Scaling up of decoupled water splitting at H_2Pro

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Dutch Israeli mini symposium on hydrogen
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A Technion Start-up - 2019

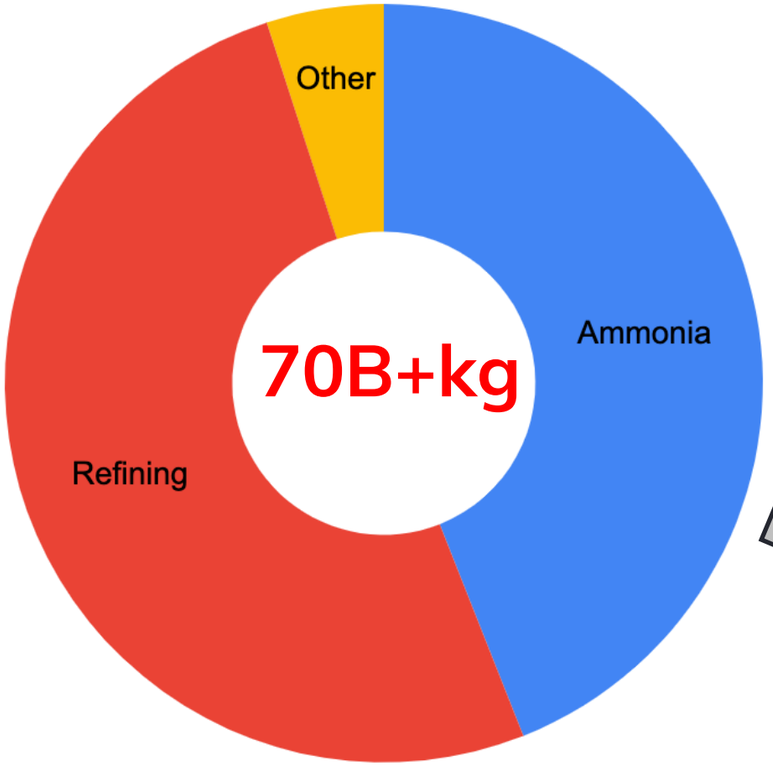
H2PRO

fueling tomorrow

Prof. Gideon Grader - Co-Founder
Prof. Avner Rothschild - Co-Founder
Dr. Hen Dotan - Co-Founder, CTO
Dr. Avigail Landman

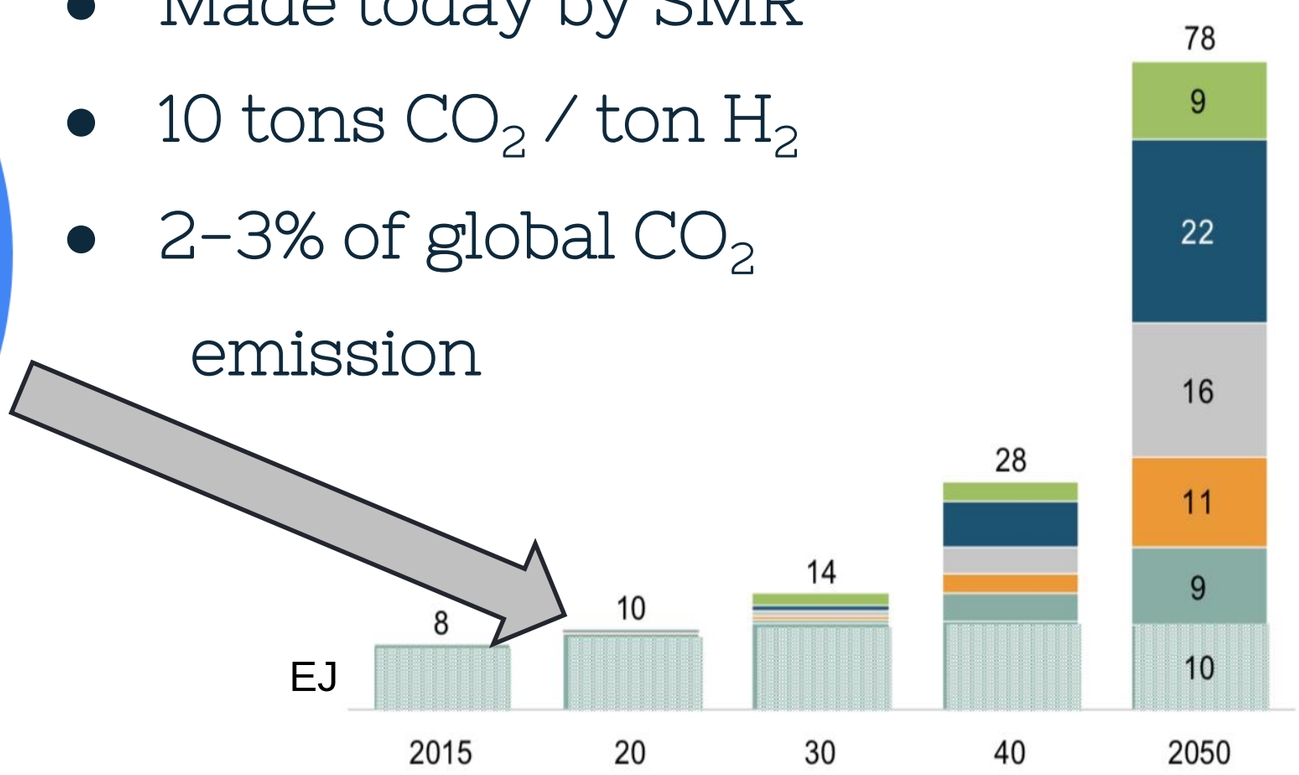
Talmon Marco - CEO
Founder @ iMesh, Viber, Juno

Hydrogen today & tomorrow: The new oil



- Made today by SMR
- 10 tons CO_2 / ton H_2
- 2-3% of global CO_2 emission

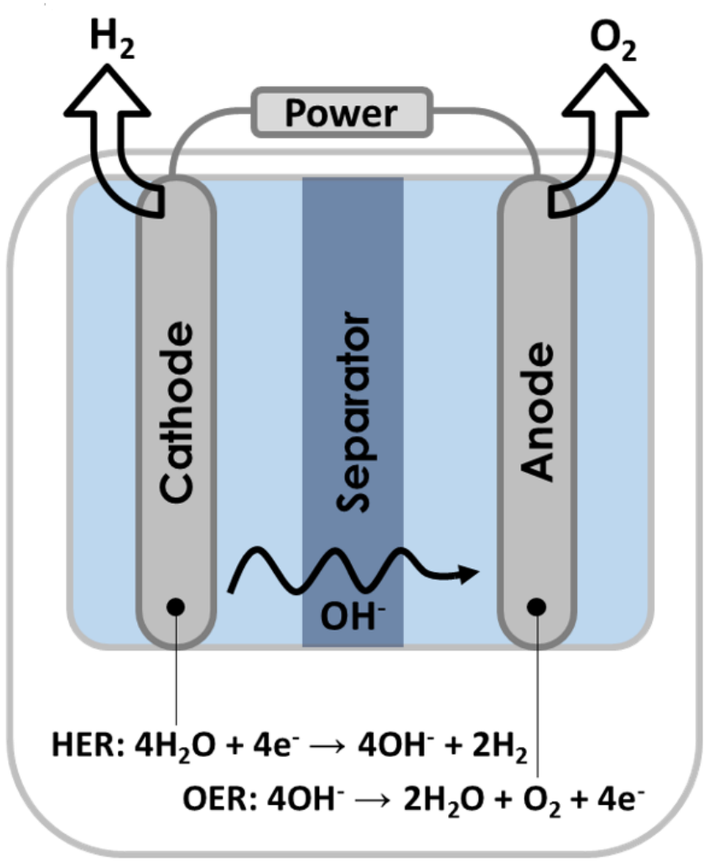
Made by electrolysis



- Cost per kg – ~$2
- Market size **$140B**

The hydrogen council

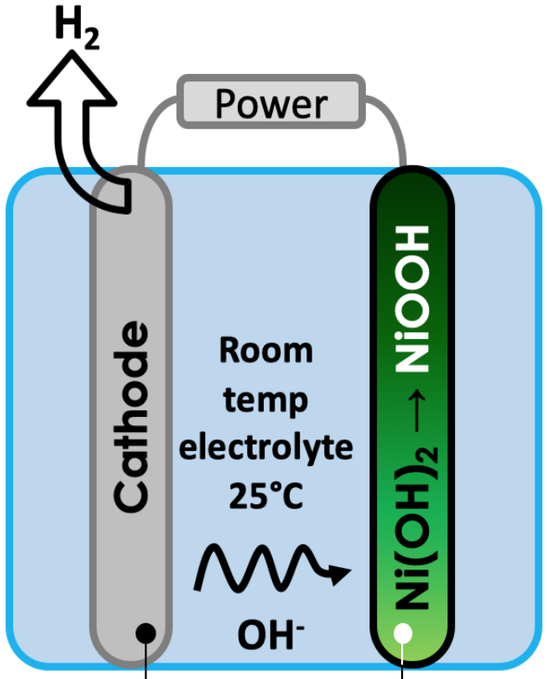
Electrolysis today: expensive & inefficient (~70%)



- High OPEX
  - Large power loss (~ 25%)
  - Mainly due to the oxygen evolution reaction (OER) overpotential (> 0.4 V)
- High CAPEX
  - Complex design
  - Materials, maintenance
- Limited production pressure
  - Compressors: inefficient and expensive
- Same concept for the last 100 years

E-TAC: a new way to split water – two steps

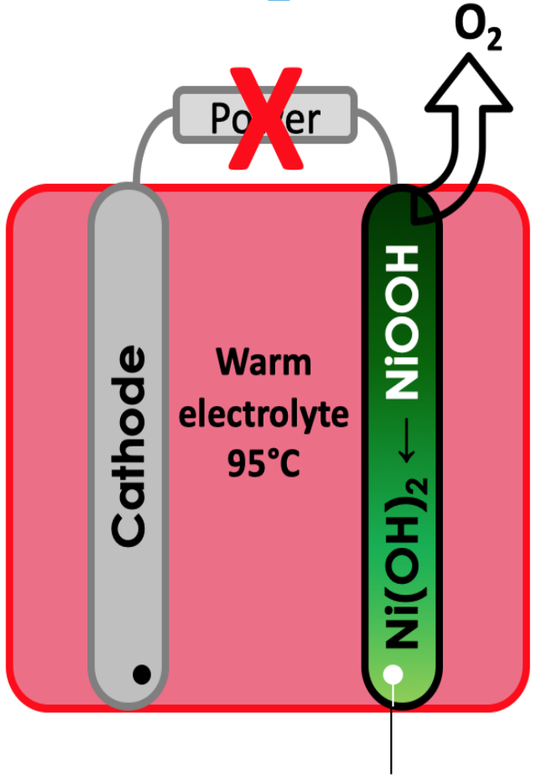
Step 1 – H_2 generation



HER: $4H_2O + 4e^- \rightarrow 4OH^- + 2H_2$

$\{Ni(OH)_2 + OH^- \rightarrow NiOOH + H_2O + e^-\} \times 4$

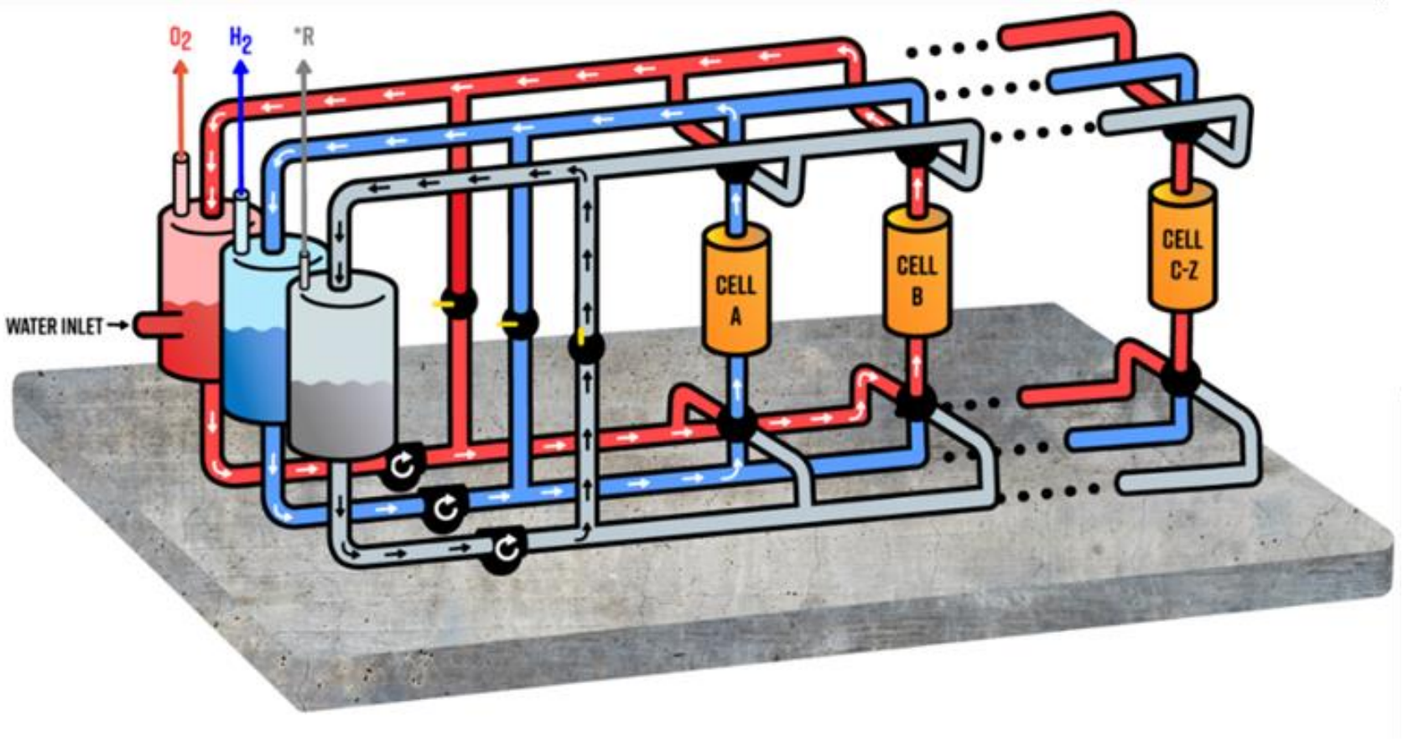
Step 2 – O_2 generation



$4NiOOH + 2H_2O \rightarrow 4Ni(OH)_2 + O_2$

E-TAC: Electrochemical – Thermally-Activated Chemical (E-TAC)

E-TAC Production process



- Simple cell construction
- High Pressure potential
- Larger safety
- Modular design
- High efficiency > 90%
- Low CAPEX

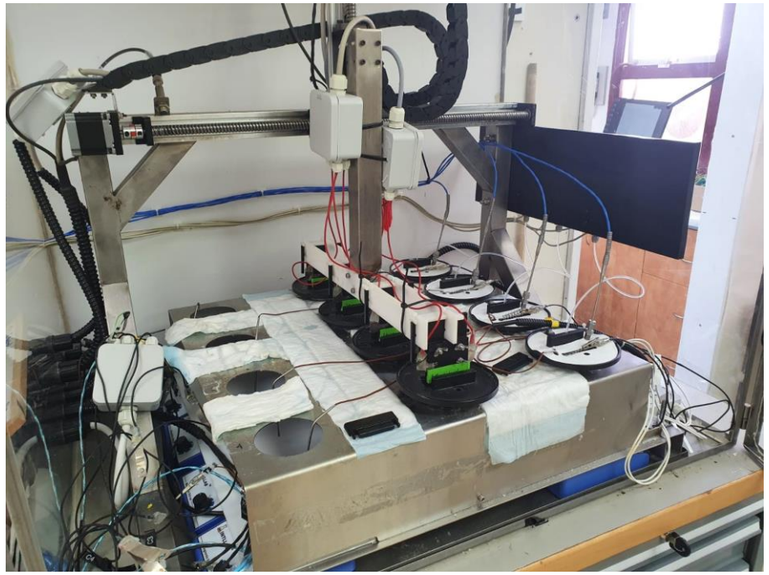
nature energy
ARTICLES
https://doi.org/10.1038/s41560-019-0462-7

Shell – New Energy Challenge
1st place 2020 competition

Electrode stability

The electrodes are stable after >50,000 Hybrid Cycles & >5,000 hrs

Electrochemical
charge discharge RT
test



Robotic arm
E-TAC
test

Development roadmap

Phase	Date	H_2 kg/day	Notes	TRL
Academic proof of concept	12/2018	0.00002	Lab level, in a beaker	3
Pre Demo	3/2019	0.001	First cell	3
Demo (M1)	7/2019	0.008	Semi automated	4
Enhanced Demo (M2)	4/2020	0.1	Fully automated, high density electrode, ~50 bar at cell level	6
HP Demo (M2.1)	10/2020		Fully automated hydrogen production at more than 40 bars	6
Prototype (M3)	4/2021	1	Scaled down design of final system, ~ 50 bar	6
Advanced Prototpye (M4)	9/2021	10	One month continuous operation	7
Pre Production (M5)	4/2022	100	Production electrodes	8-9
Production (M6)	12/2022	500	First production system	9

Scale-up →

M1

- August 2019
- 2 reactors
- Total area: 0.02 m^2

10 gr H_2/day

Scale-up →

M2

- June 2020
- 4 reactorss
- Total area: 0.48 m^2

100 gr H_2/day

Scale-up…

M3

- April 2021
- 12 reactors
- Total area: 4.8 m^2

1,000 gr H_2/day

…..Scale-up…..

M4

10 kg H_2/day

- Sept. 2021
- Total area: 41 m^2

M5

100 kg H_2/day

- March 2022
- Total area: 250 m^2

M6

500 kg H_2/day

- December 2022
- Total area: 1,000 m^2

1 MW System

Mini coating line

- Electrodes: 50 cm long
- Used in M2 & M3 systems
- Started 4/2020
- Operation: Manual

Company growth ~ 50 employees today

Expanded R&D coating line
2 m long electrodes, June 1, 2021

Design of production coating line
8 m long electrodes, Q3 2023

R&D labs & testing facility
3000 m^2 floor space

Production plant space
12,000 m^2 floor space

Financing

- Israeli company
- Pre-Seed: $1.4 MM – January 2019 (lead: Hyundai)
- Seed: $3.5 MM – August 2019 (lead: Hyundai)
- Series A1: $5 MM – March 2020 (lead: Sumitomo)
- Non-dilutive grant from Israel Innovation Authority
  - $750K (May 2019 – April 2020)
  - $650K (May 2020 –June 2021)
- Series A2: $21 MM – December 2020 (Lead: Breakthrough Energy)

  Including BAZAN & NFE

Summary

- Huge market today (… much larger tomorrow)
- Breakthrough technology
  - Strong IP
  - Significantly cheaper and more efficient than the competition
  - Easy to scale
- Strong team

Thank you