DO NOT COUNT NATURAL GAS / GAS TURBINES OUT YET
2030 & 2050 TARGETS
ECONOMICS WILL GOVERN

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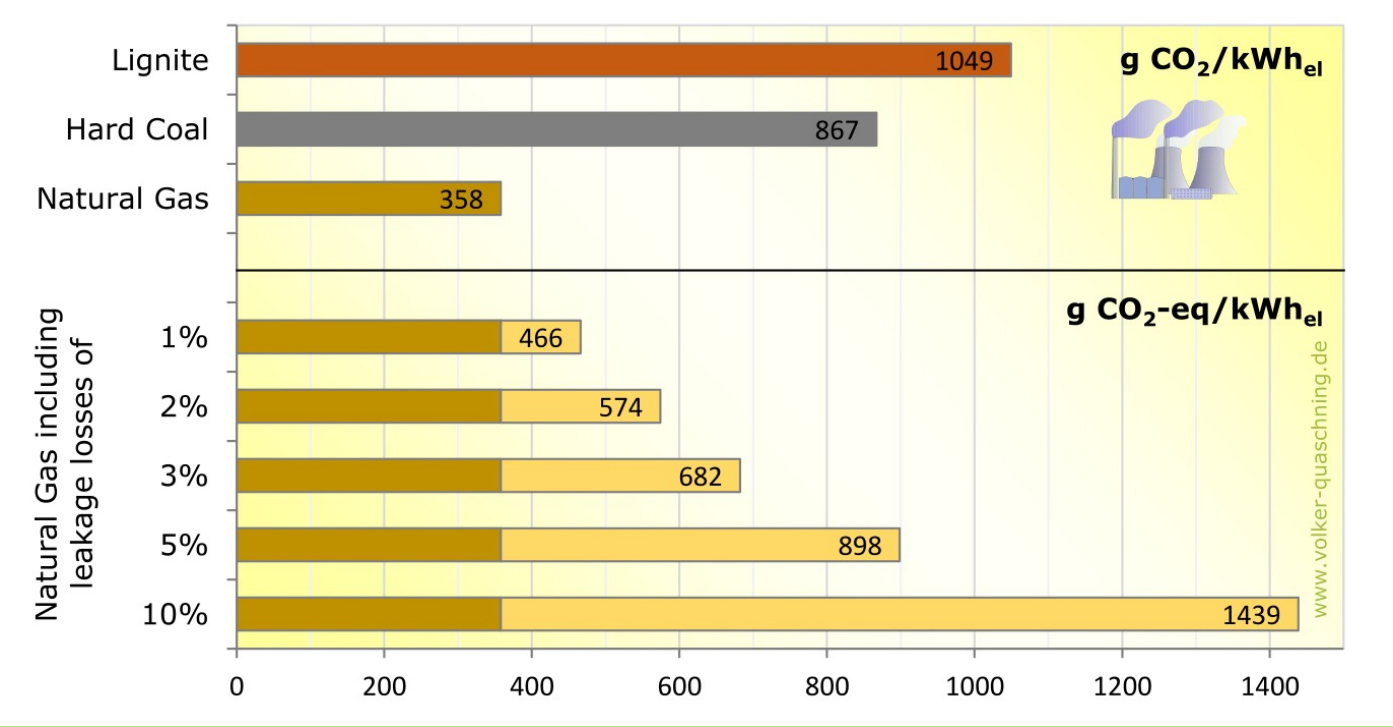
CO2 EMISSIONS FOSSIL FUELS

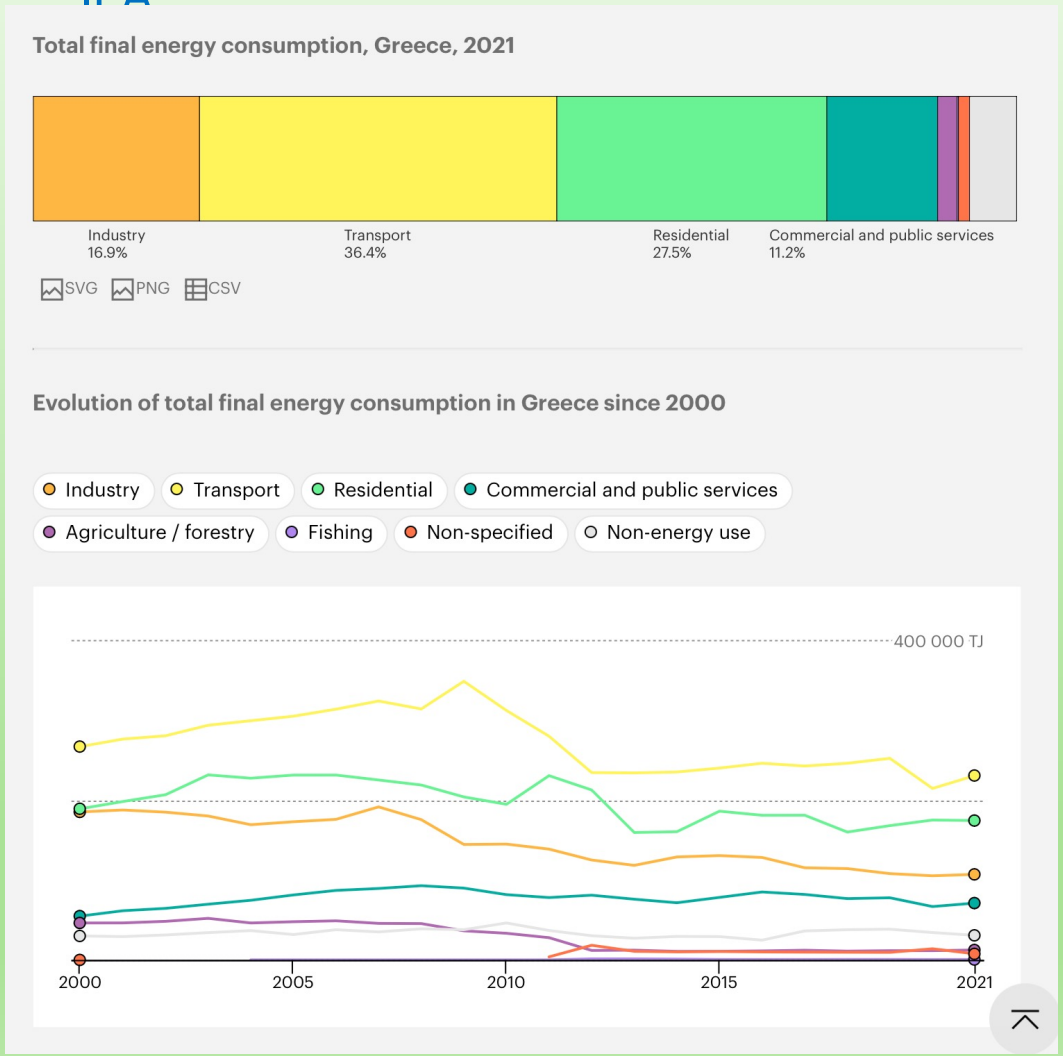
Volker-quaschning Germany

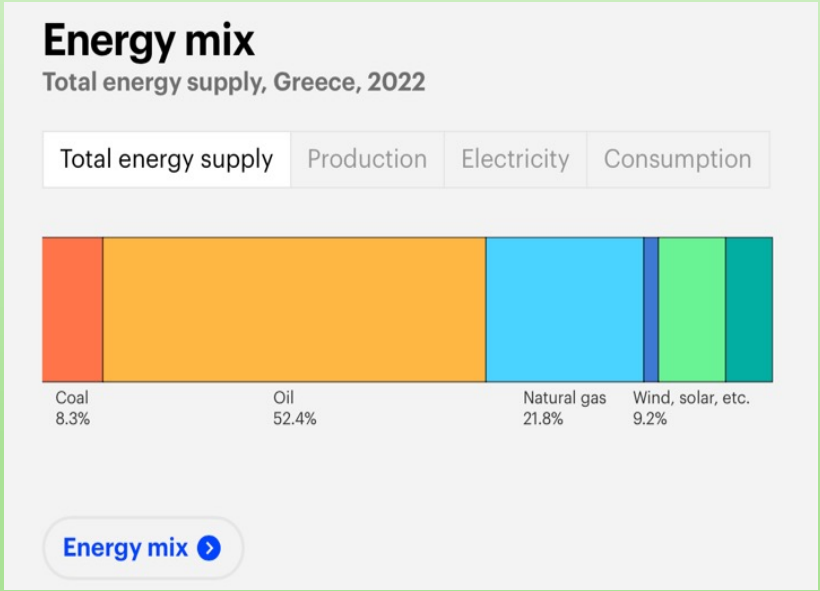


Note the Methane Leakage Problem

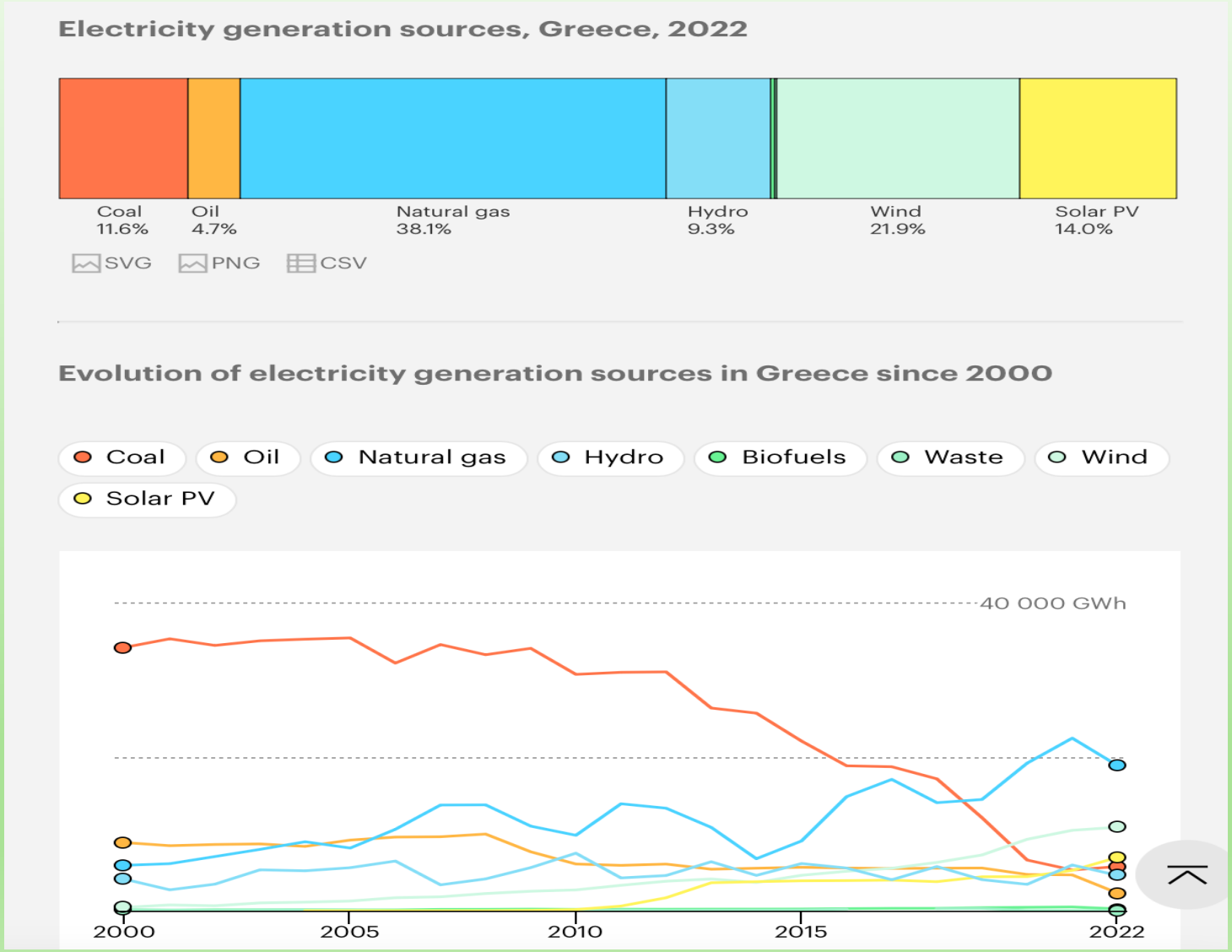
GREECE: FINAL ENERGY CONSUMPTION

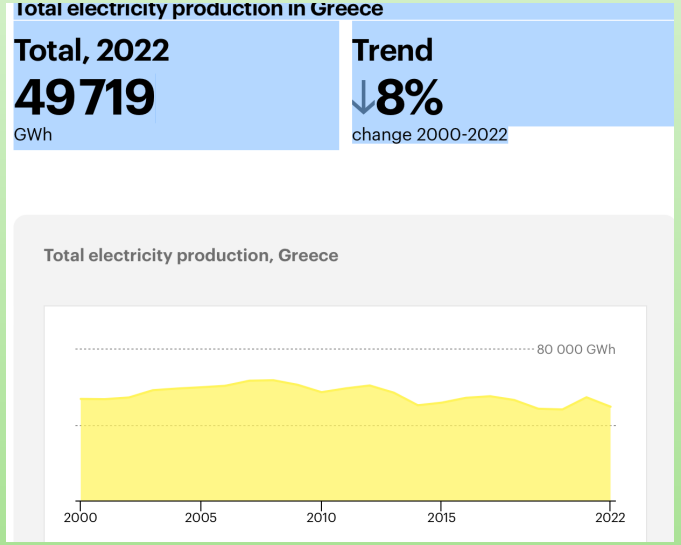
IEA





GREECE: ELECTRICITY GENERATION SOURCES





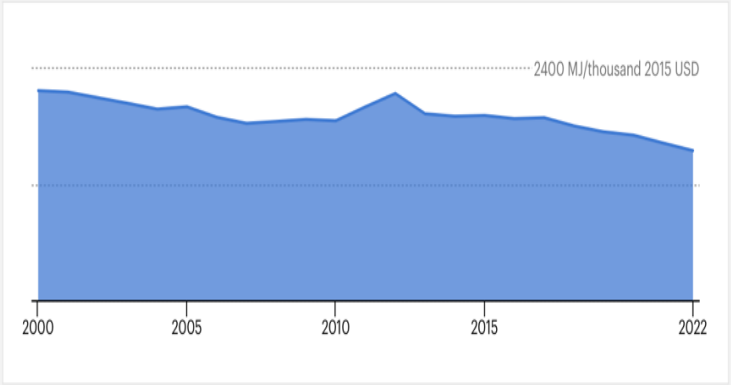
GREECE: SUPPLY PER UNIT OF GDP & **CO2**

IEA

Total energy supply per unit of GDP in Greece

Total, 2022	Trend
1551.966	**↓29%**
MJ/thousand 2015 USD	change 2000-2022

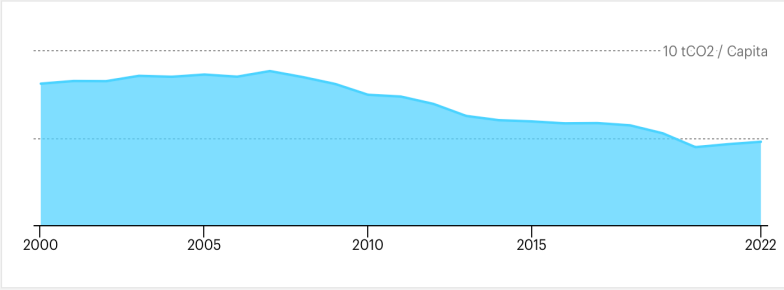
Total energy supply per unit of GDP, Greece



CO2 emissions per capita in Greece

Total, 2022	Trend
4.794	**↓41%**
tCO2 / Capita	change 2000-2022

CO2 emissions per capita, Greece



REVIEW WHERE WE ARE: GROUP 1

Focus on Technologies

1	**RENEWABLE ENERGY**
	1.1 Solar
	1.2 Wind
	1.3 EES Electrical Energy Storage
	1.3.1 Electrical Battery Storage
	1.3.2 Conventional Energy Storage
	1.3.3 Mechanical - CO2 Dome Storage
2	**HYDROGEN**
	2.1 Blue Hydrogen
	2.2 Green Hydrogen (Catalysts / Nobel Metals Concern)
	- 2.2.1 Electrolyser -**Alkaline**
	- 2.2.2 Electrolyser **PEM**
	2.3Transport of Hydrogen
	2.4 Storage of Hydrogen
	2.5 Hydrogen Derivatives – Methanol & SAF
	2.6 Fuel Cells
3	**HYDRO**
	3.1 Large Projects
	3.2 Medium / Small Projects
	3.3 Hydro Storage

REVIEW WHERE WE ARE: GROUP 2

Focus on Technologies

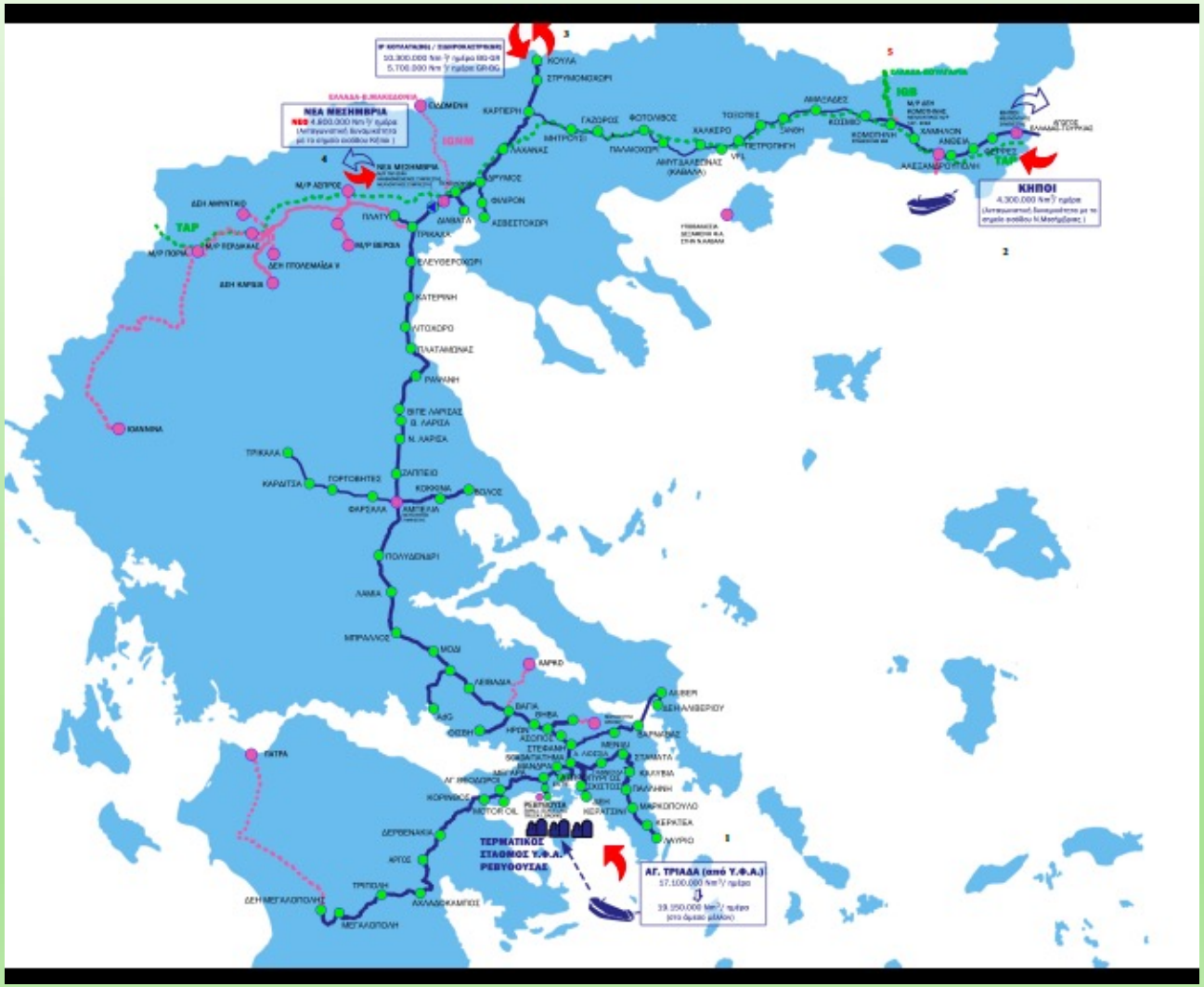
4	**NATURAL GAS**
	4.1 Heavy Industries
	4.2 Power Generation
	4.3 Gas Turbines / Internal Combustion Engines / Conventual Steam Turbines – [Pre-Combustion & After-Combustion CO2 Capture}
	4.4 Methane Leakage
	4.5 NG Power Generation -Technical Characteristics
5	**H2 AND NATURAL GAS MIX**
6	**CARBON CAPTURE**
	6.1 Capturing CO2
	6.2 Direct Air Capture (DAC)
	6.3 CO2 Sequestration
	6.4 CO2 Transport - [Gas & Liquid CO2 & Mix of the two]
	6.5 CO2 Storage
	6.6 CO2 Utilization

REVIEW WHERE WE ARE: GROUP 3
INCLUDING OTHER KEY ELEMENTS

7	AMMONIA
8	NUCLEAR POWER (NP)
9	ENERGY SAVING
	9.1 Buildings
10	DIGITIZATION
11	STANDARDIZATIONS
12	INTEGRATED PROJECTS & CO-LOCATION
13	CERTIFICATIONS
14	CARBON INCENTIVES & CREDITS

GREECE- NATIONAL NATURAL GAS SYSTEM

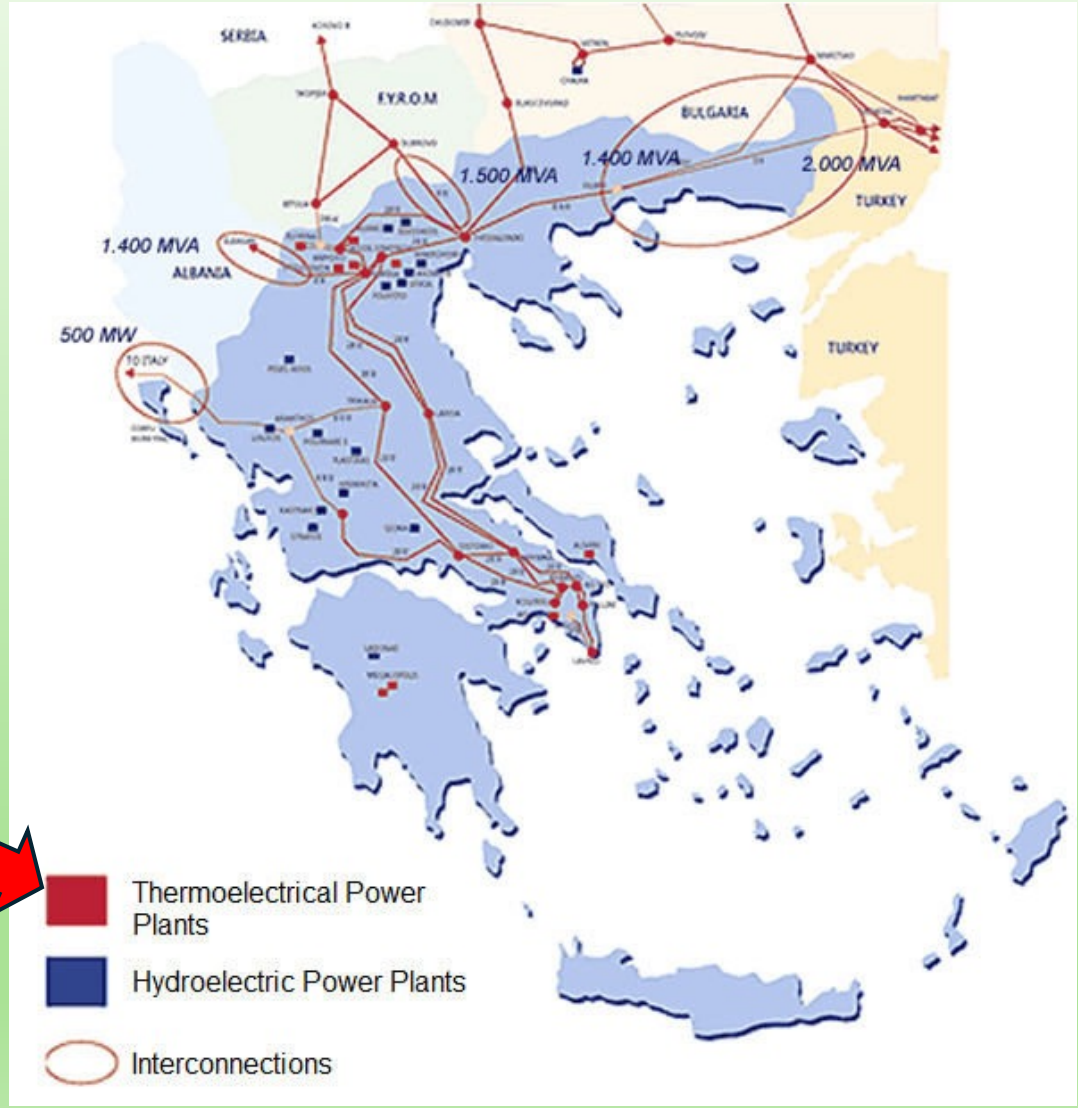
DESFA



Target
Major Users

GREECE – NATIONAL ELECTRICAL SYSTEM

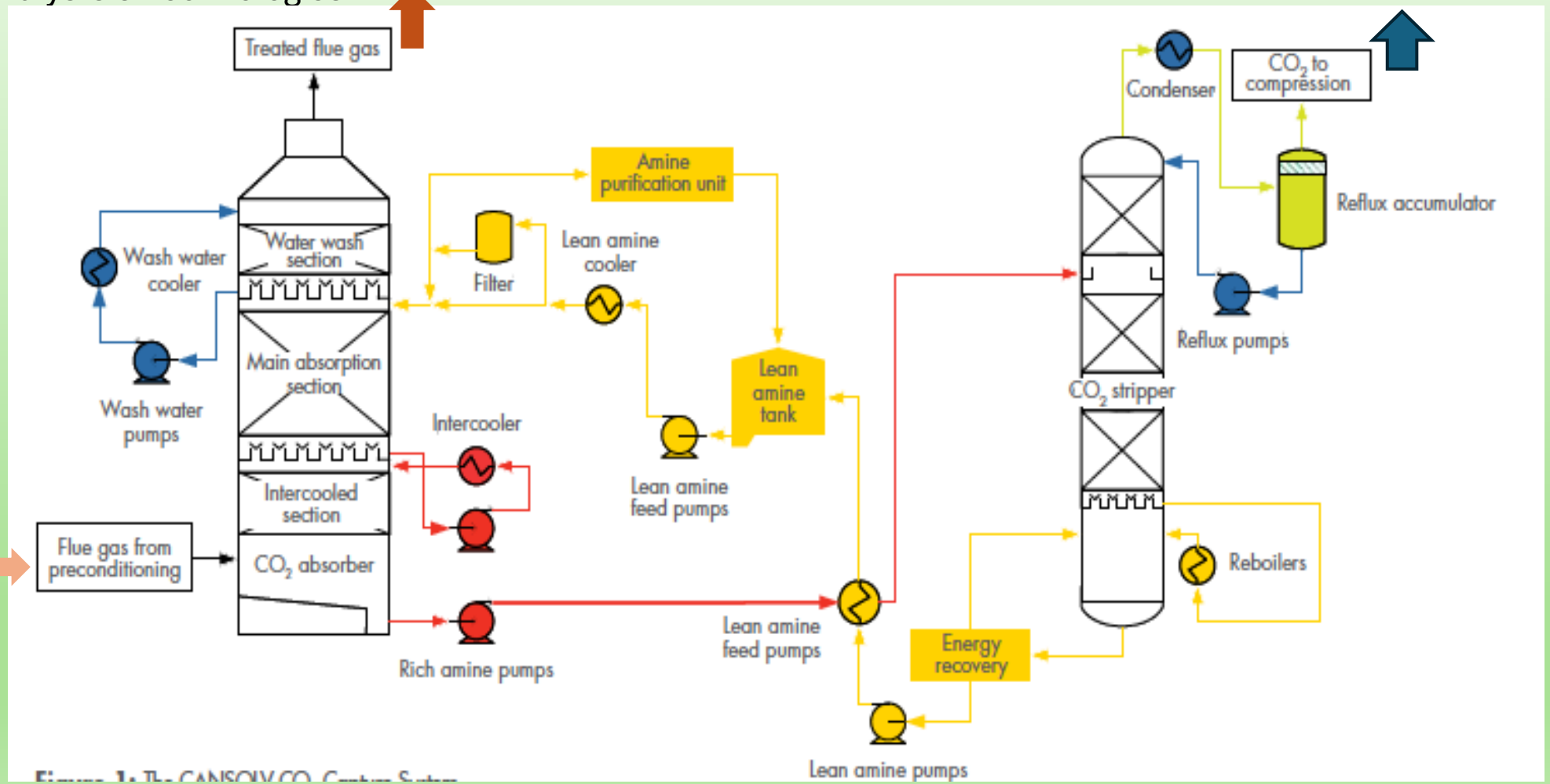
DEH



Greek Islands

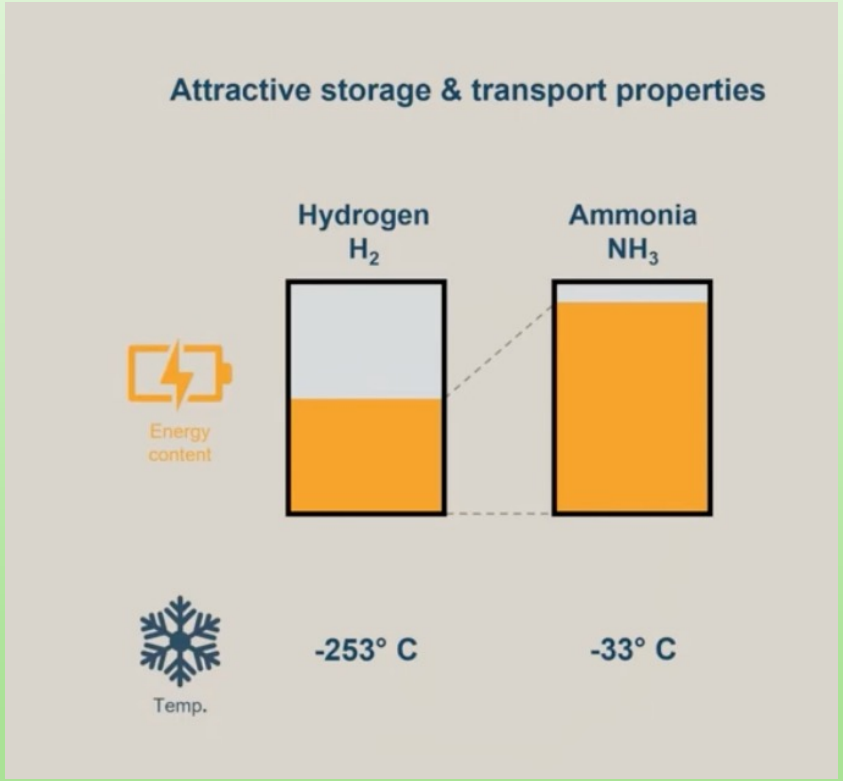
Shell CO2 Separation (from Exhaust Gas)

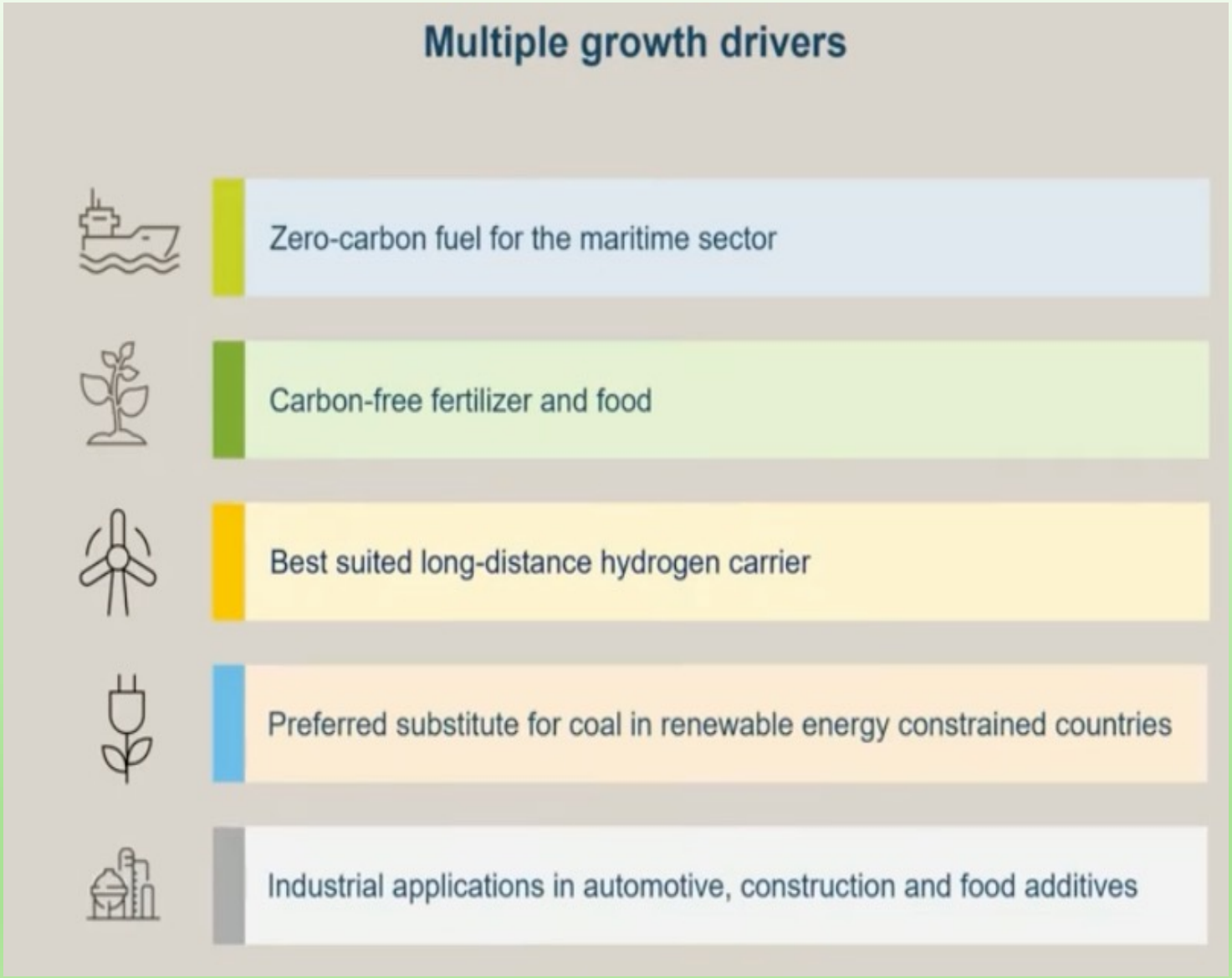
Shell Catalysts & Technologies



Why Ammonia?

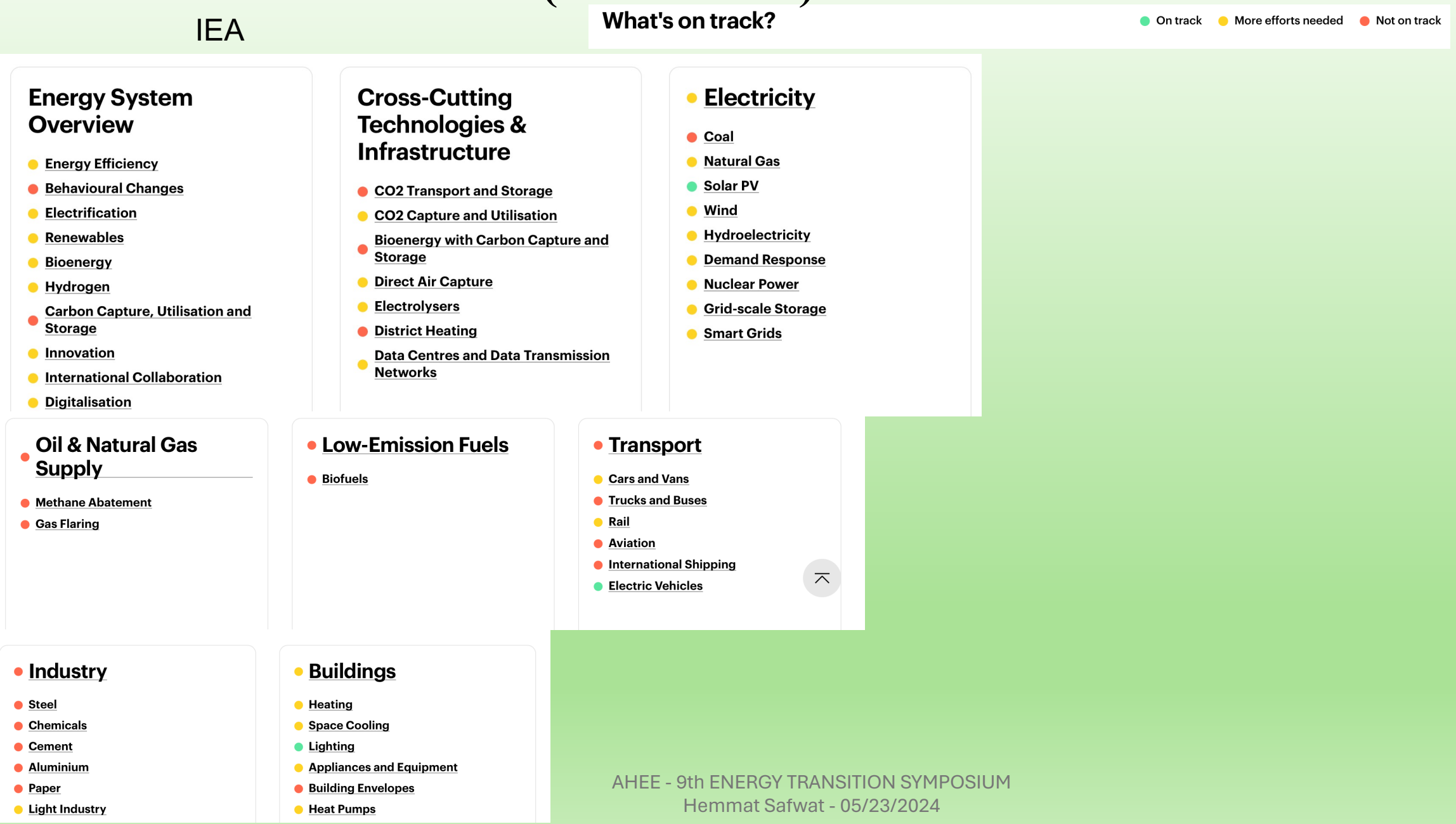
Yara Clean Ammonia



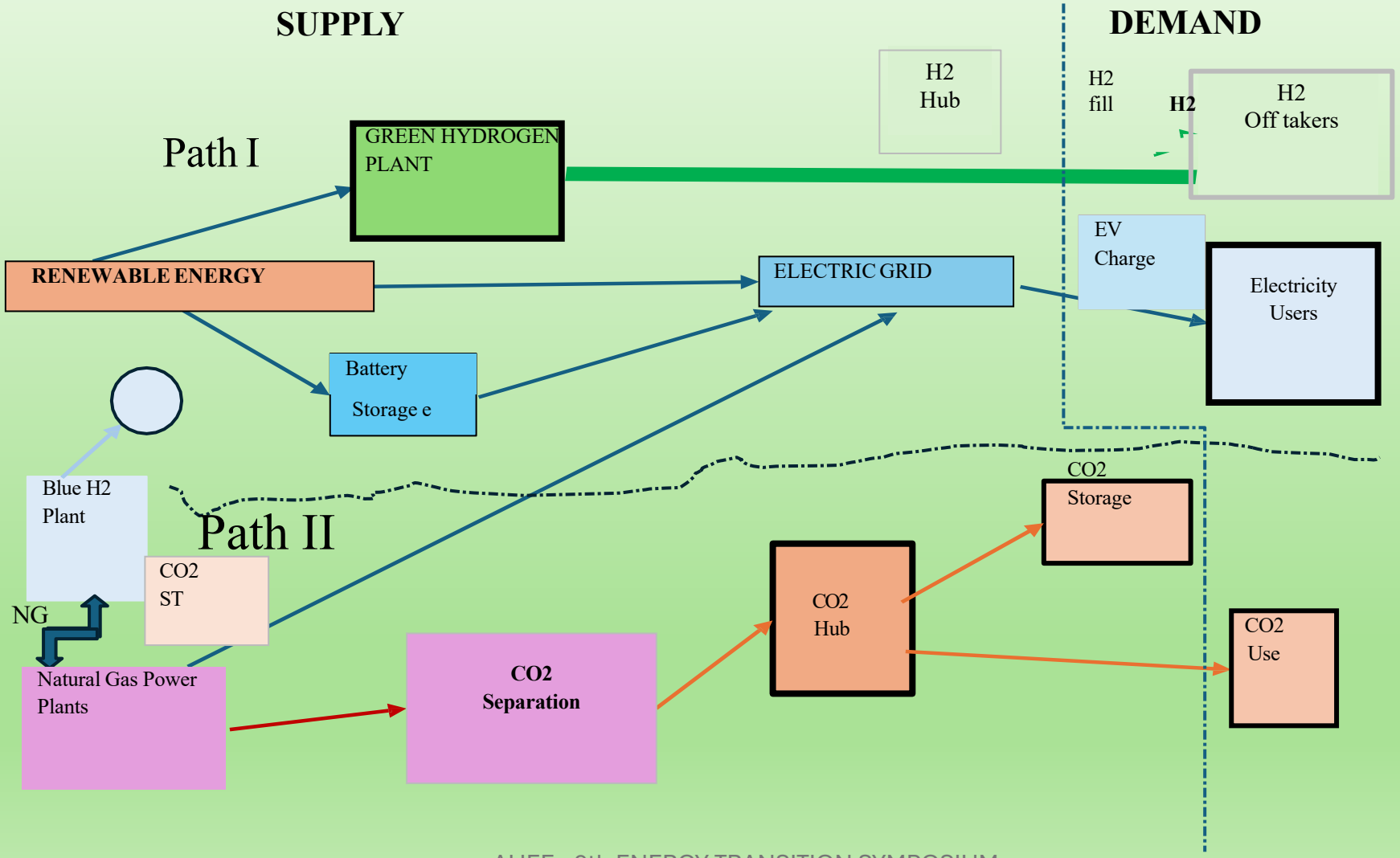


IEA Assessment (End of 2023)

IEA



PATHS TO DECARBONIZATION – I "MAIN"& II "BACKUP"



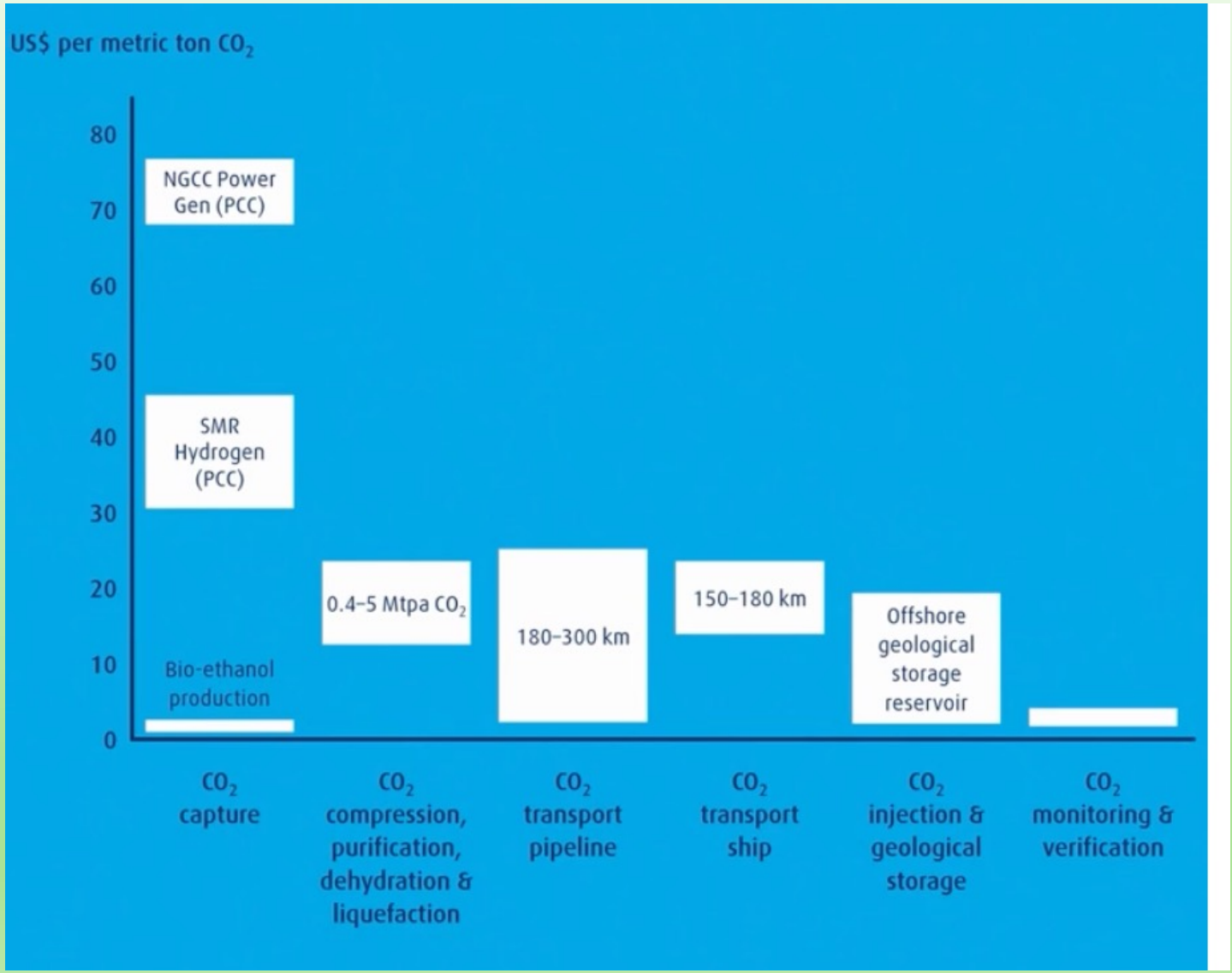
ECONOMICS – INDICATIVE PRICING

- Green Hydrogen Plant – 3.63 $/kg H2
  - ❖ Simplifying Assumptions
  - o 55 kWh/kg
  - o 35% of that energy is from RE at a priced of .04 $/kWh
  - o 65% is from network price of .08 $/kWh. This leads to a weighted average of .066 $/kWh
  - ➢ **The electrical consumption amounts to 3.63 $/kg H2. *Quite high compared to goal of 1 $/kg H2***
- Battery Storage – 0.074 $/kWh
  - ❖ Simplifying Assumptions
  - o price of 350,000 $/MWH installed
  - o The battery will be charged to level 95% and discharged to 40% level, meaning .55 MWh daily.
  - o This means approximately 200,000 kWh per year . With degradation over 10 years an average of 180,000 kWh.
  - ➢ **Average price per kWh short term storage is 0.074 $/kWh – *Excessive compared to PV tariff of less than.04 $/kWh***
- Capture of CO2 from NGCC plant -0.023 $/kWh
  - ❖ Simplifying Assumptions
  - o If one takes an example of an operating GE F4 (2GTs+1) plant with rated power of 889 MW, heat rate 5960 kJ/kWh.
  - o using a price of natural gas 3 $/mmBTU, t
  - o The fuel cost is approximately .017 $/kWh
  - o uses the high cost of capture of 75 ton of CO2
  - ➢ **Added cost per kWh is 0.023 $/kWh – *Higher than the fuel cost.***

Above costs are not all inclusive what goes in setting the tariff, but they are indicative of the challenges faced.

INDICATIVE CO2 PRICING

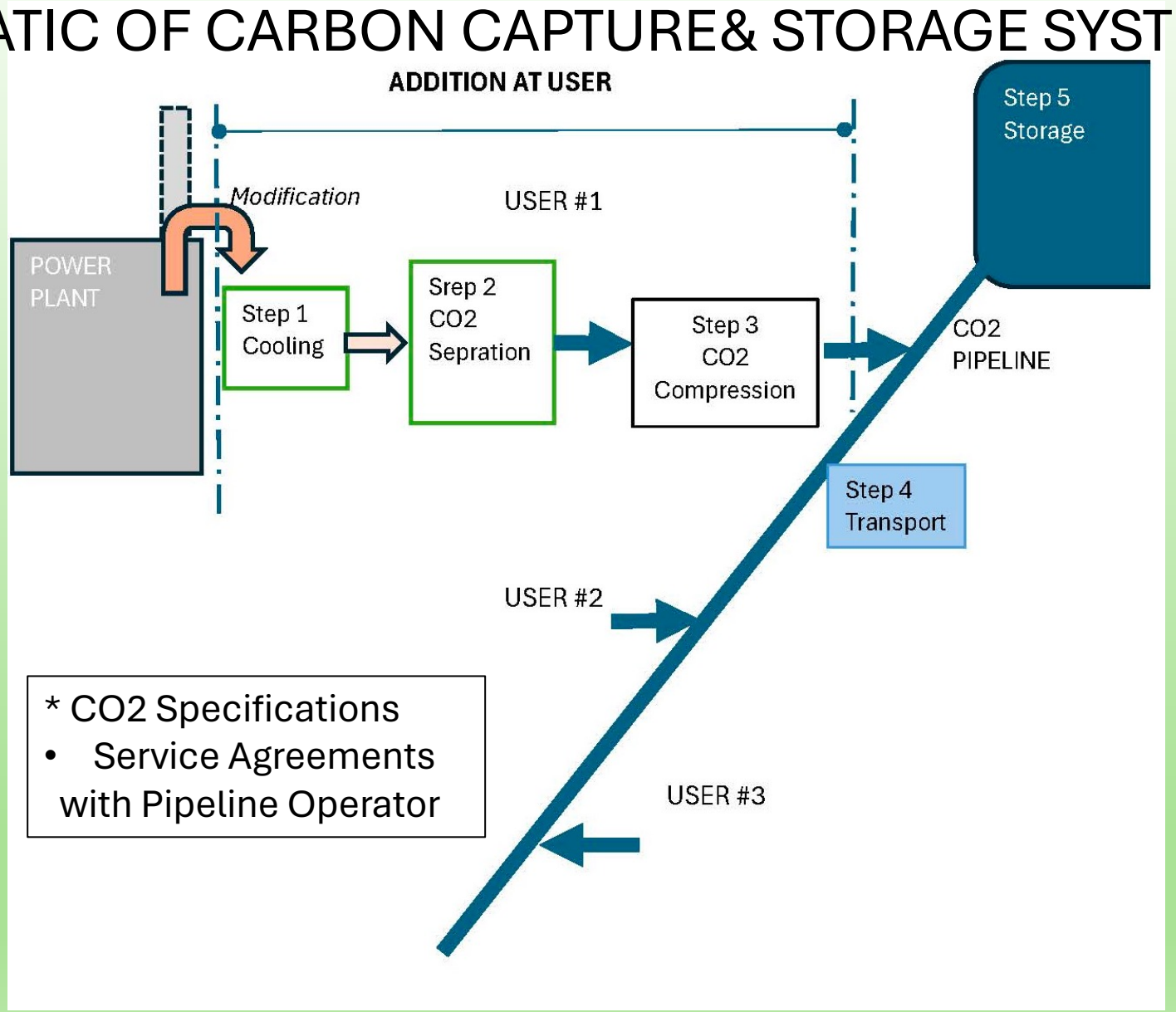
Linde



EU ETS PRICE presently is about Euro 70/ton of CO2

SIMPLIFIED SCHEMATIC OF CARBON CAPTURE& STORAGE SYSTEM

SCHEMATIC FOR CO2 CAPTURE & STORAGE SYSTEM



Numerous CO2 CCUS Projects around the world US, Canada, Norway, The Netherlands, France, Germany, UK. Denmark and others at various stages:

- *Early Development*
- *Advanced Development*
- *Under Construction*
- *Operational*

EXGAMPLE FOR CCS – PORTHOS , ROTTERDAM, THE NETHERLANDS

Gas Unie

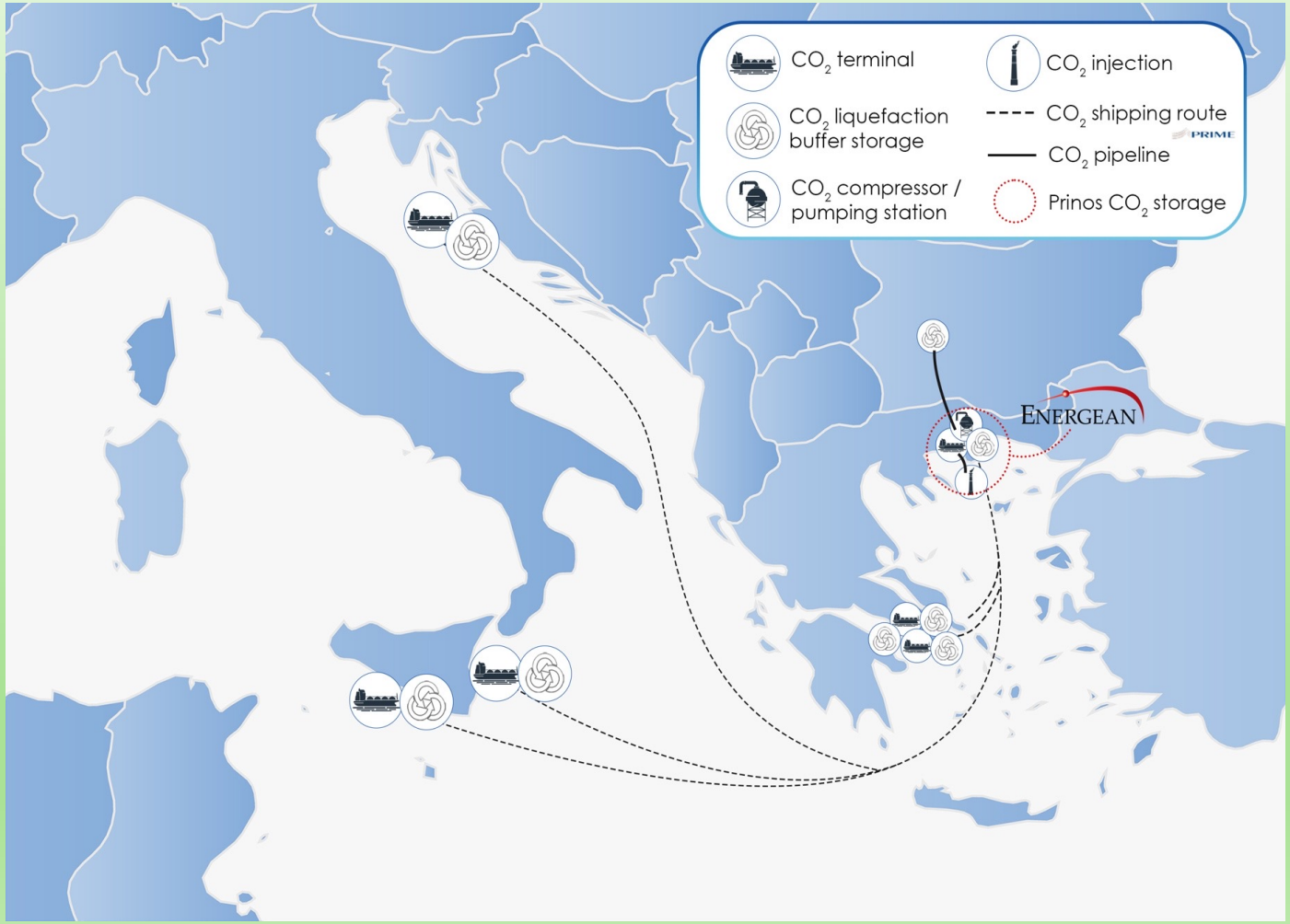
- **Porthos has taken a final investment decision to develop the first major CO_2 transport and storage system in the Netherlands. In 2024 construction will begin in Rotterdam, with the Porthos system expected to be operational by 2026. The Porthos infrastructure requires an investment of €1.3 billion. With the final investment decision reached, Porthos will now award contracts required to realize the project.**

- **Onshore 42” Dia. pipe, 35 bar, 35 km, Compressor station, 130 bar, Offshore 16” Dia. pipe, liquid CO2, 22 km**

- Porthos is a joint venture of EBN, Gasunie, and the Port of Rotterdam Authority. Porthos will provide transport and storage services to several companies in the port of Rotterdam, including **Air Liquide, Air Products, ExxonMobil, and Shell. These companies will invest in their own capture installations to supply CO_2 to Porthos**. Porthos will transport the CO_2 through the port of Rotterdam to depleted gas fields in the North Sea, approximately 20 km off the coast, where it will be permanently stored at a depth of 3 to 4 km under the seabed. Porthos plans to store about 2.5 Mton per year for 15 years, total of around 37 Mton. With that, Porthos has contracted its full storage capacity. The onshore transport system under construction allows for future CO_2 storage projects.

PRINOS CO2 – CCS, GREECE

ENERGEAN



CCS in Greece is progressing rapidly, with success at the recent EU Innovation Fund's third call for large- scale projects for Titan Cement and Motor Oil Hellas. Energean's storage project Prinos has also applied in the sixth edition of the PCI list. Finally, Greece's regulator Herema is making good progress on the policy, legal, and regulatory front.

COMMENTS:

- **Waste / Reject / Reuse**

- **Business Economics Knowledge – Energy[2] & Capital versus HAEE Energy Economics**

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2 Book Published 2022 - AMAZON

CONCLUDING REMARKS - GREECE

- Energy Savings
  - ❑ Buildings
  - ❑ Transport
- Time is Pressing: **Natural Gas – Carbon Capture (Path II of Slide # 15)**
- Alignment of Main Users of Natural Gas for CCUS Services.
- Tackle the Difficulty of GTs Lean CO2 Exhaust
- **ACCELERATE CO2 CCUS IMPLEMENTATION – (consider large Islands)**
- Consider Importation of Ammonia from MENA (Tackle NH3 Combustion in GTs)
- **ECONOMICS WILL GOVERN**: Technologies Combination + Regulatory Requirements & Incentives:
  - For the User Covering its needs of kWh's electricity and /or kWh's heat energy at the right price for kWh with maximum avoidance of CO2.

Thank you

For further details consult the paper under the same title

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