Power-to-X in Molten Salt (Reactors)

Ask Emil Løvschall-Jensen
Co-founder Seaborg ApS
CEO Hyme Energy ApS

SEASALT GROUP COVERS TWO CORNERSTONES OF THE ENERGY SPECTRUM

Seasalt Group

Founded Q4 2021

Seaborg

4th generation **nuclear energy** technology company developing an inherently safe nuclear Compact Molten Salt Reactor to be deployed on barges on a global scale

Hyme Energy

Energy storage technology company set to deploy hydroxide salts as an inexpensive, grid scale energy storage system to complement renewable energy production

hyme
Sustainable. Available.

PATENTED CORROSION CONROL

Proprietary NaOH Moderator

(sodium hydroxide)

Chemistry implementation in the CMSR

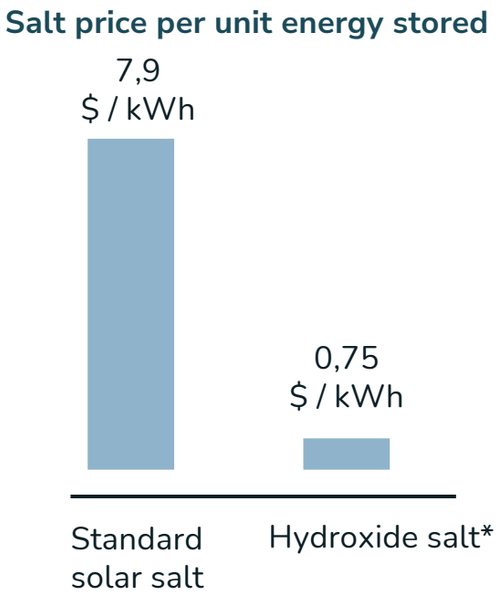
- Active corrosion mitigation
- Efficient moderator with 10 times the slowing-down power of graphite - i.e. **much smaller scale reactor**
- Excellent chemical stability
- Liquid from 318°C to 1388°C

Applied in:

The Potential Game Changer: **Hydroxide Salts**

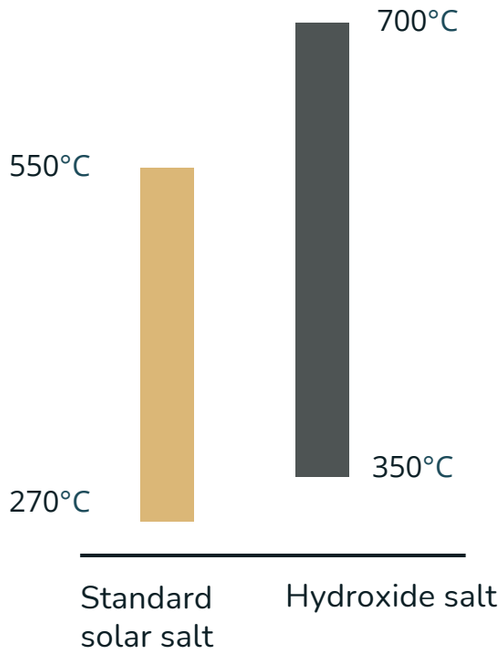
Price

Up to 10x reduced cost for storage medium



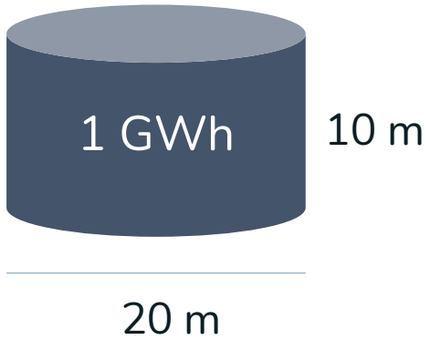
High temperature

700°C storage broadens use cases and gives higher power-to-power efficiency



Compactness

30% less volume needed means material and construction costs are lower.

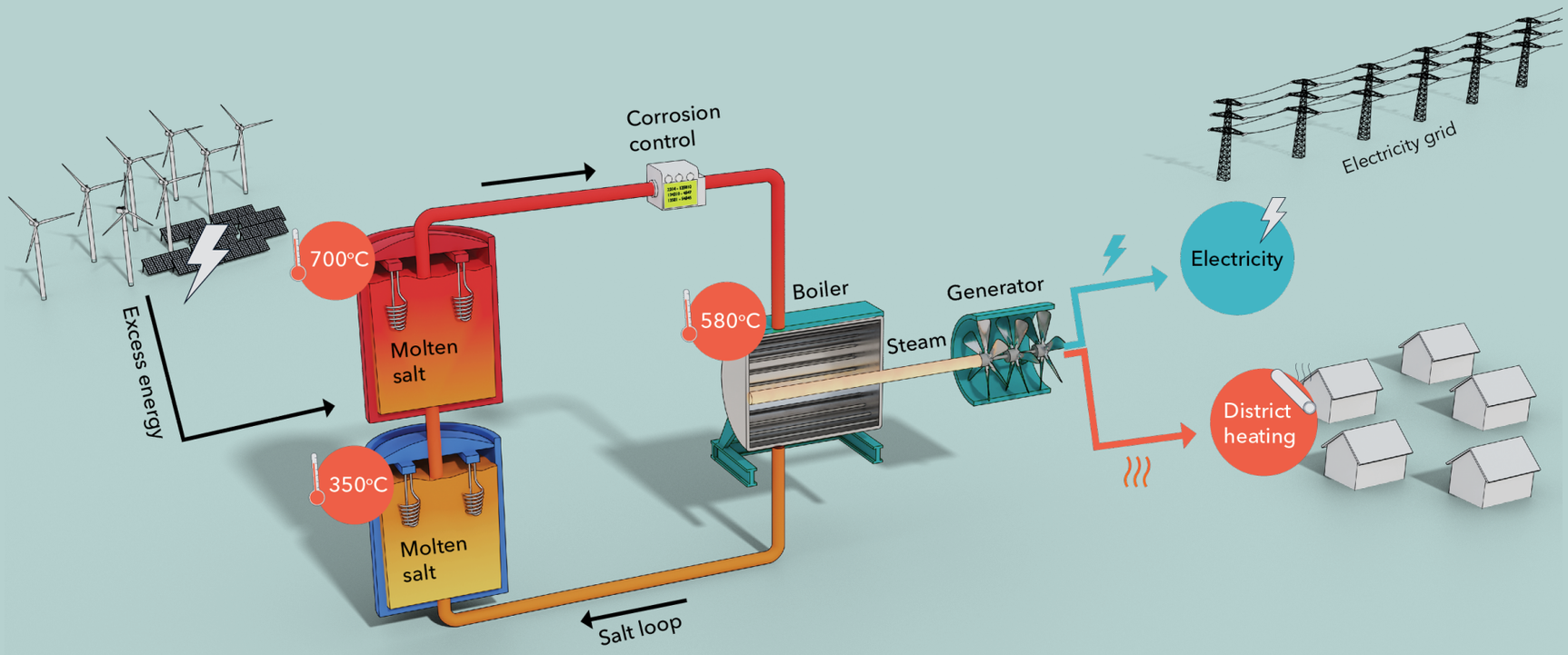


* Sodium hydroxide is a cheap biproduct in the production of chlorine

Other hydroxide highlights

- Good heat transfer properties.
- Materials are abundant.
- Hydroxide mixes can have melting points as low as 180 degrees

A number of possible use cases



Brief specifications

- Can store from MWh up to several GWh
- Charge, discharge and capacity is almost freely scalable
- Heat loss as low as 0.5% a day

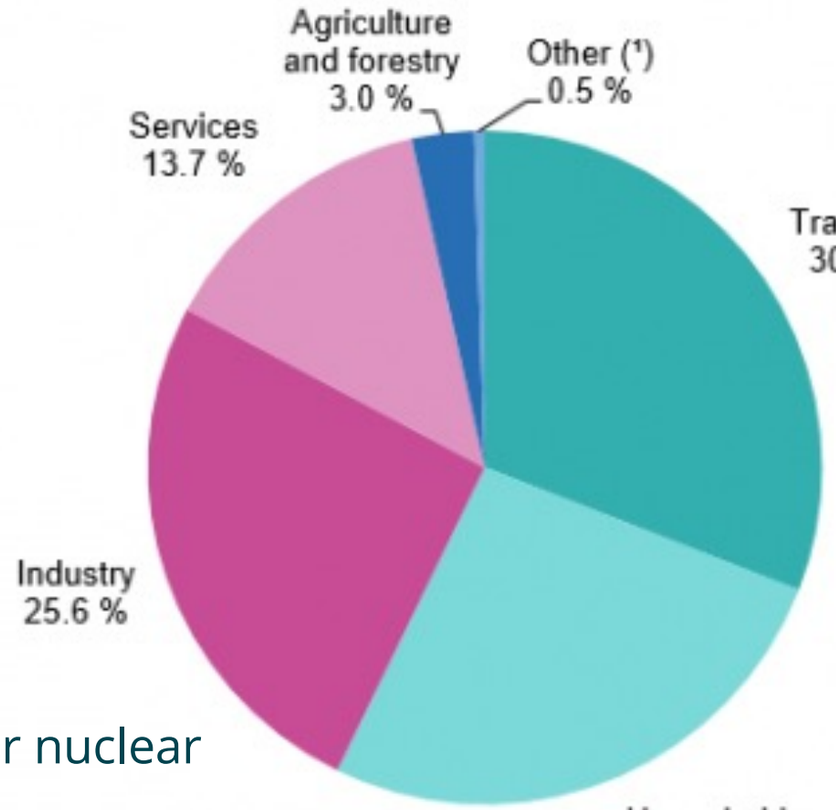
Power to **Combined Heat and Power** (CHP) (eff. ~90%)

Power to **power** through advanced cycles (eff. 50%+)

Electrification of industry **process heat**

Enabler for **high temperature power-to-X processes**

Final energy consumption by sector, EU, 2019
(% of total, based on tonnes of oil equivalent)



Power-to-X

Electrification
Above ~200C
fossile based today

Future: power, biogas or nuclear

Heat and power

(1) International aviation and maritime bunkers are excluded from category Transport.

Source: Eurostat (online data code: nrg_bal_s)

eurostat

PtX for transportation

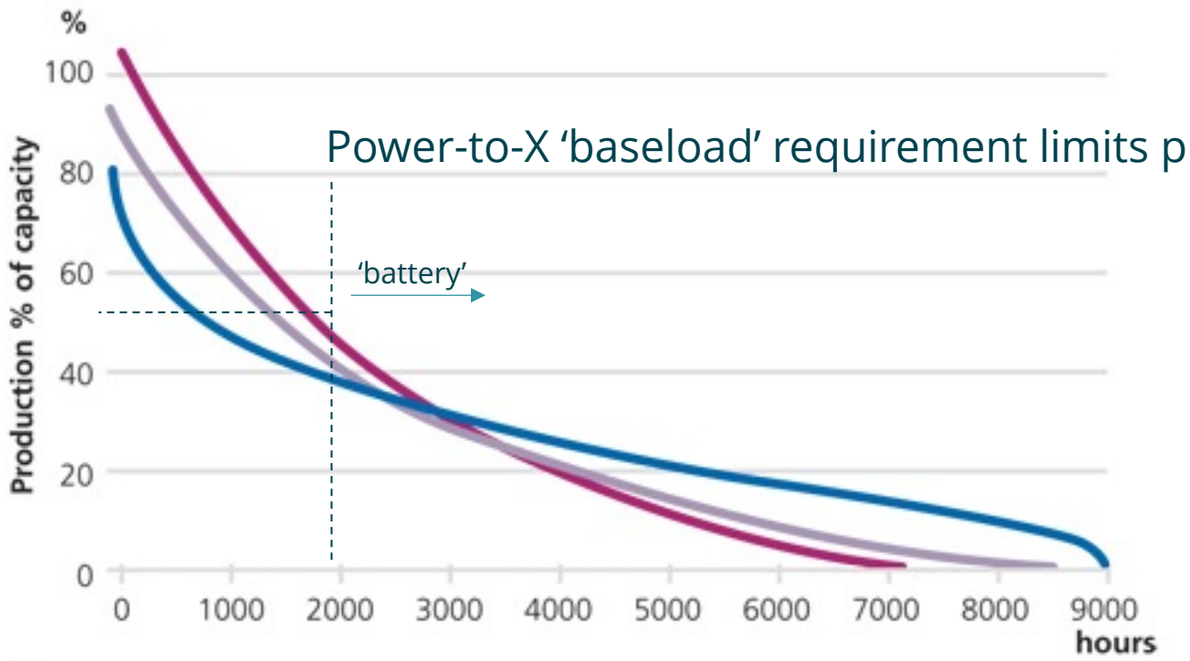
	Liquid Hydrogen	Ammonia	Methanol
Energy Density [MJ / L]	8.4	11.5	17.8
Levelized cost of Storage [$ / GJ]	3.24	1.09	0.70
Suitable for long-distance transportation	New vessels	Existing	Existing
Challenges for long term storage	Technical	Toxicity	-
Feedstock availability	H_2O	H_2	CO_2

No challenges · Some challenges · Major challenges

Liquid Hydrogen is complex to **transport** and economically **expensive**.
Ammonia offers a better transport solution.

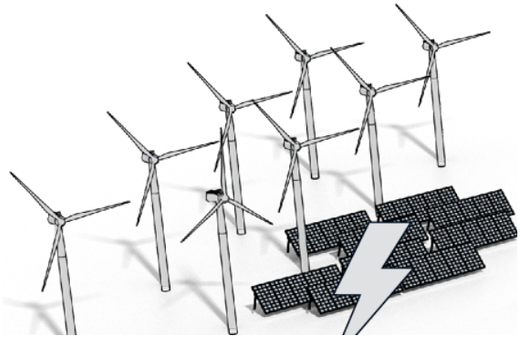
Source: UNECE (2021)

The challenge of PtX production continuety with intermittent sources



Power-to-X 'baseload' requirement limits production hours

Enabling efuels production by providing flexible heat and power



High temp. salt storage

Steam / Heat

High quality heat for more flexibility heat steps in power-to-X

Power to increase production hours

H_2O (Desallination)

H_2

- PEM
- Alkaline
- High-temperature Electrolysis
- Thermochemical

Captured Nitrogen

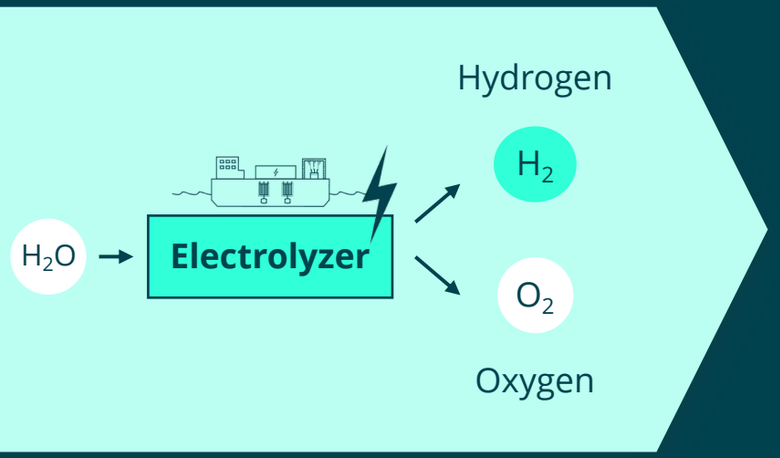
Captured or biogenic CO_2

eFuels (refining)

Hydrogen technologies

The Hydrogen production process starts with water as feedstock. H_2O molecules are separated through an electrolyze process, to originate hydrogen and oxygen.

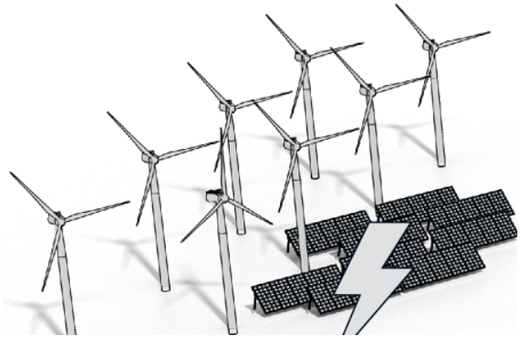
There are several electrolier technologies currently available in the market.



	Alkaline **Alkaline water**	PEM **Polymer electrolyte membrane**	SOEC **Solid oxide electrolysis cells**
	Electric current directly on water	Separation by membrane	High voltage applied to high temperature steam
Current Market Share	80%	20%	0%
Expected Market Share (2030)	50%	33%	17%
Expected Market Share (2050)	0%	20%	80%

Source: Maersk Mc-Kinney Moller Center for Zero Carbon Shipping – Position Paper – Fuel Option Scenarios

Enabling efuels production by providing high-temperature



H_2O
(Desallination)

High temp. salt storage

Steam / Heat

High quality heat for more flexibility heat steps in power-to-X

Power to increase production hours

H_2

Copper Chloride hybrid H_2 cycle enabled at ~500C

~~Power to X~~

SEABORG

Nuclear to X

SEABORG IN A NUTSHELL

Privately held and
privately funded company

90+ employees

Scaling to **150 employees** in current funding

HQ in Copenhagen, Denmark

Business office in South Korea & Singapore

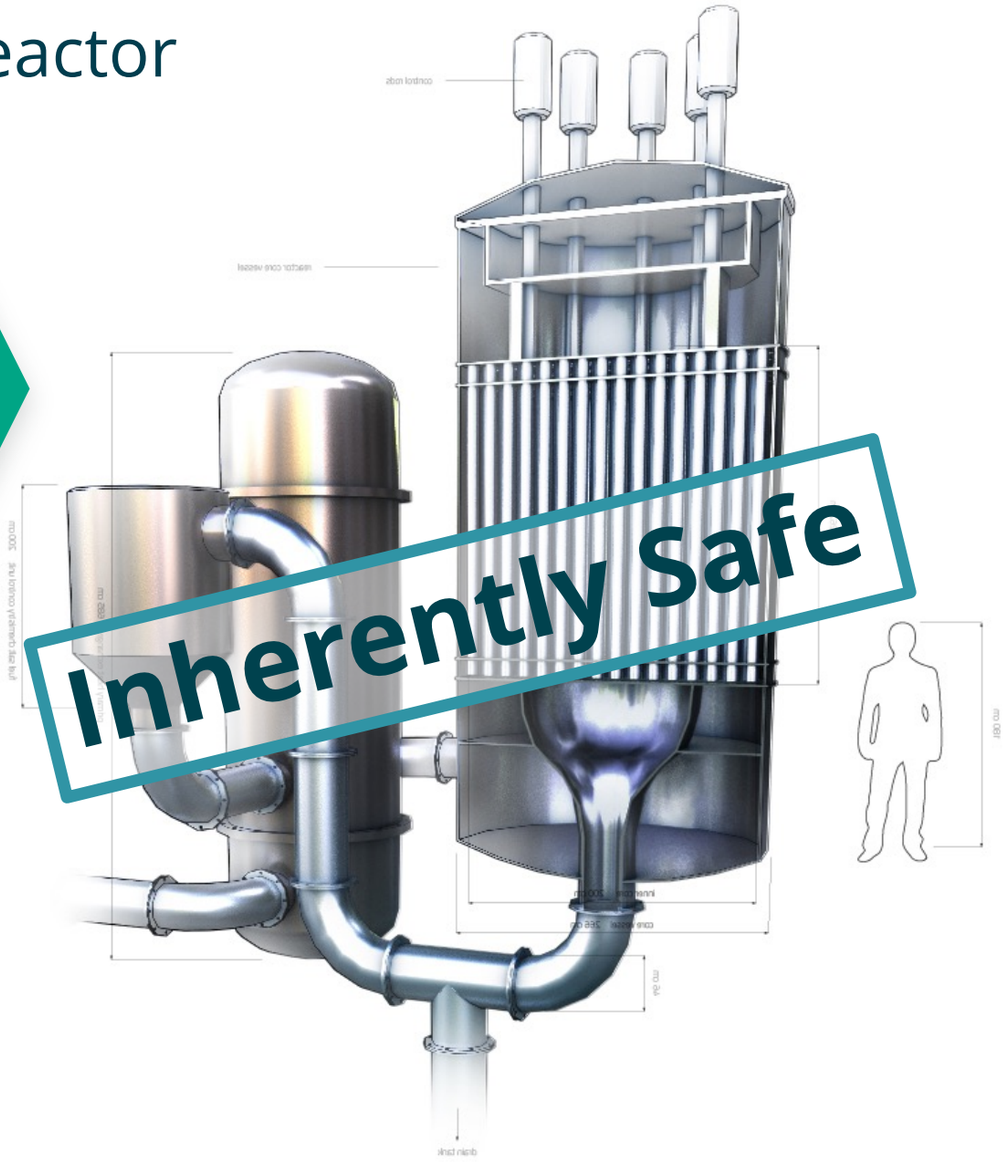
Partnerships with shipyards, nuclear players and heavy industry

SAFE, CHEAP AND CLEAN NUCLEAR

Seaborg's modular Compact Molten Salt Reactor

The Seaborg CMSR is **inherently safe**. It:

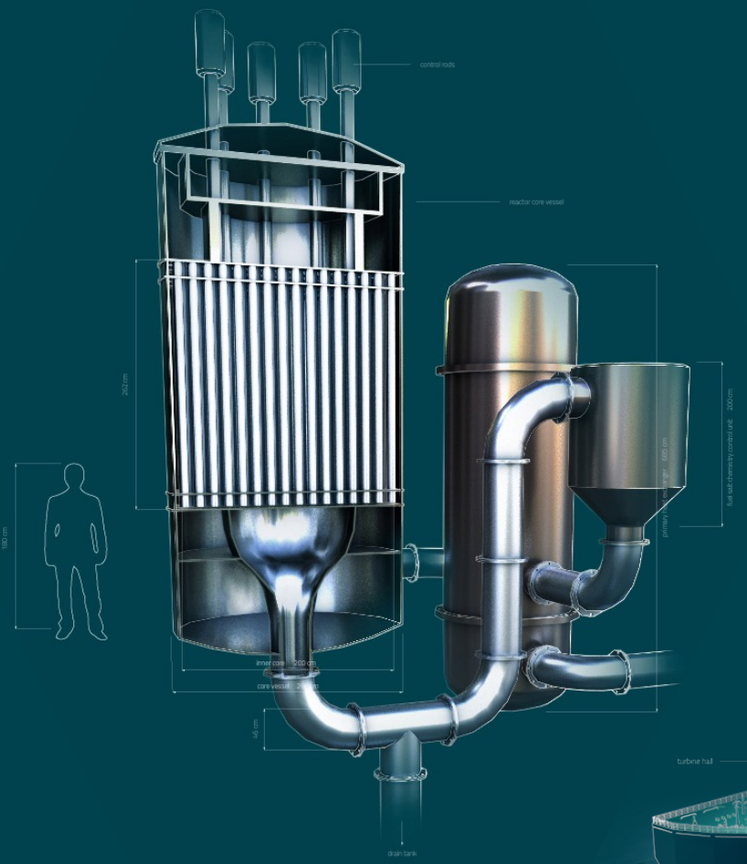
1. **Cannot** melt down or explode
2. **Cannot** release radioactive gases to air or water
3. **Cannot** be used for nuclear weapons
4. Operates for **12 years without refueling**



Molten Salt Technology:

- Fundamentally different reactor type
- Successfully built and operated in the 60's

SEABORG IN A NUTSHELL



Developing

The Compact Molten Salt Reactor

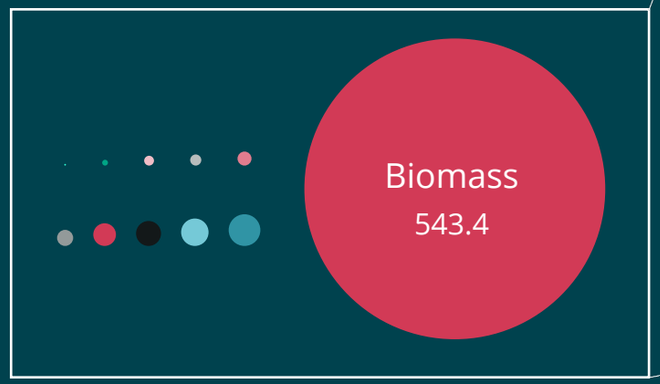
- Small modular nuclear reactor
- Mass produced
- Deployed on barges
- 200-800 MWe power barges

The most compact solution in the market

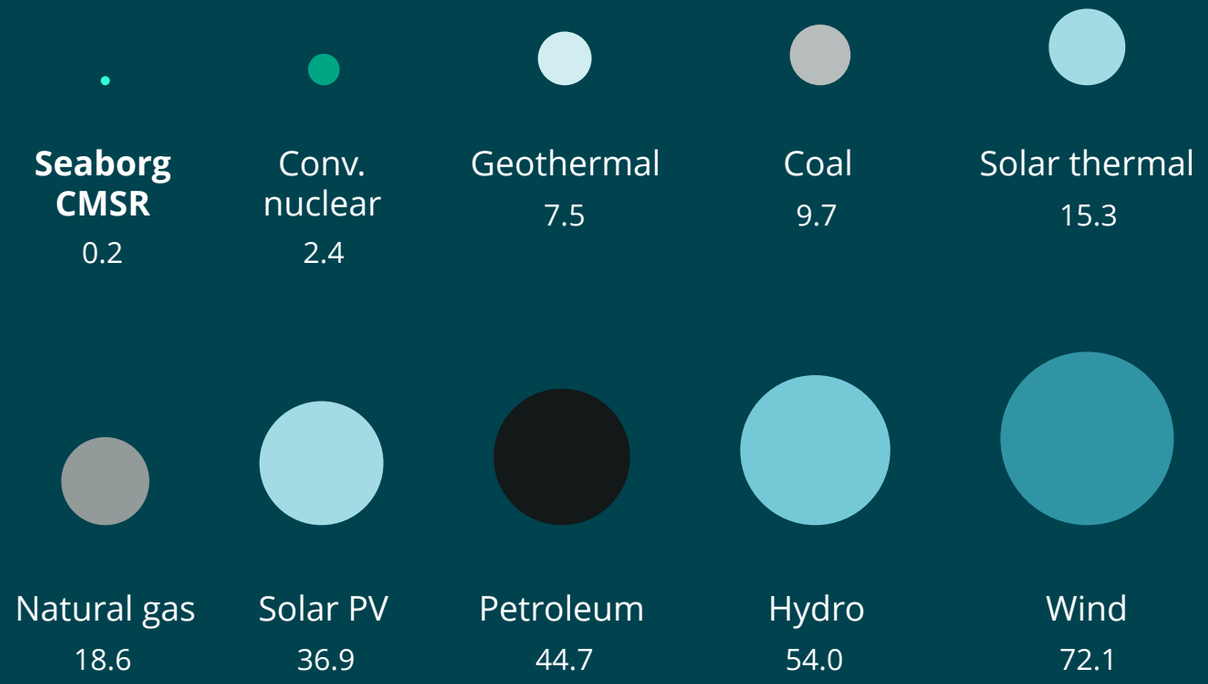
Seaborg's Power Barge only takes up roughly 0.5 km^2 of land.

Combined with a constant and high output of 200-800 MWe, the CMSR uses **only 0.2 km^2** on average to produce 1 TWh of power.

That is **better than any solution currently in the market.**



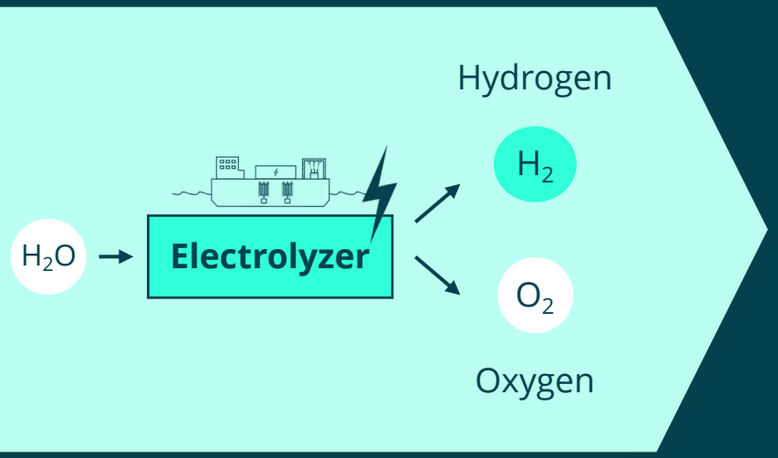
Land use intensity (km^2/TWh/year)



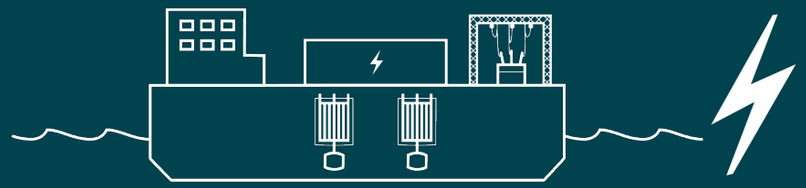
Source: A.M. Trainor, R.I. McDonald & J. Fargione – Energy Sprawl is the largest driver of land use change in United States (2016).

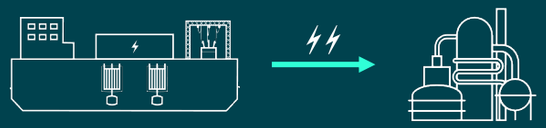
POWER TO H_2

Green Hydrogen Production Process powered by the CMSR Power Barge



What does the CMSR offer to PtX?





$ **1.8 - 2.7** / Kg H_2

Highly reliable and constant power supply

Non-constant generation sources require additional costs (storage costs)

Competitively priced electricity

$ 3.2 - $ 9.9 / Kg H_2

$ 2.4 – $ 8.5 / Kg H_2

Fossil Free Production

Substitute natural gas as feedstock for Hydrogen and Ammonia production

Flexible deployment

The CMSR and PtX facilities can be located wherever there is a need for it.

INEXPENSIVE

Transform energy markets and **out-compete fossil fuels** to create a bright future with abundant clean energy for everyone.

UNPRECEDENTED OPPORTUNITY

Executing a rapid **world-wide deployment** of the Compact Molten Salt Reactor via **shipyard serial production** of power barges.

SEABORG

Rethinking nuclear

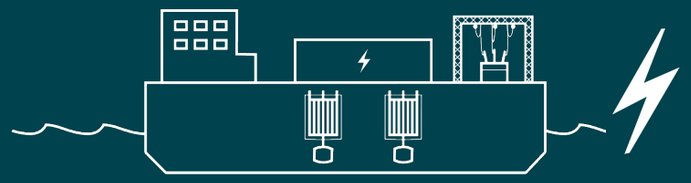
Ask Emil Løvschall-Jensen
inquiries@seaborg.com
09.06.2022

PtX POTENTIAL WITH CMSR

Both CMSRs and electrolyzers are modular by design, enabling a high degree of facility customization and scale-up.

800 MW

Electrical input

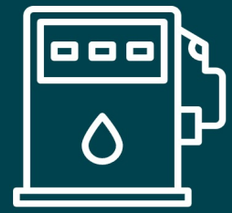


384,000 kg

Daily hydrogen production

USD 1.8-2.7

Hydrogen cost per kg



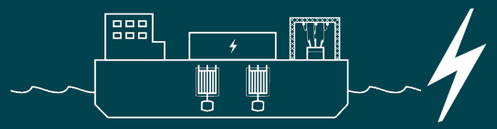
Preliminary numbers for a utility scale facility

SEABORG

POWER TO AMMONIA

Green Ammonia Production Process powered by the CMSR Power Barge

1 **Power** from the CMSR Power Barge



2 **Sea water**

RO Desalination

Brine

H_2O

Electrolyzer

H_2

Hydrogen

O_2

3 **Air**

Air separation

O_2 He

N_2

Ammonia Synthesis Process

NH_3

Ammonia

Marine Fuels

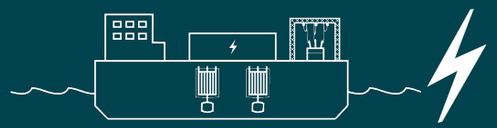
Hydrogen

SEABORG

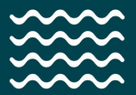
POWER TO METHANOL

Green Methanol Production Process powered by the CMSR Power Barge

1 Power
CMSR Power Barge



2 Sea water



RO Desalination

Brine

H_2O

Electrolyzer

H_2
Hydrogen

O_2

3 CO_2

CO_2

Methanol Synthesis Process

H_2O

CH_3OH
Methanol

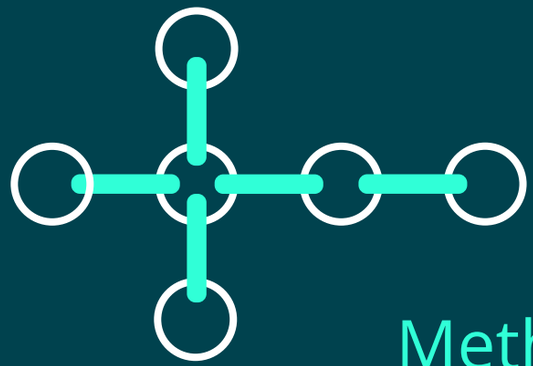
Marine Fuels

Automotive Fuels

Hydrogen

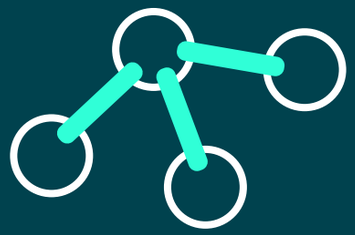
H_2

CH_3OH



Methanol

NH_3



Ammonia