SUNSHINE PROJECT

“HYBRID ENERGY STORAGE FOR SOLAR AND WIND ENERGY AT TERRANOVA SOLAR”

Power-to-Gas Conference, May 7th 2018, Horta Antwerp

CONTENT

- Project TNS
- Technical Challenges “Sunshine”
- Feasibility Study “Sunshine”
- Future Developments
- Conclusions

PROJECT TNS

2010: After failure of Nilfos

➔ foundation of Terranova
➔ clean- up of the site
➔ 87 ha

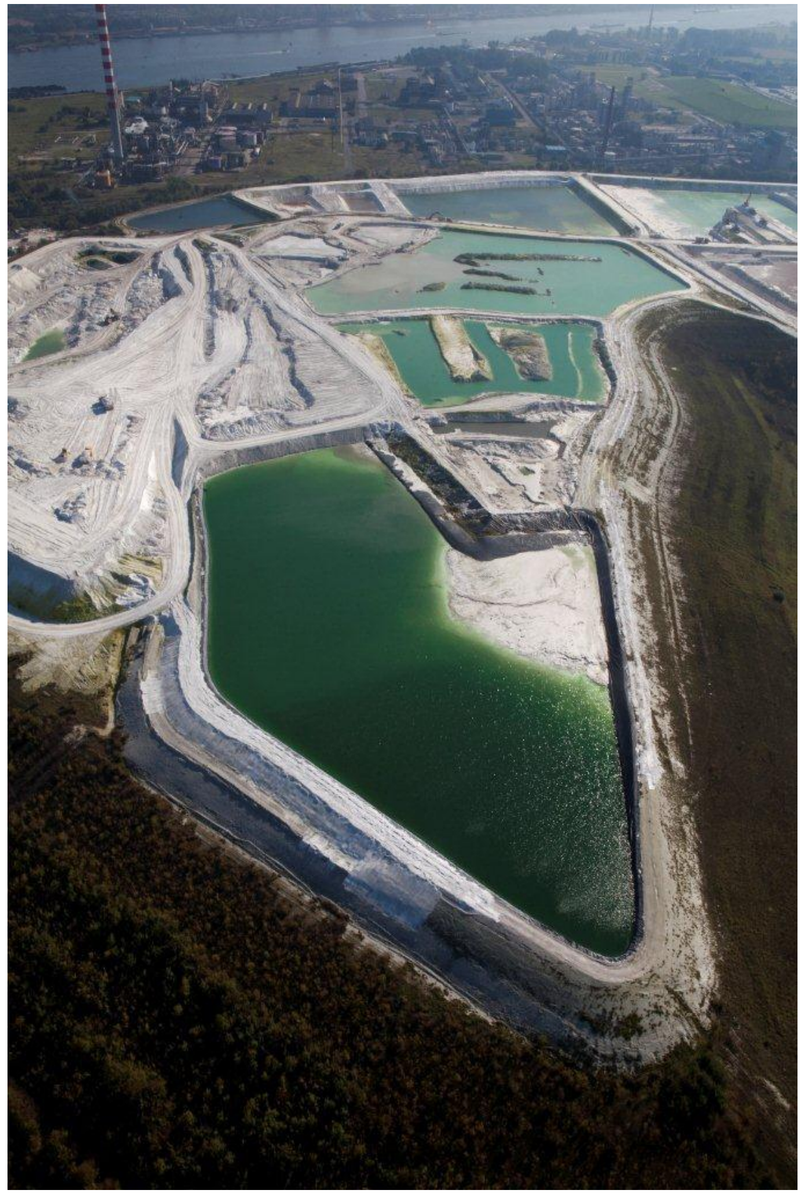
PROJECT TNS

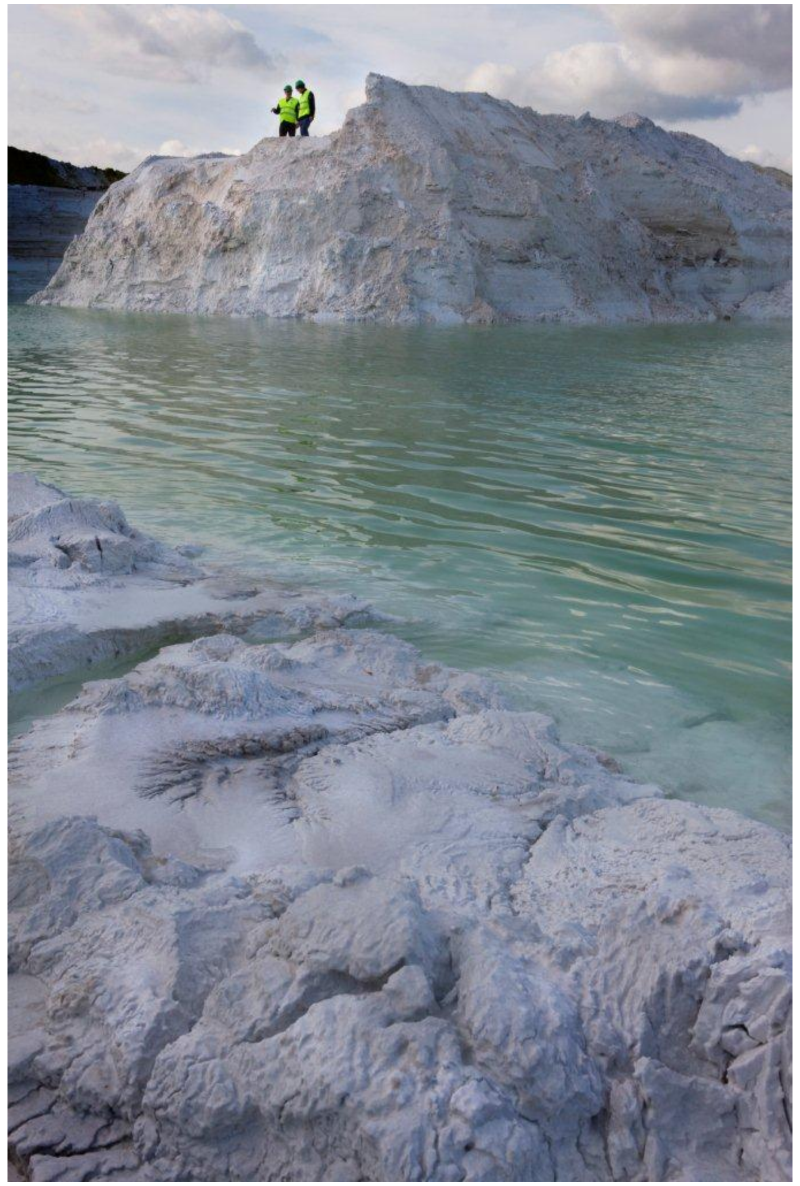
What did we do?

- Neutralization of 750.000 m³ acid water

- Remediation of groundwater

- Coverage of the gypsum





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PROJECT TNS

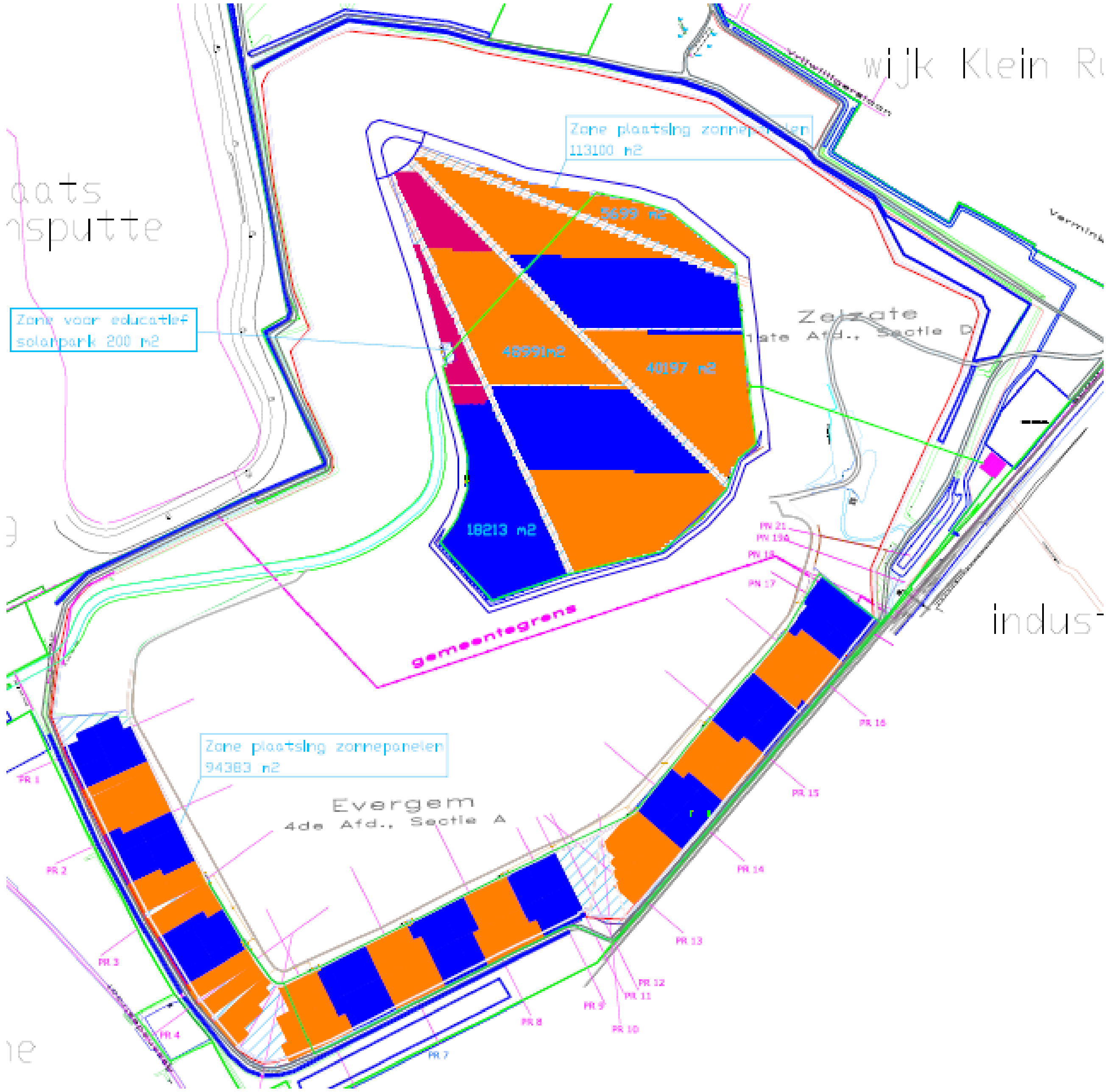
The partners of Terranova Solar

TERRANOVA SOLAR

aertssen | DEC Environmental Contractor | Jan De Nul GROUP www.jandenul.com | ENVISAN Environmental Technologies | FINIWO | POM Provinciale Ontwikkelingsmaatschappij Oost-Vlaanderen

TERRANOVA SOLAR | WaterstofNet | flux50 ENERGISING THE FUTURE | GHENT UNIVERSITY | TOTAL | North Sea Port Together. Smarter.

PROJECT TNS

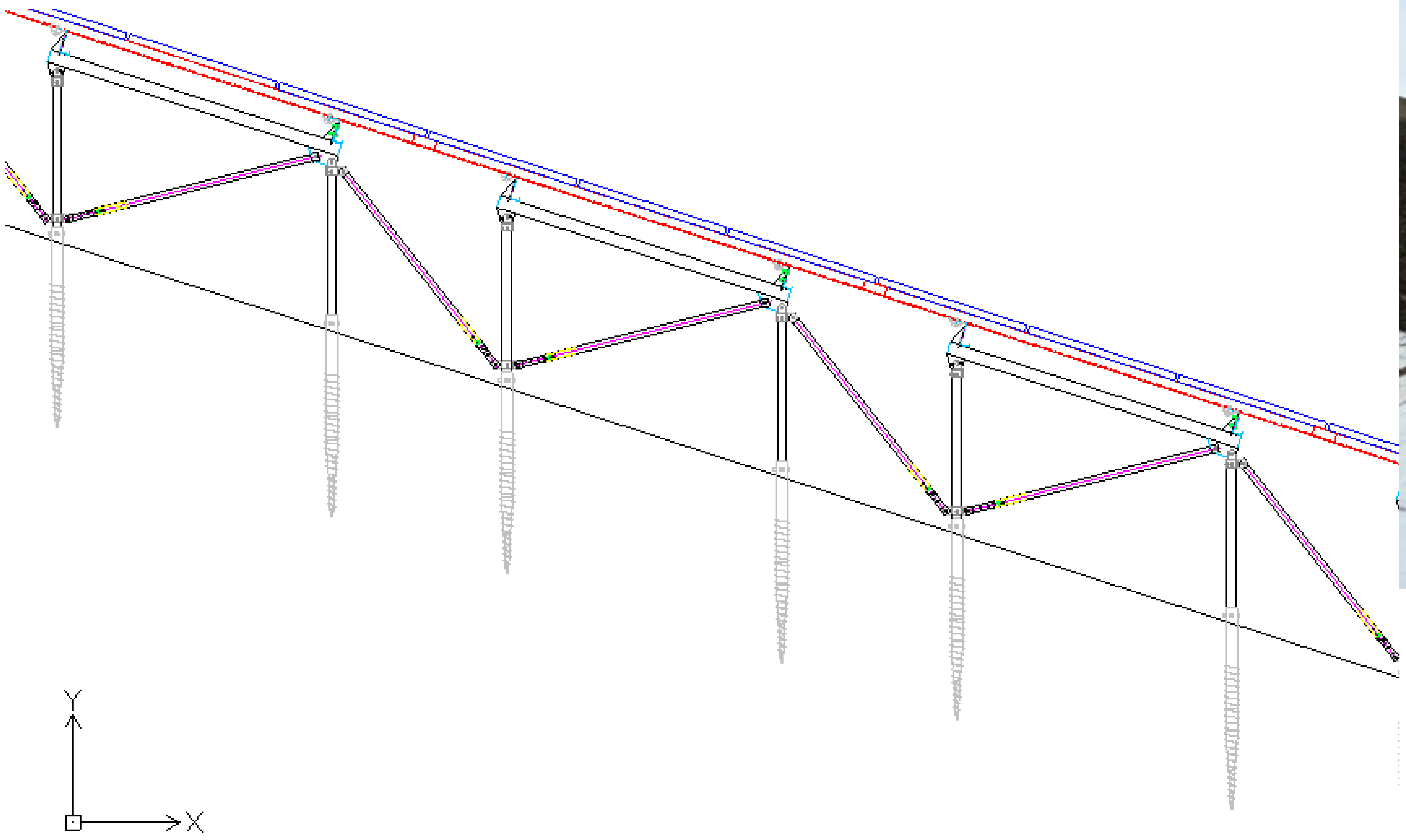

Zone plaatsing zonnepanelen
94383 m2
Evergem
4de Afd., Sectie A
gemeentegrens
18213 m2

PROJECT TNS

- Biggest solar plant of the Benelux
- More than 200.000m²
- Total injection 15MW AC
- ≈ 4500 families
- 55.500 solar panels
- 33.000 screws
- More than 420 km cables

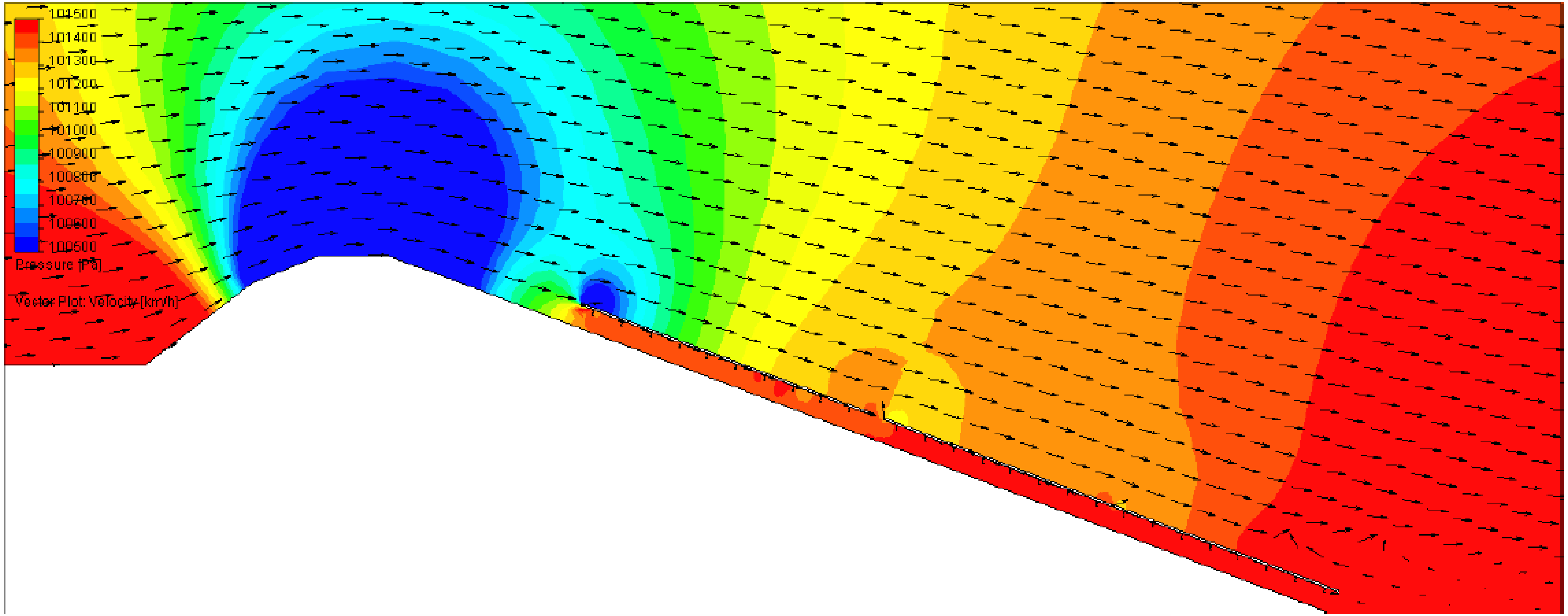
PROJECT TNS

View on the South slope



PROJECT TNS

One of the studies



PROJECT TNS

PROJECT TNS

PROJECT TNS

PROJECT TNS

More than 7000 visitors over 5 years

June 2018: Start education center

PROJECT TNS

Next steps:

- Production of hydrogen out of 100 % green electricity
- One of the 20 H2 stations in Flanders (2020)

PROJECT TNS

A lot of questions to investigate:

- The possibilities to bring H2 to the user (for example ships or forklift in the harbor?)
- What is a minimum (capacity) to be profitable?
- At what price are we compliant to the market?
- At what pressures?
- How to store?

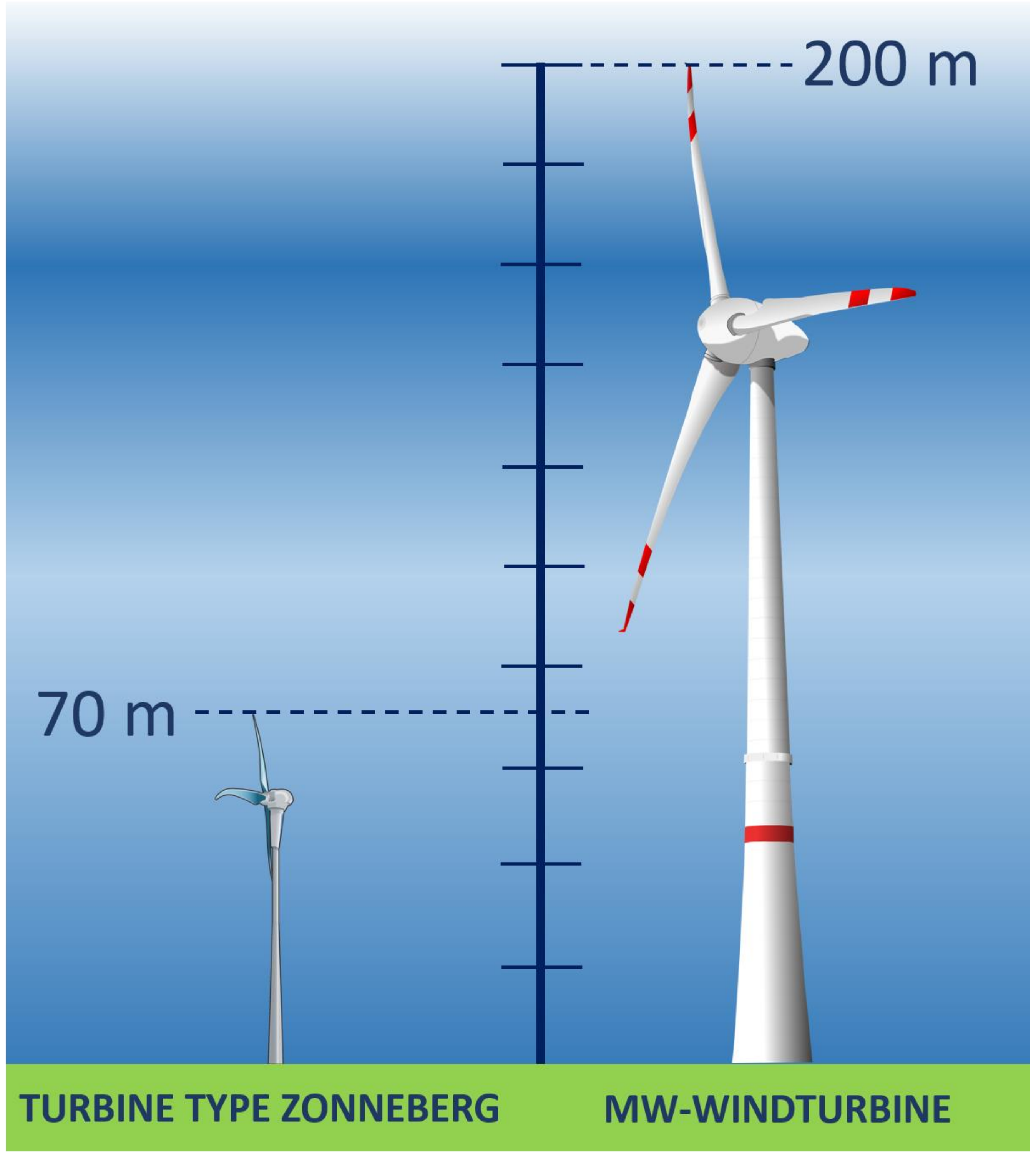
PROJECT TNS

1ste step:

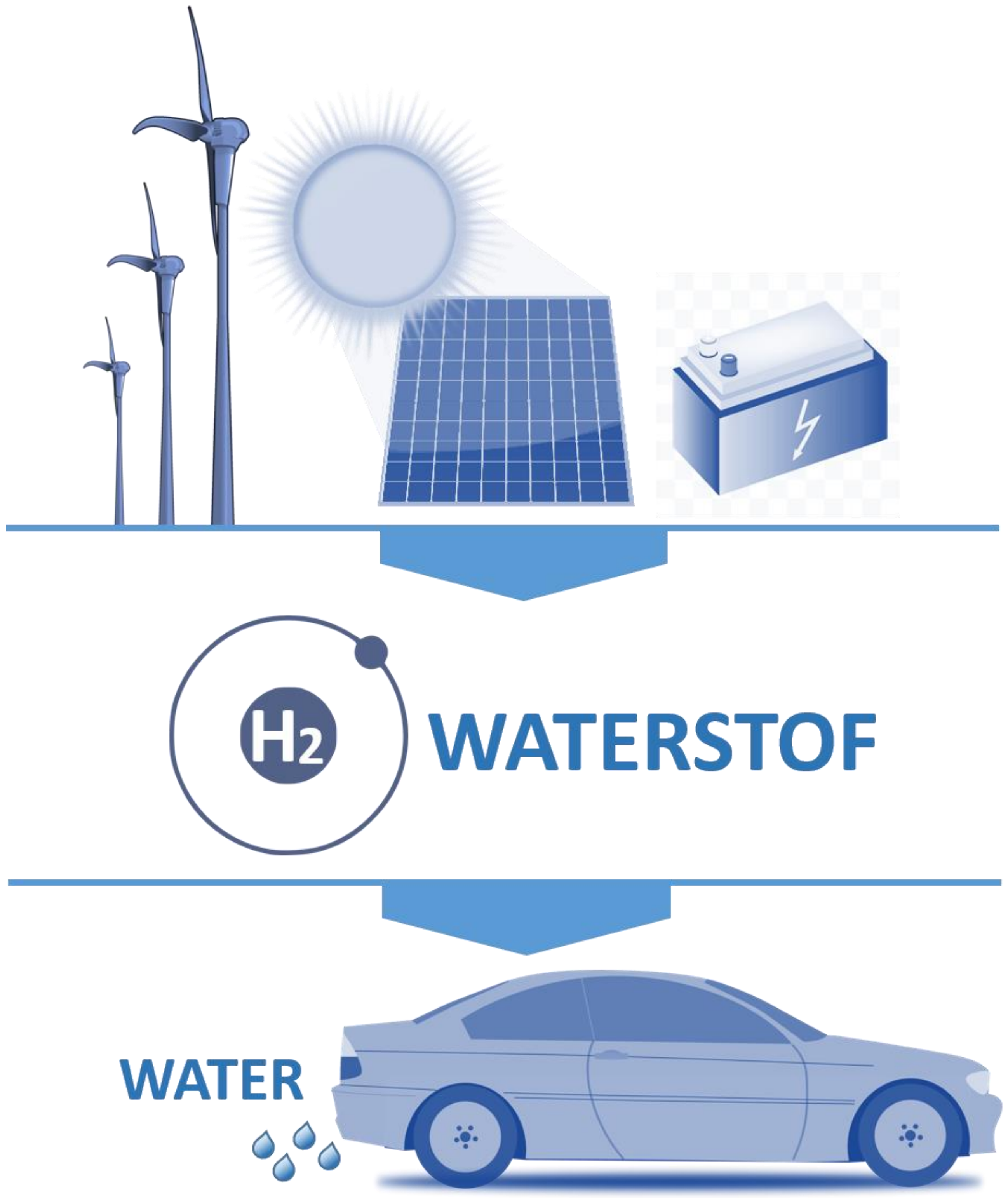
extra windmills &

a battery

PROJECT TNS



PROJECT TNS



TECHNICAL CHALLENGES “SUNSHINE”

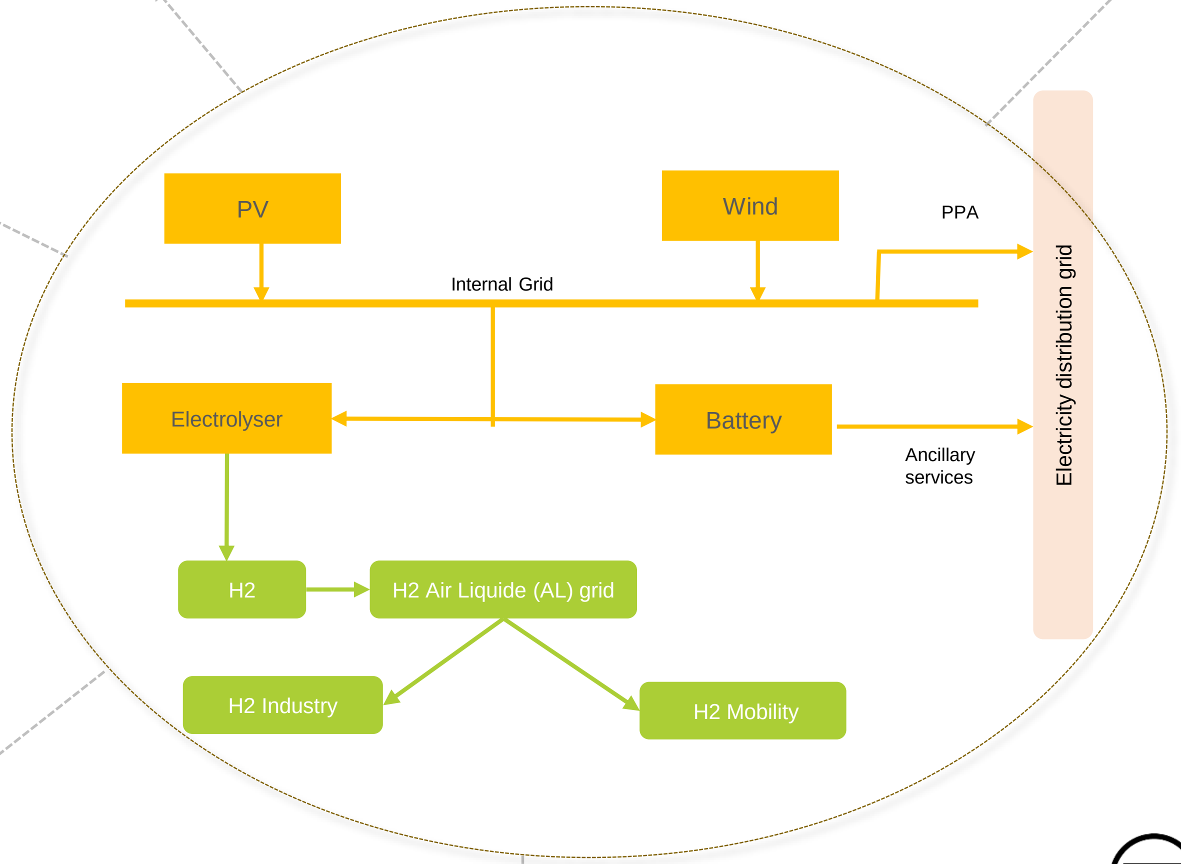
- Current PV park at the Terranova Solar site of **15 MW** [in production]
- Potential to add 15 MW of solar production

Terranova Solar has project ongoing for the installation of 6 small XANT wind turbines of 300 kW [ongoing]
- Some big wind turbines not far away (from EDF Luminus)

PPA

- A part of the produced electricity is injected in the DSO grid and bought by a supplier (PPA)
- Pricing subjective on profile & predictability

Internal local grid on which the local production assets are connected
- Separate project [Brightfield project]



TNS

The Terranova Solar site has 2 DSO connection points (INFRAX & EANDIS)

P2H

Local produced and green electricity can be transformed to hydrogen energy carrier due to the electrolysis process
- **1 MW electrolyser**
- Utilisation Factor (UF) of the electrolyser from primordial importance

Ratio power vs energy: Solar profile is "over dimensioned" compared to electrolyzer

H2

Energy carrier to store energy
- Could be used as electrical storage or as product
- Applications in industry, mobility, ….

AL

The H2 transportation grid of Air Liquide is running next to the TNS site (major advantage)
- AL is willing to buy all the injected H2 into the grid at a defined price

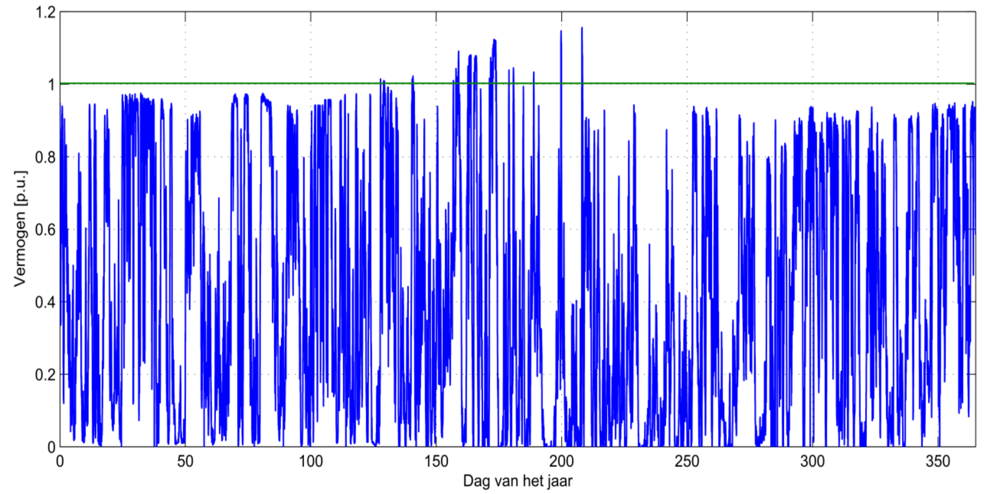
Battery as energy storage of the produced electricity
- Optimisation of the electrolyser use (UF and technical issues)
- Possibility to have impact on PPA profiling/predictability and/or ancillary services

TECHNICAL CHALLENGES “SUNSHINE”

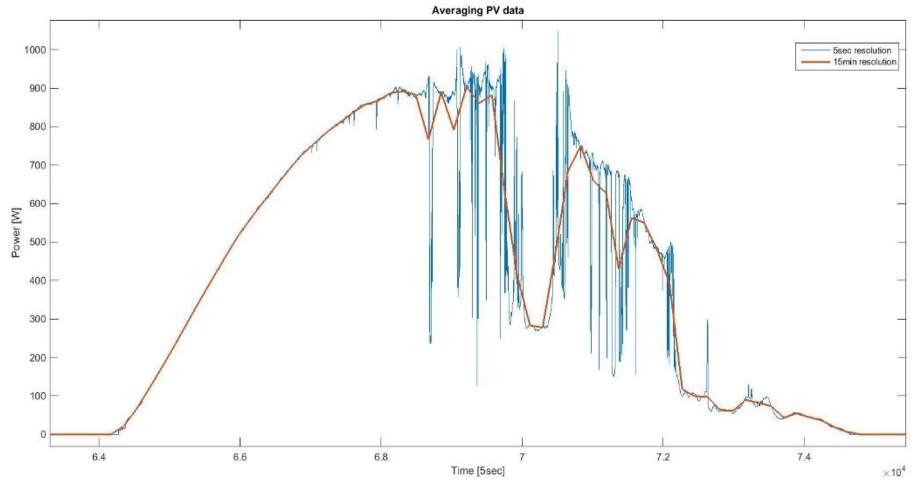
VARIABILITY OF YIELD

Yield of PV and Sun not only a function of location and emplacement, but even more strongly depending on (local) weather conditions.

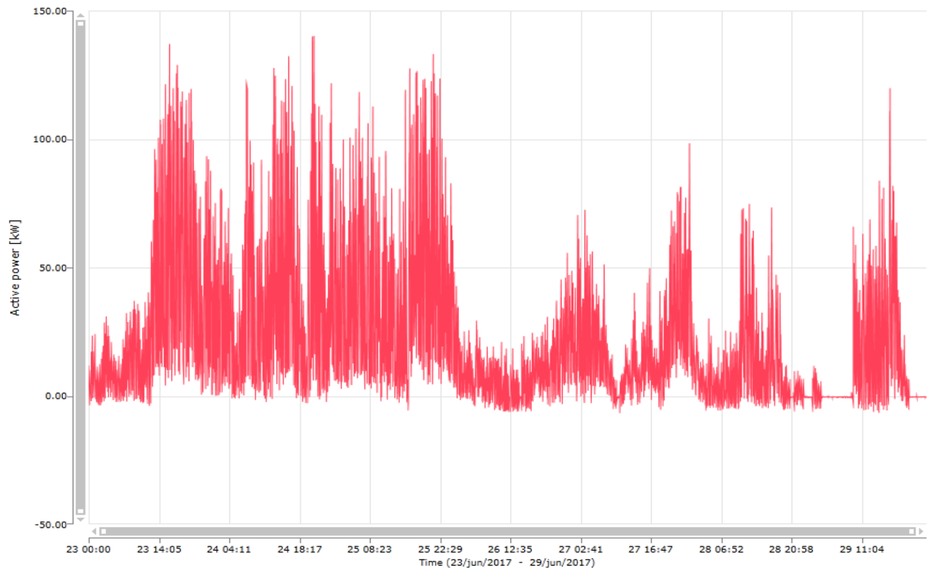
The instantaneous yield can be strongly differ from the averaged 15 minute values, who are usually handled for yield calculations.



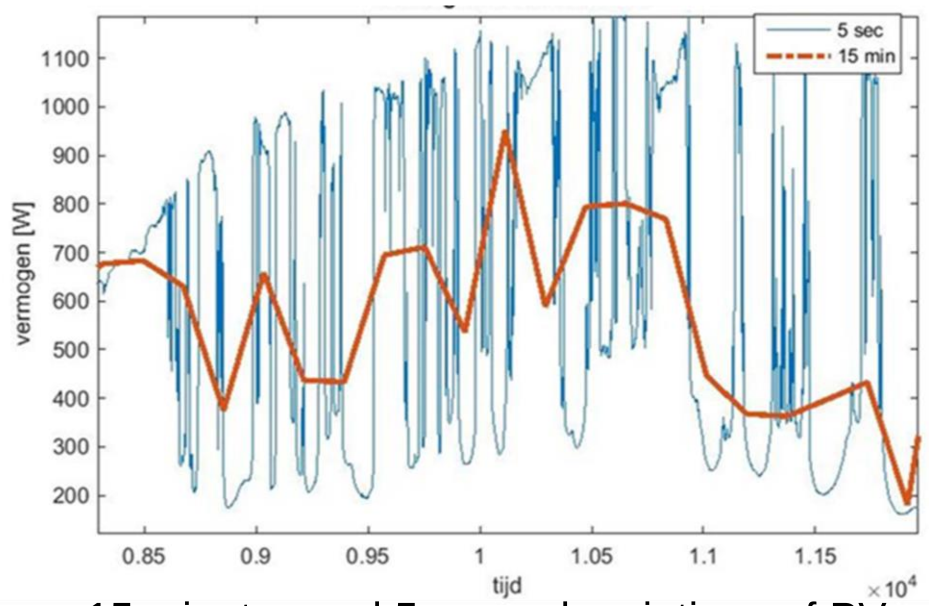
Normalised 15 min values Off Shore Wind in BE



Daily and 5 minute variations of PV



1 min values of a 150kVA Wind turbine



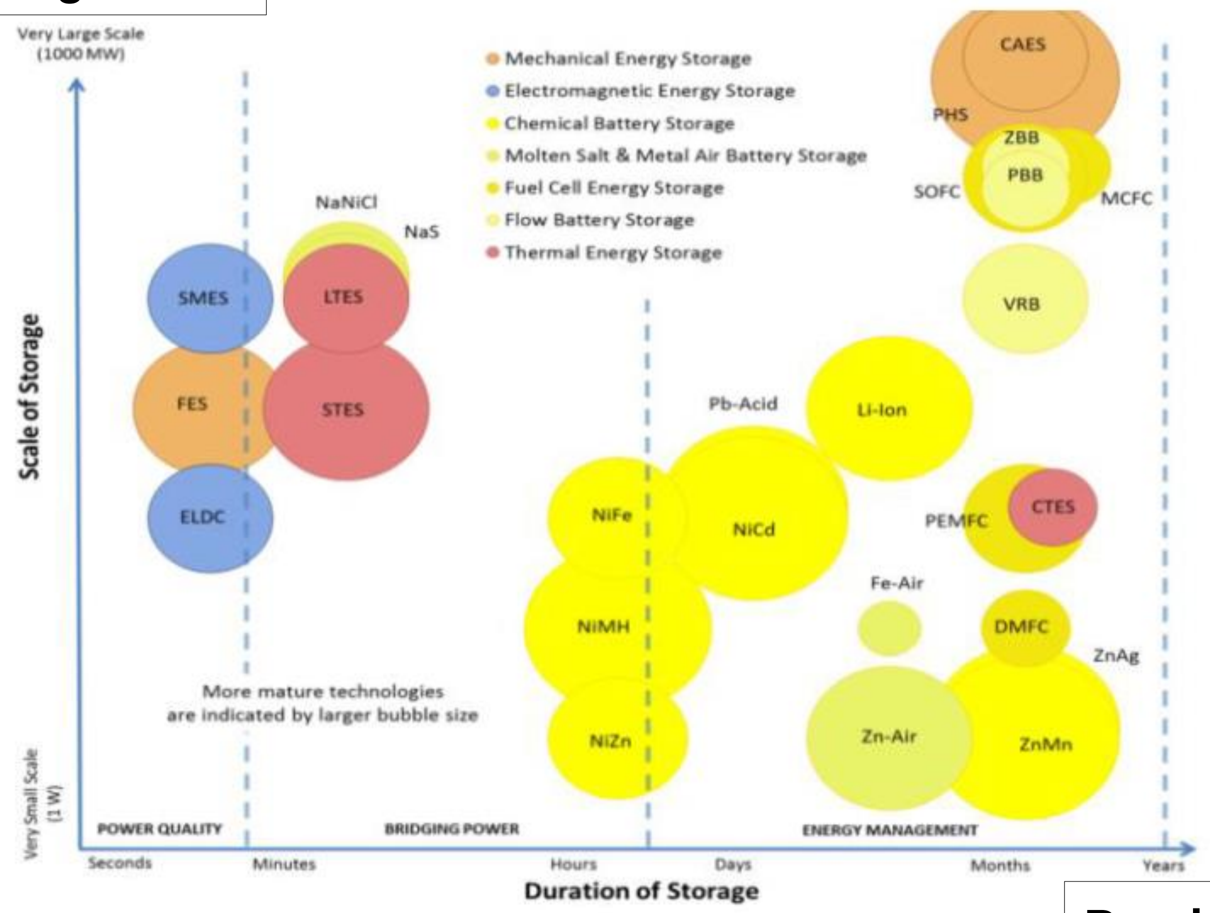
15 minutes and 5 second variations of PV

TECHNICAL CHALLENGES “SUNSHINE”

CHALLENGES FOR STORAGE SYSTEMS

- Combining energy and power in load/production profiles
- “Merit order” of storage (cf. production sites): Ragone plot
- **How long and how fast do I have to store how much energy?**

Providing Power



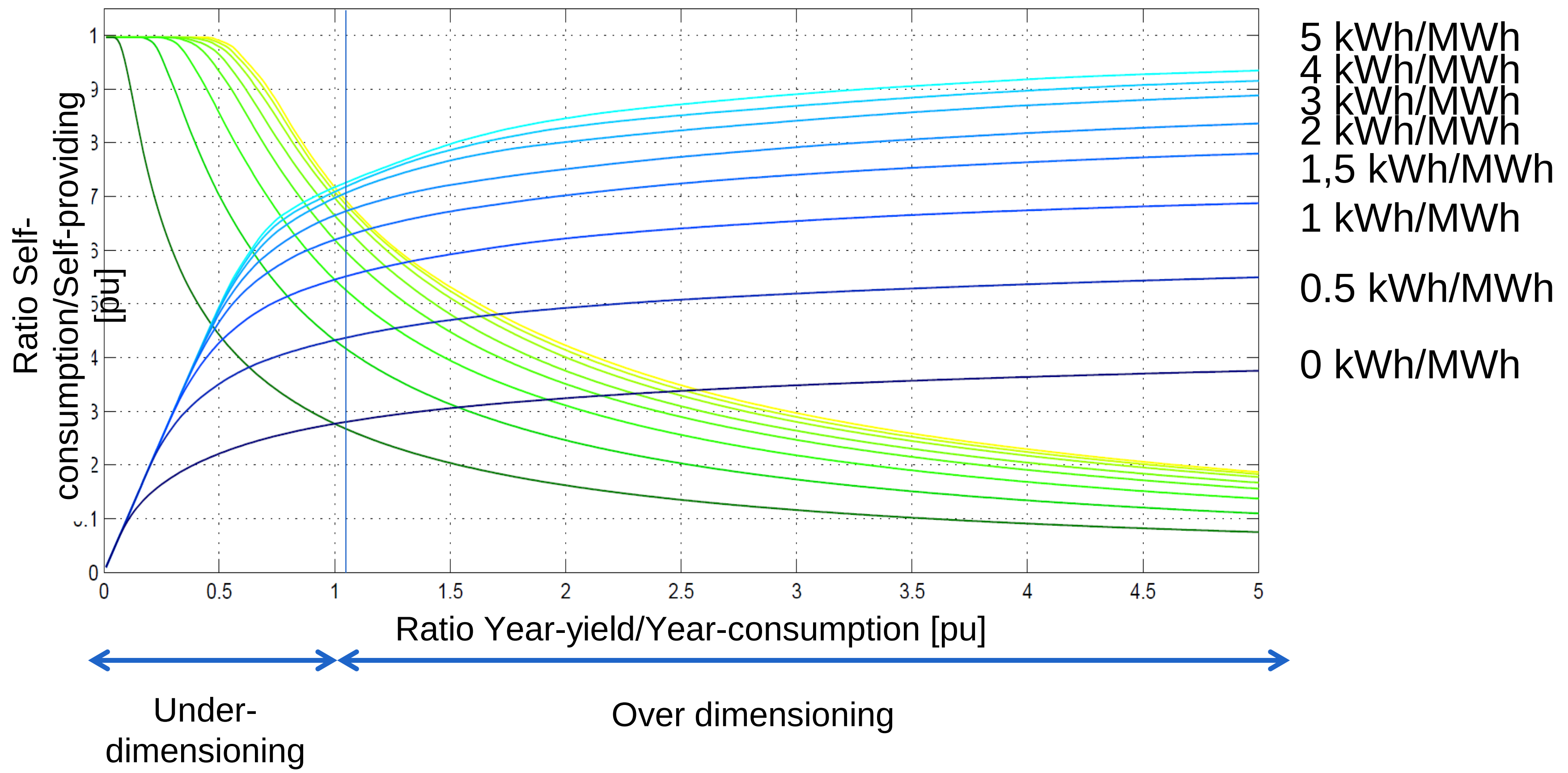
Providing Energy

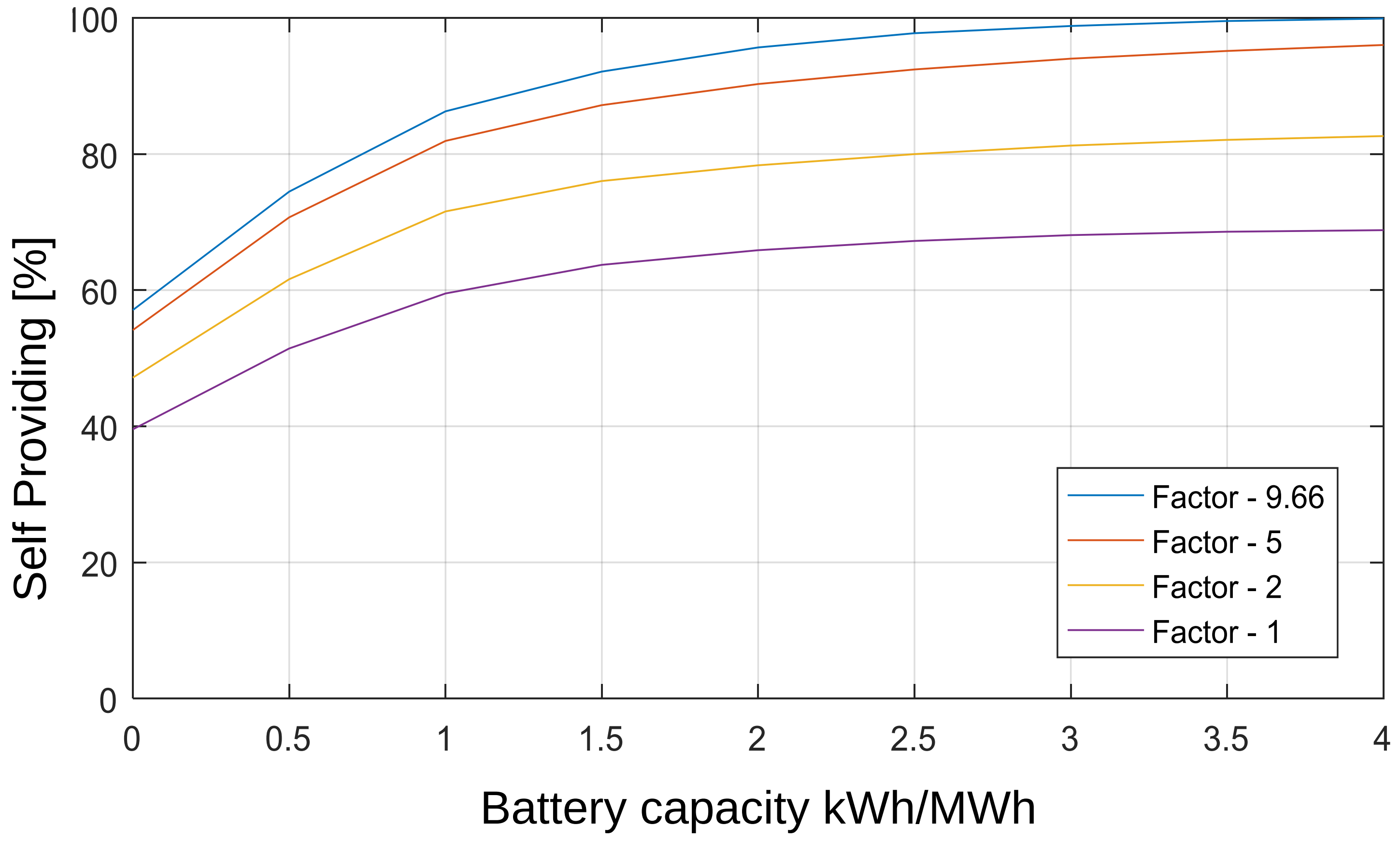
TECHNICAL CHALLENGES “SUNSHINE”

CHALLENGES FOR STORAGE SYSTEMS

Added Value over dimensioning PV/Wind?

- No Storage – Added value rather small
- Complete independency possible but highly over dimensioning and expensive
- Increase of Z_v with increasing “yield/consumption” decreases with increasing capacity



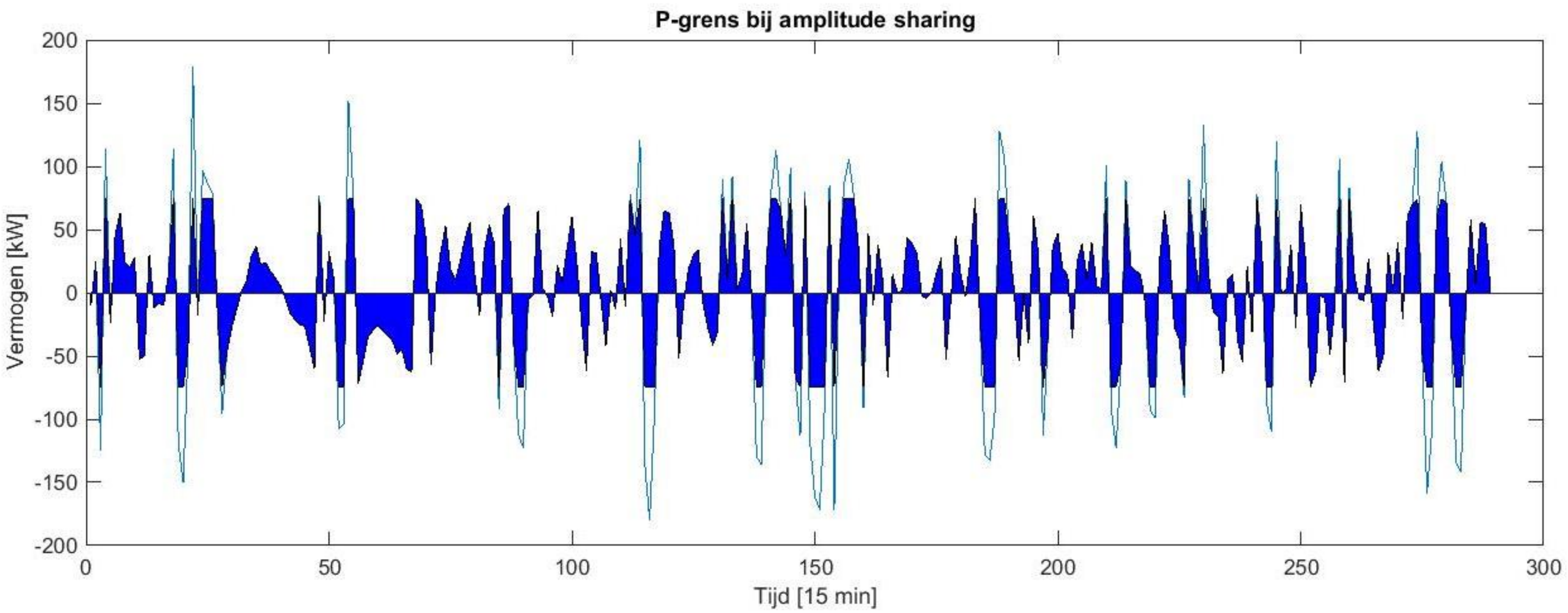


TECHNICAL CHALLENGES "SUNSHINE"

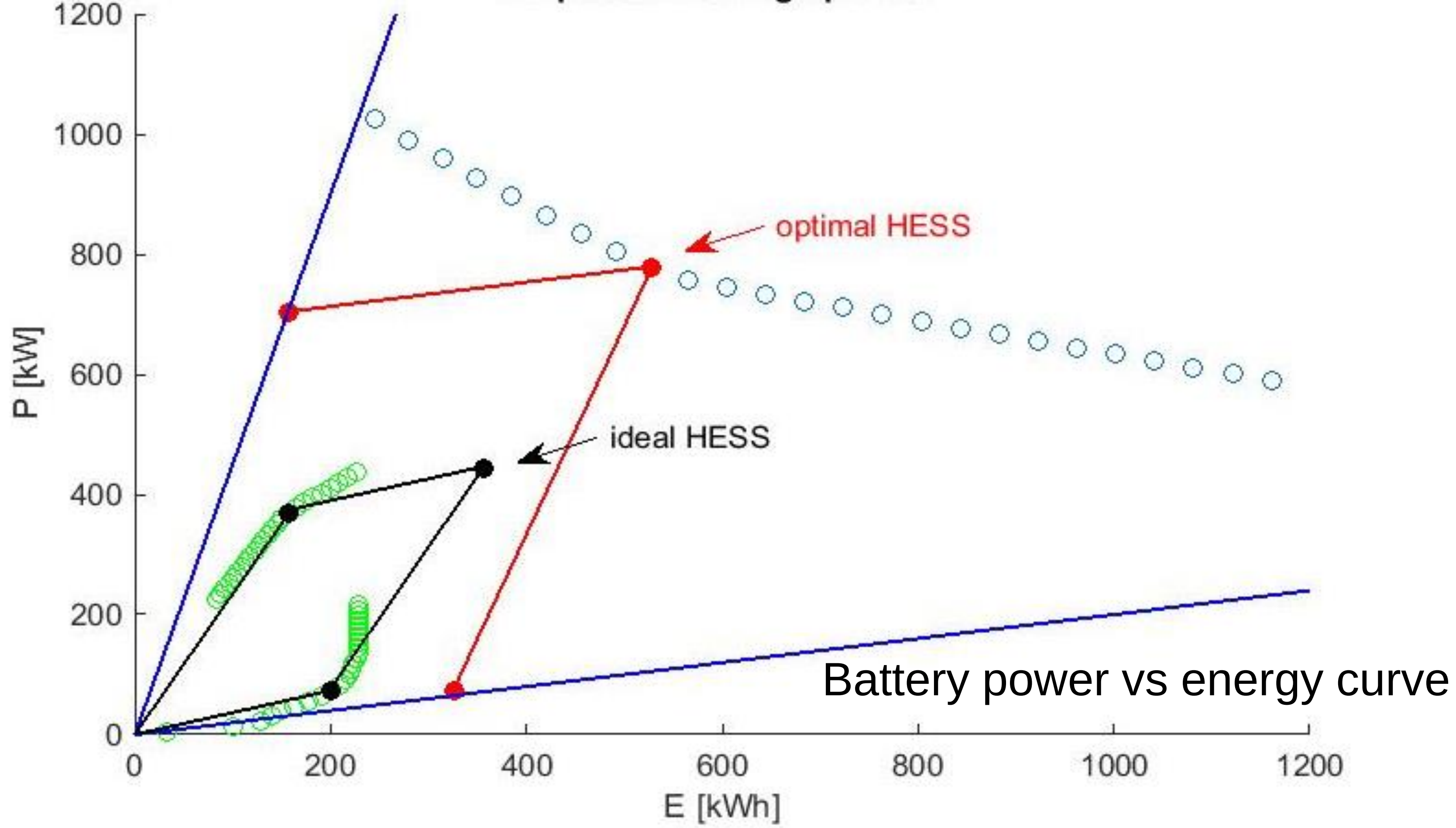
CHALLENGES FOR STORAGE SYSTEMS

Hybridisation in storage as key solution

- Oversizing energy or power using one single technology
- Combine energy provider with power provider → Cover fast power variations
- Drawbacks compensated by strengths of multiple technologies



Flywheel power vs energy curve



TECHNICAL CHALLENGES “SUNSHINE”

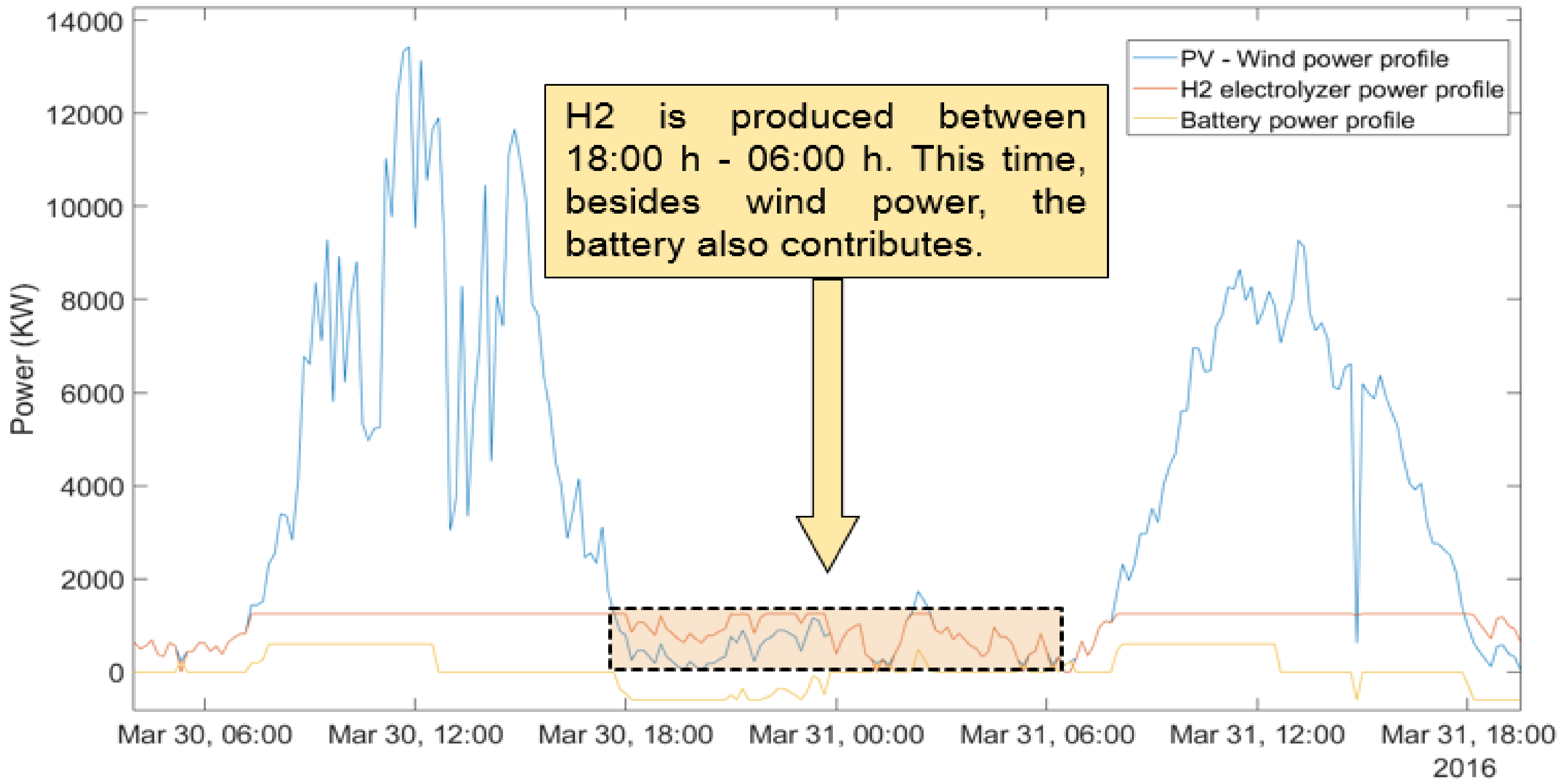
AIM

Setting: 15MWp PV + 2MW Wind

Challenge: 100% UF for 1 MVA electrolyser 100%

Comparative study of storage systems in both power and energy

→ **Depending of variability of yield, power of battery is more important than energy content.**



Battery specifications	P_{nom}: 300 KW $E_{capacity}$: 3000 KWh	P_{nom}: 600 KW $E_{capacity}$: 3000 KWh	P_{nom}: 900 KW $E_{capacity}$: 4500 KWh
Utilization factor	68%	70%	74%

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TECHNICAL CHALLENGES "SUNSHINE"

SCENARIOS

- From crucial importance is to optimize the use of the 1 MW electrolyzer (Utilization Factor).
- Analysis shows that mainly adding a wind profile increases the UF.
- Impact of adding battery limited due to "oversized" solar power (15 MW solar vs 1 MW electrolyzer)

0.1	Energy Production: PV (15 MW) Energy Storage: ELEC (1 MW)	UF 41,5%
0.2	Energy Production: PV(15 MW) + WIN (2 MW) Energy Storage: ELEC (1 MW)	UF 65,5%
0.3	Energy Production: PV (15 MW) Energy Storage: ELEC (1 MW) + BATT (1 MW – 1 MWh)	UF 45%
A1.1	Energy Production: PV (15 MW) + WIN (2MW) Energy Storage: ELEC (1 MW) + BATT (1 MW – 1,2 MWh)	UF 69,5%
A1.2	Energy Production: PV (15 MW) + WIN (2MW) Energy Storage: ELEC (1 MW) + BATT (1 MW – 2,4 MWh)	UF 73%
A1.3	Energy Production: PV (15 MW) + WIN (2MW) Energy Storage: ELEC (1 MW) + BATT (1 MW – 3,9 MWh)	UF 76%

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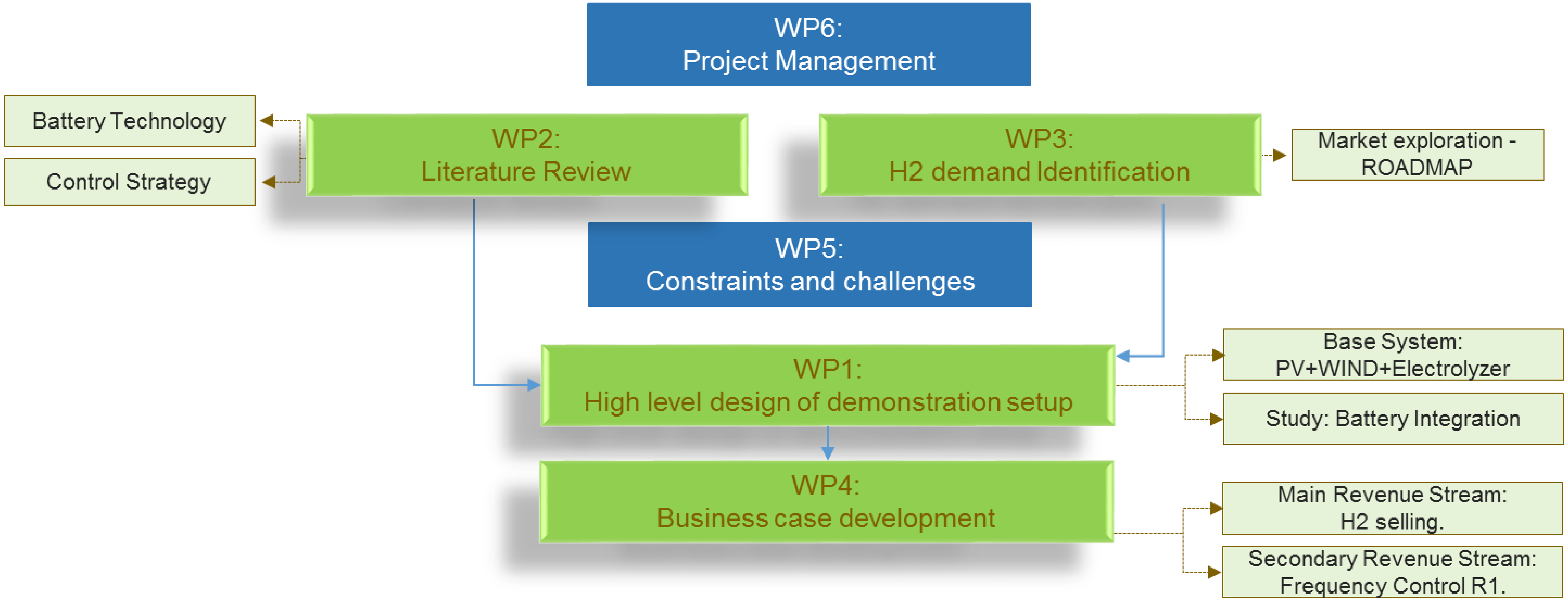
FEASIBILITY STUDY “SUNSHINE”



FEASIBILITY STUDY “SUNSHINE”

H_2 MARKET EXPLORATION - ROADMAP

2019-2020		2021	2023-2025	2030
Direct injection in H_2 pipeline	Access to existing HRS	New HRS	Transport Companies	Coming Customers
				
H_2 Pipeline (AL) allows opportunities for the Project allowing easy penetration on existing market.	On short term, mobility application can be initiated by utilizing the existing HRS in the port of Antwerp.	City of Ghent is interested in H_2. New HRS can be installed due to Increment of H_2 demand	New mobility application on transport companies, Concepts in development: Trucks, Trains, Ships.	Industries at high H_2 scale: can be incorporated in the roadmap.

Added Value of Green Certificates (EU level, Regional Level, etc.).

AL = Air Liquide / TNS = Terranova Solar / HRS=H_2 refueling stations

FEASIBILITY STUDY "SUNSHINE"

HIGH LEVEL DESIGN SUMMARY

System

- Technical optimal sizing for several scenarios.
- Analysis: **Impact of Battery Integration.**
    - To Optimize Electrolyzer (UF).
    - To Provide Frequency Control.

Findings

- **Electrolyzer:**
    - Electrolyzer dimensioning (1MW vs 1,25MW).
    - The 1MW Electrolyzer is more efficient.
- **Battery:**
    - For both electrolyzer, a bigger battery size increases the utilization factor, but decreases IRR.
    - System can be optimized with a secondary revenue stream: Frequency control.
    - State of art: The Li-ion battery offers high power/energy densities.
- **Control Strategy:**
    - SoC regulation for multiple battery applications.

Scenarios of analysis

	PV+WIND+ELE+BATT	PV+WIND+ELE+BATT+ Frequency Control
	15MW	15MW
	2MW	2MW
	1,2MWh / 1MW	1,8MWh / 1,5MW
H2	1MW	1MW
UF	69,5%	69%
FC	N/A	R1 100 MHz 1MW

Scenario A

- Primary Battery application: To optimize Electrolyzer running hours

Scenario C

- Battery application: To optimize the Electrolyzer running hours and provide Frequency Control (FC).

FEASIBILITY STUDY "SUNSHINE"

TECHNO-ECONOMIC ANALYSIS

Business Description

- Direct injection in H_2 pipeline.
- **Profitability analysis, cases: A / C.**
- Primary revenue stream: Selling H_2 production.
- Secondary revenue stream: R1 Frequency control.

Financial Model

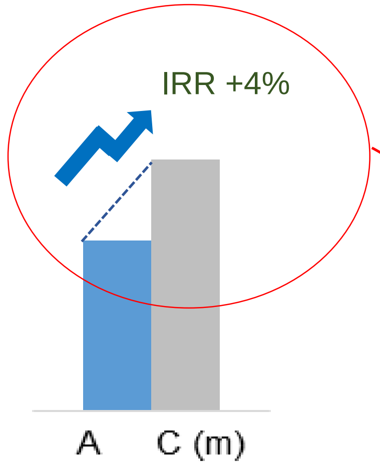
- Investment: **@2018/2020** (Elec / Batt CAPEX)
- Grants (G) / Equity (E) / Loans (L) % Variation.
- R1: 1MW - 100mHz. 50% of the bid period (C (m)).
- H_2 Selling Price: range of analysis 2,5 €/Kg up to 7€/Kg.

WITH SUBSIDIES

- Starting point of profitability at H_2 selling price higher than 5 €/kg.
- Frequency control can have potential positive impact on profitability.
- System profitability: Promising scenarios from 2018 to 2020.

SUMMARY WITH SUBSIDIES 2018

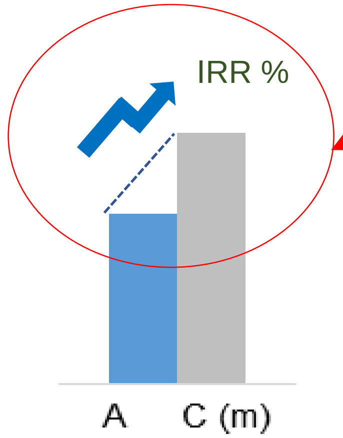
Year 2018
Research, development and demonstration Project at a relevant scale



+4% IRR

SUMMARY WITH SUBSIDIES 2020

Year 2020
Full scale solution and demonstration on the specific site



FUTURE DEVELOPMENTS

Waterfall diagrams

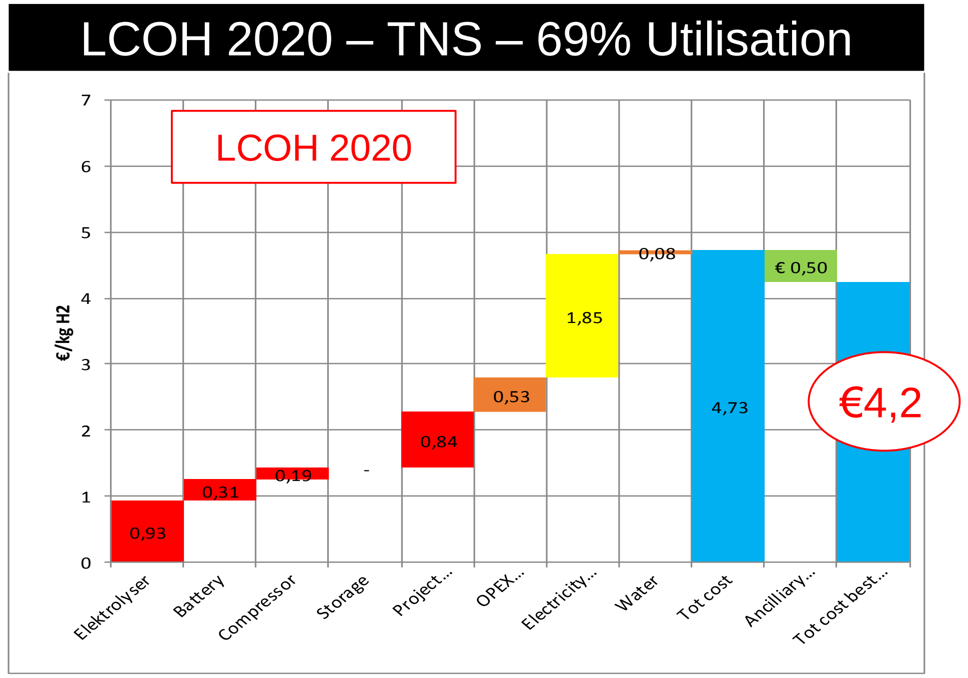
- **Scenarios at 2020, 2030, 2050:**
  - Decreasing Electrolyzer and Battery CAPEX (€/kW).
  - More renewables will lead to more need for ancillary services
  - LCOH analysis.

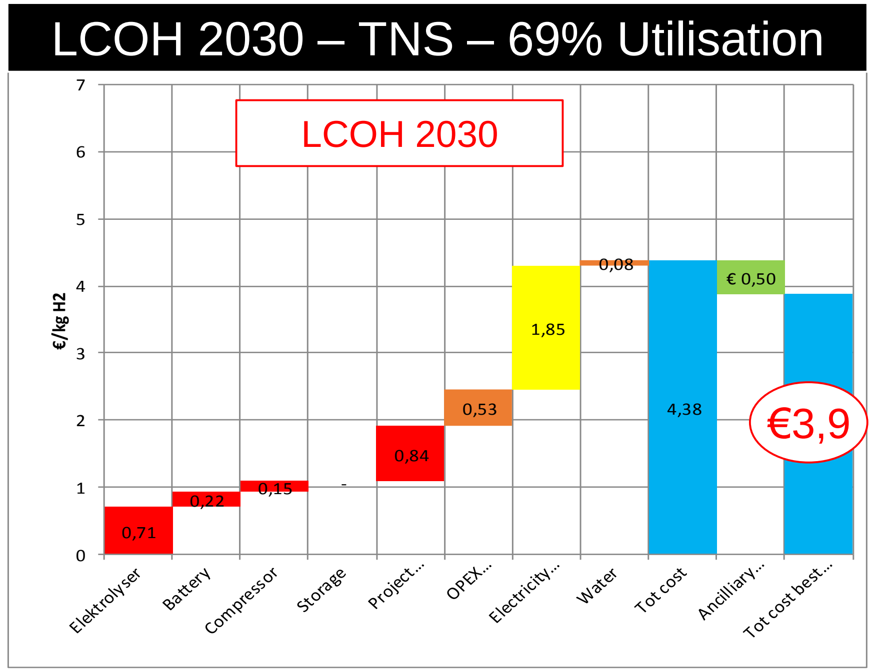
H2 Future evolutions

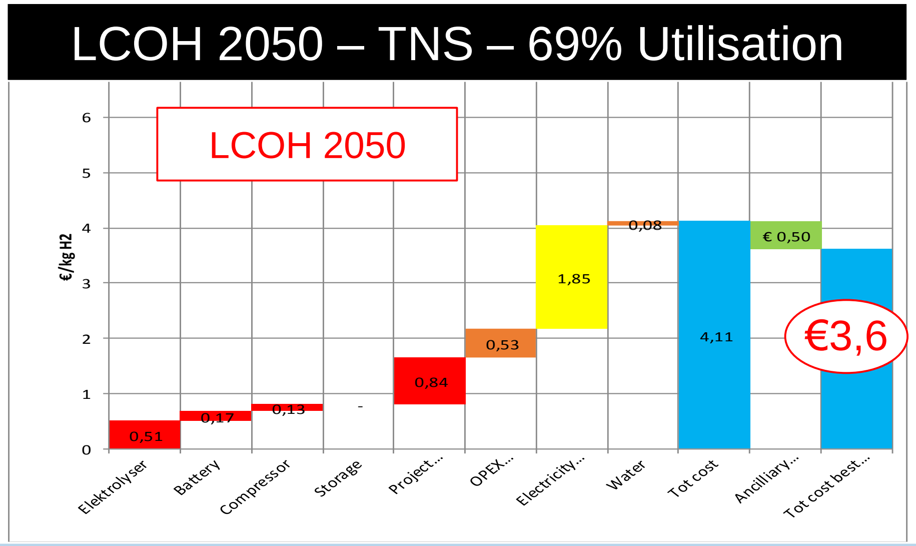
- **H2 selling price** €/kg is key factor for the business case.
- A lot of uncertainty & variation
- Potential **added value for "Green H2"** solutions & certification
- Make link with increasing willingness to pay for **Green H2**

R&D Development project

- The demonstration project can become the perfect playground **for R&D opportunities 2018** (synergy battery – electrolyzer), **Industrial project at 2020.**







1. Decreasing CAPEX (battery & electrolyser) & increasing performances
2. Increasing need for TSO ancillary services
3. Increasing competitiveness for H2 applications (mobility, industry, ….)

CONCLUSIONS

1. **Project**
   - Study the technical and economic feasibility of a “hybrid” energy storage concept (batteries and hydrogen) at the premises of a solar plant, to be extended with extra wind power, in order to create added value for the produced electricity.
2. **H_2 selling price (€/kg) is key factor for the business case**
   - With subsidies, starting point of profitability should be up to 5 €/kg.
   - Potential added value for “Green H_2” solutions & certification.
   - Increasing H_2 market competitiveness and new H_2 end consumers can be attracted on the long run.
3. **Primary reserve services to ELIA (TSO Belgium)**
   - **Potential positive impact** on profitability but future evolutions on price **highly uncertain.**
   - **Frequency control** revenue can increase profitability, **only** providing services minimum **50% of the year**. Currently uncertain scenario.
4. **Project Opportunity**
   - Reproducibility in other ports or industrial sites with local & renewable energy production assets.
   - Mainly wind profile increases the UF of electrolyzer.
   - Existing local & renewable energy production asset. The demonstration project can become the perfect playground for R&D and BusDev opportunities (synergy battery – electrolyser).
5. **Initial predefined trajectory of the SUNSHINE project**
   - Research, development and demonstration project at a relevant scale.
   - Full scale solution and demonstration on the specific site.

PARTNERS & STAKEHOLDERS OF THE SUNSHINE PROJECT

Terranova Solar	Total	Other
TERRANOVA SOLAR ENVISAN ENVIRONMENTAL WORKS Provincie Oost-Vlaanderen Voor ieder van ons aertssen FINIWO Jan De Nul GROUP DEME Zonneberg	lampiris TOTAL	WaterstofNet GHENT UNIVERSITY flux50 HAVEN GENT

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