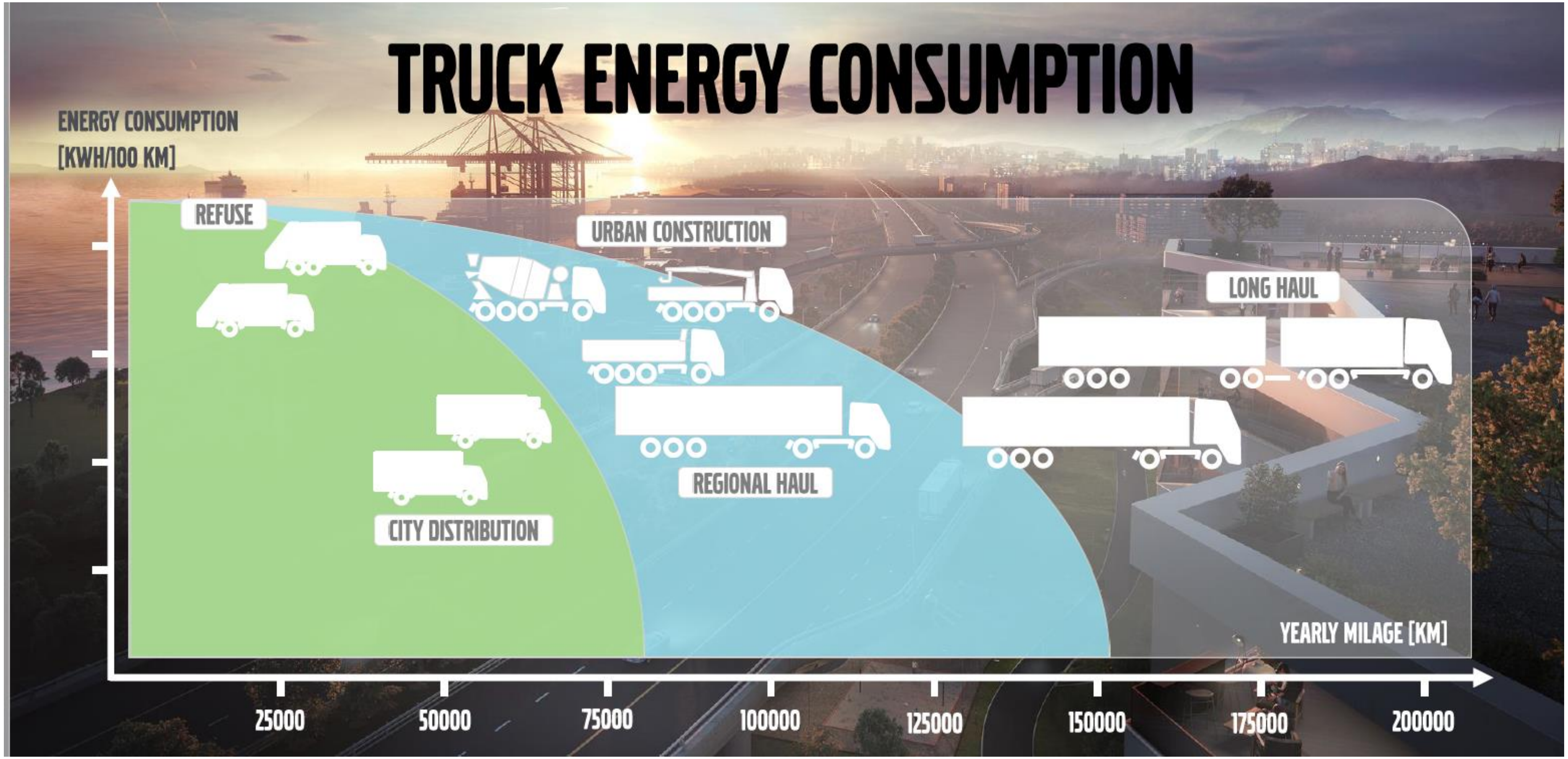
Global hydrogen demand 90 Mt

Europe hydrogen consumption by sector (% of total and tonnes per year)

- Refining and ammonia sector represent 80% of the 8.4 Mt consumption



Ref: Hydrogen Europe 2021



The best solution differs depending on regions and type of transports.

cellcentric

Volvo Fuel Cell Truck

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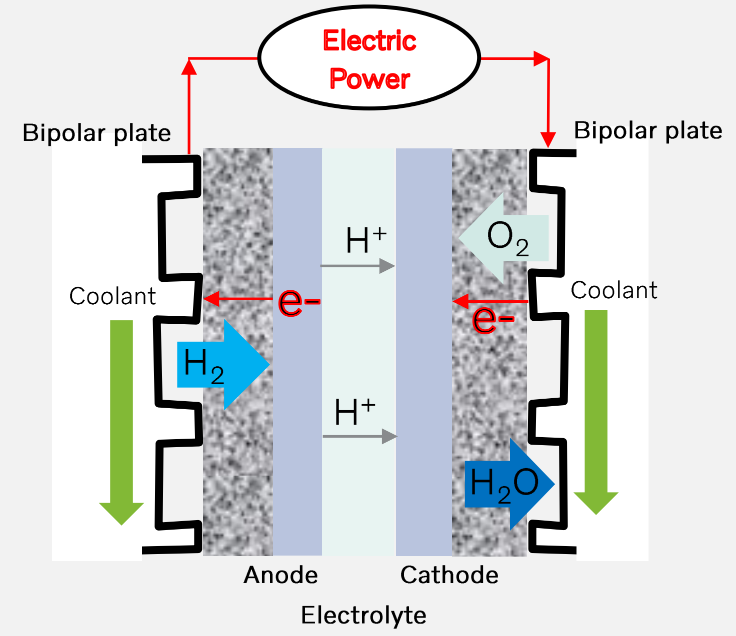
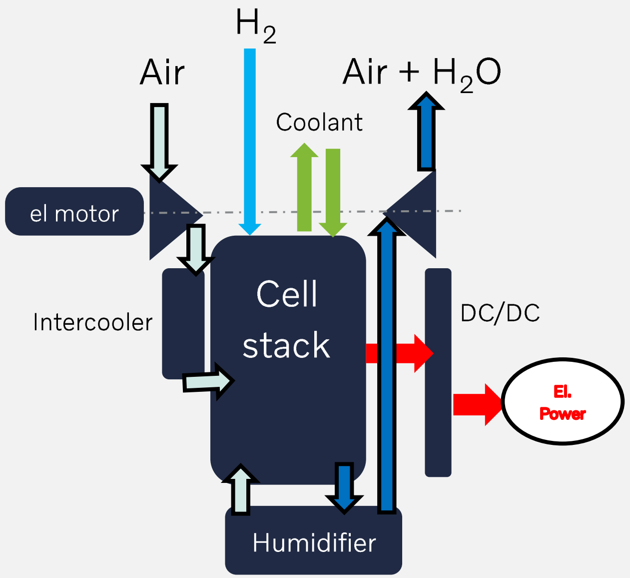
FUEL CELL HEAVY DUTY SYSTEMS DEVELOPMENT VEHICLE COMBINATIONS UP TO 65 TON FOR GLOBAL USE

Fuel cell technology overview
- Key areas to master in the fuel cell technology

- Primary Heavy Duty fuel cell technology
  - High durability
  - High efficiency
  - Full load capability
  - Mass production possible component design



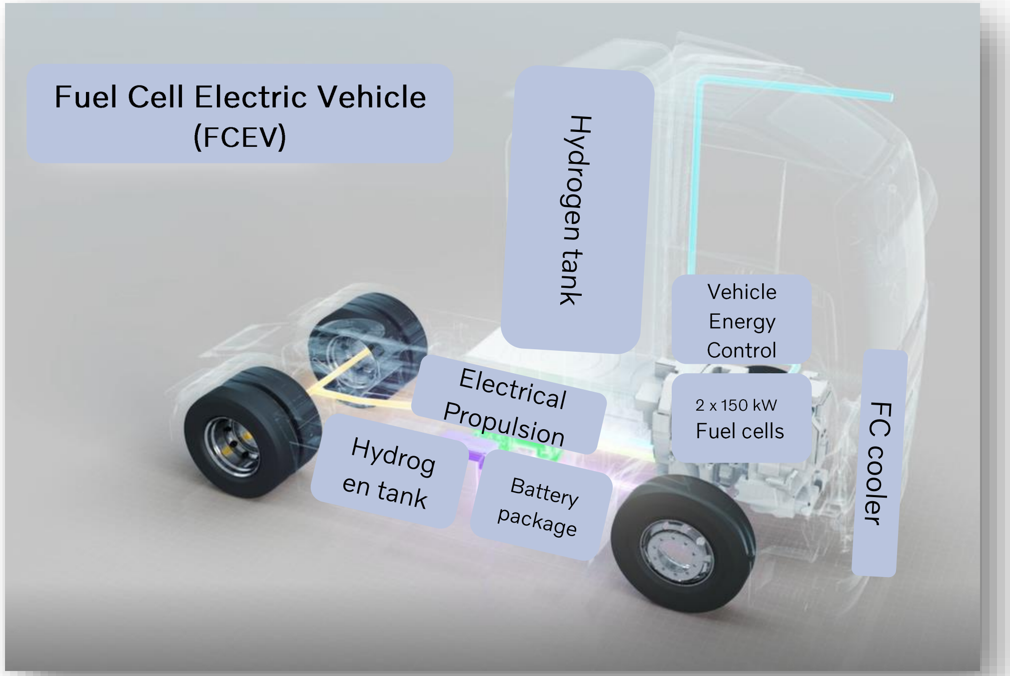


150 kW Net power unit

Fuel cell Electric Vehicle System

Energy & Efficiency Control System:

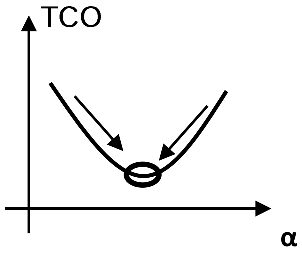
Braking new ground in Power Technology Integration



Fuel cell	**Power capability** depending on degradation and cooling capabilty
Battery system	**Power and energy capability** depending on degradation and cooling capability
Electric Motor	**Power capability** depending on cooling capability
Trans-mission	**Torque demand** depedning on proulsion need
Propulsion Cooling	**Power capability** depedning on degradation and ambient temperature
Brake & brake recovery	**Power capability** depedning on battery state of charge and cooling capability
Transport mission	**Power and energy requirements** depending on transport application (GCW, air drag etc.) and local topography and speed limits

TCO optimization

Energy & Efficiency Control & mission management



VOLVO

The Hydrogen Filling Options – Current Status

H₂ PRHYDE
Protocol for heavy-duty Hydrogen refuelling

2025

2030 ?

350 BAR

- Early Busses
- Early Trains
- Early Hyundai Trucks
- Need higher filling speed

700 BAR

CARS

- Cars, with small nozzle
- Standard for buses under development
- Main track with high filling speed
- **~10% compression loss**

CRYO-COMPRESSED

- High-pressure and cryogenic storage vessels to increase gravimetric and volumetric capacities
- **Potentially lower cooling** and **compression losses** then liquefication

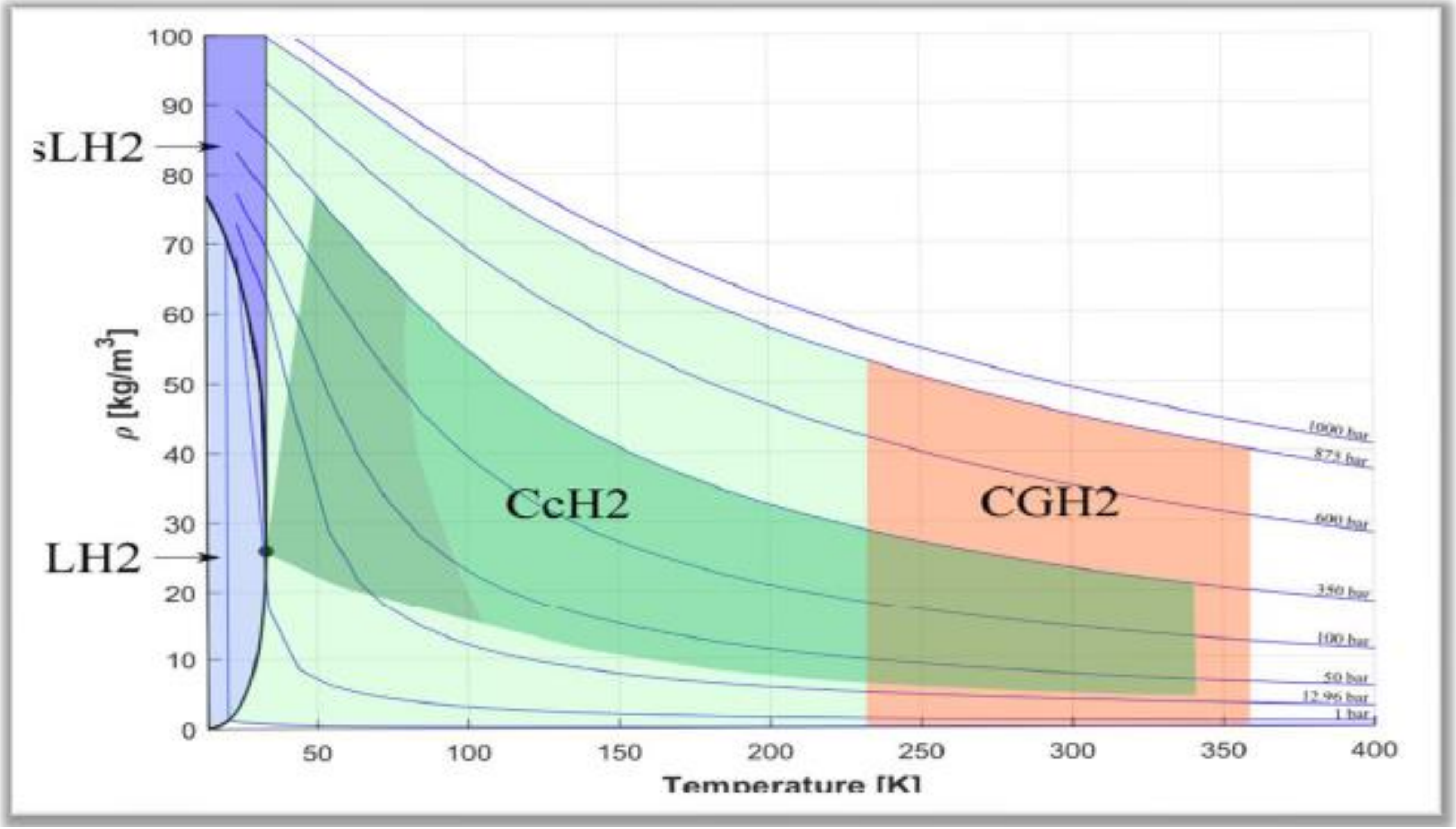
Liquid

- For long distance aircrafts 2035
  Usage for land transports?
  If so, when and how? Cost?
- Not widely available until 2030+
- Germany promote
- Safety issues not fully explored
- **Currently 30% energy loss for liquification**

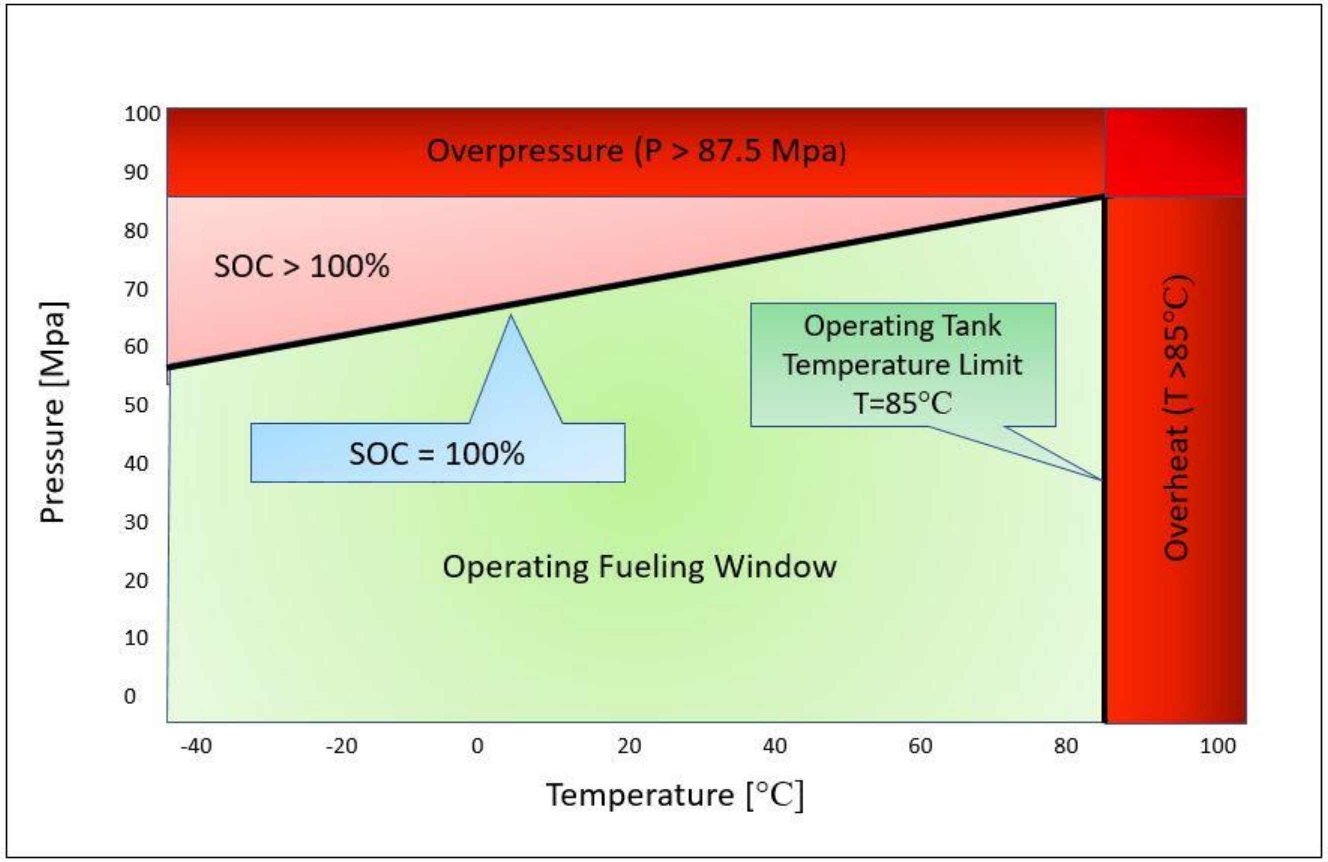
~0.5 kWh / liter | ~1 kWh / liter | ~2 kWh / liter | ~2 kWh / liter

Reference: Diesel: ~10 kWh / liter

Pressure – density Hydrogen



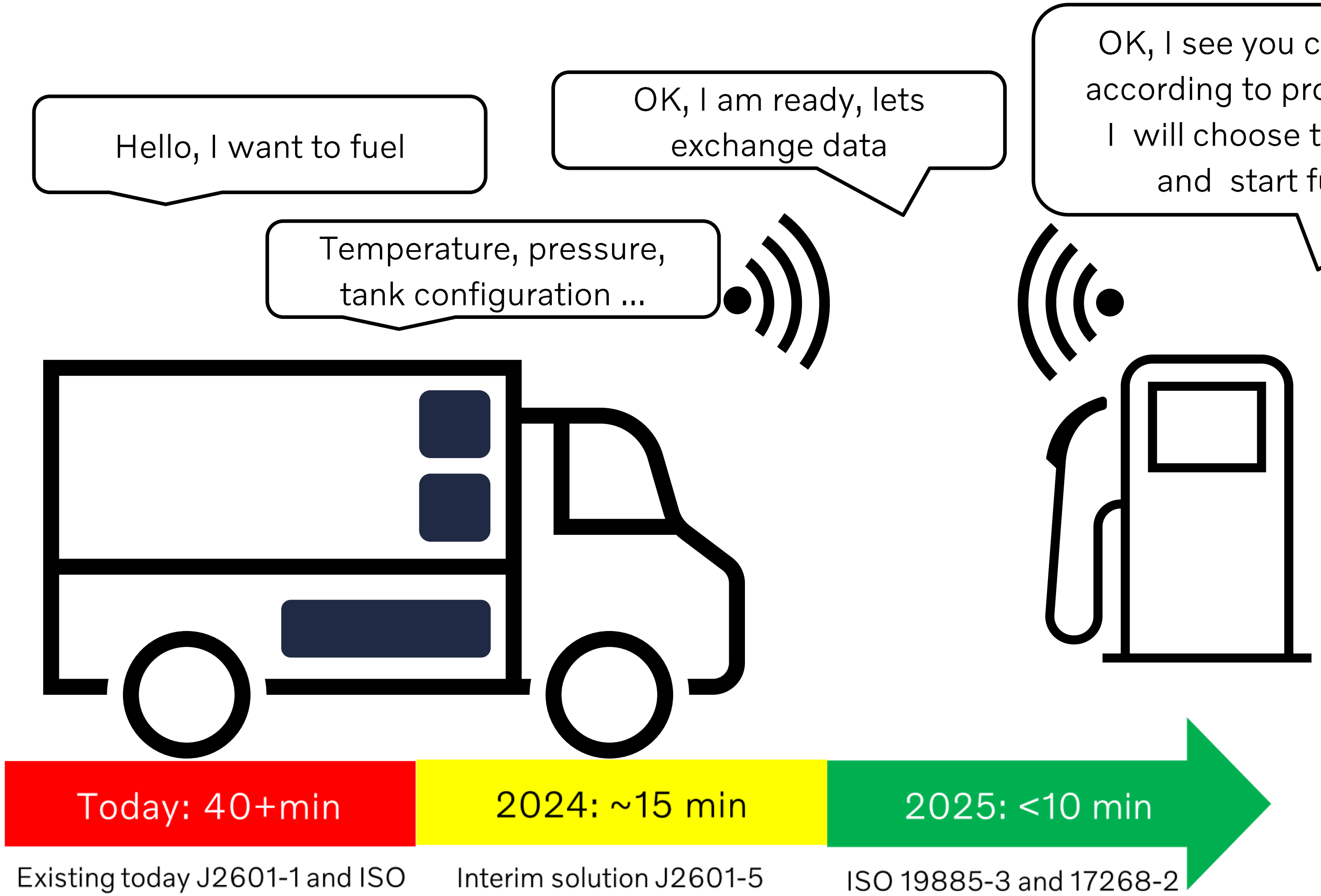
Safe fueling window – 700bar



Heat is generated during fueling

- Joule-Thomson effect of throttling gas from high pressure to lower pressure (non-ideal gas behaviour – i.e dipole interactions and size of molecules)
- Heat of compression (ideal gas behaviour)

Typical fueling situation – Gaseous refueling



Existing today J2601-1 and ISO 17268 for passenger cars

Interim solution J2601-5

ISO 19885-3 and 17268-2

Ongoing standardisation during 2023-2025 to make this work:

- **Nozzle/receptacle capable of high flow**
- **Protocol for fast and safe fuelling**
- **Data transfer structure and hardware**
- **Update of hydrogen fuel quality**

THREE TOPICS THAT MUST BE IN PLACE TO BUILD A MARKET

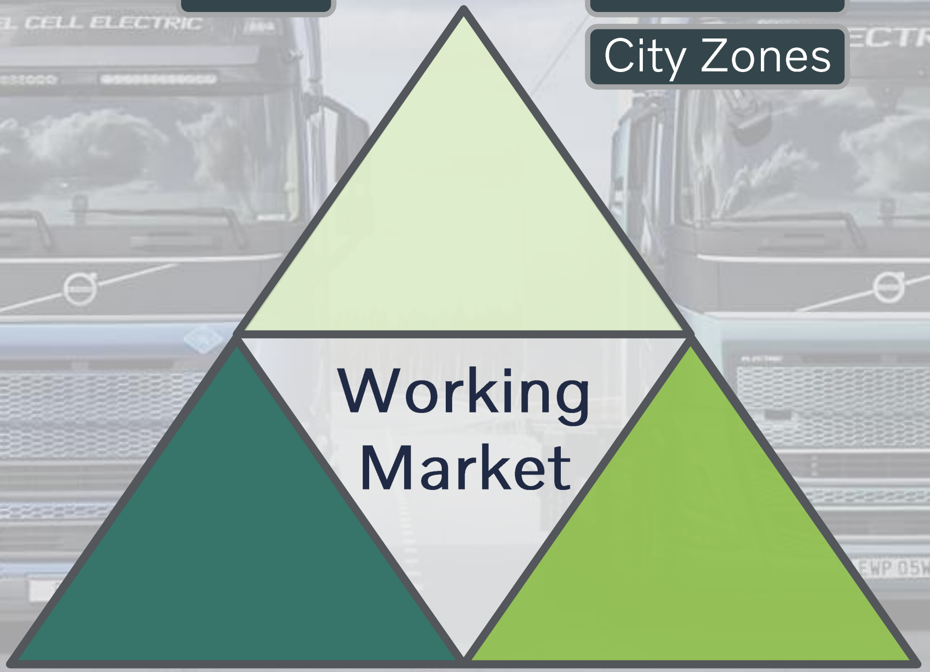
- Active support for infrastructure roll out and early vehicles (valid for all new energies)
- Need for new and different vehicle and energy taxation principles

Policies

Taxes

Subsidies

City Zones



Energy availability

Energy fill / charge speed

Energy cost

Energy filling density

Revenue ability

Product / operational cost

Product offering

Infrastructure

In summary:

Three technological paths needed:

- To decarbonize heavy transportation;
  - battery electric,
  - fuel cell electric
  - combustion engine, (that run on biofuels Hydrogen and e-fuels)
- The best solution depending on regions / type of transports.

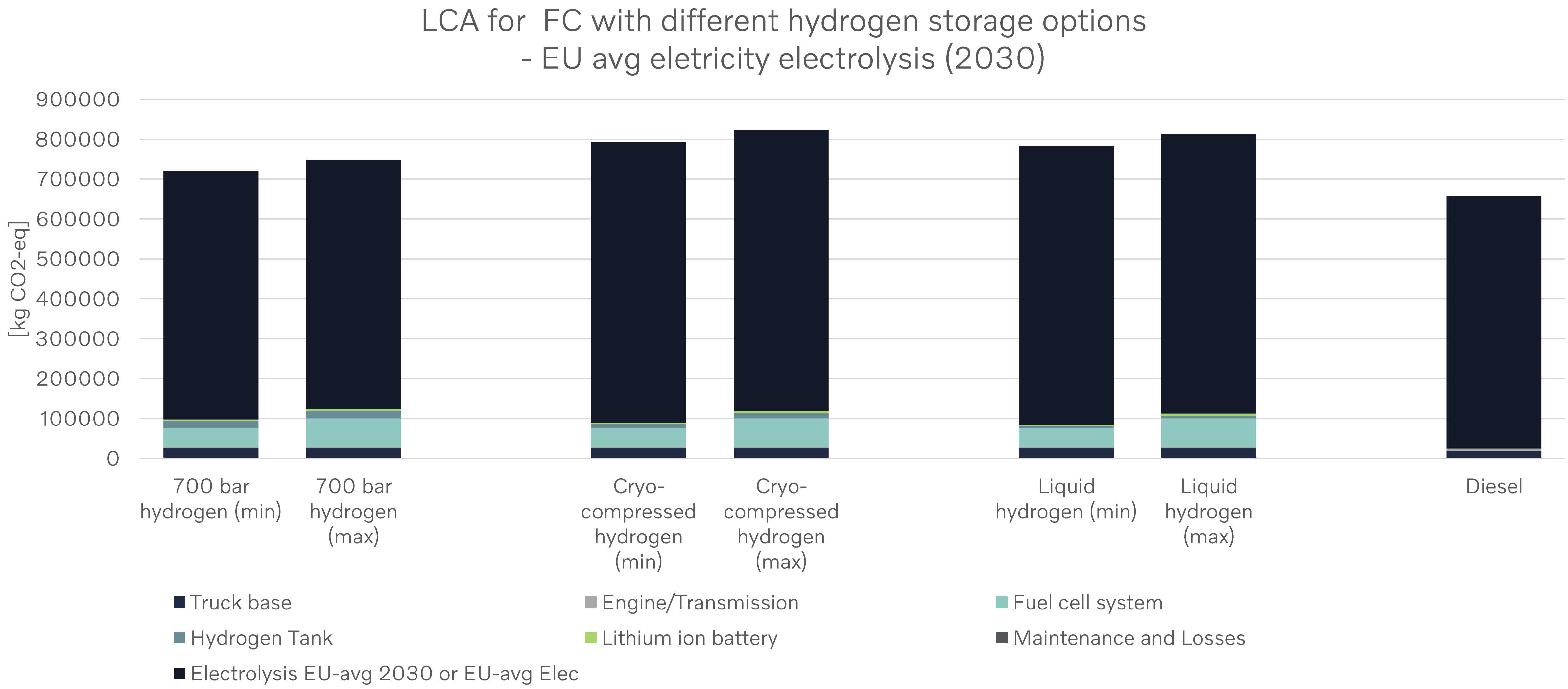
Fuel cell electric trucks:

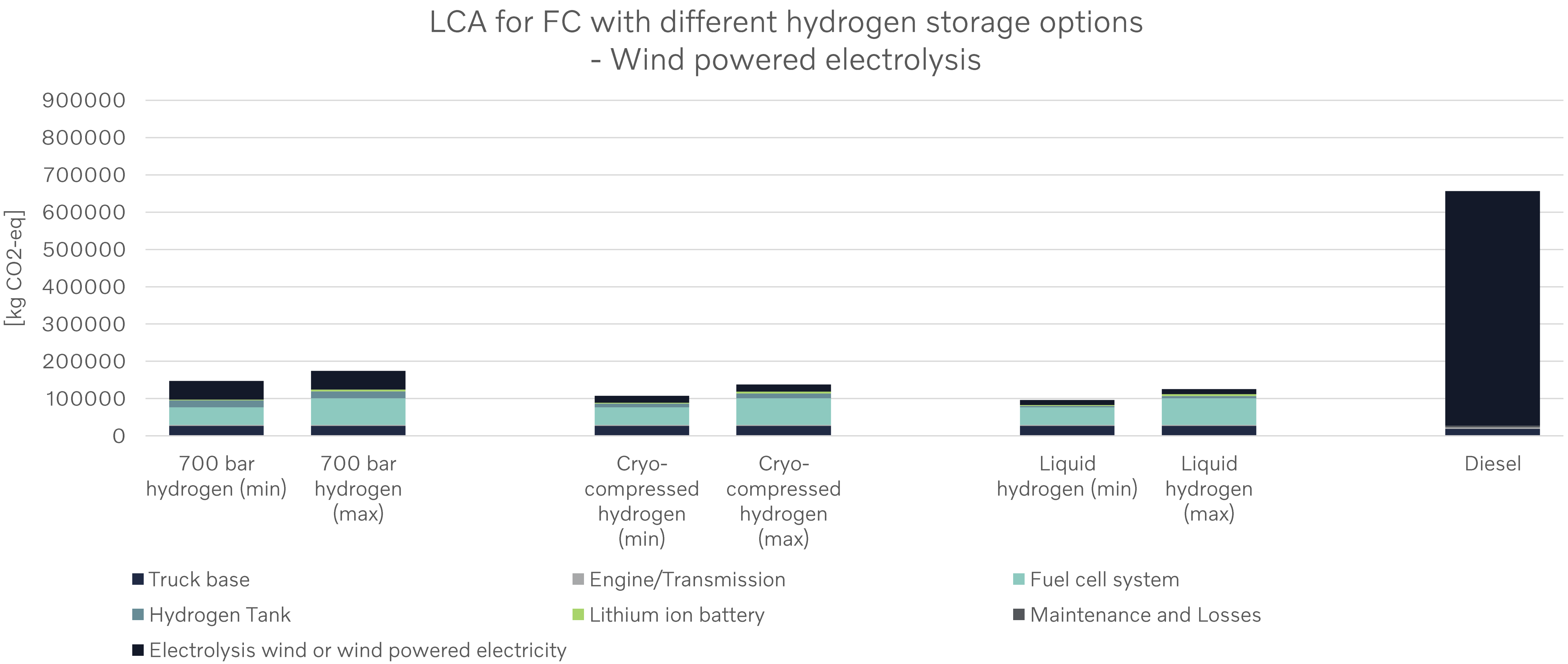
- Volvo Trucks has started testing its first trucks using fuel cell technology.
- Commercially available in the second half of this decade.
- Suitable for long distances and heavy, energy-demanding assignments, (complementing battery electric trucks (BEV).) .
- The fuel cell electric trucks will have an operational range comparable to many diesel trucks – up to 1000 km – and a refueling time of less than 15 minutes.

Infrastructure:

- Hydrogen technology is still in an early phase of development
- One of them is large-scale supply of green hydrogen.
- Refueling infrastructure for heavy vehicles is still to be developed.
  - We expect the supply of green hydrogen to increase significantly during the next couple of years, since many industries will depend on it to reduce CO_2.

Backup

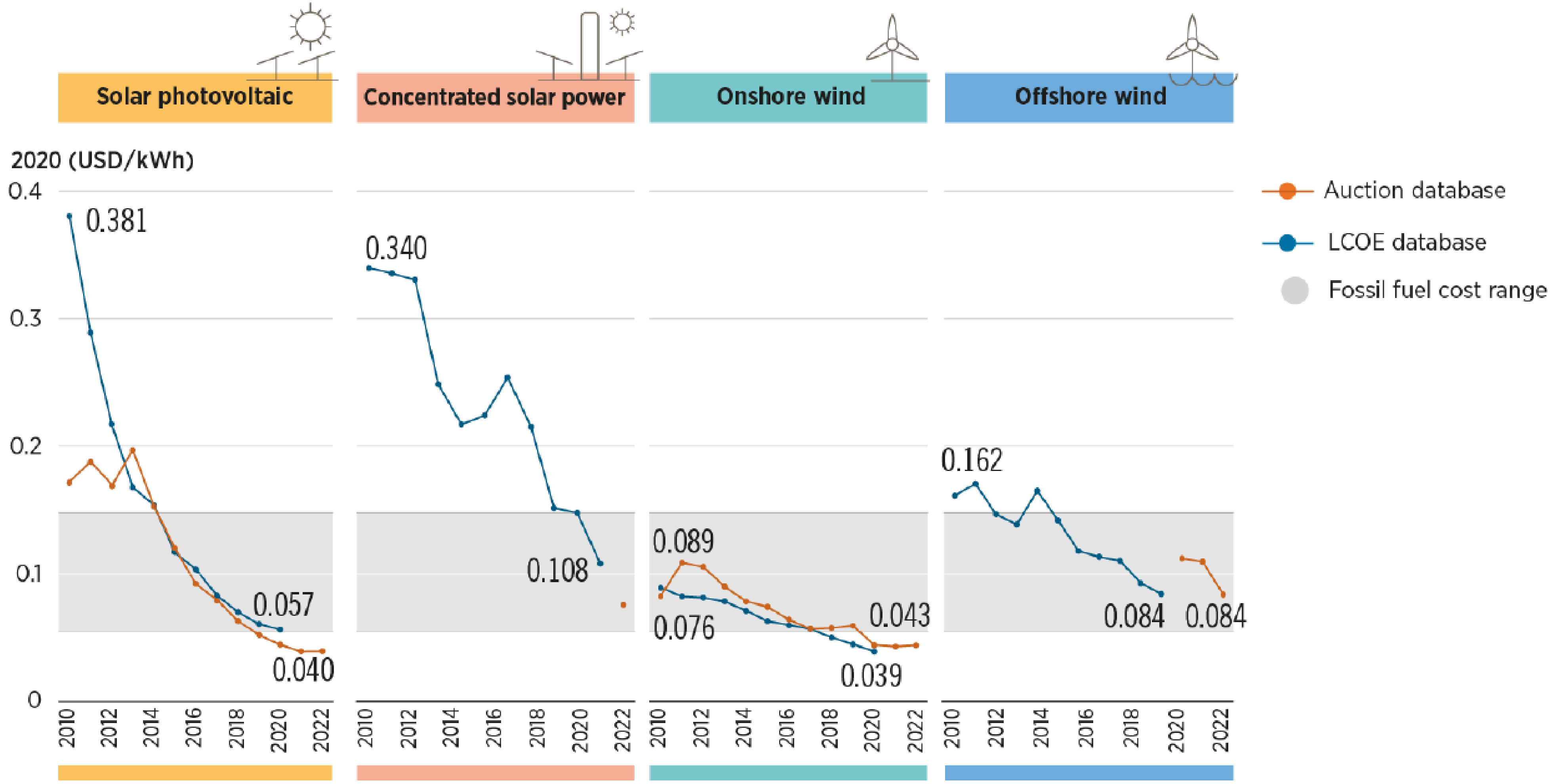

LCA for FC with different hydrogen storage options
- EU avg eletricity electrolysis (2030)
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
[kg CO2-eq]
700 bar hydrogen (min)
700 bar hydrogen (max)
Cryo-compressed hydrogen (min)
Cryo-compressed hydrogen (max)
Liquid hydrogen (min)
Liquid hydrogen (max)
Diesel
Truck base
Engine/Transmission
Fuel cell system
Hydrogen Tank
Lithium ion battery
Maintenance and Losses
Electrolysis EU-avg 2030 or EU-avg Elec



LCA for FC with different hydrogen storage options
- Wind powered electrolysis
[kg CO2-eq]
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
700 bar hydrogen (min)
700 bar hydrogen (max)
Cryo-compressed hydrogen (min)
Cryo-compressed hydrogen (max)
Liquid hydrogen (min)
Liquid hydrogen (max)
Diesel
Truck base
Engine/Transmission
Fuel cell system
Hydrogen Tank
Lithium ion battery
Maintenance and Losses
Electrolysis wind or wind powered electricity

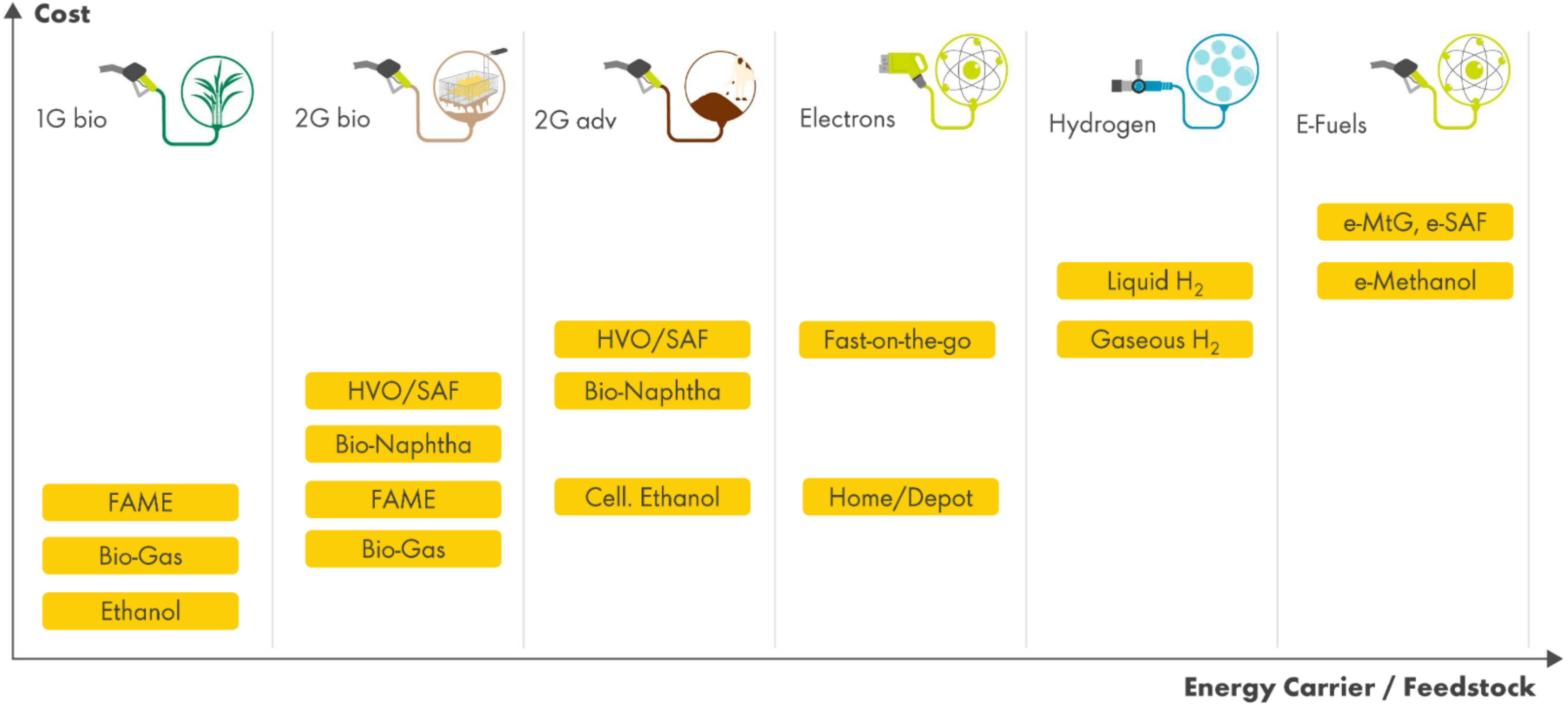
Renewables-based electricity: already cheapest power option in most regions

IRENA
International Renewable Energy Agency



Global weighted average levelised cost of electricity from utility-scale solar photovoltaic (PV) projects fell by 85% 2010 - 2020, concentrating solar power (CSP) 68%; on-shore wind 56%, off-shore wind 48%.

Cost ladder of decarbonisation fuels



Ref: Shell

Summary

Q&A