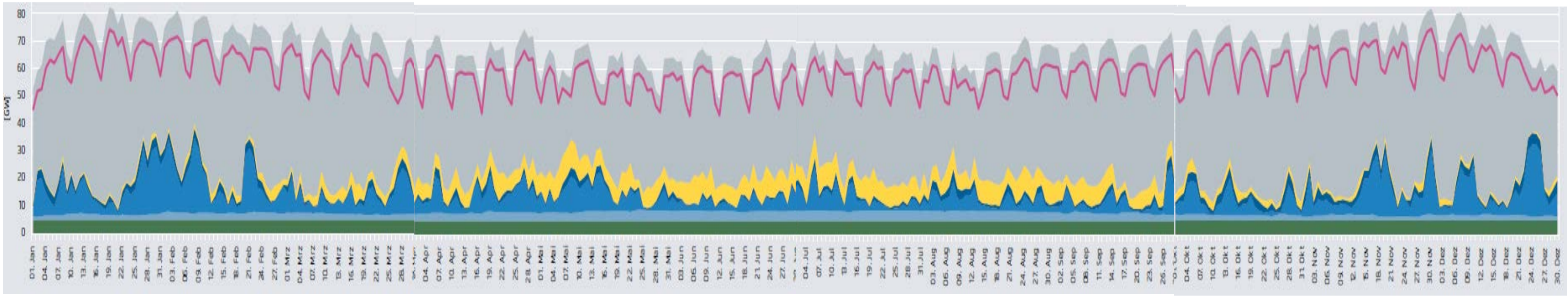
Electricity storage & hydrogen feedstock production with a battolyser

Fokko Mulder,
f.m.mulder@tudelft.nl
Chemical Engineering
Materials for Energy Conversion and Storage (MECS)

TU Delft
Delft University of Technology

Renewable energy system?

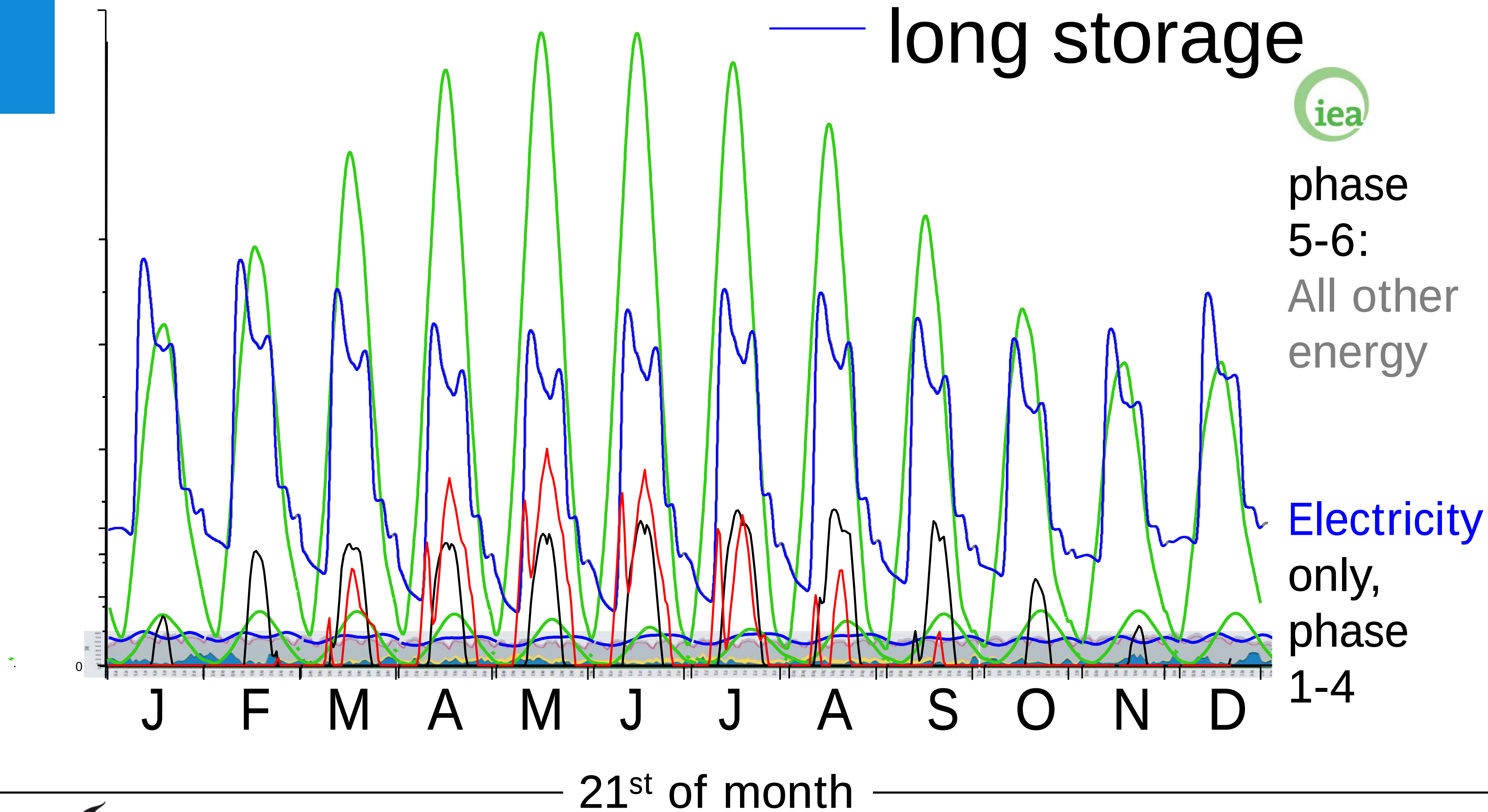
100% Renewable?



Energy transition?

100% Renewable?

Solar power dominance...



Mulder, J. Renewable and Sust. Energy 2014

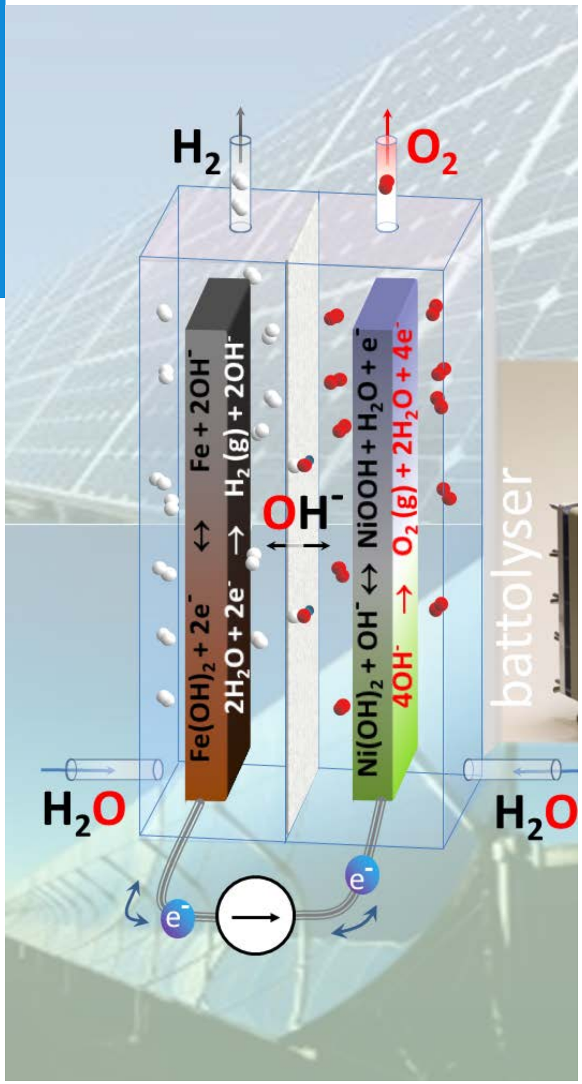
Efficient use of renewable electricity:

1. Direct use: most efficient
2. Short term storage in batteries very efficient
3. Long term storage in fuels less efficient

Battolyser:

integrate short & long term storage
in one device

‘Battolyser’ basic reactions:



Negative electrode:

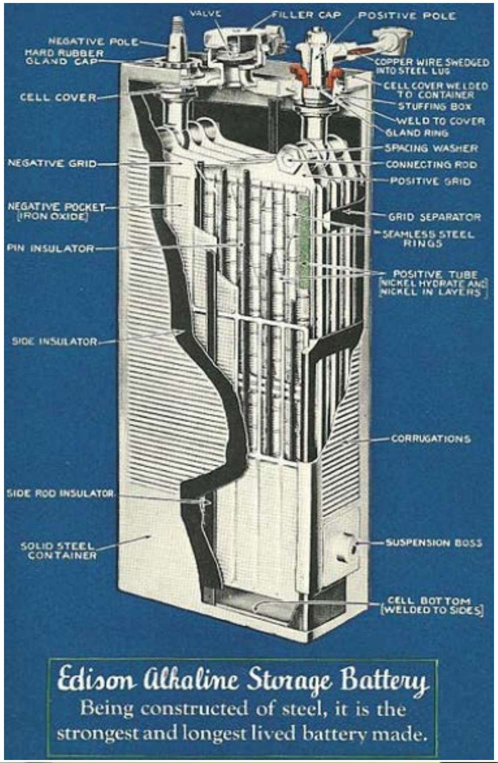
$$Fe(OH)_2 + 2e^- \leftrightarrow Fe + 2OH^-$$

$$2H_2O + 2e^- \rightarrow H_2\,(g) + 2OH^-$$

Positive electrode:

$$Ni(OH)_2 + OH^- \leftrightarrow NiOOH + H_2O + e^-$$

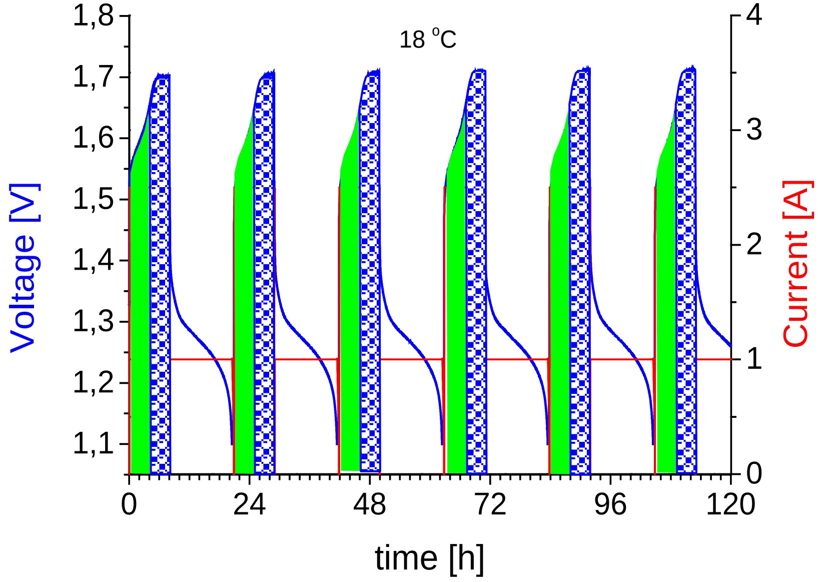
$$4OH^- \rightarrow O_2\,(g) + 2H_2O + 4e^-$$

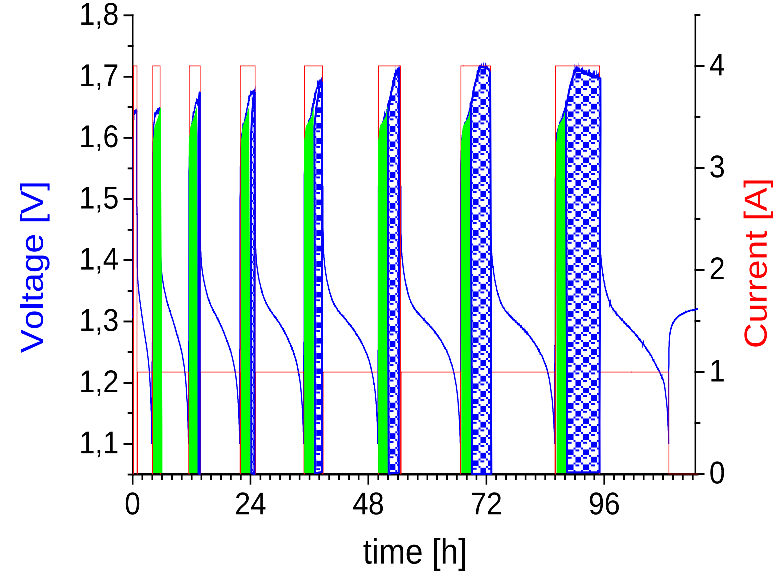


Combine the
most durable
Alkaline Ni-Fe battery
and
most durable
Alkaline electrolyser
in one

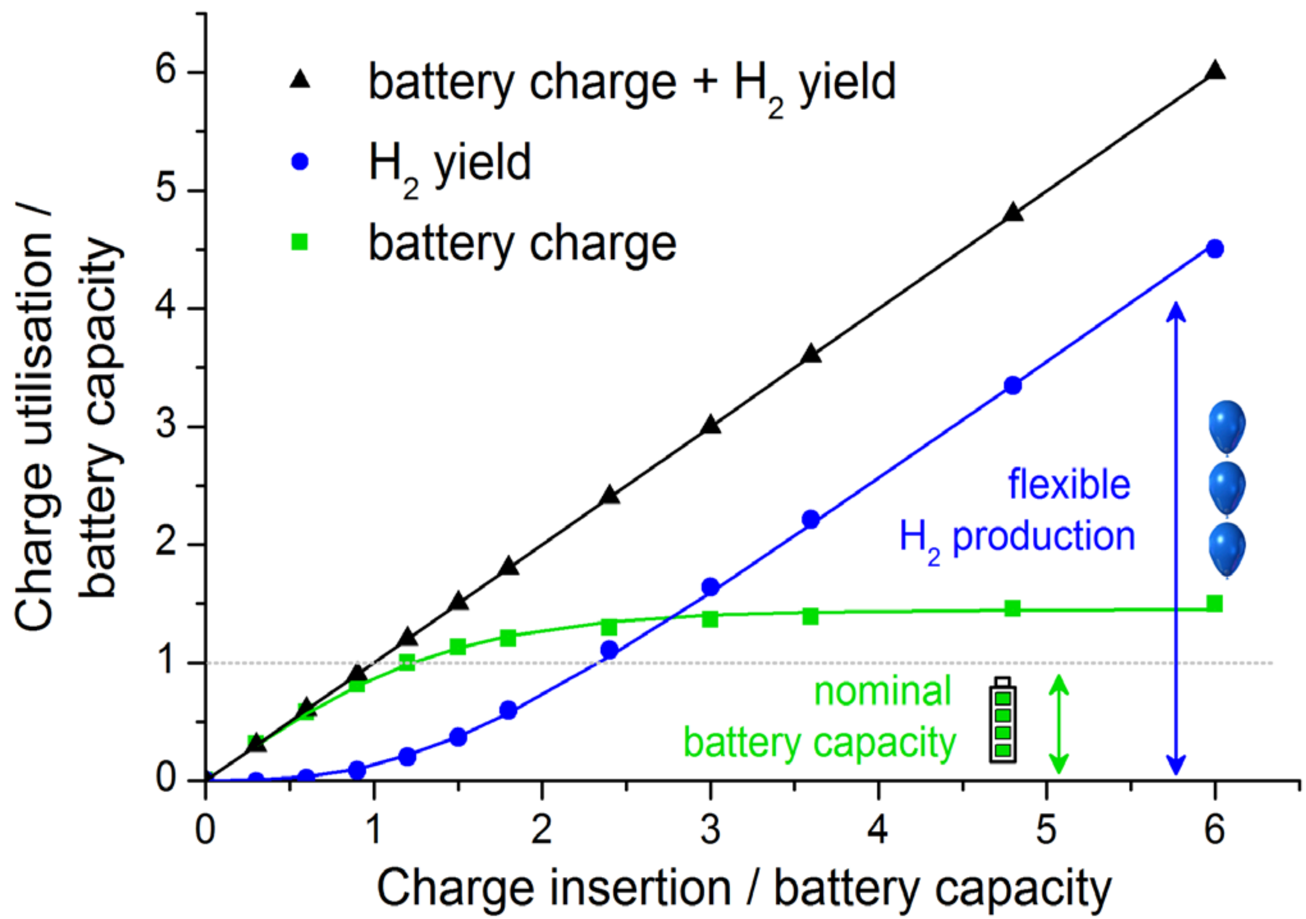
Electric car from 1912 with Ni-Fe battery,
still operational

Charge (green) + electrolysis (bubbles) and discharge (white)



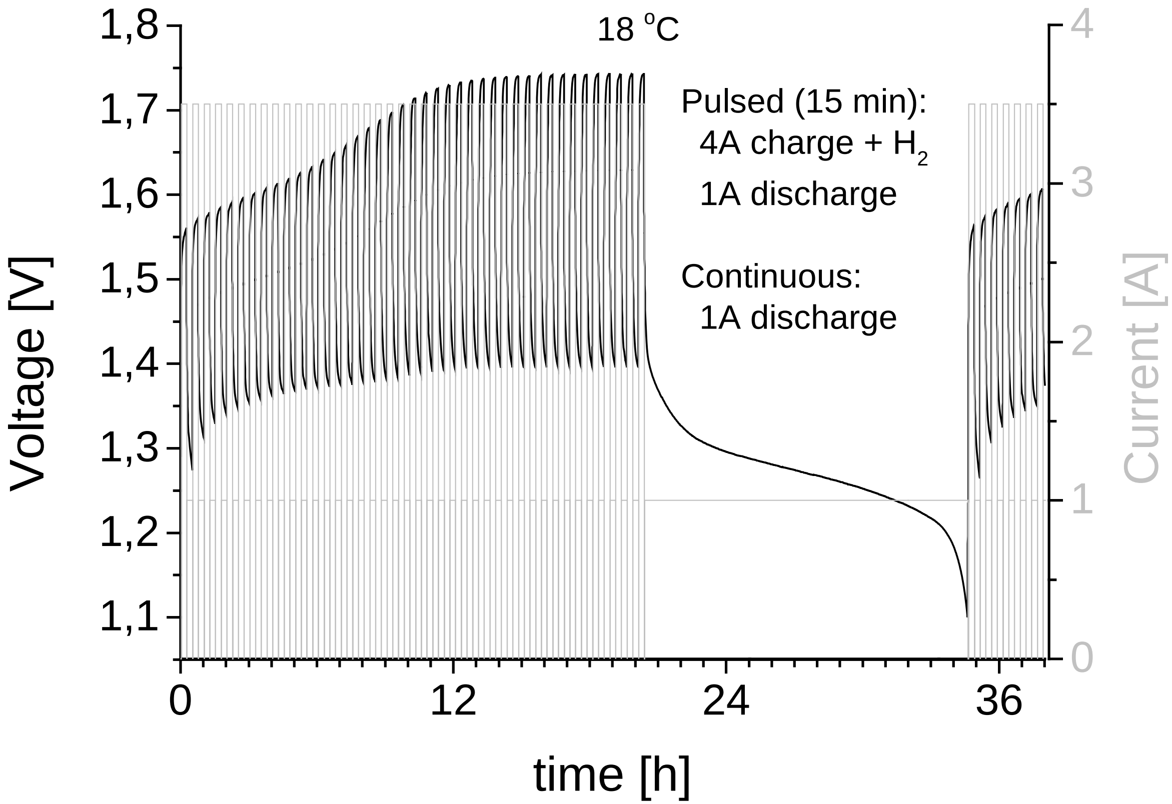


Current: applied currents during charge, electrolysis, and discharge
Voltage: that is the voltage that results when using these currents
Several cycles with constant (left) or increasing (right) current insertion.



Flexible operation: one can choose amount of charge insertion

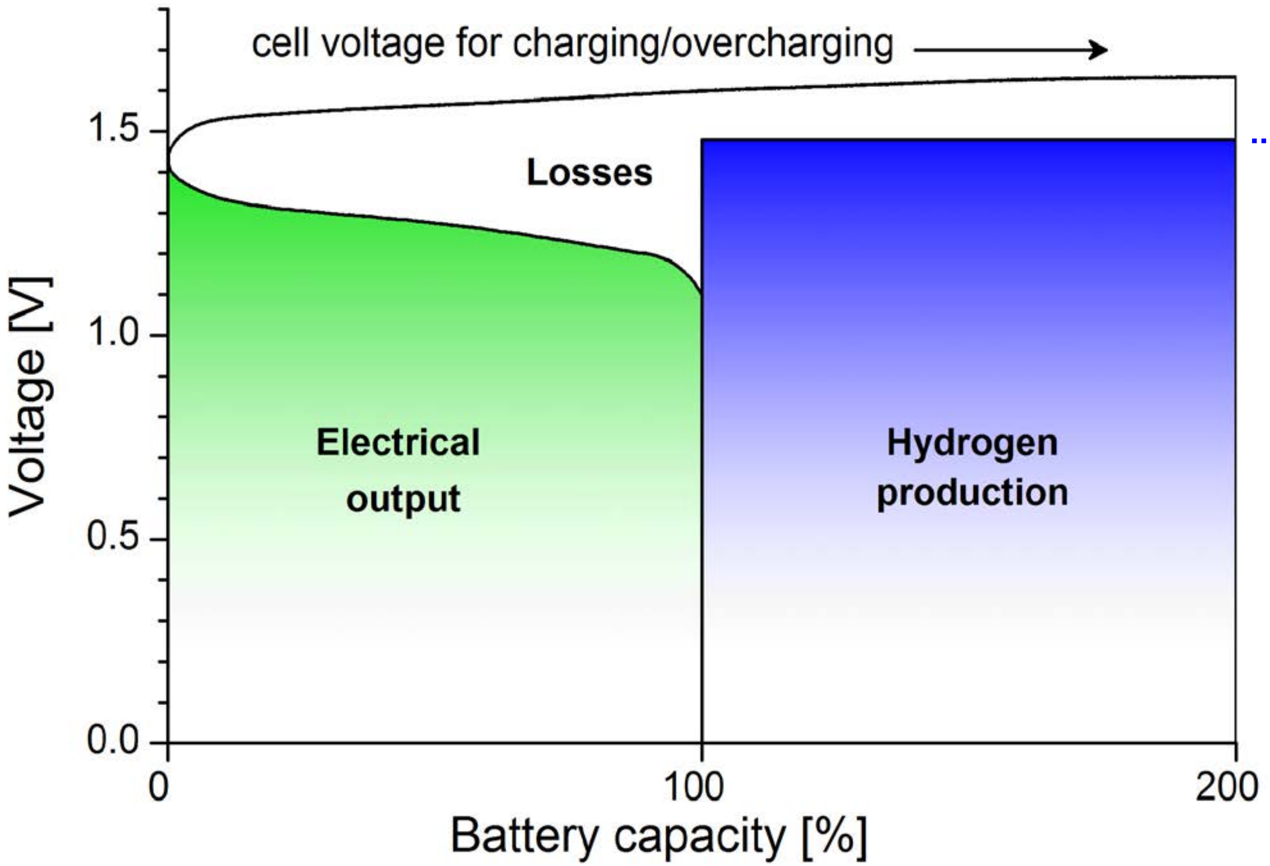
Charge and discharge switching capabilities



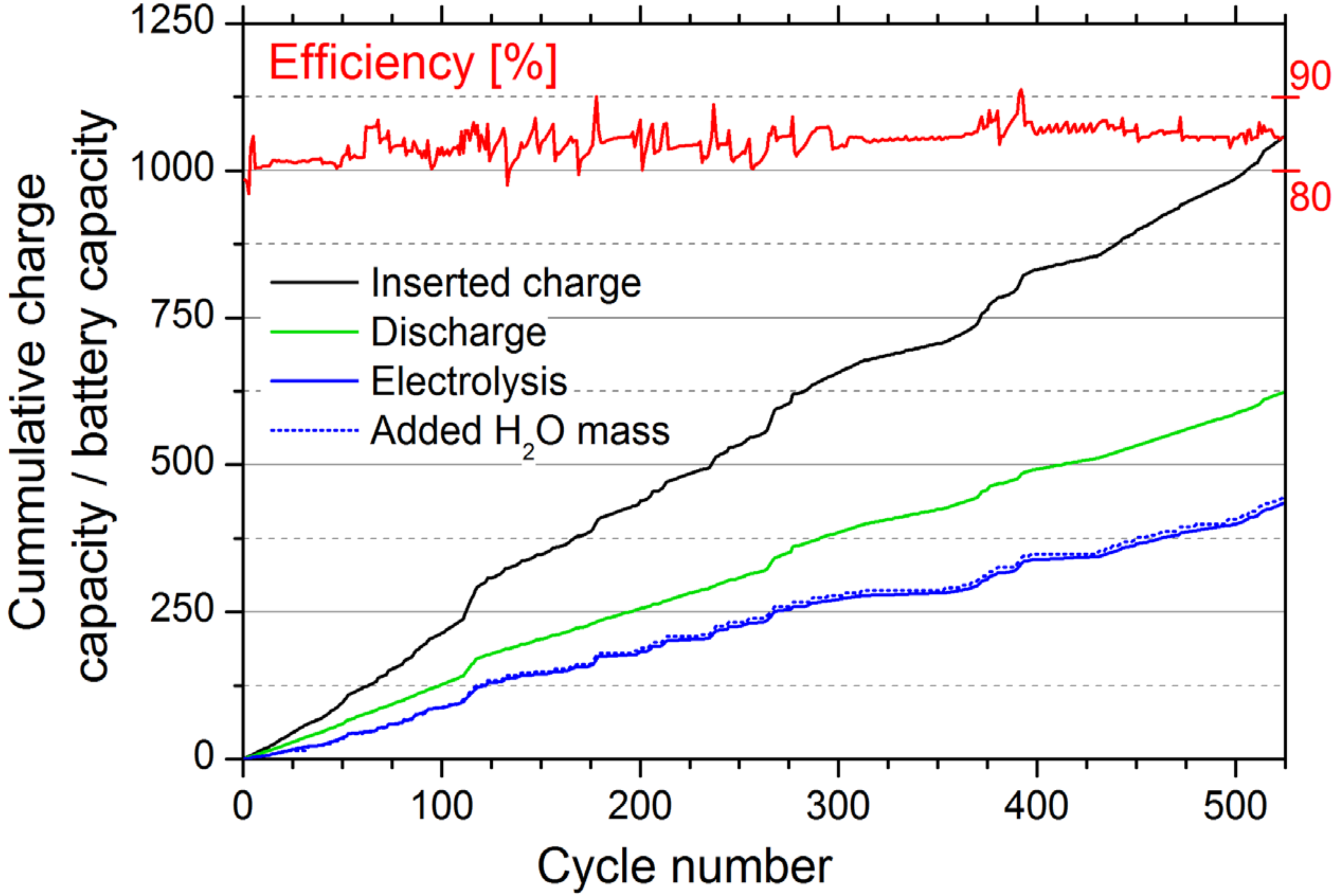
15 minute switching

Compatible with 15 minute electricity market time slots

Energy efficiency:



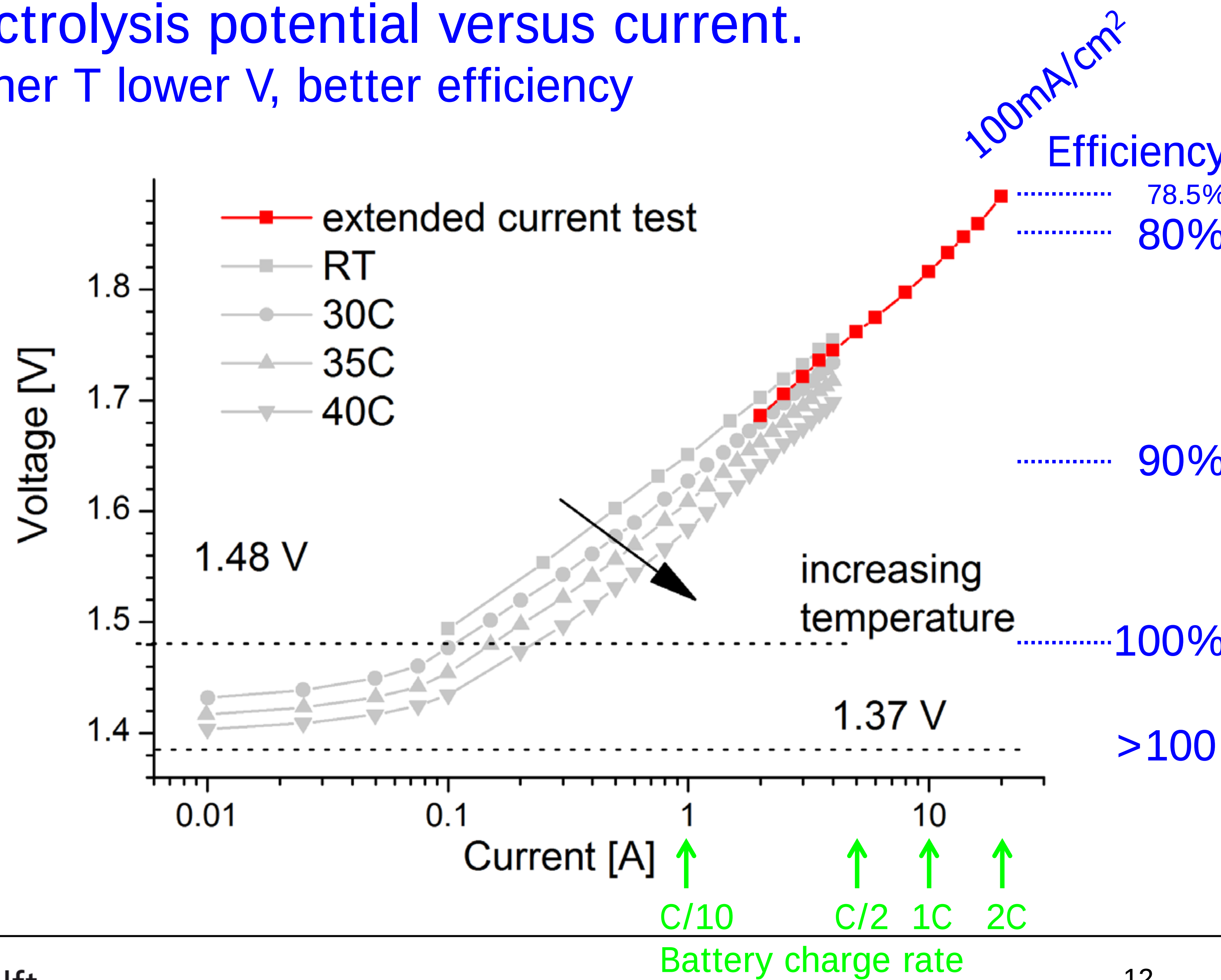
1.48V Thermo-neutral potential = HHV

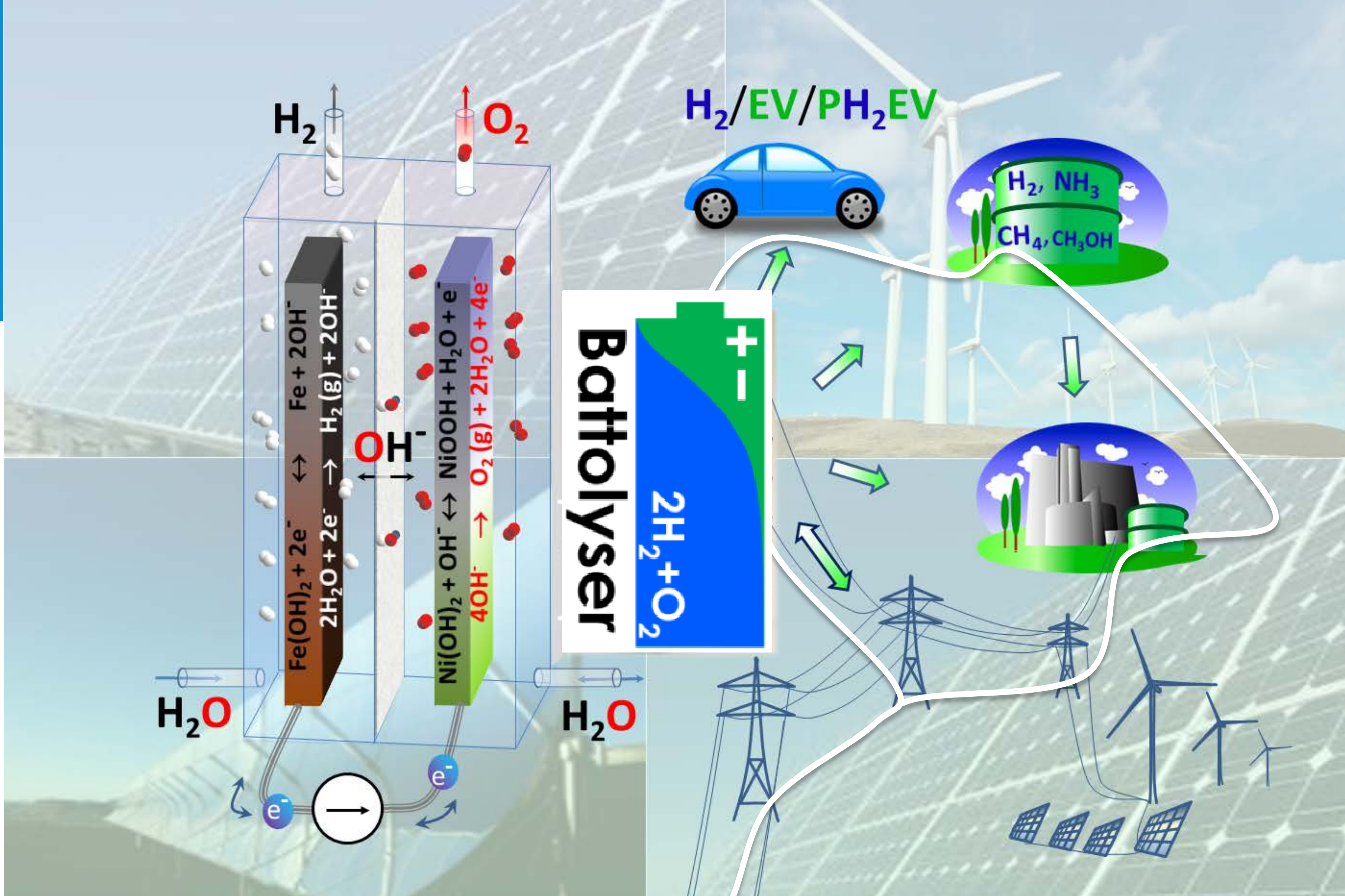


Efficiency [%]
90
80
Inserted charge
Discharge
Electrolysis
Added H_2O mass
Cummulative charge capacity / battery capacity
0
250
500
750
1000
1250
0
100
200
300
400
500
Cycle number

Electrolysis potential versus current.

Higher T lower V, better efficiency





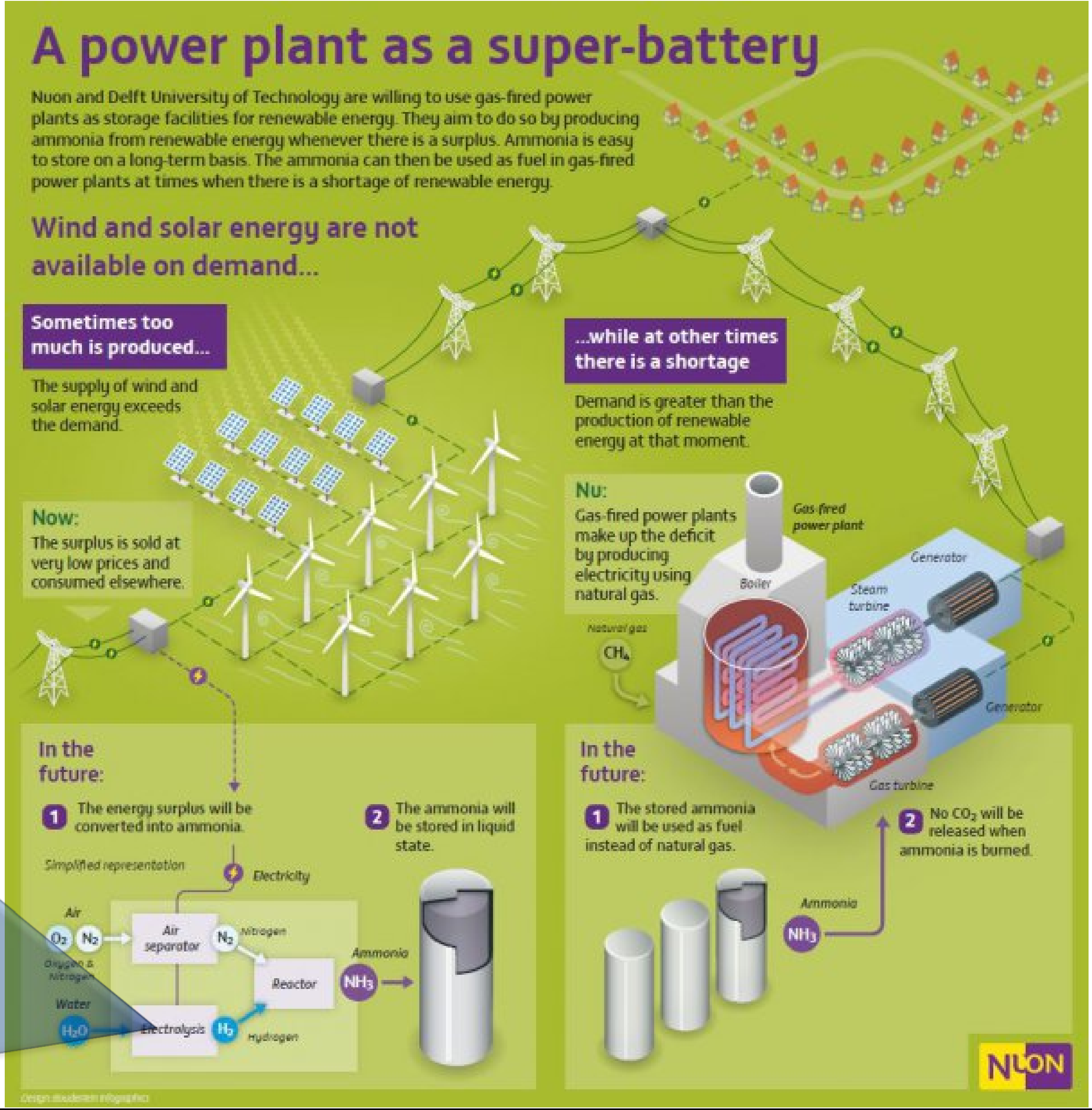
Energy & Environmental Science 2017

HOT paper

P2A: Power to ammonia

Applied and Engineering Sciences

TU Delft



News: Upscaled battolyser at Magnum powerplant Eemshaven, planned 2019

waddenfonds


VATTENFALL

About Vattenfall | Sustainability | Investors | Press and media | Careers | About energy

News | Media bank | Contacts

Builds combined electricity storage and hydrogen production facility at Dutch gas power plant.

2018-06-12

YARA

+ −

$2H_2+O_2$

Battolyser

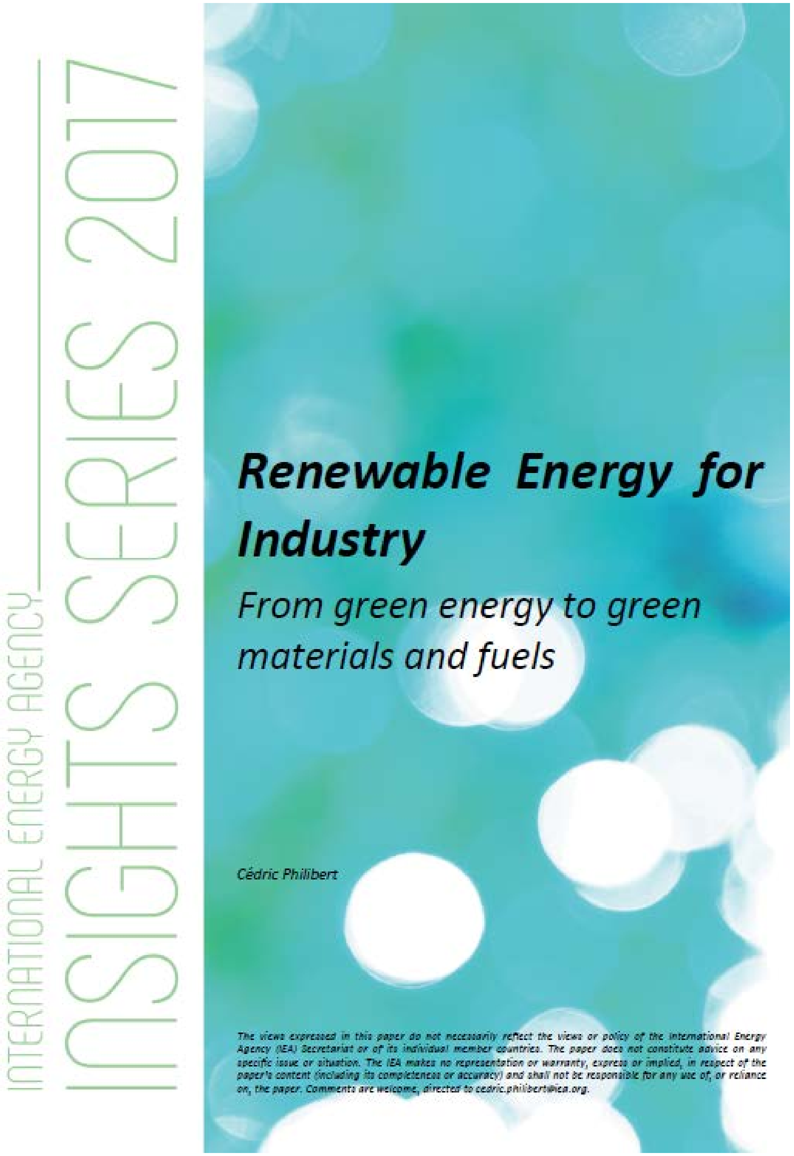
TU Delft

PROTON VENTURES

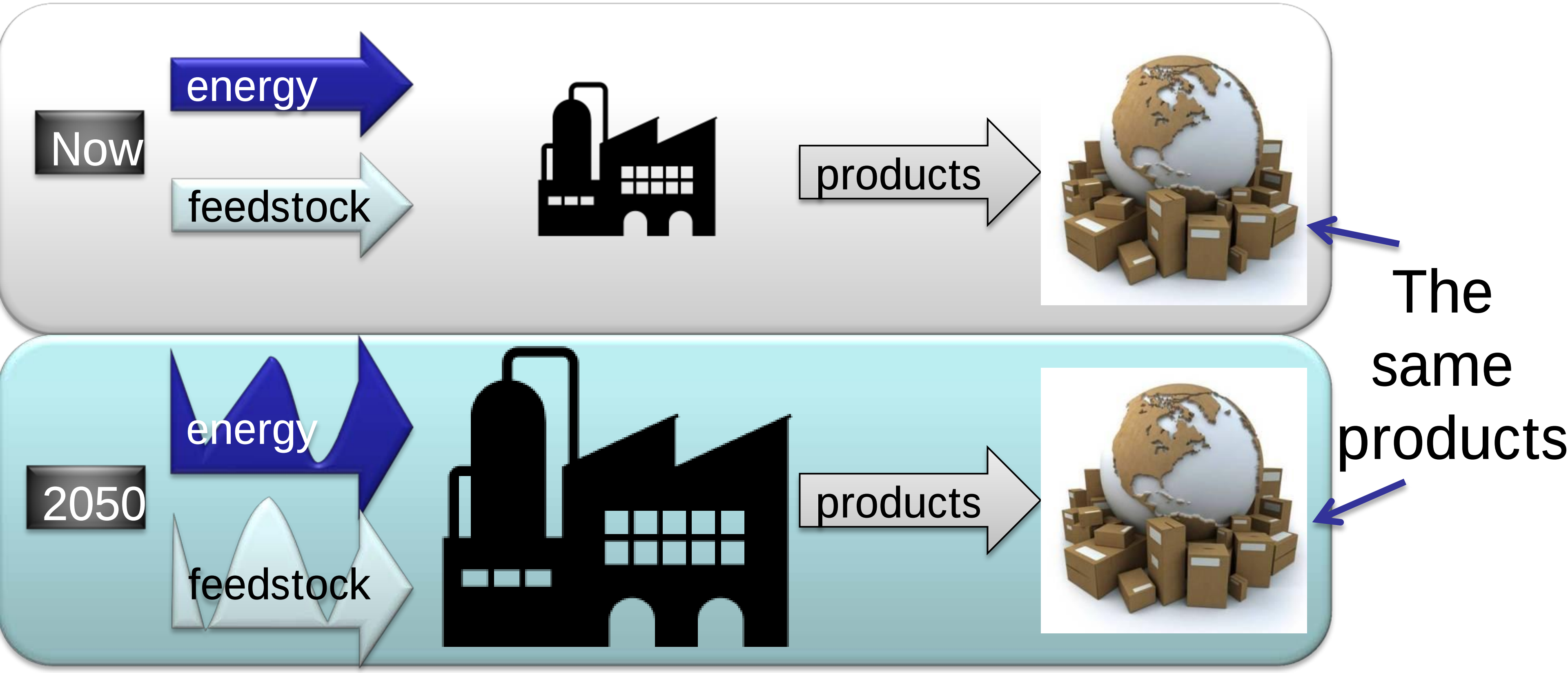
If you have H_2 you can 'clean' many processes in industry

- Steel
- Ammonia
- Cement
- Methanol

IEA 2017:



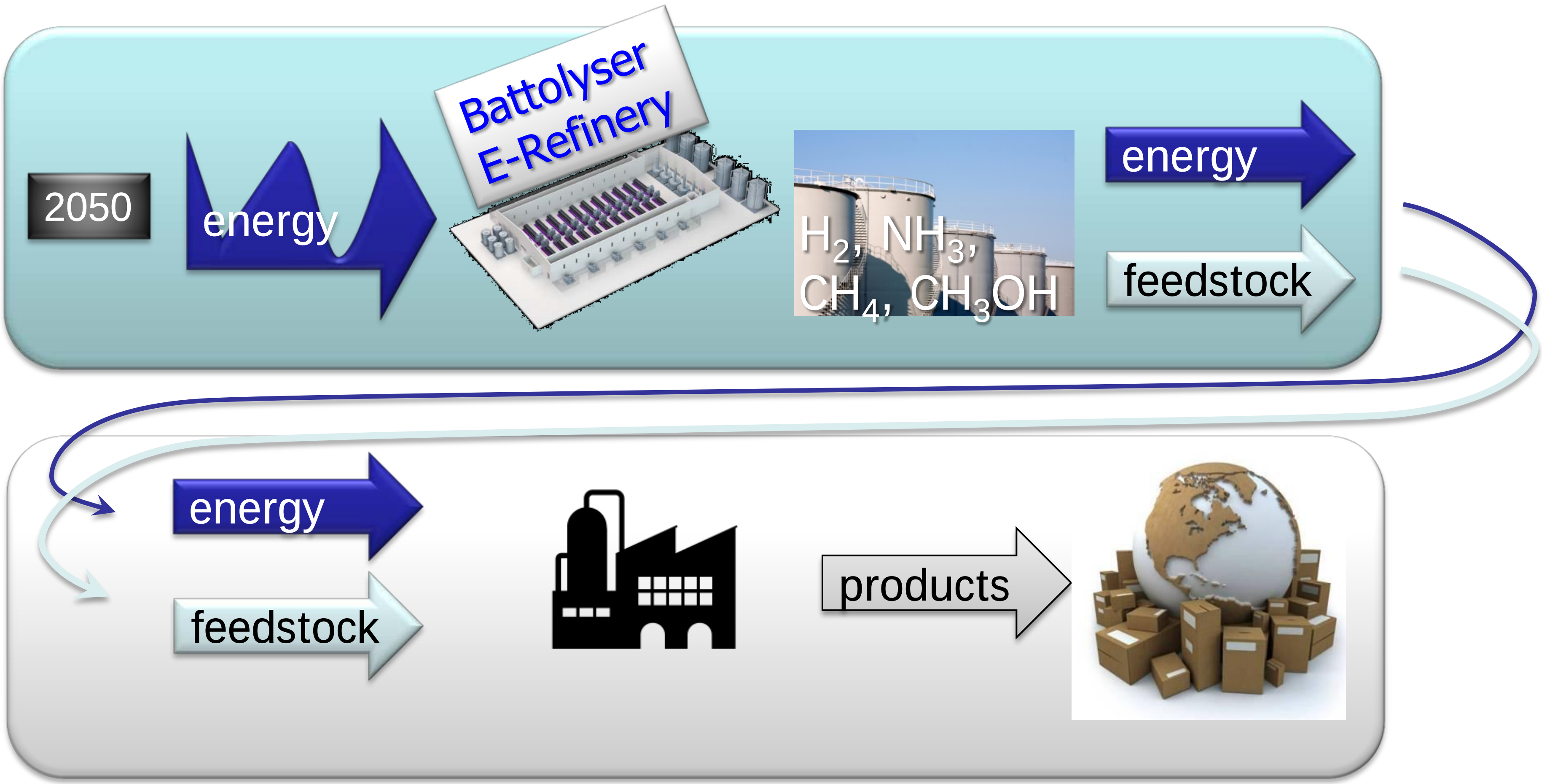
➢ Energy & feedstock transition:



Larger capacity to handle intermittency, lower capacity factor?

TU Delft

➢ Greening of energy and feedstock supply



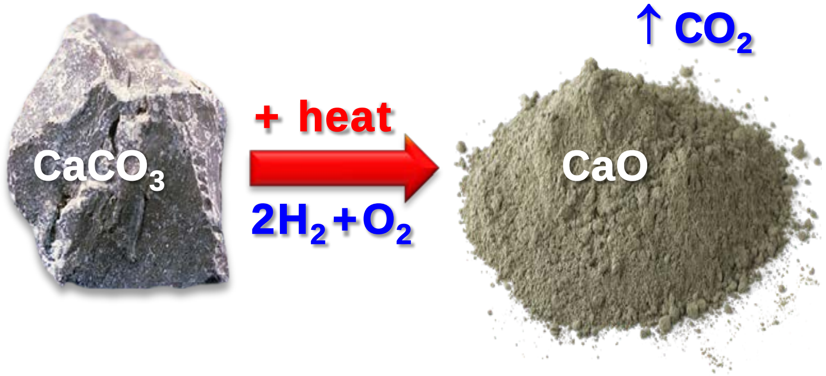
TU Delft

H_2 Feedstock & power

- H_2, power and N_2 for NH_3 synthesis
- H_2, power and CO_2 for Sabatier or Fischer-Tropsch process

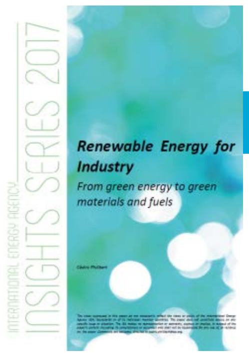
Environ. Sci. Technol., 2011, 45, 8609

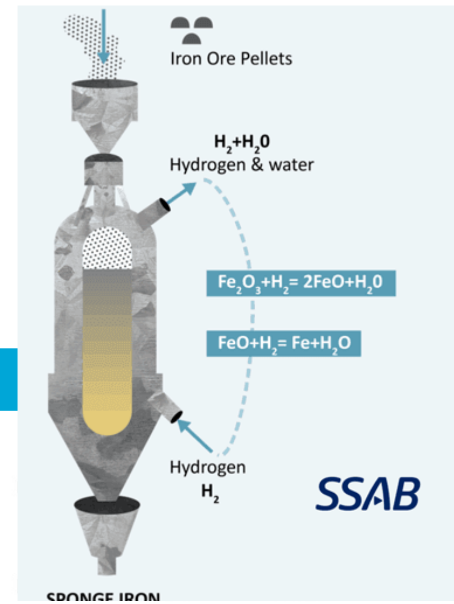
- H_2 & power for concrete production and CO_2 harvesting



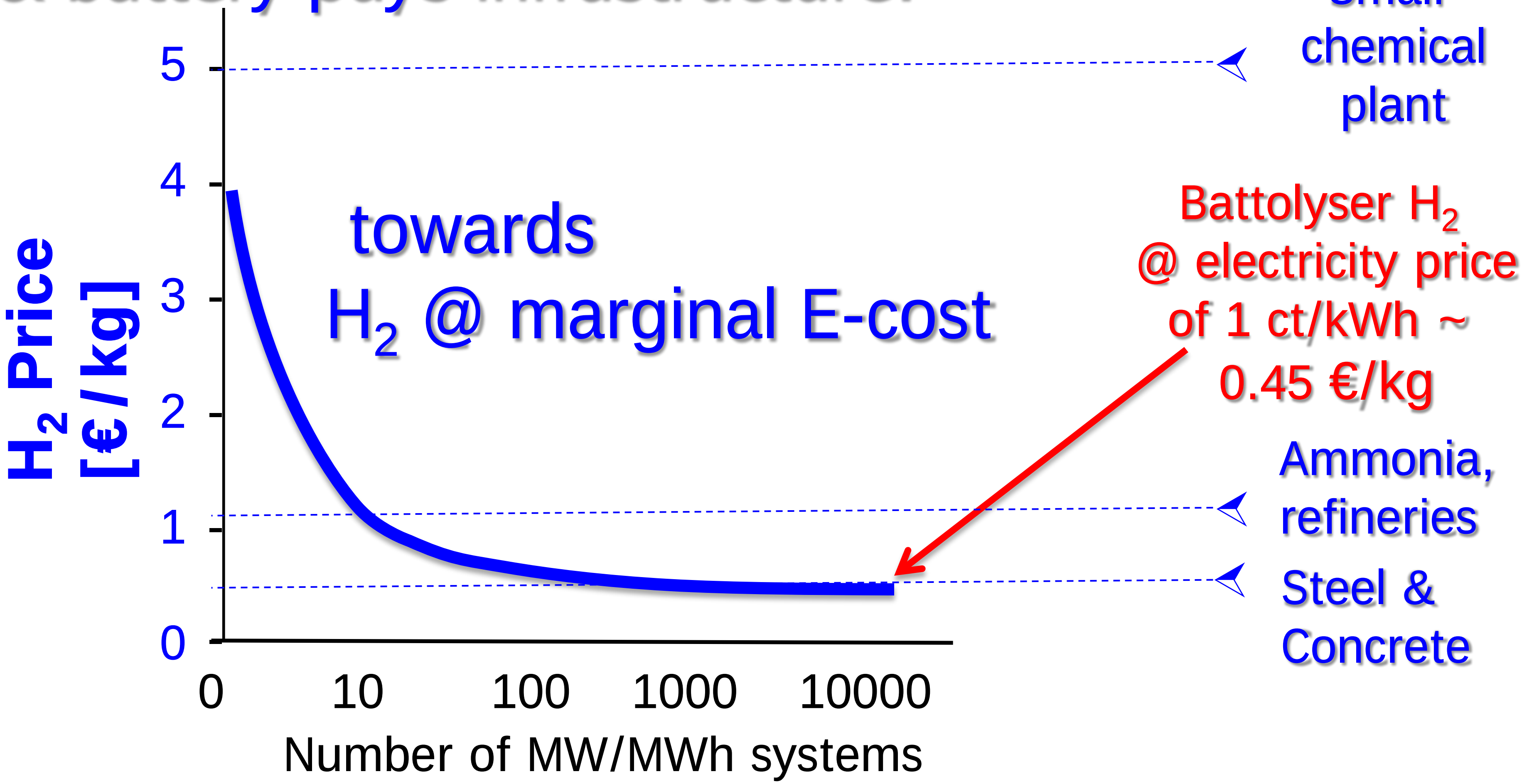
- H_2 & power for fossil free iron reduction

$$Fe_2O_3 + 3H_2 \rightarrow 2Fe + 3H_2O$$



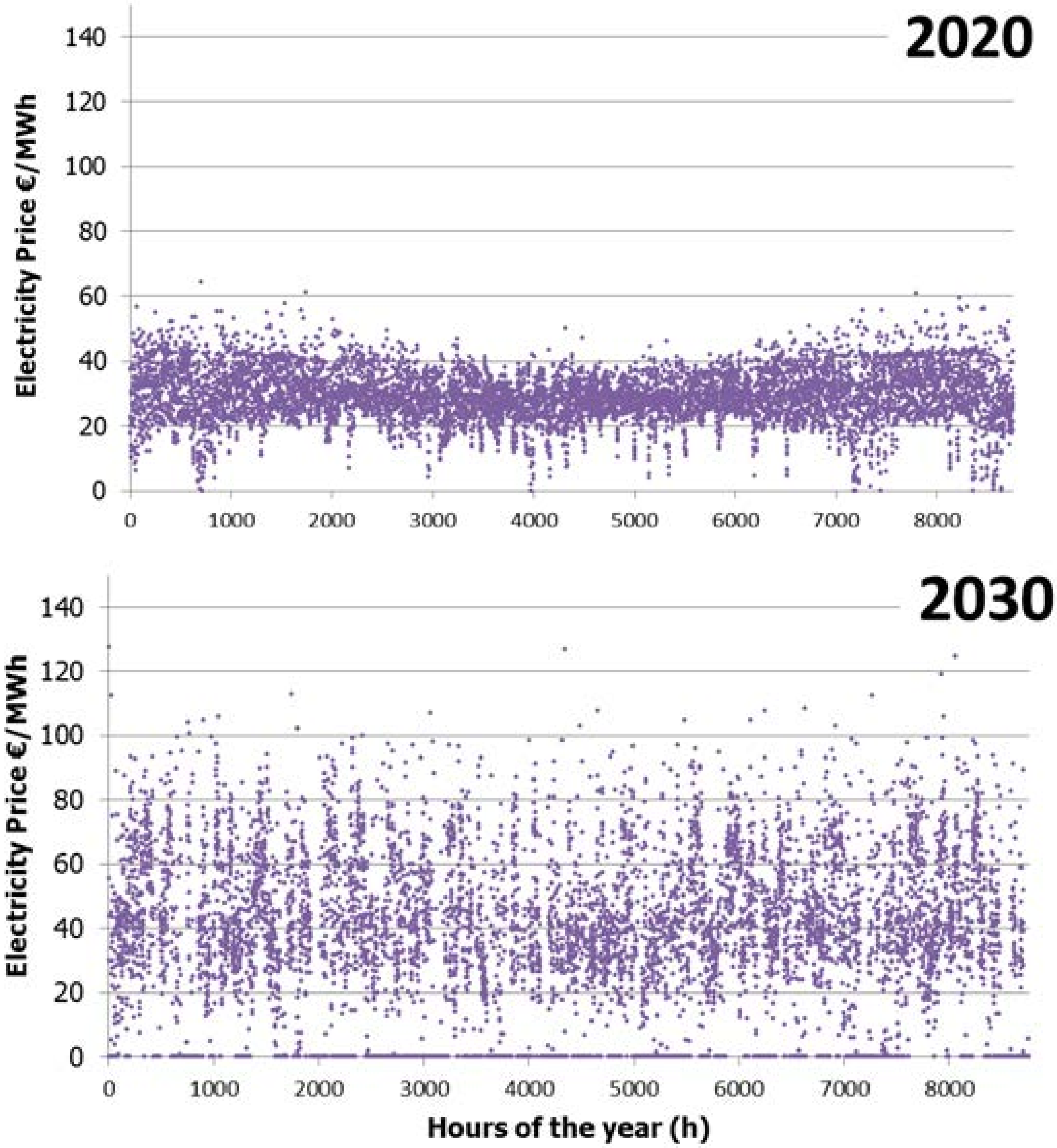


Abundant renewables, scaling up & battery pays infrastructure:



Battolyser

Power 2 Ammonia project with ISPT and partners

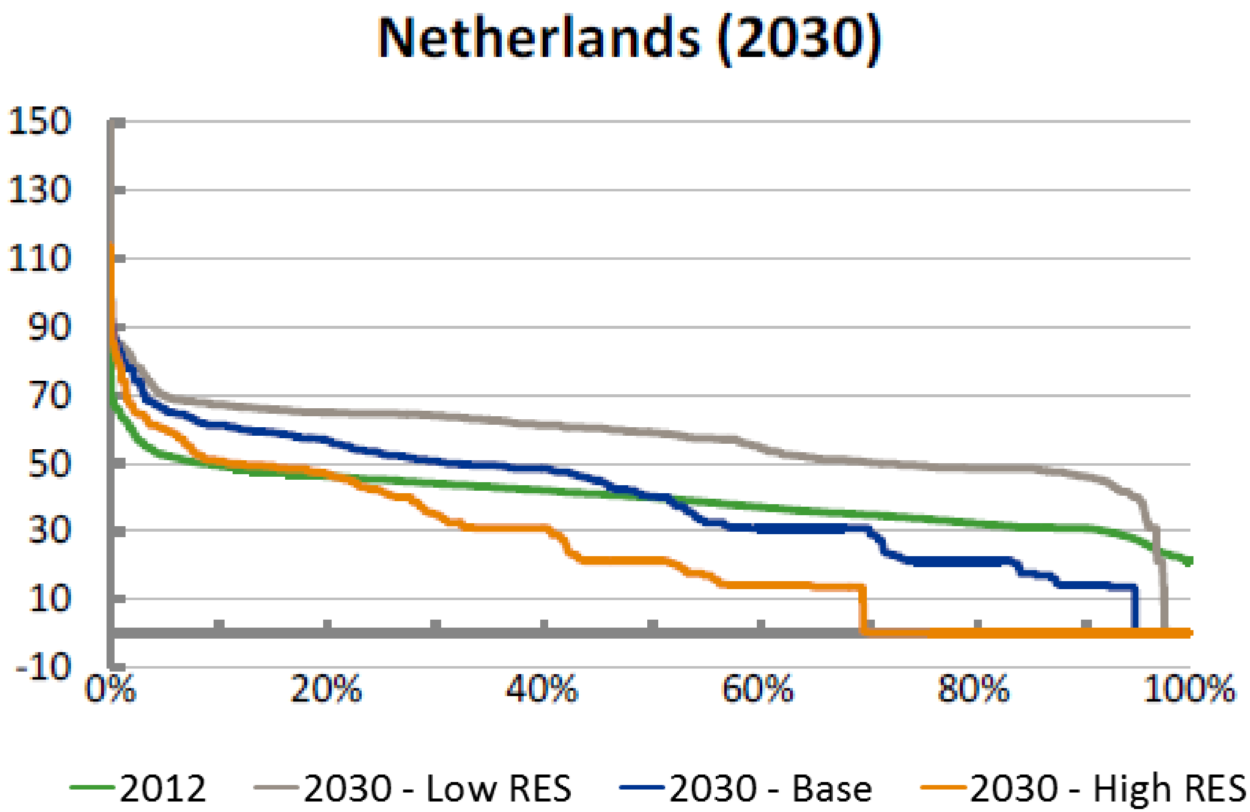


Simulations day-ahead market of CE Delft

Larger price differences: Many low & many high price hours: storage opportunity

Wind electricity price

North Sea Power to Gas Platform 2014

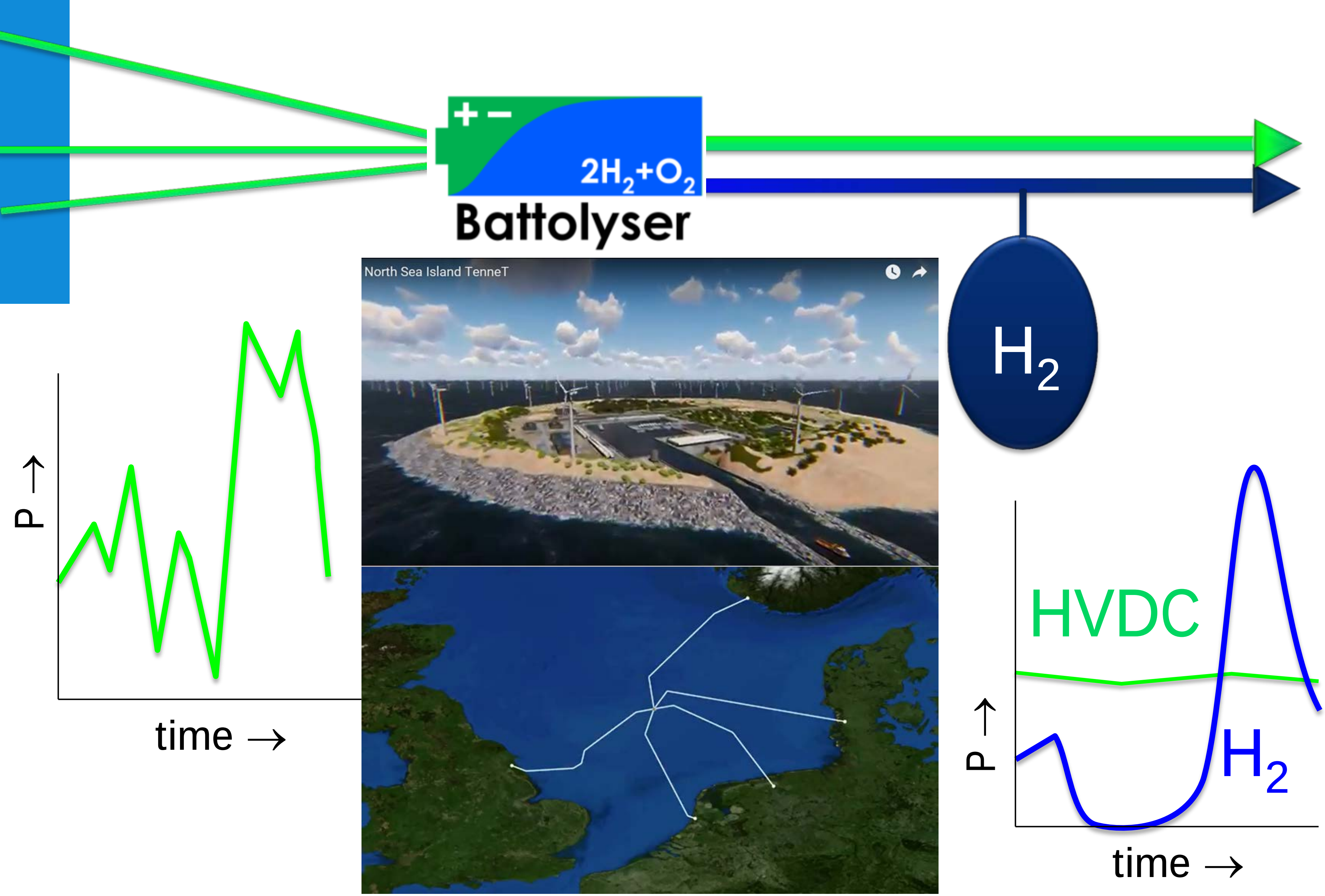


Source: DNV GL

High renewables:
Many low price
< 1ct/kWh
hours, curtailment

ENTSO-E Vision4 scenario 2014,
not high in RES any more today...

Delft University of Technology


+ −
2H2+O2
Battolyser
H2
North Sea Island TenneT
P ↑
time →
HVDC
H2
P ↑
time →

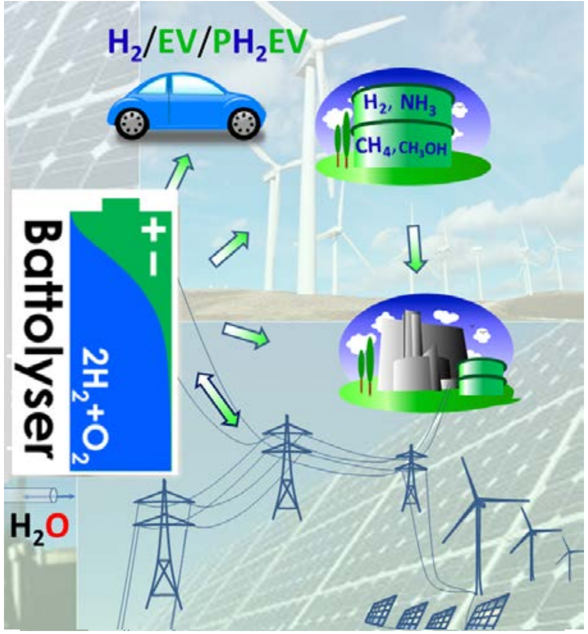
Battolyser tests

- Energy efficiency > 82-92%
- Scalable, no precious metals
- Highly robust
- Switches instantly
- Competitive with static batteries and electrolysers

2 FOR 1

NWO Applied and Engineering Sciences

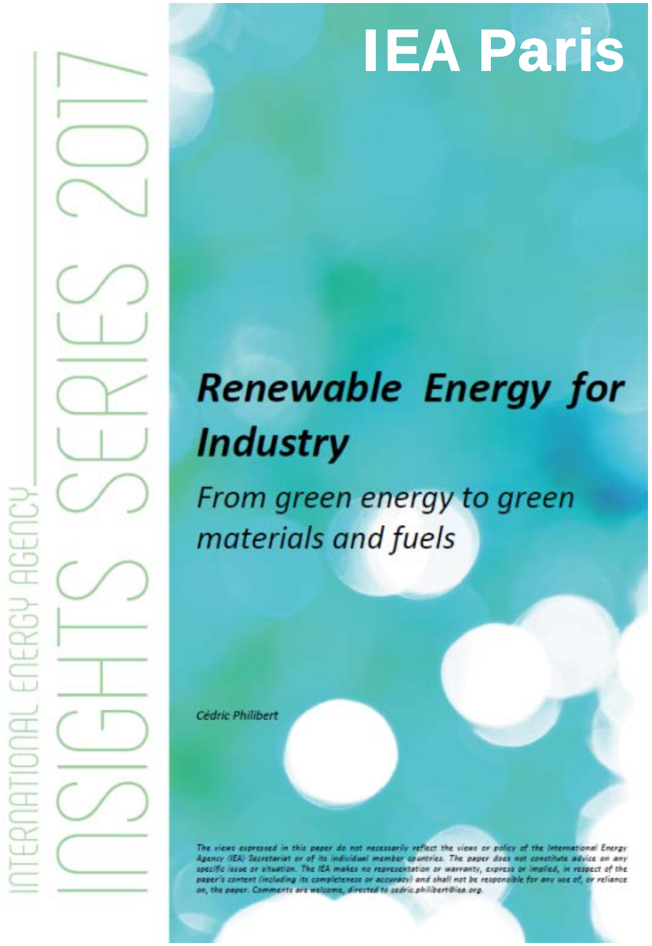
& industrial partners

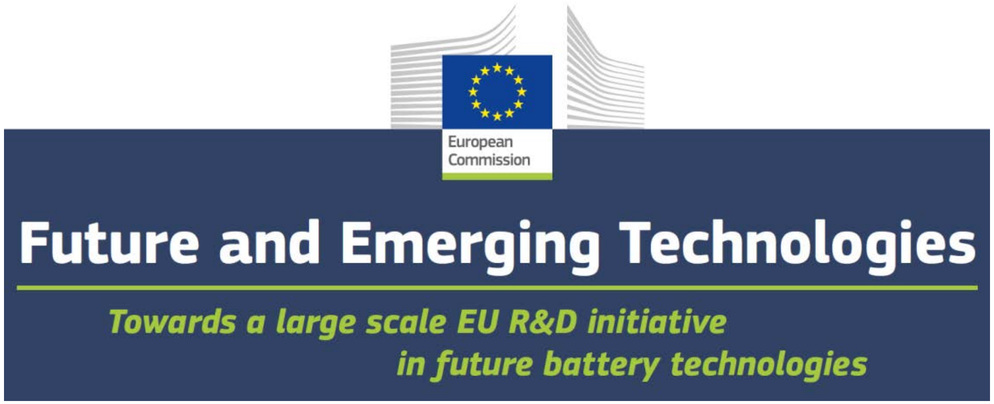


waddenfonds

Battolyser exposure

IEA Paris





Battery Alliance EU

https://setis.ec.europa.eu/system/files/set_plan_batteries_implementation_plan.pdf

Acknowledgements:

Audrey Iranzo
Jebin James
Joost Middelkoop
Robin Moller-Guland
John Nijenhuis
Frans Ooms
Herman Schreuders
Berhard Weninger
& Industrial partners

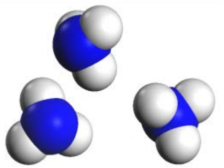
waddenfonds

NWO | Applied and Engineering Sciences

P2A

ISPT

Ammonia NH_3 for large scale energy storage?



Energy future	➢ Renewables implementation needs storage.
Production	➢ based on abundant elements N, H, and cheap catalysts: scalable. ➢ can be produced using abundant renewable electricity and CO_2 free.
Storage	➢ energy density NH_3: 22.5 MJ/kg (HHV) ➢ liquid at 10bar, 20ºC and 1bar, -35ºC ➢ current containers can contain 100000 ton NH_3~ 625 GWh.
Use	➢ clean use in fuel cell, combustion engine, gas turbine. No CO_2. ➢ fertilizer industry: CO_2 neutral fertilizers
Acceptance	➢ poisonous, but 100^+ yr industrial know-how ➢ current NH_3 production costs >1.5% of world energy use >5 EJ/yr ➢ Bio degradable (fertilizer)