



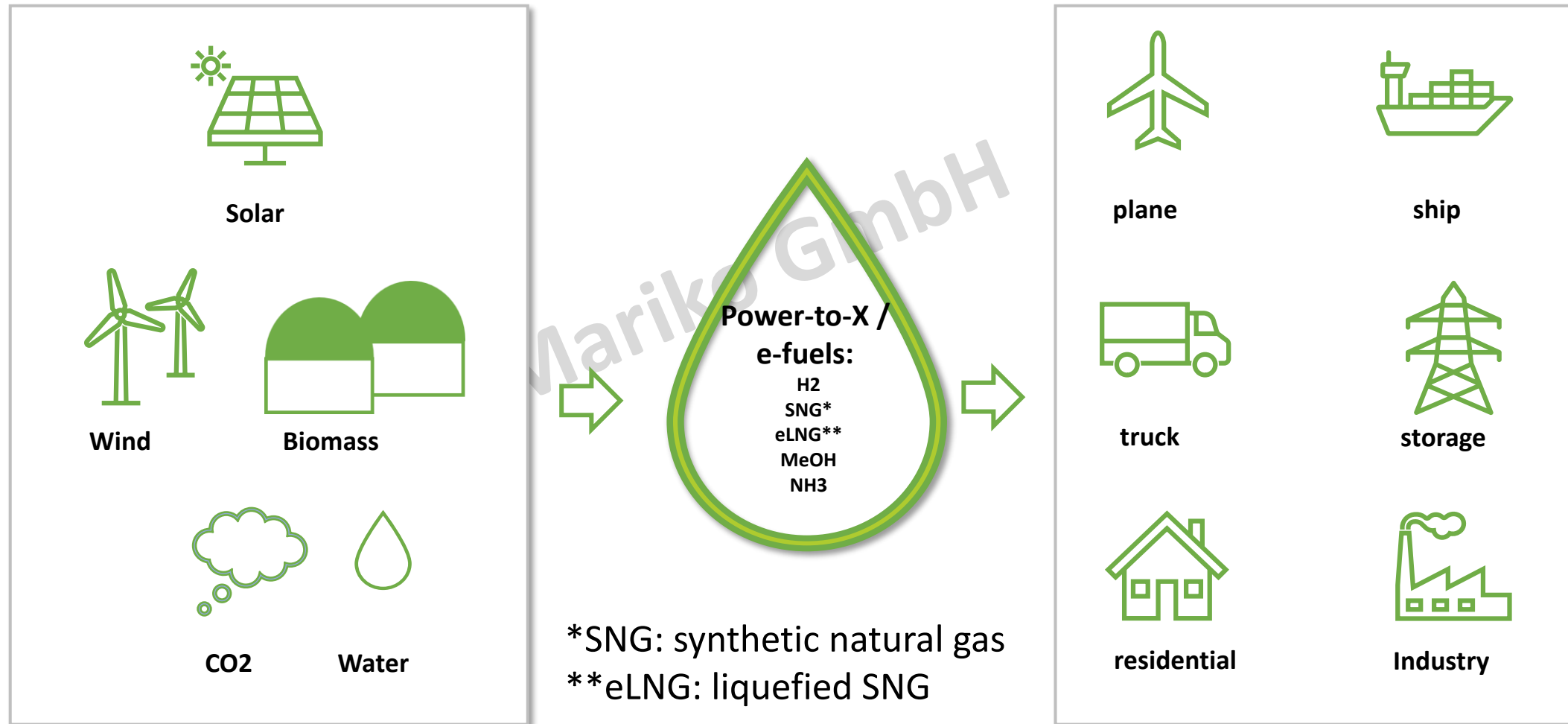
Decarbonizing the shipping industry

# PROBLEM

- **dependency** 90% of all fossil fuels are produced by less than 10 countries
- **price insecurity** natural gas and oil prices show extreme volatility
- **supply insecurity** due to political instability
- **unfair wealth distribution** increasing social instability
- **climate change** fossil fuels are the main influencing factor



# e-fuels / Power-to-X fuels are produced from renewable electricity, water, CO<sub>2</sub> or nitrogen and are climate neutral







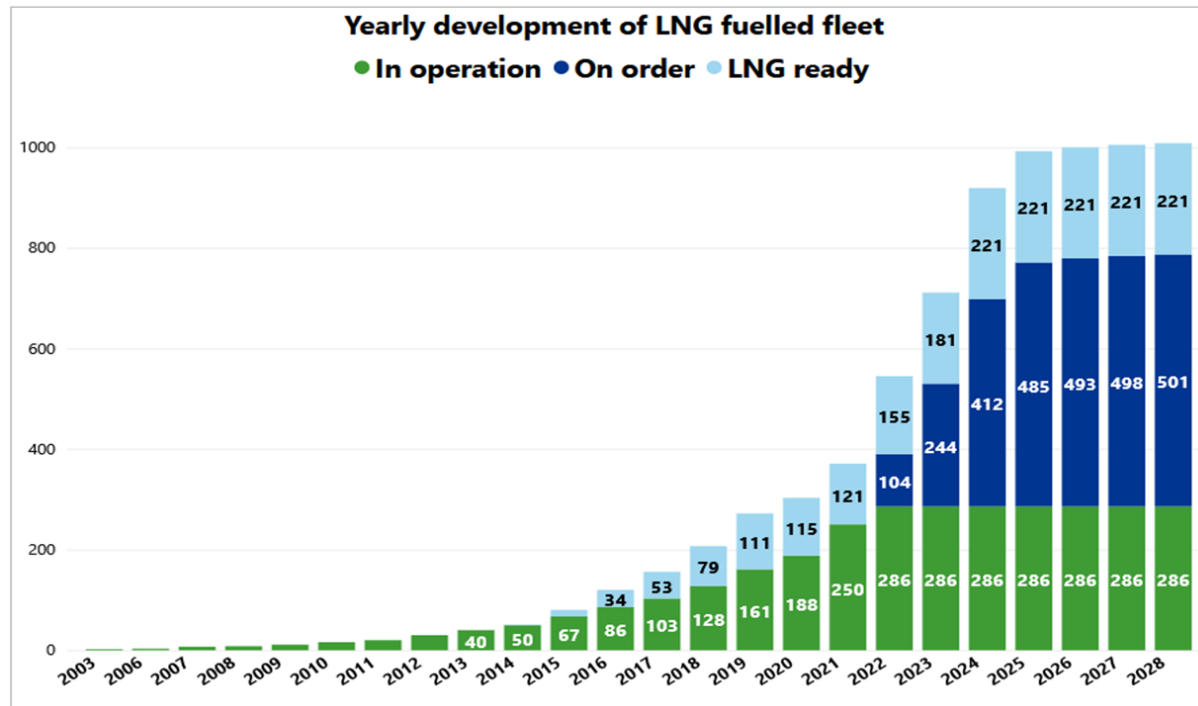
# Of all green fuel alternatives, eLNG is best suited for fast roll-out

Holistic comparison of green fuel technologies for shipping using 3 categories and 12 sub-categories

Category	Sub-Category	Biodiesel / Biogas Waste	Biodiesel FAME / Biogas plants	FT Diesel	Green Hydrogen	Green Methanol	Green Ammonia	eLNG	Remark
Feasibility	Prod. maturity today								Technological maturity of prod. technology; Ammonia: HB process lacks efficiency
	Infrastructure today								Availability of infrastructure
	Vessels today								Availability of vessels
	Volume pot. 2050								can fuel cover 100% of fuel need in 2050?
	Prod. maturity 2030+								Technological maturity of prod. technology 2030+
	Scaleability								scaling up of plants to very high output (GW/a) possible
Environment	non-CO2 direct air em.								e.g. NOx, SOx, particulate matter
	greenhouse gas em.								CO2, methane, NOx; Ammonia: Risk of N2O emissions (GHG factor = 256 x CO2)
	soil								area of arable land needed, soil depletion
	water scarcity								sweetwater requirement
Total Costs	LCOE prod. today								levelized costs of energy as compared to fossil fuel
	LCOE prod. 2030+								Ammonia: it is assumed that a process can be found substituting the HB process

Sources:  
DNV (2022), MAN (2022), ntv (Parsch, S.) 3.11.21

# LNG demand for shipping is growing exponentially, market volume minimum for green LNG fuels is 18 Mio tons / a by 2030



LNG demand by 2025:  
 $992 \text{ ships} \times 18.000 \text{ tons/a} =$   
 $= \text{approx. } 18 \text{ Mio tons / a} =$   
 $= \text{approx } 18\% \text{ of } 2030 \text{ IMO target } ^1)$

Source: DNV (2022); MAN (2022)

1) considering energy density ratio SFO / LNG, using WESMAR data, assuming equal efficiencies SFO / LNG engines

# LNG\* infrastructure in shipping is ready to use and is growing rapidly; Methanol and Ammonia have a long way to go

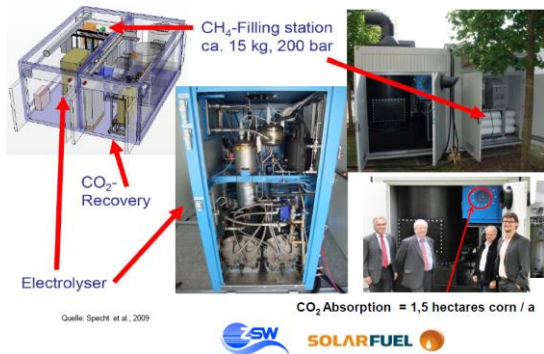
Number of infrastructure components and vessels by fuels technology

INFRASTRUCTURE and VESSELS	Bunkering Infra- structure	in operation	decided	under discussion	Vessels	Remark
Battery					253	Battery ships are small and limited in range (7,5 MWh max)
LNG	487	316	63	108	402	
LPG	n.a.	n.a.	n.a.	n.a.	17	only gas tankers
Methanol	117	117	0	0	16	only oil/chemical tankers, Ropax
Ammonia	195	195	0	0	0	

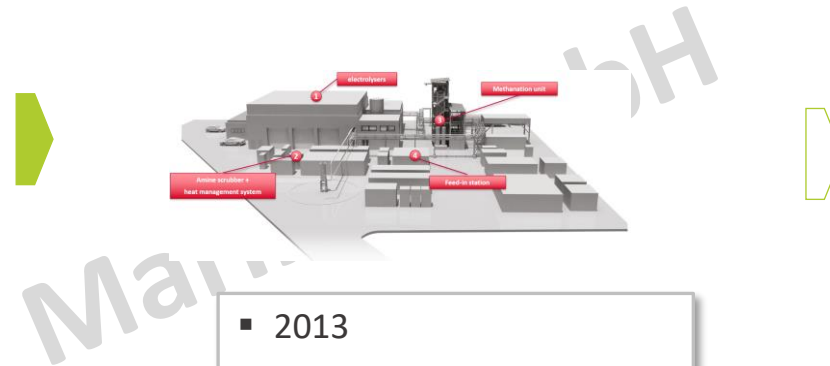
\*LNG: liquefied (fossil) natural gas

Source: DNV (2022)

# kiwi core team has scaled up the SNG technology from lab to industrial scale, and has proven customer journeys



- 2010
- Prototype
- Built by ZSW / Solarfuel
- **25 kW** electrolyzer
- 4 MWh/a
- ~ 0,3 households



- 2013
- industrial scale sample factory
- designed and built by Solarfuel / financed by Audi
- **6 MW** el.
- 9600 MWh SNG/a
- ~ 800 households

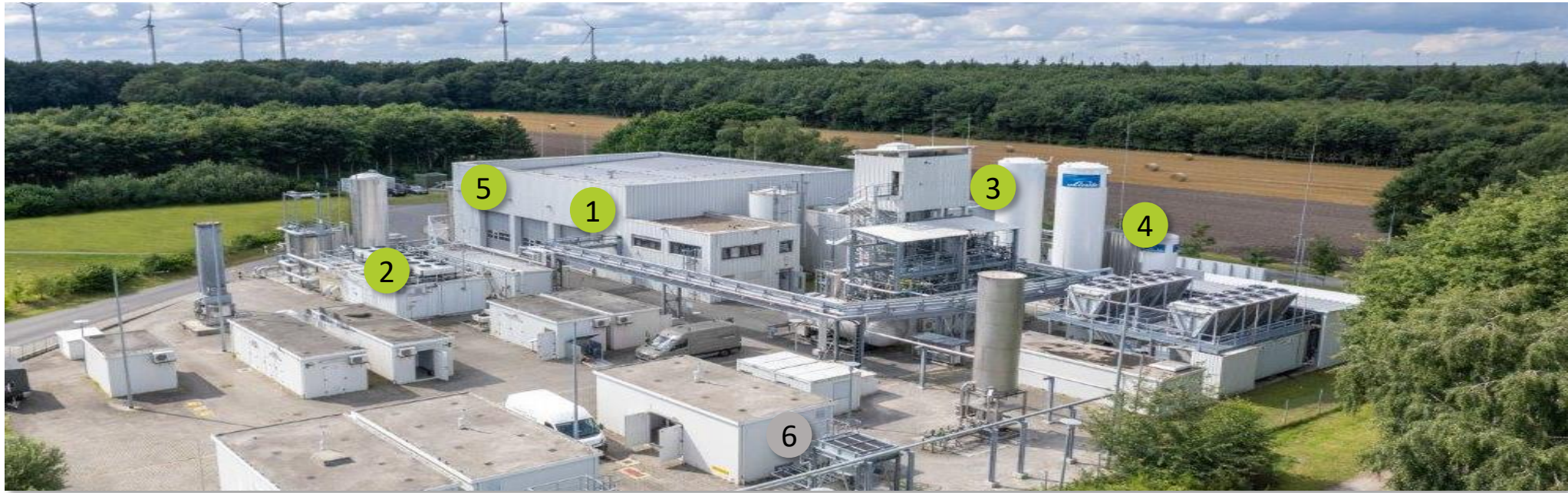


- 2013-2021
- optimization and debugging
- 24/7 fully automatic
- operation follows wind energy supply curve
- **Projects and customer journeys for Audi and others**



# kiwi's industrial plant is the "sample factory"

Operative since 2013 - ready for rollout



Three electrolyzers



Biogas treatment plant



Methanation reactor



Liquefier and e-LNG filling  
Station



Hydrogen filling station



Grid injection plant

# The "sample factory" produces green H<sub>2</sub> products

- **green hydrogen**
  - best in class H<sub>2</sub>-quality (99,999%)
- **green synthetic natural gas (SNG)**
  - injected into natural gas grid
  - transported via natural gas grid to customer
- **green liquefied SNG (eLNG)**
  - 99% methane, no impurities
  - 20 tons storage tank

# Customer Audi AG: A4 Avant g-tron and A3/A5 Sportback g-tron

**-80%**

CO<sub>2</sub> emissions (wtw)





## BP: Green hydrogen in fuel production

**2018: 12 tons of green hydrogen delivered to the refinery of BP in Lingen, Germany. Green hydrogen was used in the fuel production.**



# 2021: World's first production of eLNG for a container ship (Customer: MAN)



## WirtschaftsWoche

In Brunsbüttel wurde jetzt das weltweit erste Schiff mit synthetischem Erdgas betankt, das aus erneuerbaren Energien hergestellt wurde. Politiker glauben, dass der grüne Kraftstoff Öl und Kohle ersetzen könnte.



## nordic market

Wirtschaft Wissenschaft Gesellschaft Bildung

## WIRTSCHAFT

Die Schifffahrt auf dem Weg zur Klimaneutralität

29.09.2021



MAN Energy Solutions  
Future in the making

Company Careers Digital Cent

Energy & Storage

MAN Energy Solutions | Company | MAN Energy Solutions | Press Releases | Press details

Thursday, September 30, 2021

## World's first bunkering of containership with renewable synthetic natural gas advances sustainable shipping

"This is an important lighthouse project, essentially a proof of concept for the maritime energy



# kiwi designs, builds and operates PtX plants; next level is 100-300 MW<sub>el</sub> (installed electrolyzer capacity)

rollout 6 MW / 100 MW / 1000 MW on its way



- 6 MW (el.)
- > 1000 tons eLNG or SNG p.a.

## **TODAY**

- operative since 2013
- debugged
- CO<sub>2</sub> from biogas
- ready for scaleup
- Werlte | Lower Saxony

CAPEX: ~ 30 Mio €

- 100-300 MW (el.)
- **30-90.000 tons eLNG or SNG p.a.**

- project kickoff: 2022
- start of op: 2027
- biogenic CO<sub>2</sub>
- port
- Northern Germany

CAPEX per 100 MW: ~ 200 Mio €

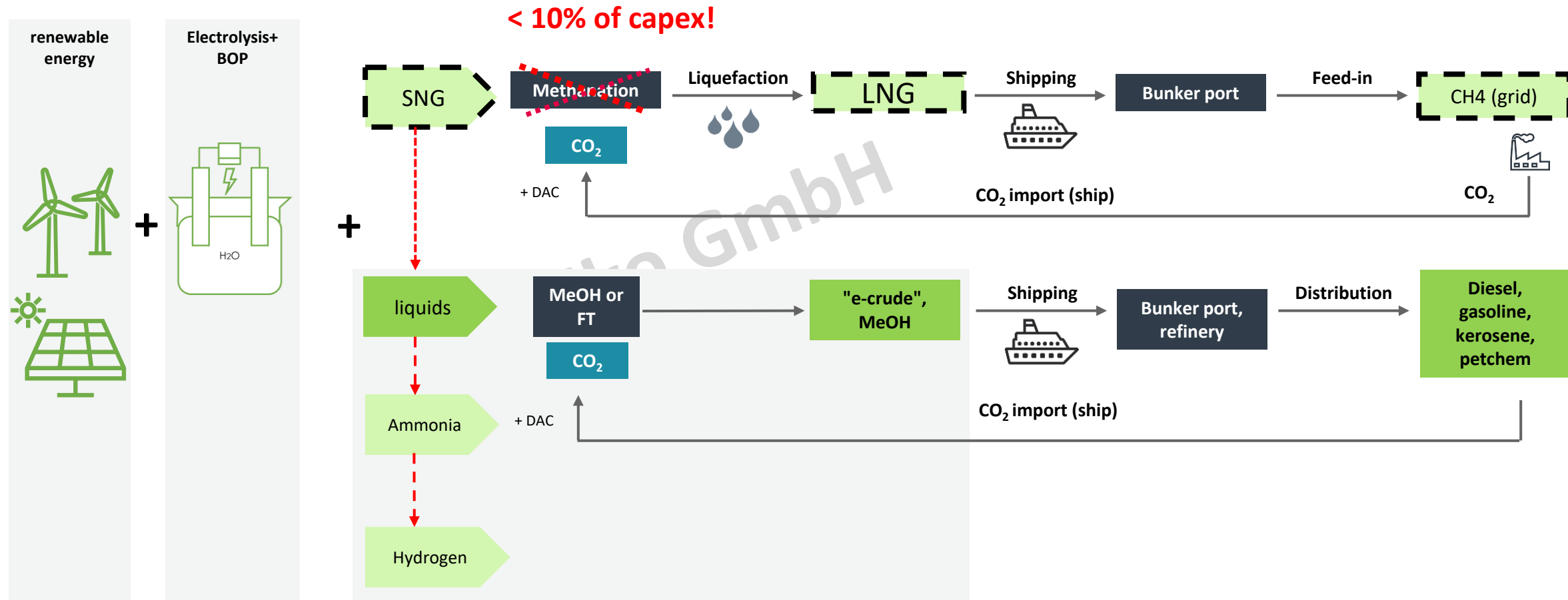
- 1-30 GW (el.)
- **up to 9 Mio tons eLNG or SNG p.a.**

- under evaluation
- project planned 2023+
- CO<sub>2</sub> imported and/or DAC
- port
- Site confidential

CAPEX per GW ~ 1,5 bln €

# kiwi plant design is market-oriented, adaptive and modular

Possible combinations or changes of reactor technologies





Decarbonizing the shipping industry