Materials for intensified alkaline water electrolysis

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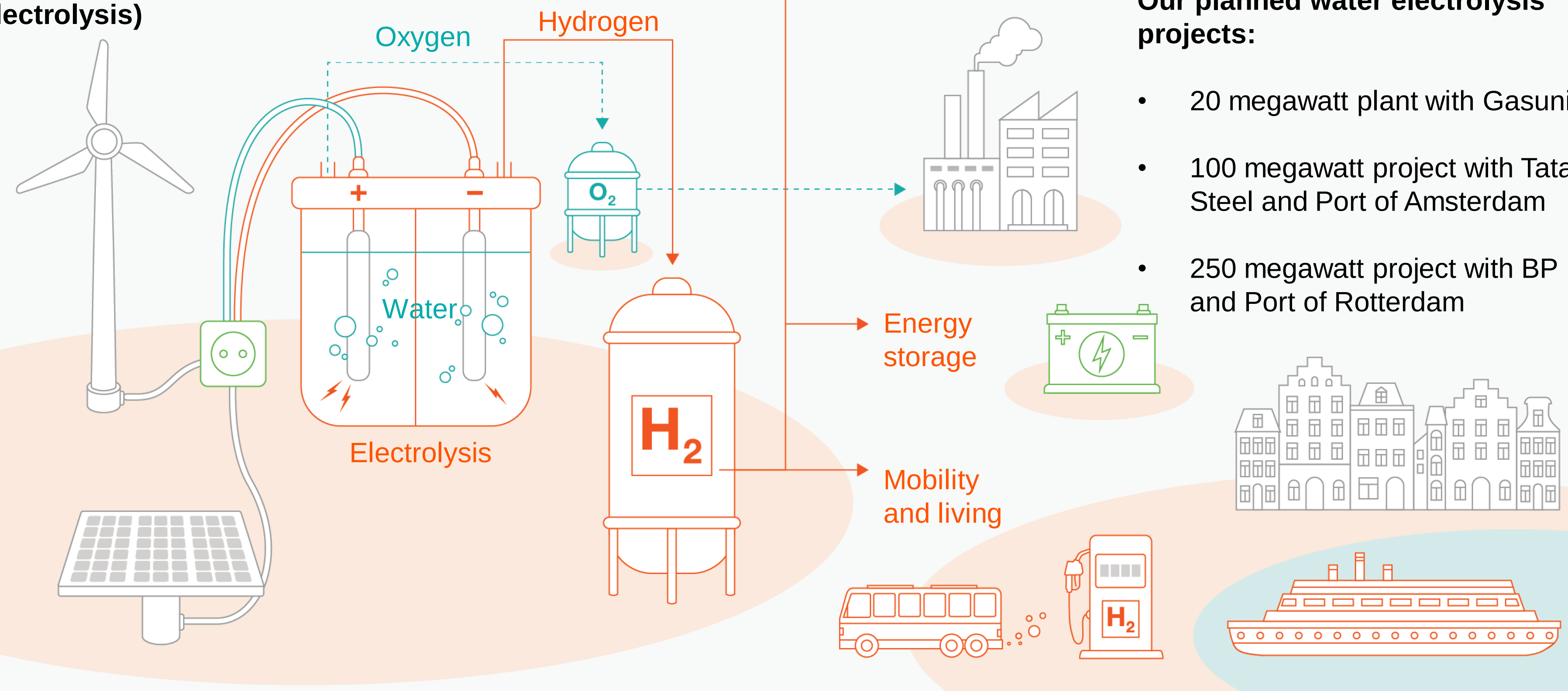
Electrochemical Conversion & Materials
Den Haag – 21/06/2019

Green Hydrogen at Nouryon

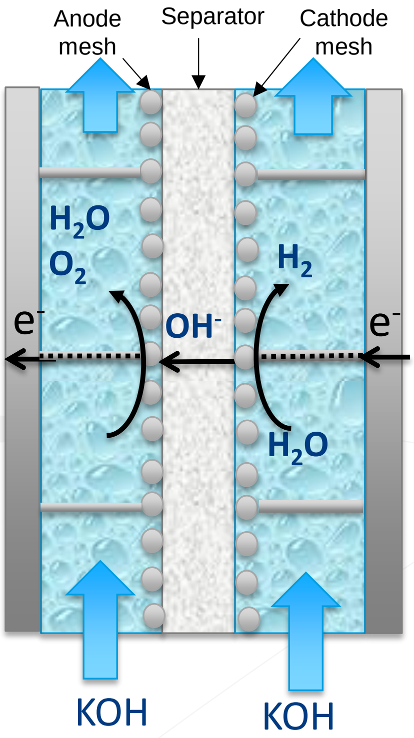
Our current electrolysis capacity: 1 GW (chlor-alkali, sodium chlorate and water electrolysis)



Our planned water electrolysis projects:

- 20 megawatt plant with Gasunie
- 100 megawatt project with Tata Steel and Port of Amsterdam
- 250 megawatt project with BP and Port of Rotterdam

Alkaline water electrolysis



	Alkaline water electrolysis
Current density	2-9 kA/m^2
Operating conditions	90 °C, up to 30 bara
Electrolyte	30% KOH
Cell thickness	1.5-8 cm
Electrode area	Typically ~2 m^2
Anode	Nickel
Cathode	Nickel (activated)
Separator	Porous separator (typically Zirfon)
Bipolar plate	Nickel / Ni-plated steel
Gaskets	Teflon, EPDM

+ cheap & robust
+ no critical raw materials
- Large & relatively inflexible

Commercial stacks

Nouryon

Current density

Atmospheric alkaline

High
(6-9 kA/m^2)

thyssenkrupp

AKC

Low
(2-4 kA/m^2)

NEL

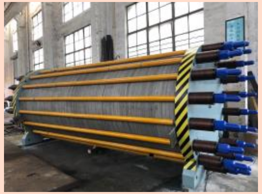
Pressurized alkaline

High
(6-9 kA/m^2)

McPhy

Low
(2-4 kA/m^2)

PERIC



Suzhou

Hydrogen-Pro

Current costs of alkaline water electrolysis

Nouryon

Material cost

+

Manufacturing cost

Stack cost

100-600 €/kW

Balance of plant

200-400 €/kW

+

Other project costs

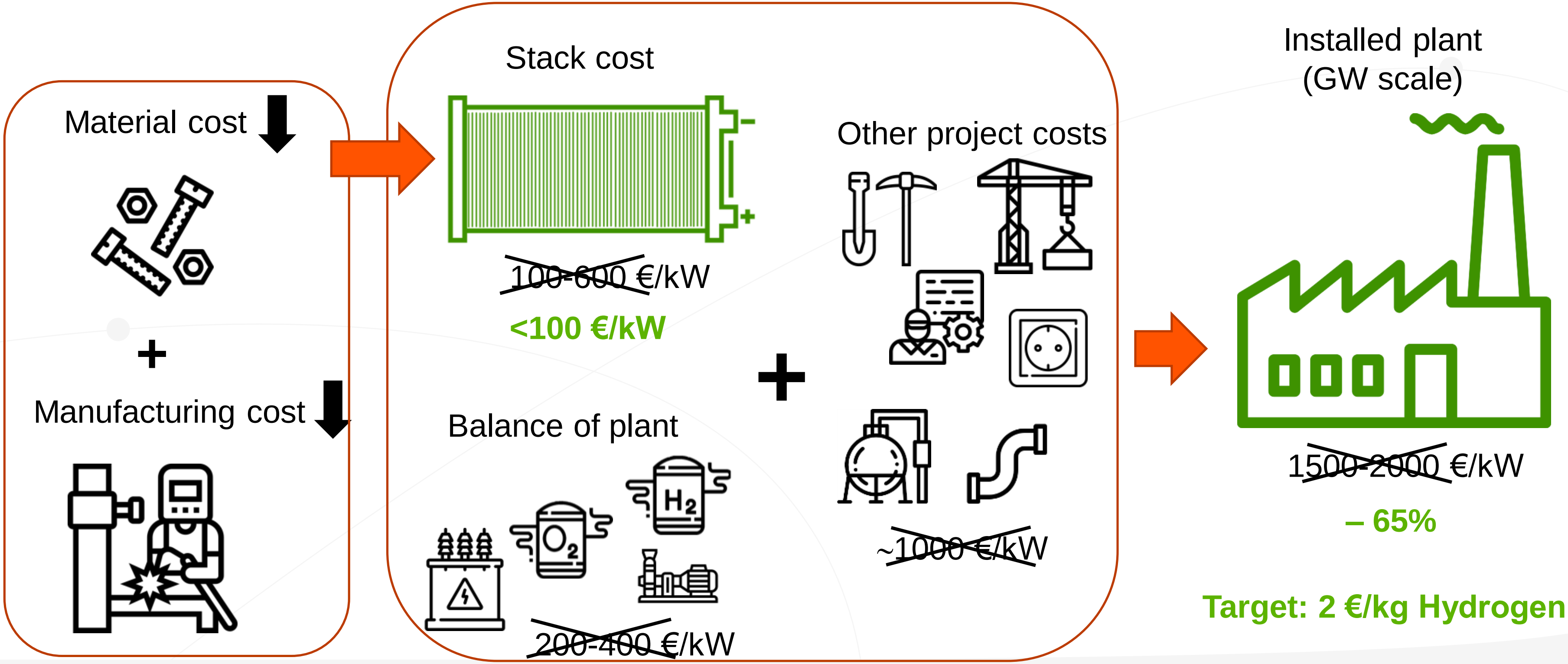
~1000 €/kW

Installed plant
(+/- 20 MW)

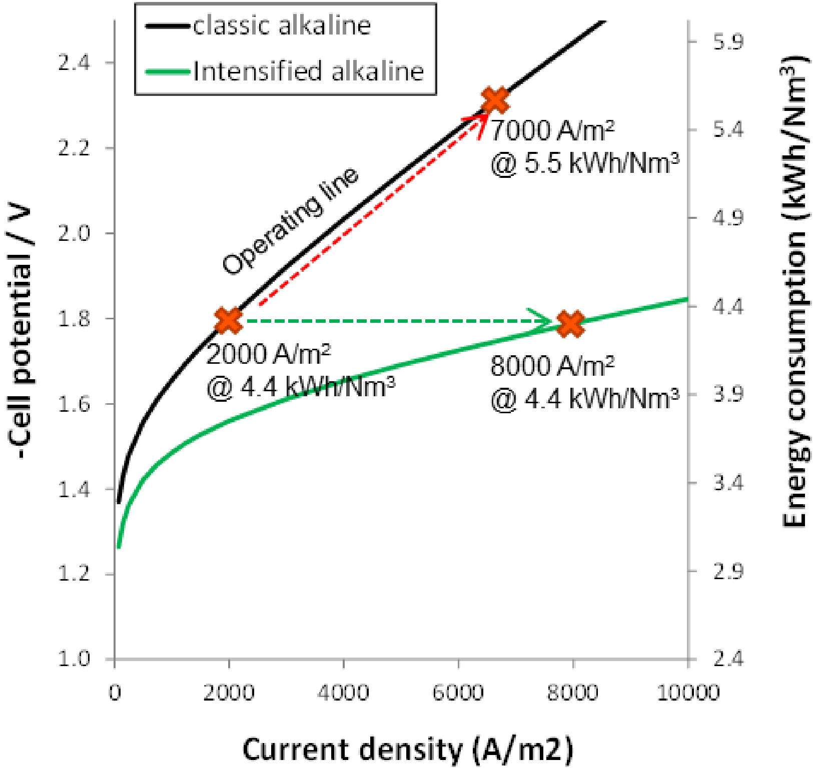
1500-2000 €/kW

Nouryon

Target costs



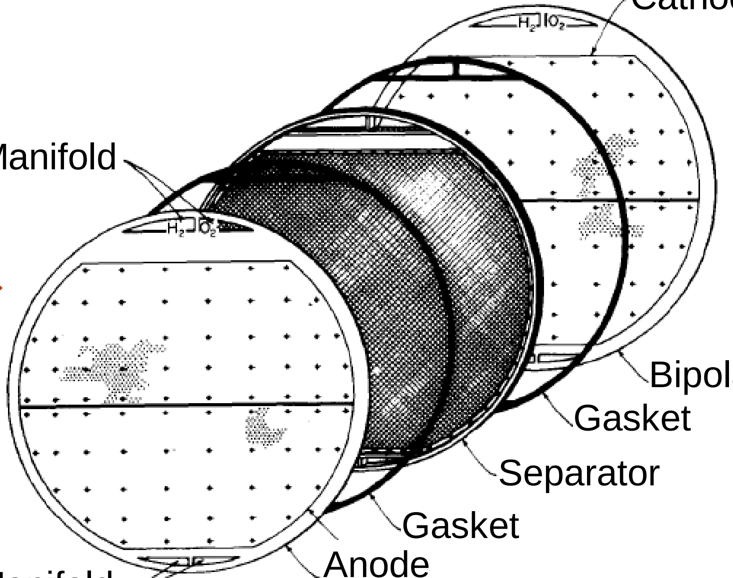
Alkaline electrolysis: intensification



In intensified electrolysis we aim to change the operating line through improved electrodes, membranes and cell designs, enabling increased current density without increased energy use.

Stack components

Designs of commercial stacks are very different, but they all have the same main components:



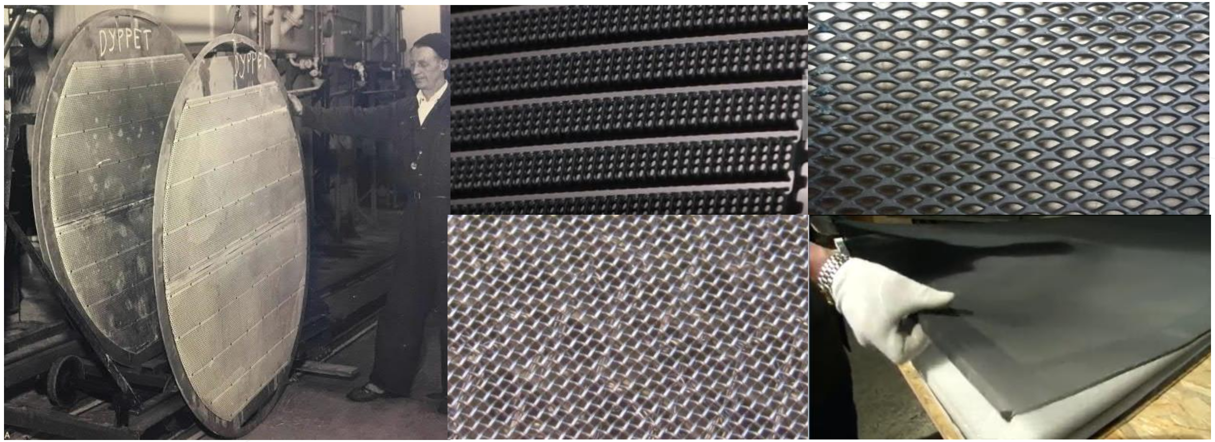
. 1. Norsk Hydro electrolyzer. Exploded view of an electrolyzer cell.

Image sources: NEL, Grundt, Int. J. Hydrogen Energy, 1982

Stack components

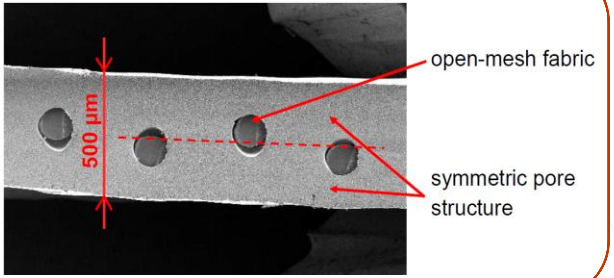
Nickel electrodes with catalytic coatings

Manufactured typically by electroplating, thermal spraying, or thermal decomposition



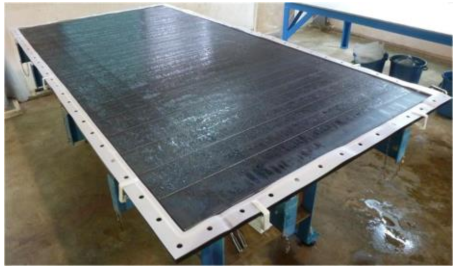
Membranes (Zirfon)

Manufactured by tape casting



Gaskets/seals

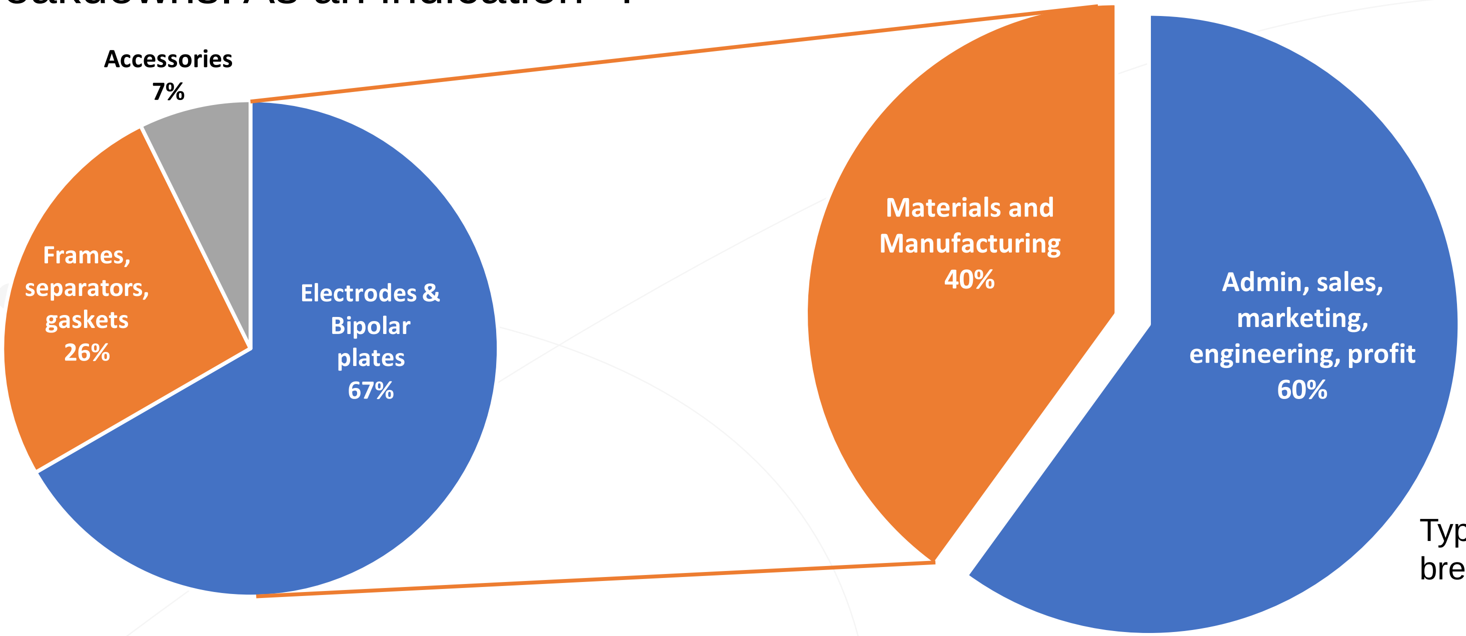
Typically: EPDM / Teflon



Cost breakdown

Different stack designs have different cost breakdowns. As an indication[1]:

Materials and manufacturing contribute significantly to the stack cost:

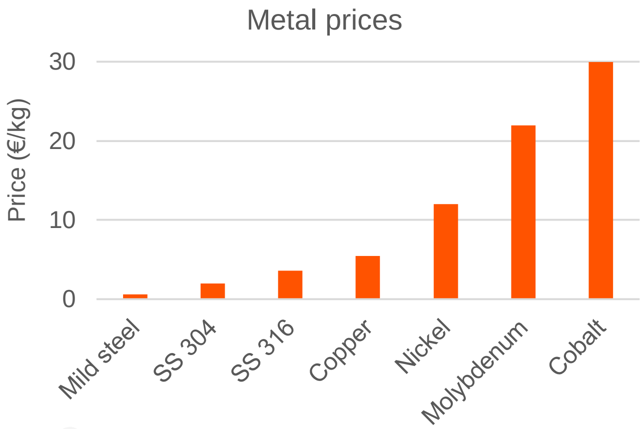


Typical product cost breakdown[2]

[1] FCHJU Report: Study on development of water electrolysis in the EU (2014)
[2] PLTW, Introduction to manufacturing processes

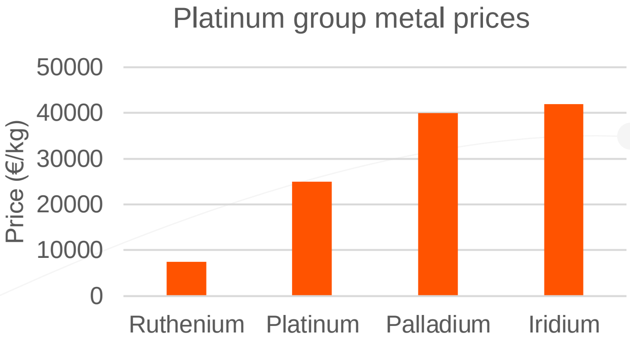
Material prices

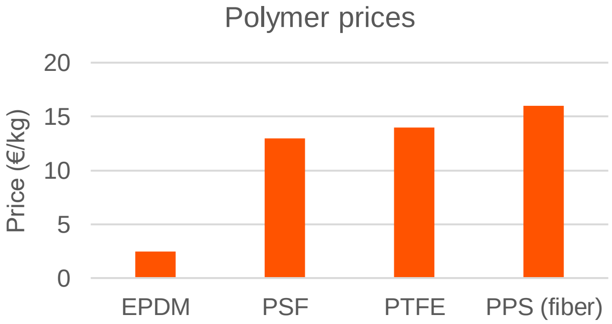
Nouryon



Bipolar plate*	Material cost per m^2
Pure Nickel	534 €/m^2
Ni-plated steel **	62 €/m^2

The material choice is crucial!

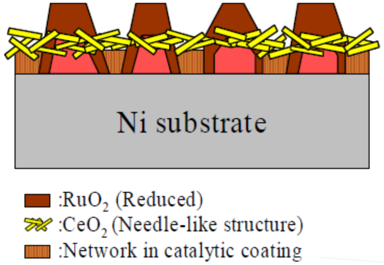




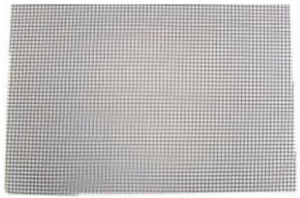
Notes:
* Hypothetical flat Bipolar Plate of 5 mm thickness.
** Mild steel plated with 200µm Ni (thickness estimated from ECS Transactions, 16 (39) 31-39 (2009))
Price sources: Chemical Economics Handbook, www.infomine.com, www.worldsteelprices.com

Materials for cathodes (example Asahi Kasei)

Asahi Kasei Chemicals Coorporation (AKCC) cathodes for H_2 evolution [1]



Characteristics of AKCC cathodes [1]

	New Cathode (2003-)	Conventional Cathode (1983-)
Main composition	RuO_2	NiO
Manufacture	Thermal decomposition	Plasma-sprayed
Overvoltage ($6kA/m^2$)	90mV	140mV
Coating thickness	Less than 10 μ m	200-300 μ m
Substrate	t 0.1-0.2mm wire mesh	t 0.5-1.0mm expanded
Photograph		
Estimated material cost of catalyst coating per m^2	150 €/m^2	19 €/m^2

Improved materials are not necessarily cheaper.

Cathodes for intensified electrolysis

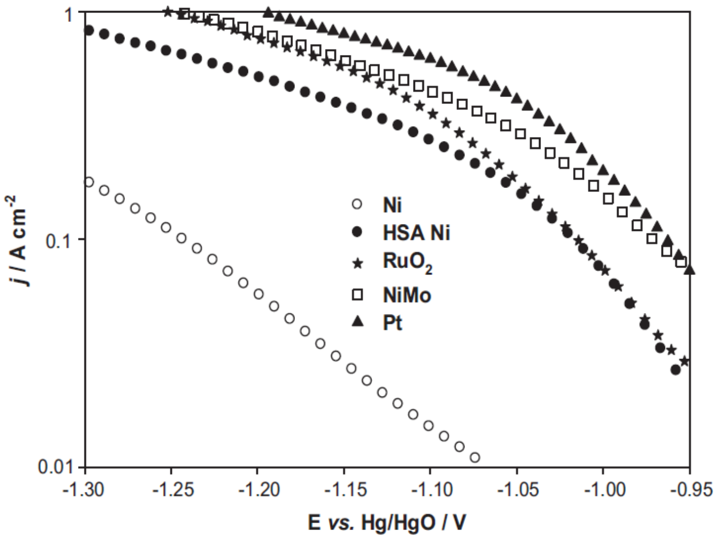


Fig. 4 — Tafel plots for hydrogen evolution at various coating materials in 4 M NaOH at 333 K.

Source: [3]

Electrode material	Description	Estimated material cost of catalyst coating per m²
High surface area Nickel	NiO, 200 µm thickness [1]	19 €/m²
NiMo	NiMo alloy (50-50 wt%) 100 µm thickness [2]	27 €/m²
Pt-Ru alloy	3,5 g/m² Pt, 1,5 g/m² Ru loading [3]	98 €/m²
RuO_2	20 g/m² Ru loading [1]	150 €/m²

Not only the functionality is important.
The cost is important too!

[1] ECS Transactions, 16 (39) 31-39 (2009), JP2016148074A
[2] Electrochimica Acta, 29 (11), 1551-1556 (1984)
[3] Int. Journal of hydrogen energy, 36, 15089-15104 (2011)

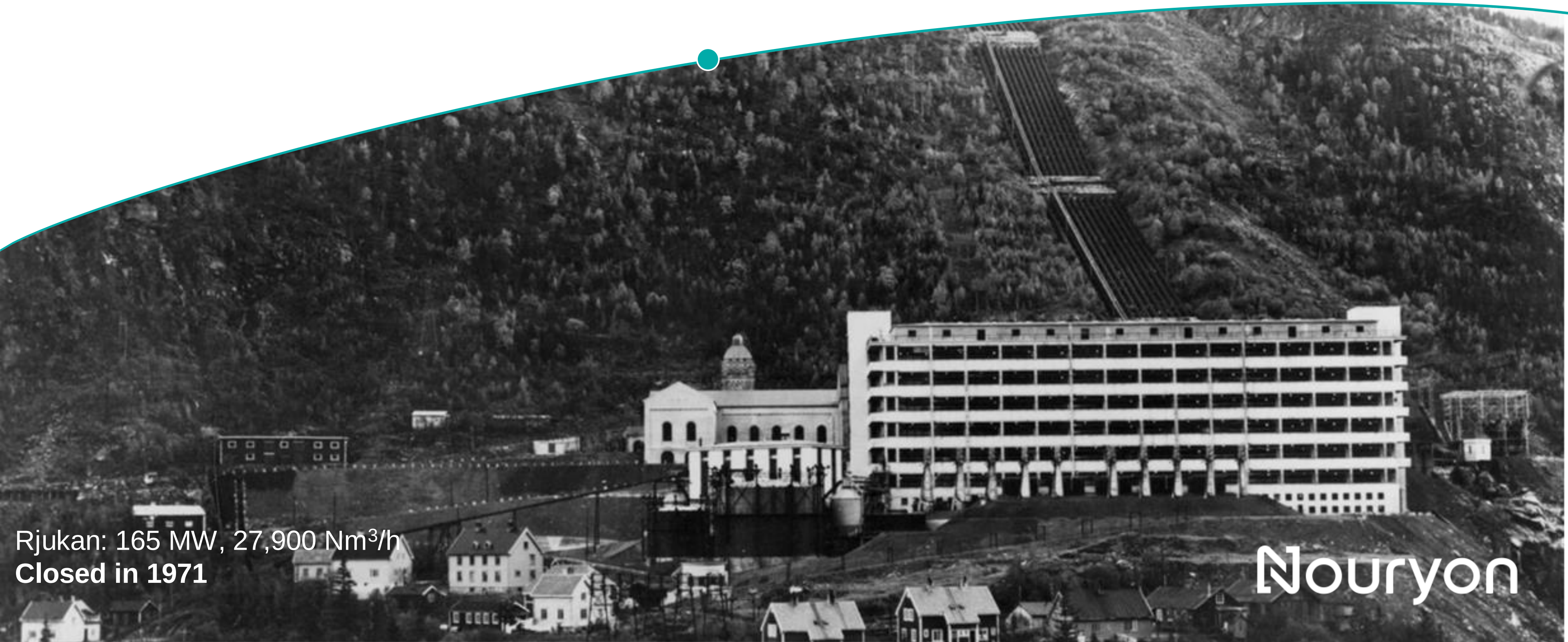
Conclusions

With the current electrolyzer designs we don't reach the target price of H_2 to make electrolysis competitive to the fossil fuel route. We need to intensify and re-design!

- We need to develop improved and low cost electrolyzer components:
  - Better electrodes & membranes: excellent performance & lifetime at high current densities
  - Improved cell designs: minimize power losses, optimal flow conditions, operation at high current density, pressure and temperature

- We need to improve the stack manufacturing processes:
  - Low cost manufacturing techniques that minimize the material usage while preserving high performance
  - Move towards continuous manufacturing processes and automation of stack assembly

Thank you for your attention!



Rjukan: 165 MW, 27,900 Nm^3/h
Closed in 1971