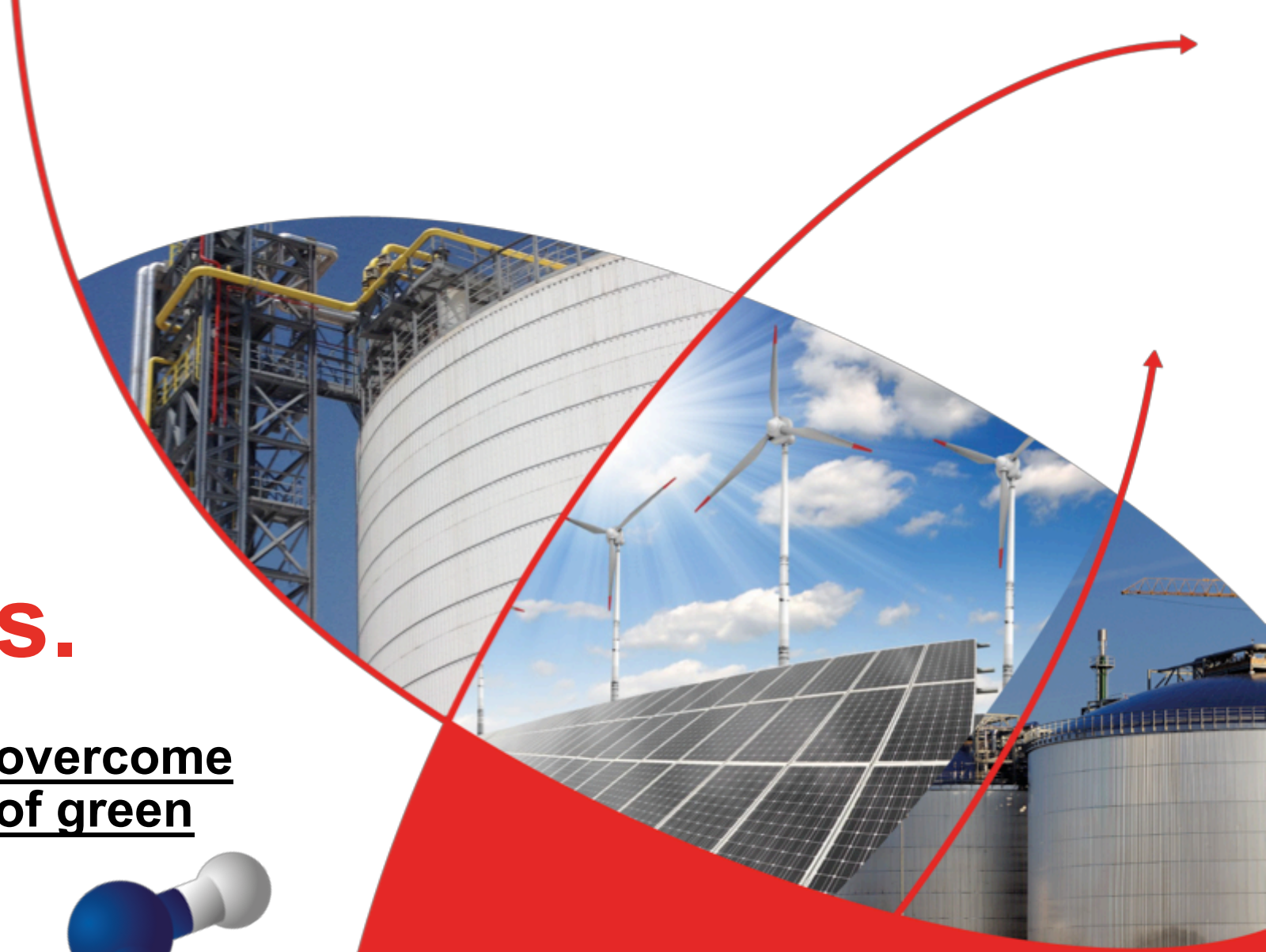
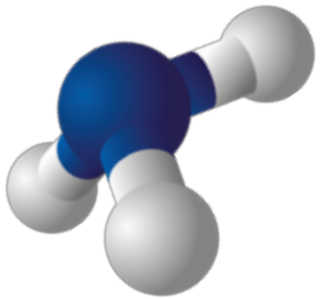
PROTON VENTURES



NH3 FUEL Ass.

The Battolyser as a tool to overcome problems by intermittency of green energy production

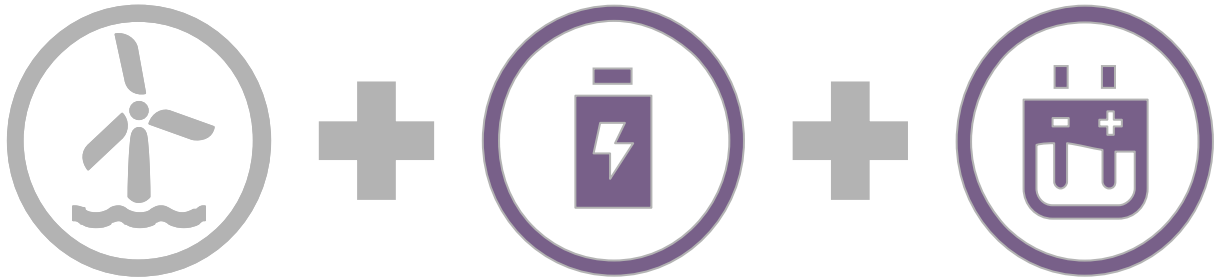


www.protonventures.com

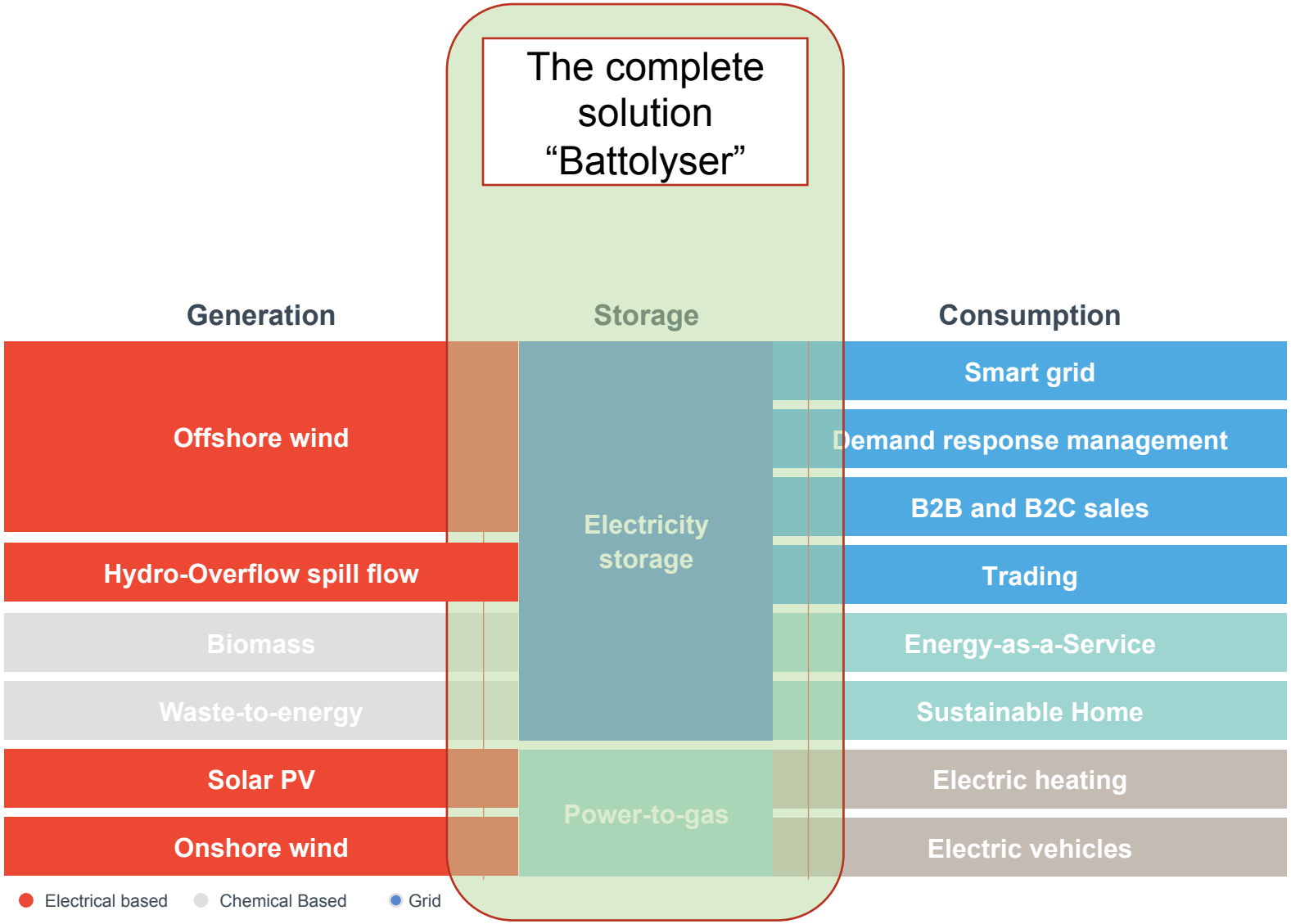
Proton in discussion with Trudeau and Rutte in canada on 24-25 October 2018 in Ottawa

Battolyser

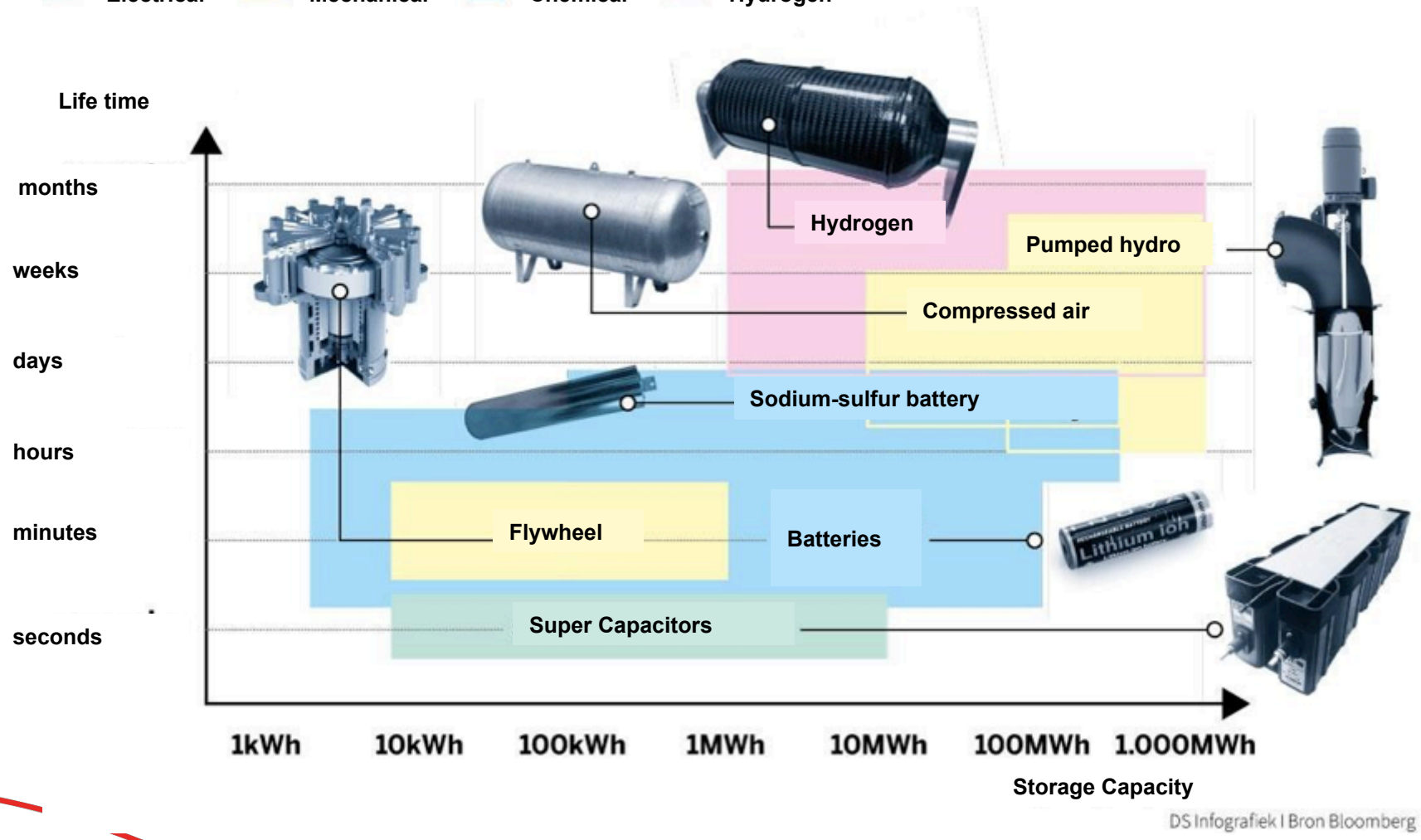
- the multi-billion € energy storage breakthrough



- **Electricity storage and hydrogen production in one**

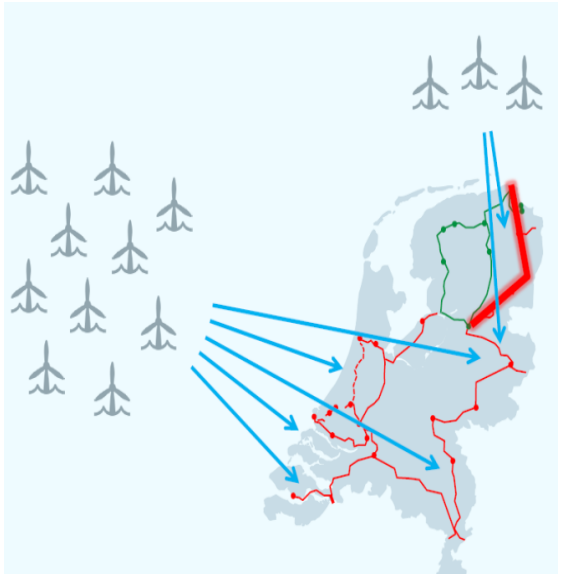

The complete solution “Battolyser”
Generation
Storage
Consumption
Offshore wind
Hydro-Overflow spill flow
Biomass
Waste-to-energy
Solar PV
Onshore wind
Electricity storage
Power-to-gas
Smart grid
Demand response management
B2B and B2C sales
Trading
Energy-as-a-Service
Sustainable Home
Electric heating
Electric vehicles
Electrical based
Chemical Based
Grid

Technologies to store energie/power



Large scale storage may be required sooner than we think to avoid high system costs that will eat in our (subsidy free) business cases

Get electrons to end consumer

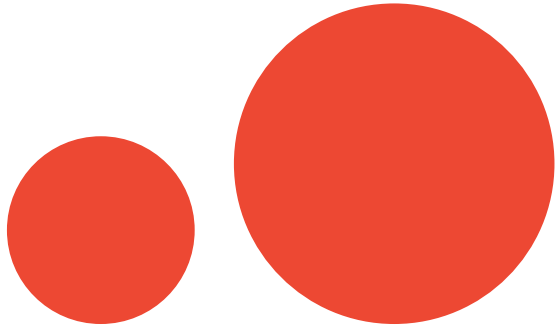


- **Physical transport of electrons** runs into its limits (NL / GE) – before 2030 already

Oversupply - Value of output decreases

Curtailment loss GE/NL[1]	**~€ 1bn**	?
Hours with negative prices GE	**146**	**> 2000[2]**

Cumulative offshore wind production



NL + GE 2017
~25 TWh

NL + GE 2030
~110 TWh

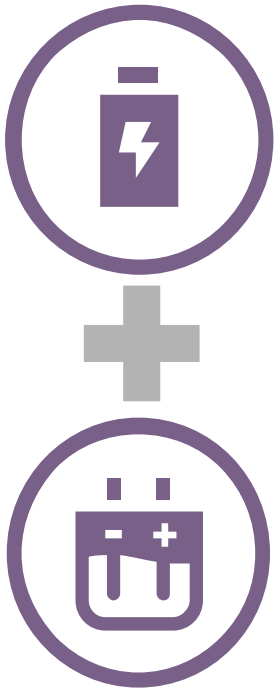
1. Tennet annual report 2017
2. DNV GL – P2G study 2030

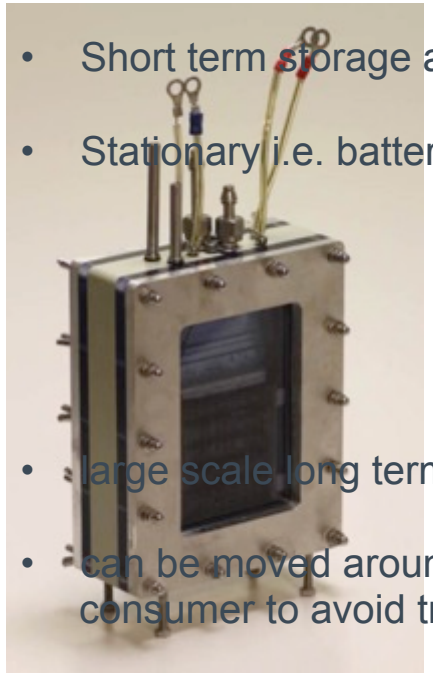
Batteries are the obvious storage choice these days to provide short term flexibility, but it will run into its limits for the system's large scale long term storage needs

A lot of buzz around hydrogen in the NL

- Big (petro)chemical cluster looking into ways to decarbonise
- First talks about hydrogen tenders in Tennet to alleviate stretched power grids

To decarbonize the power system we need a breakthrough long term storage technology based on hydrogen in addition to batteriesA





- Short term storage and flexibility e.g. grid services
- Stationary i.e. batteries cannot be moved around
- large scale long term (seasonal) storage
- can be moved around in pipelines, vessels, etc. to the end consumer to avoid transport of electrons

Battolyser – innovative new technology

- Integrates the functionality of the Ni-Fe battery and the alkaline electrolyser in one flexible, switchable and efficient solution
  - Ni-Fe battery: robust battery, stems from Edison's days
  - As the battery is charged, it starts naturally producing hydrogen

Prototype built in 2016 at the coast. Pilot project 2018.

TU Delft

PROTON VENTURES

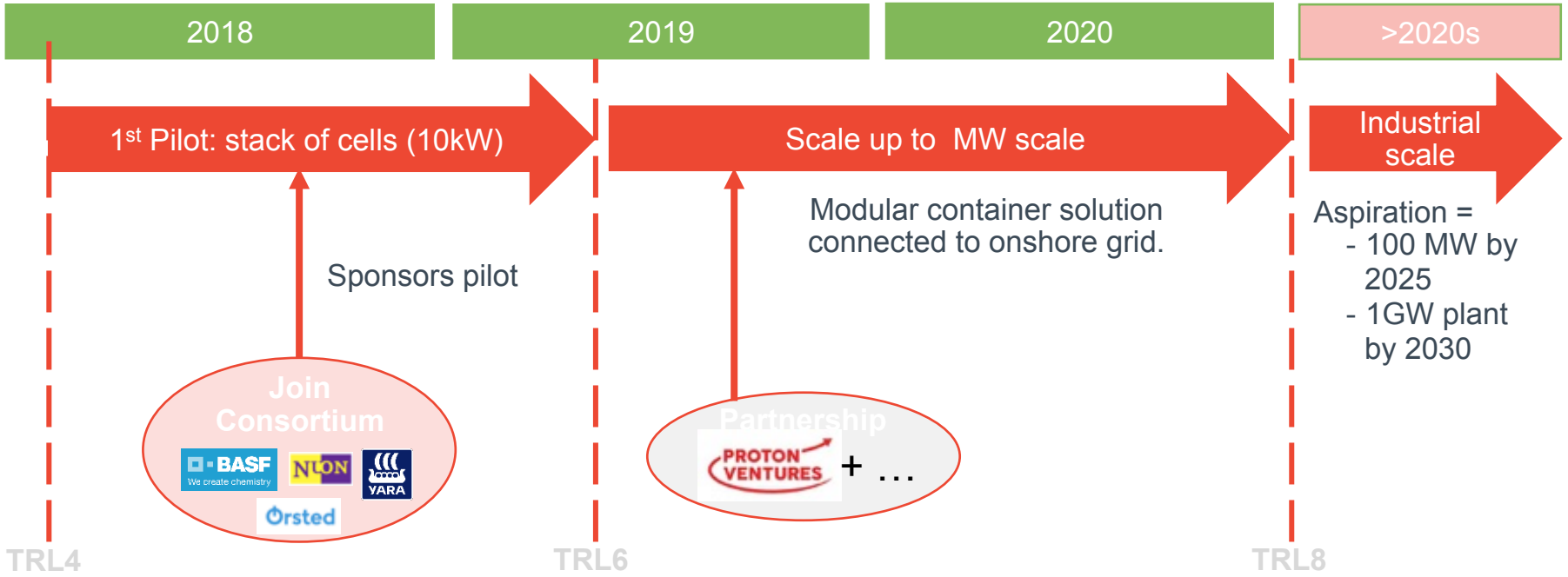
The technology stands out compared to standalone battery and electrolyser technology

1. **CAPEX** — two functionalities in one simpler system for less than the price of two separate systems.
2. **Lifetime** — Very robust battery with proven lifetime of 20-30 yrs *(vs Li-ion:10-12yrs)*
3. **Utilisation** — Very compatible with variable power production: over-charging capabilities[1] & excellent battery reversibility[2] lead to high degree of utilitisation *(whereas standalone electrolyser requires baseload to be economically viable)*
4. **Efficiency** — High overall combined efficiency
5. **Materials** — Nickel and Iron abundantly available *(vs Li-Ion: cobalt)*

9.

- 1 It can convert excess power to hydrogen far beyond the battery capacity without much efficiency loss. Since it can overcharge , no power controls are required, making it simpler
- 2. Excellent **battery reversibility** after prolonged charge insertion and electrolysis, even after more than 500 deep discharges and (over) charges to more than 1000 times the nominal capacity

We have some very concrete action plan to further mature the Battolyser technology to its full potential



Now **60k € + FTE** **May 2019 - FID** **€ 950k / MW + FTE**

Ammonia production

Base case :

Solar PV array

Not grid connected

Maximising capacity

Storing for day to day continuous basis

3,9 KWh/Nm3 H2 base electrolyser

~12 hours storage battery storage (site specific)

Ammonia production

Base case comparison:

1 Electrolyser of 1,2 MW at 100% utilisation makes app 3,3 MT/day (Nfuel-1)

At 50% solar input:

1 electrolyser of 1,2 MW plus 12 MWH battery storage

Or

3 Battolysers of 1 MW produce also 3,3 Mt/day with (each 3 MWh storage)

Battolyser advantage

Maximising ammonia loop performance throughput the day/year

Reducing Capex with cheaper battery tech for H2 production

Reducing foot print of overall unit with only battery storage

No curtailment of energy anymore (H2 can be used for heat or transported as ammonia)

High efficiency in storage and H2 production

Future

Battolyser BV in operation for development and sales (Proton Ventures BV, TU Delft)

Patents in place as well as name registered worldwide

Further development of electrodes to reduce costs

Progress report on demo in Ammonia Conference in Rotterdam (6-7 June 2019)

Sales of kW units anticipated late 2019.

Monia on iceland:

the world is discovering Ammonia sd Energy carrier

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More about Battolyser

3rd European NH3 Rotterdam, the Netherlands

Where:	**Rotterdam**
Location:	**Probably the Zoo at max 200 visitors**
Date:	**6 and 7 June 2018**
Topic:	**P2A; a new era**
See:	www.nh3event.com