



Electrification of the Chemical Industry

VoltaChem, energized for action!

Update program results & next steps

Martijn de Graaff, business development manager

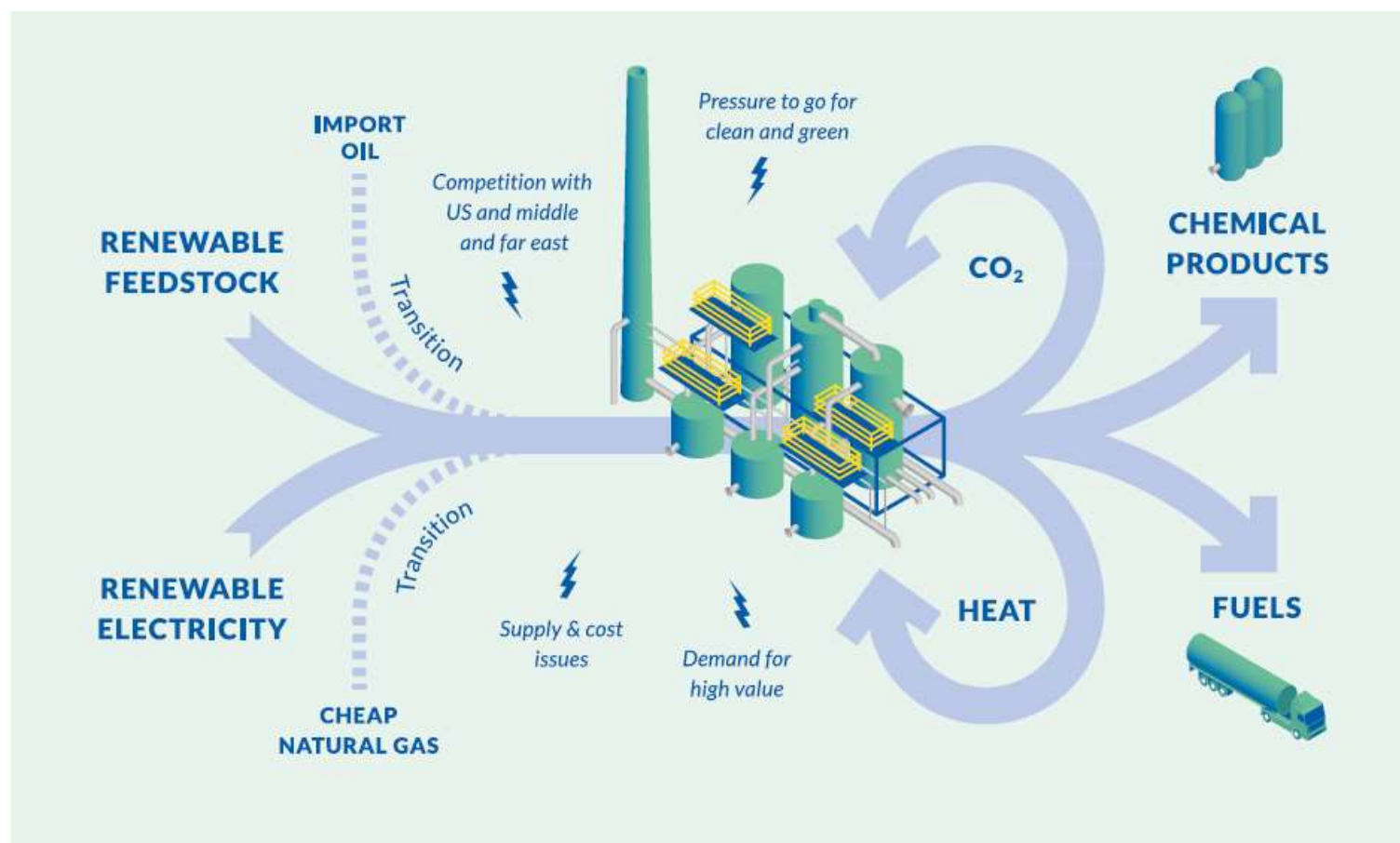
Powered by:

TNO innovation
for life

 **ECN**

Industry as enabler for sustainability

From fossil feedstock to renewable electricity as primary energy source



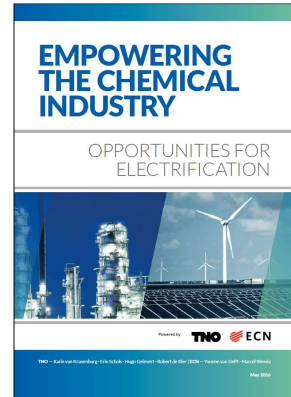
Why...

Transition to a sustainable society ...

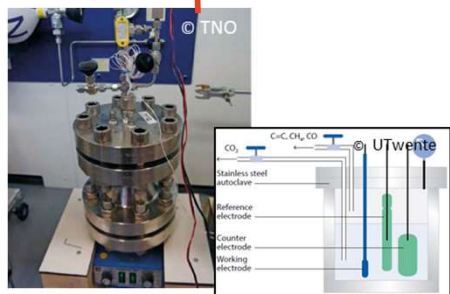
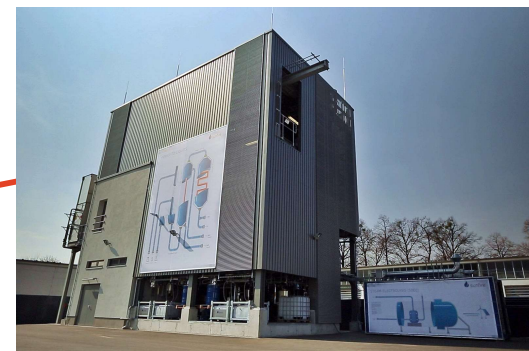
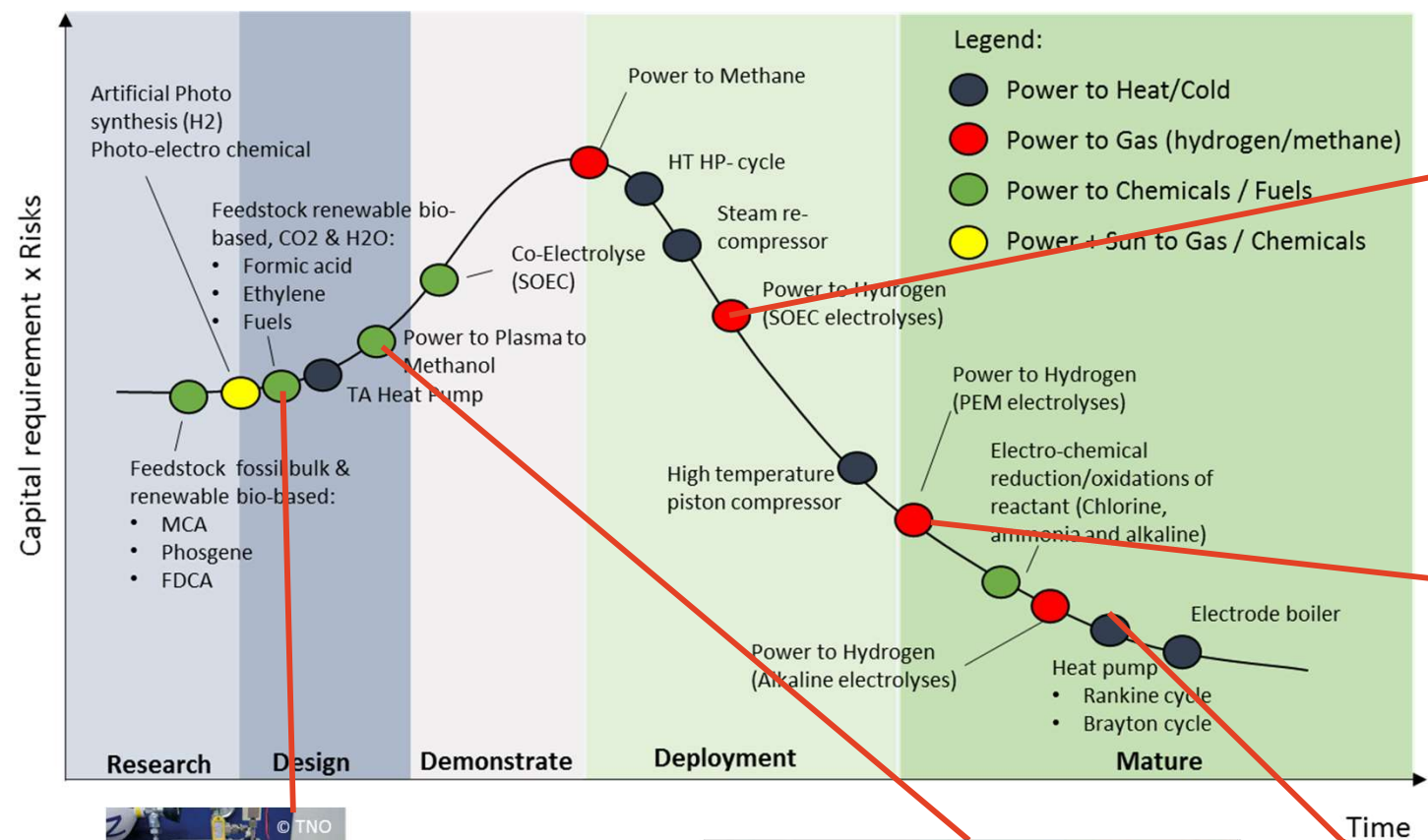
- Deep decarbonization of industrial clusters.
- Closing the loop of energy and materials.
- Energy storage for fluctuating renewable electricity.

... creates market opportunities

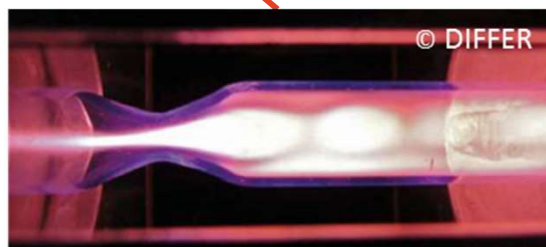
- Overall increased production efficiency.
- Utilizing upcoming feedstocks and energy sources.
- Production of new materials and fuels.
- Increasing sustainability profile.



What...



Electrochemical reactor development



Upcoming technologies: Plasma



Extension of operating windows in heat upgrading

Who...

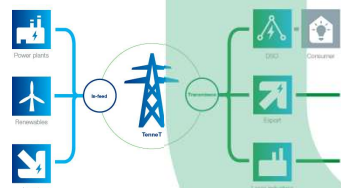
Electricity sector



Fossil electricity



Renewable electricity



Grid operators



Component providers



Technology providers



Solution providers



Engineering service providers

Equipment industry



Refineries



Commodity chemicals



Biochemicals



Specialty chemicals

(Petro)chemical industry



Fuels



Materials



Fertilizers

Where...

Figure 8: The Dutch chemical cluster

Chemical and petro production facilities

- Out of top 50
- Top 50

14 of the top 50 chemical companies have production facilities in Netherlands

Groningen-Eemsdelta

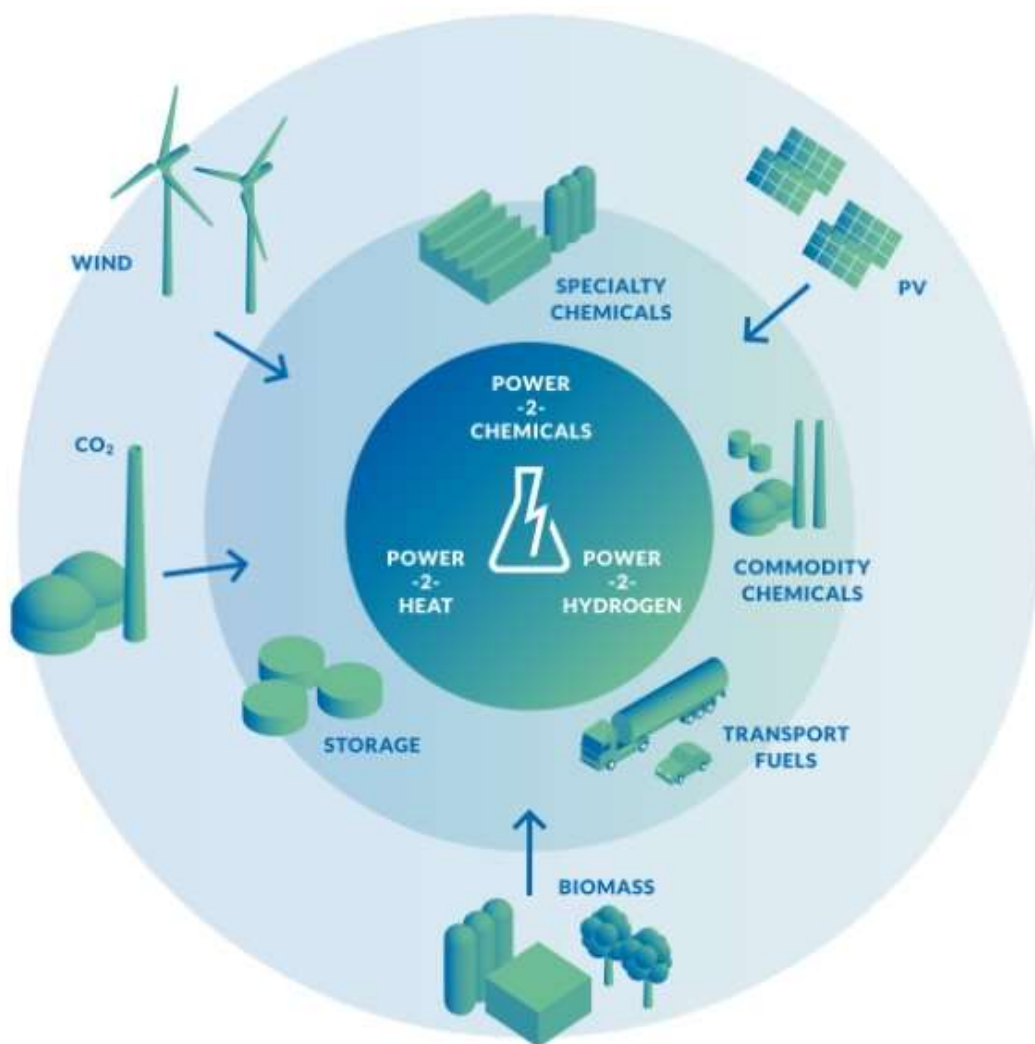
- Steam cracker
- Olefins consumer(s)
- Refinery
- Refinery + olefins producer
- RAPL (crude oil)
- PALL (naphtha)
- Industrial gases pipeline
- Ethylene pipeline
- Propylene pipeline

Antwerp-Rotterdam

Limburg-NRW

Source: VNO, Internal data, 2011; Port of Rotterdam, www.portofrotterdam.com/nl/Over-de-haven/haven-algemeen/Pages/achterlandverbindingen.aspx; Port of Antwerp, Europe's World Scale Chemical Cluster, 2005

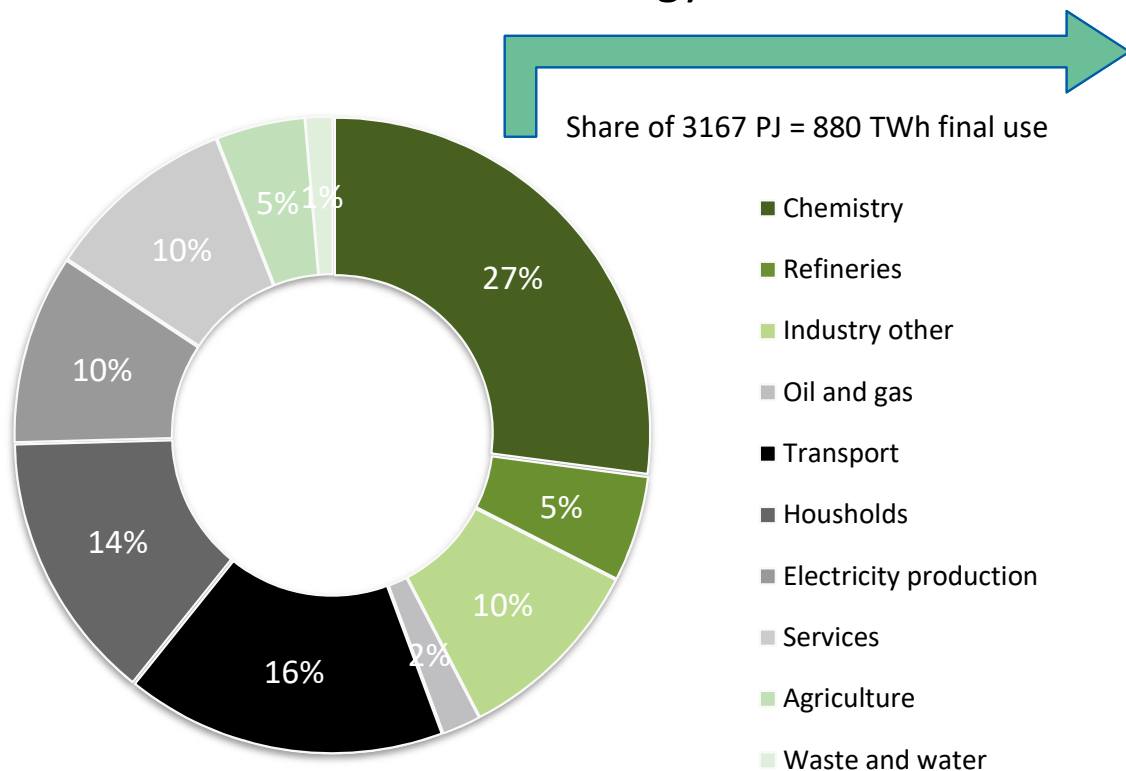
VoltaChem: Our mission



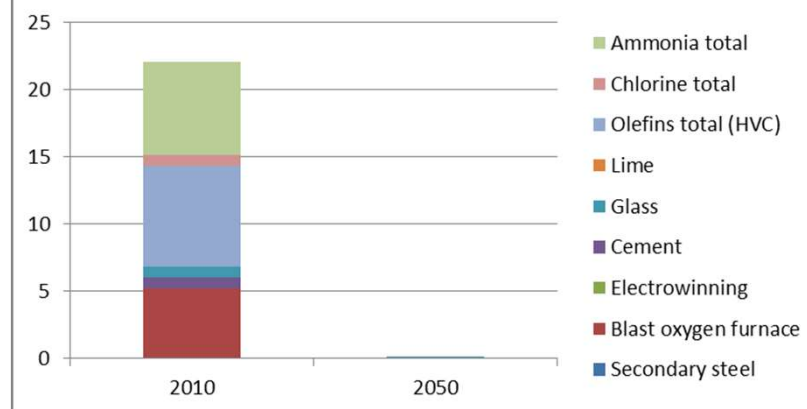
- Public-Private ***Shared Innovation Program*** of ~4 M€ / year, initiated in 2015 by TNO, ECN and Topsector Chemistry.
- **Accelerate innovation and implementation of industrial electrification** for *decarbonization of industrial production*.
- Initiate and facilitate ***collaborative development*** of technology and associated business models.
- Addresses both the *indirect and direct use of electricity* within the chemical industry, involving stakeholders from ***chemicals, energy & equipment supply***.

Our application focus

National Dutch energy use

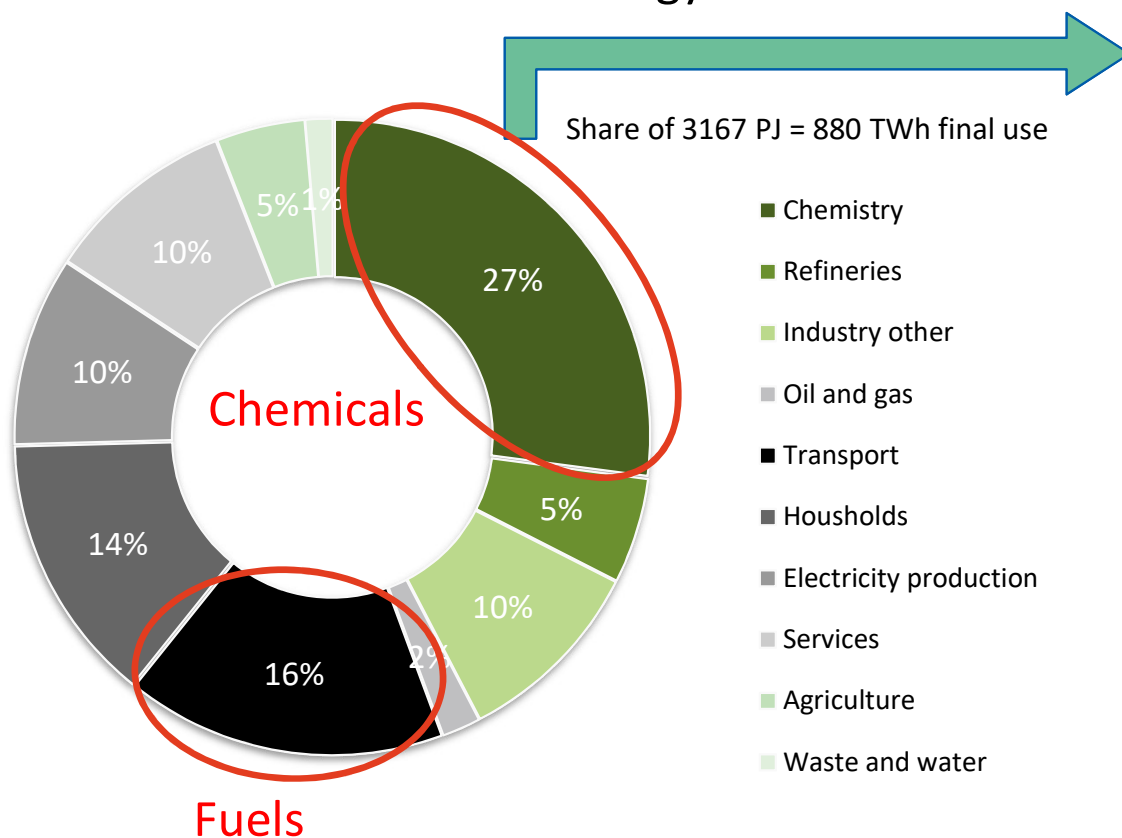


Direct CO2 emissions (Mt)

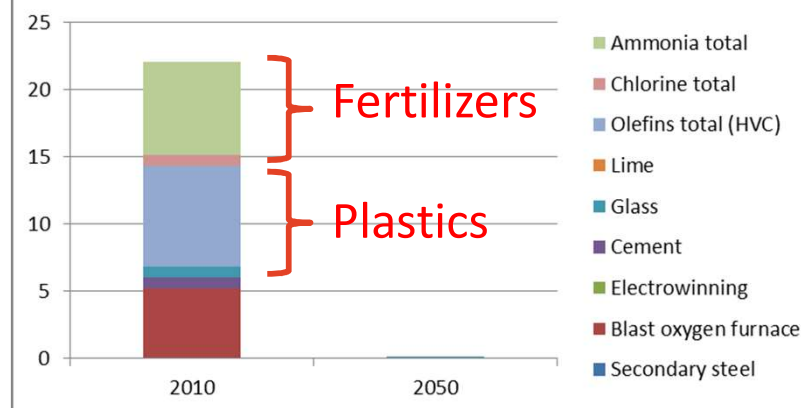


Our application focus

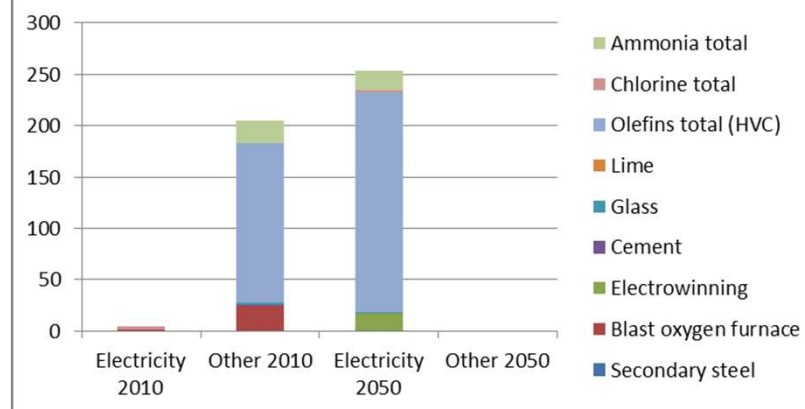
National Dutch energy use



Direct CO2 emissions (Mt)

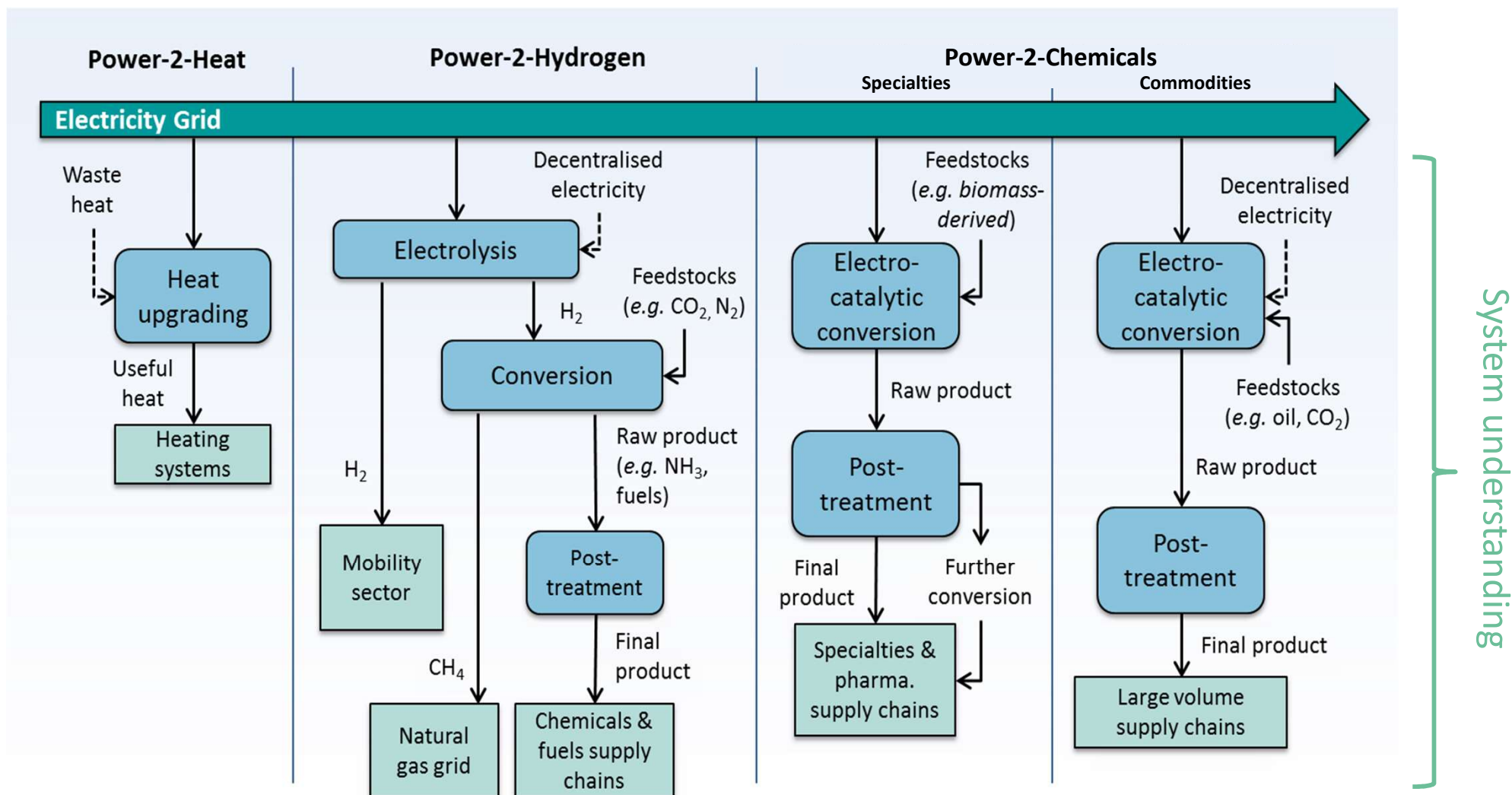


Energy consumption (TWh)



Focus on value chains: Fuels, Plastics & Fertilizers

Our technology focus



Maturity of Technology

Application areas:

Guiding choices in the Program lines

Program lines:

Development of key technologies

Power-2-Heat

Making processes more efficient through upgrading, compression heat pumps, and alternative concepts



Power-2-Hydrogen

New electrolyser concepts producing hydrogen as a feedstock for production of fuels and added-value chemicals



Power-2-Chemicals

Advanced electrochemical conversion technologies combined with process integration, modeling, and costing



Power-2-Integrate / System integration

Analysis of business cases and synergies between industries to advise companies and support policy decisions



Idea phase
TRL 1 – 2



Lab research
TRL 2 – 4



Pilot testing
TRL 5 – 6

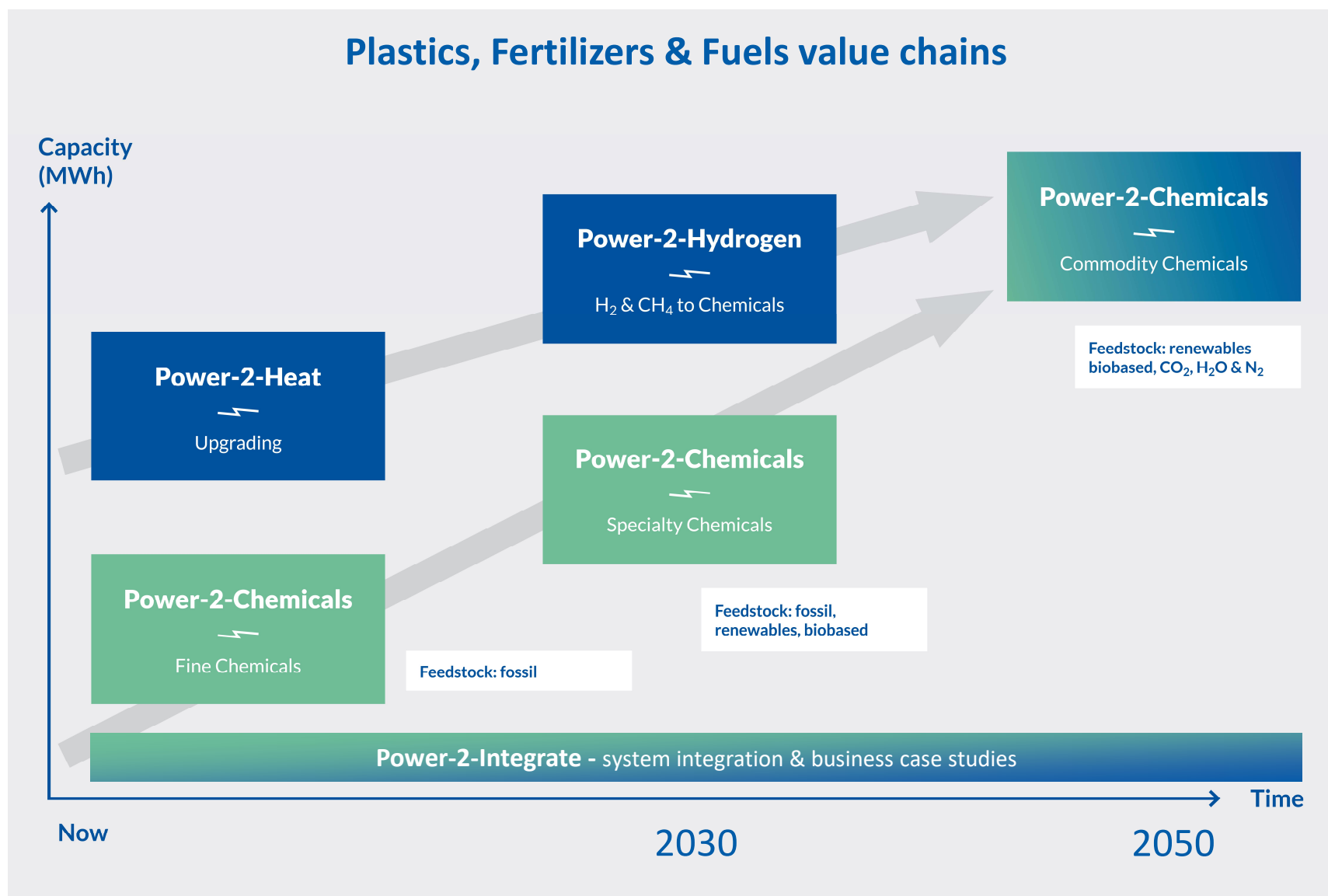


Towards
commercialization
TRL 7 – 9

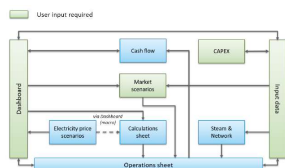


Tools validated
& applied

Implementation roadmap

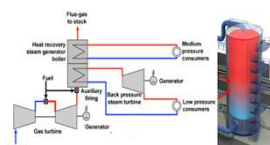


Our development focus



Power-2-Integrate

Technology **scouting** & developing ***economic, life-cycle & system models*** to better understand electrification opportunities.



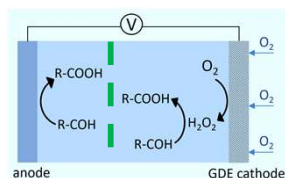
Power-2-Heat

Developing and testing ***electrically driven heat production systems*** for *low and high temperature*.



Power-2-Hydrogen

Developing and testing ***electrochemical production of hydrogen and further conversion*** towards *fuels and added value chemicals*

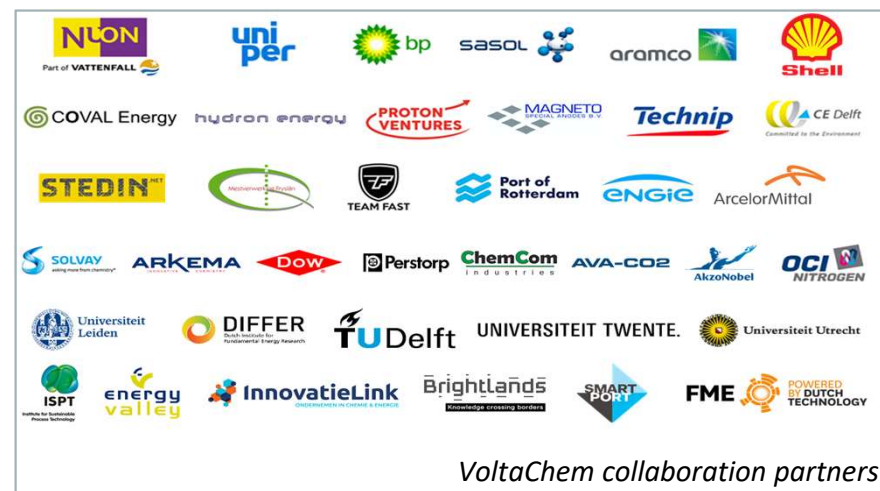
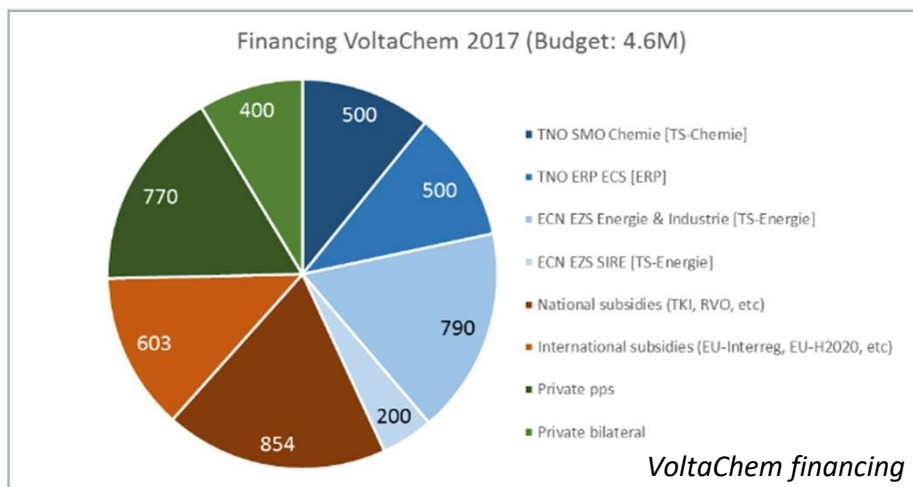


Power-2-Chemicals

Developing a ***paired electrosynthesis technology platform*** for:

- selective oxidation of *biobased feedstock to chemical intermediates for plastics*.
- direct conversion of *CO₂ to commodity chemicals & fuels*.

VoltaChem results overview 2017



21 projects
(2017)

Community participation: *Technology scouting and discussion group*
Exclusive events, conference reports, roadmap updates, high-level results.

Programme participation: *Pre-competitive programmatic R&D*
Multi-year participation in the adaptive long-term research program.

Project participation: *Pre-competitive linear development*
Pre-competitive multilateral projects with fixed scope/time/budget and non-exclusive rights.

Commissioned projects: *Contract R&D*
Exclusive bilateral projects with fixed scope/time/budget and exclusive rights.

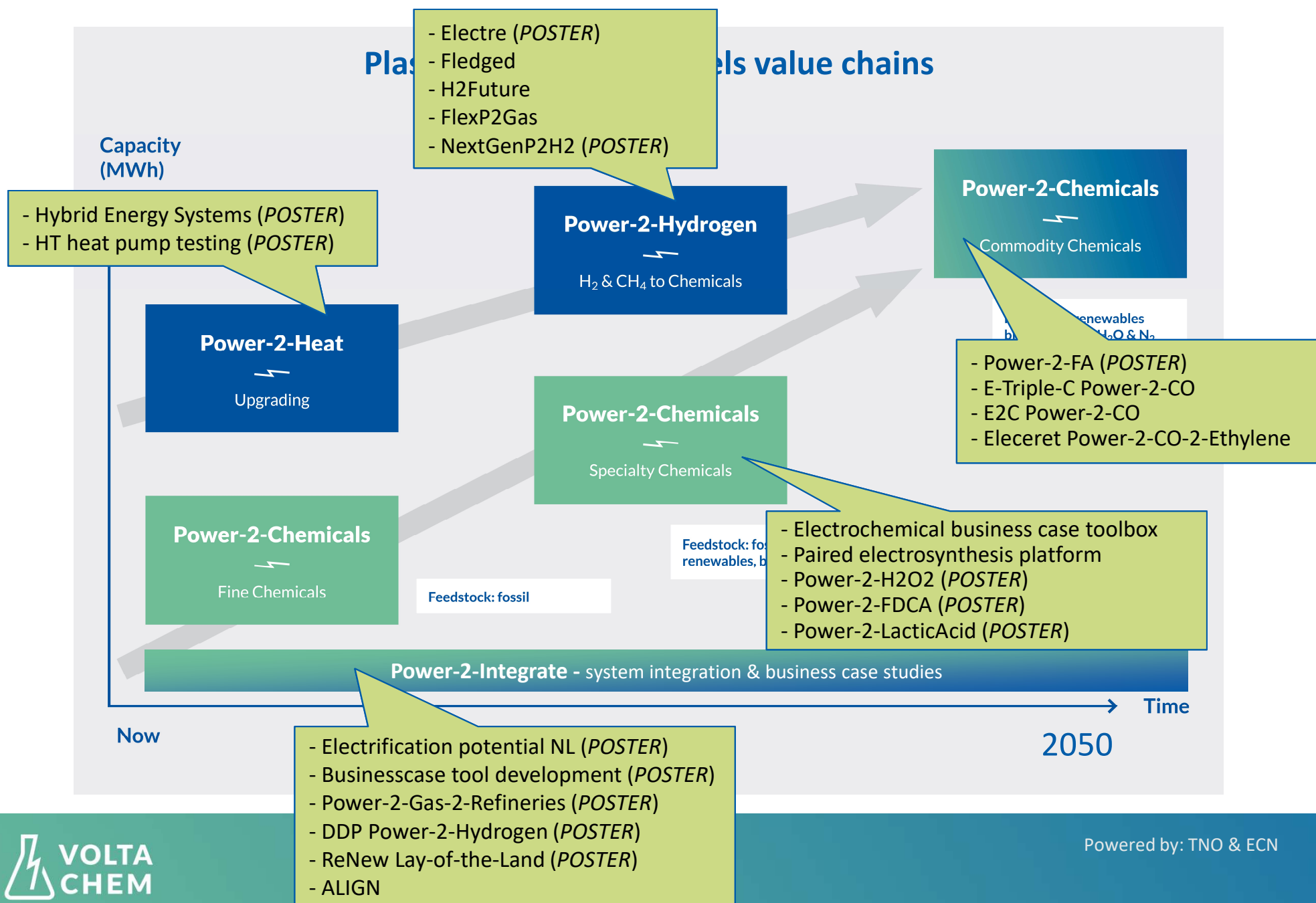
Indirect participation: *Subsidy schemes*
Involvement in public subsidy schemes (H2020, NWO, INTERREG) in which VoltaChem participates.

VoltaChem collaboration models

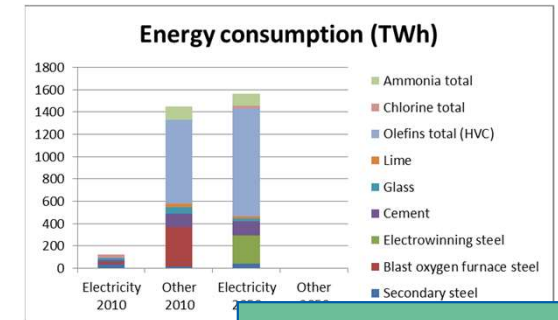
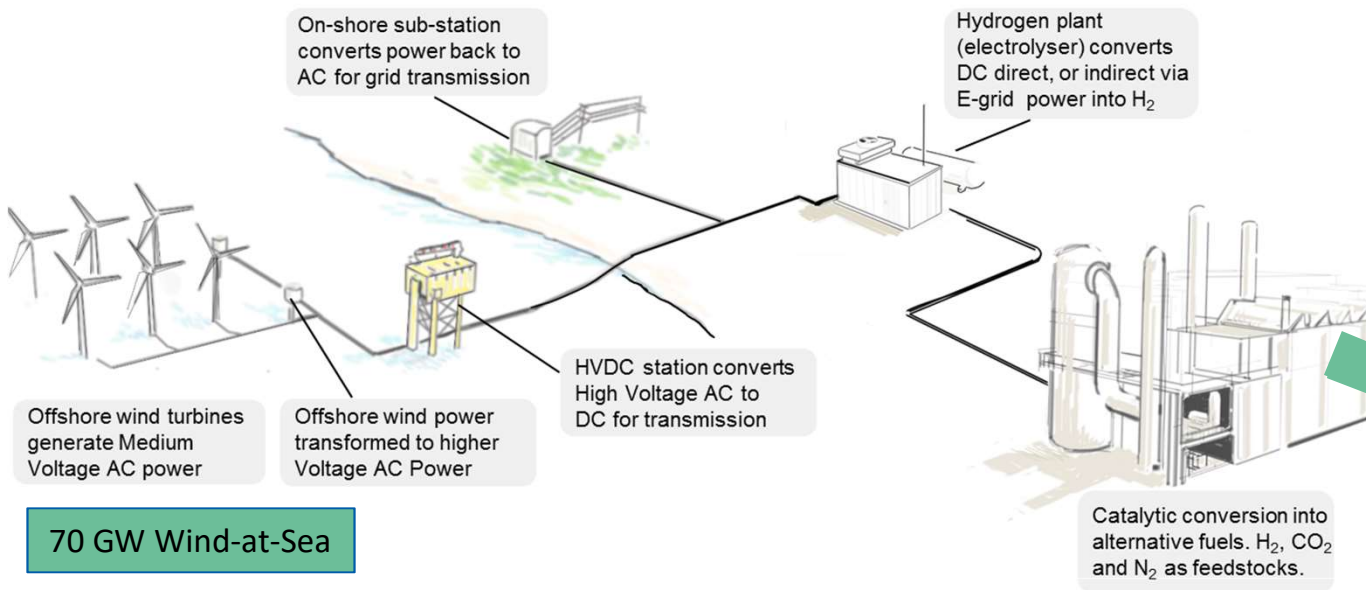
Results 2017 (compared to 2016):

- 11 → 21 projects
- 22 → 38 collaboration partners
- 7 → 15 paid community members
- 1 → 6 patent applications

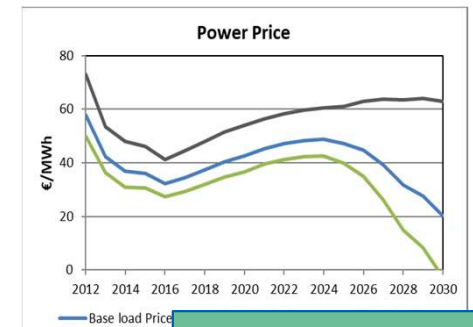
VoltaChem activities 2017



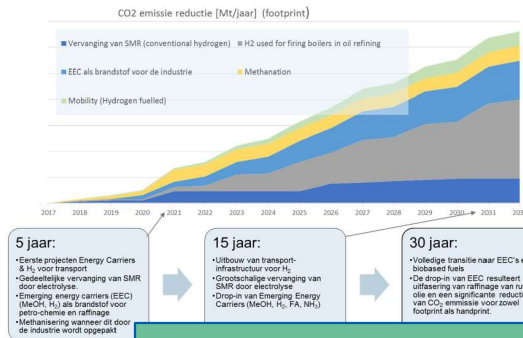
Results Power-2-Integrate



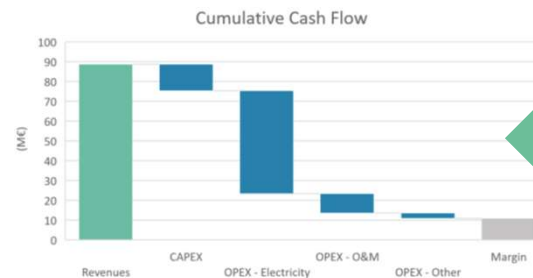
Electrification Potential NL



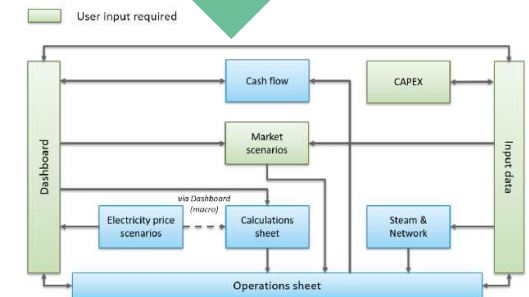
Power price models



DDP Power-2-Hydrogen roadmap



Power-2-Gas-2-Refineries cases



Businesscase calculation tool

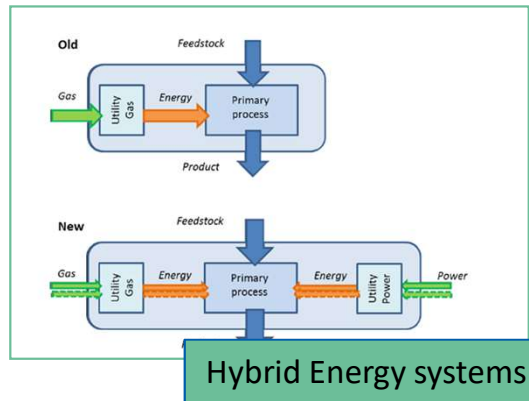
Results Power-2-Heat



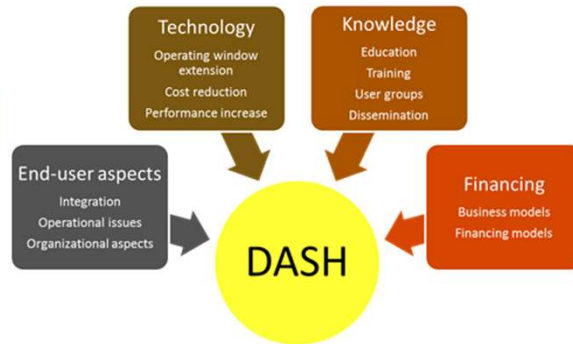
10kWth Thermo-Acoustic Heat pump



200 kWth Heat pump test system

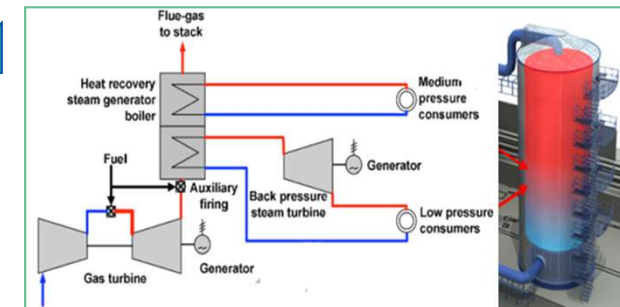


Hybrid Energy systems



DASH

Flexible Industrial Heat
Management Platform



Flexible heat & power generation

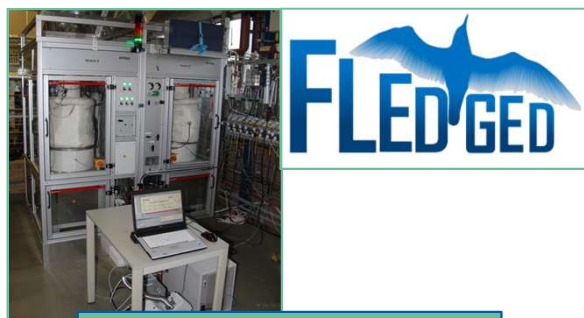
Results Power-2-Hydrogen



Electrolyzer component testing



50 kWe PEMWE system



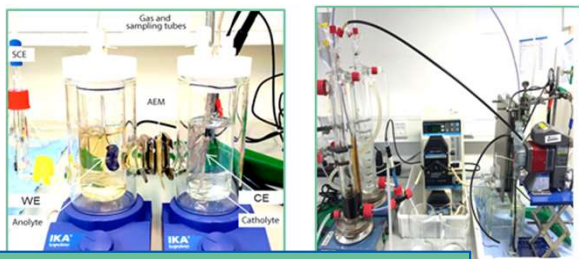
Bench-scale Power-2-DME

Green Hydrogen Platform
for fuels & feedstocks



Demonstration 6 MWe PEMWE in steel production

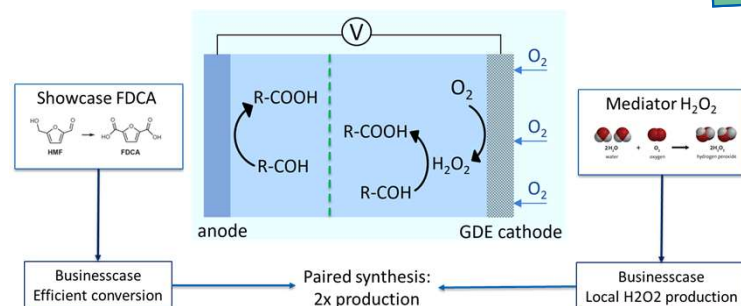
Results Power-2-Chemicals



Proof-of-principles H₂O₂ & LA

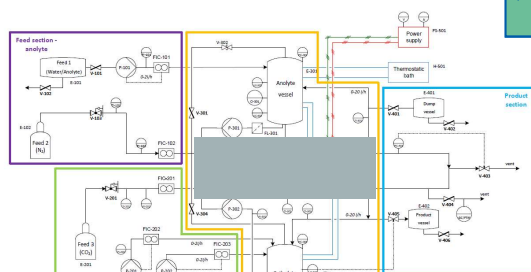


Bilateral electrochemical synthesis projects



Paired electrochemical synthesis platform

Future electrochemical
Biobased & CO₂ conversion

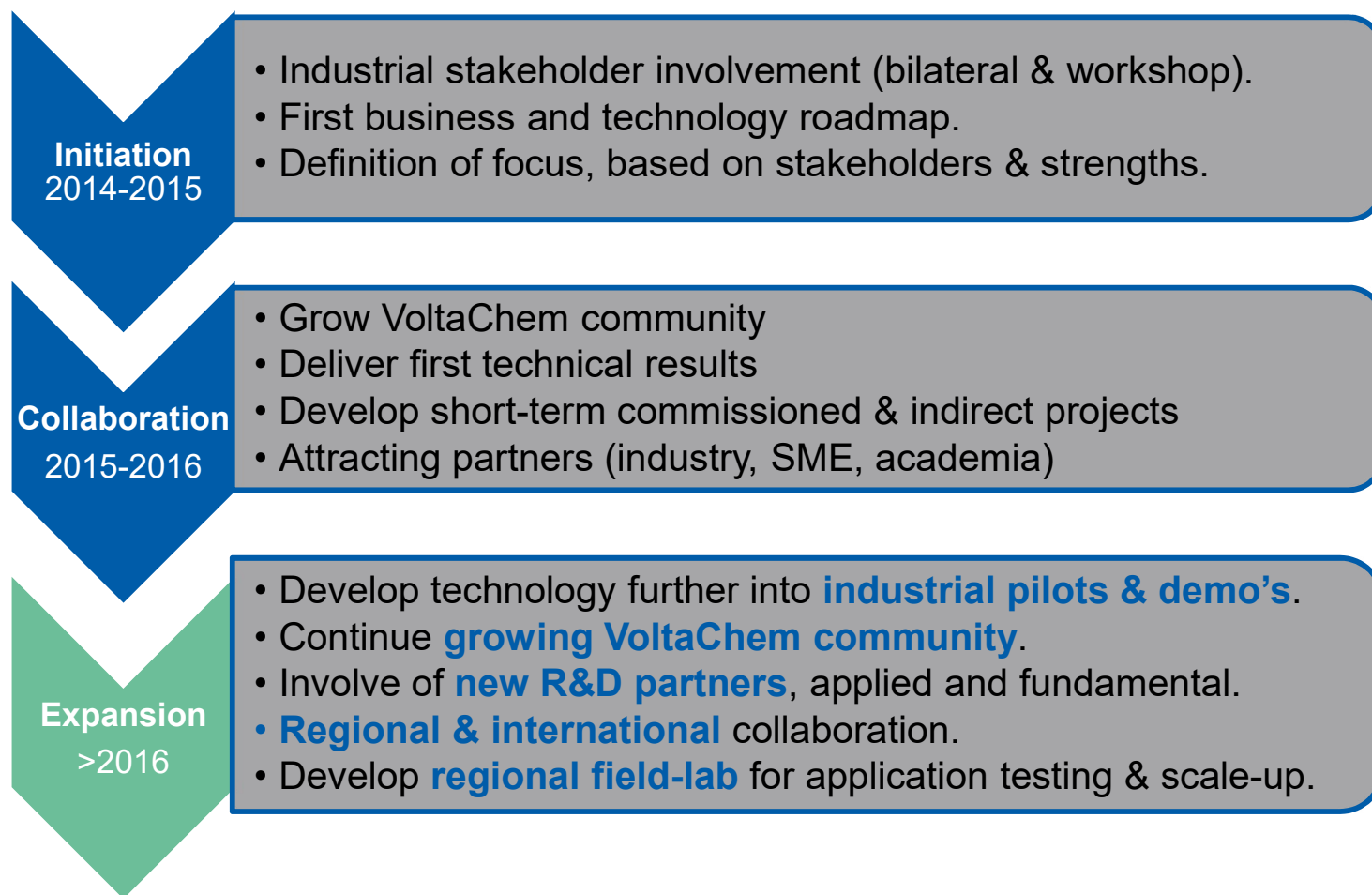


Pilot design Power-2-FA



Bench-scale Power-2-FDCA

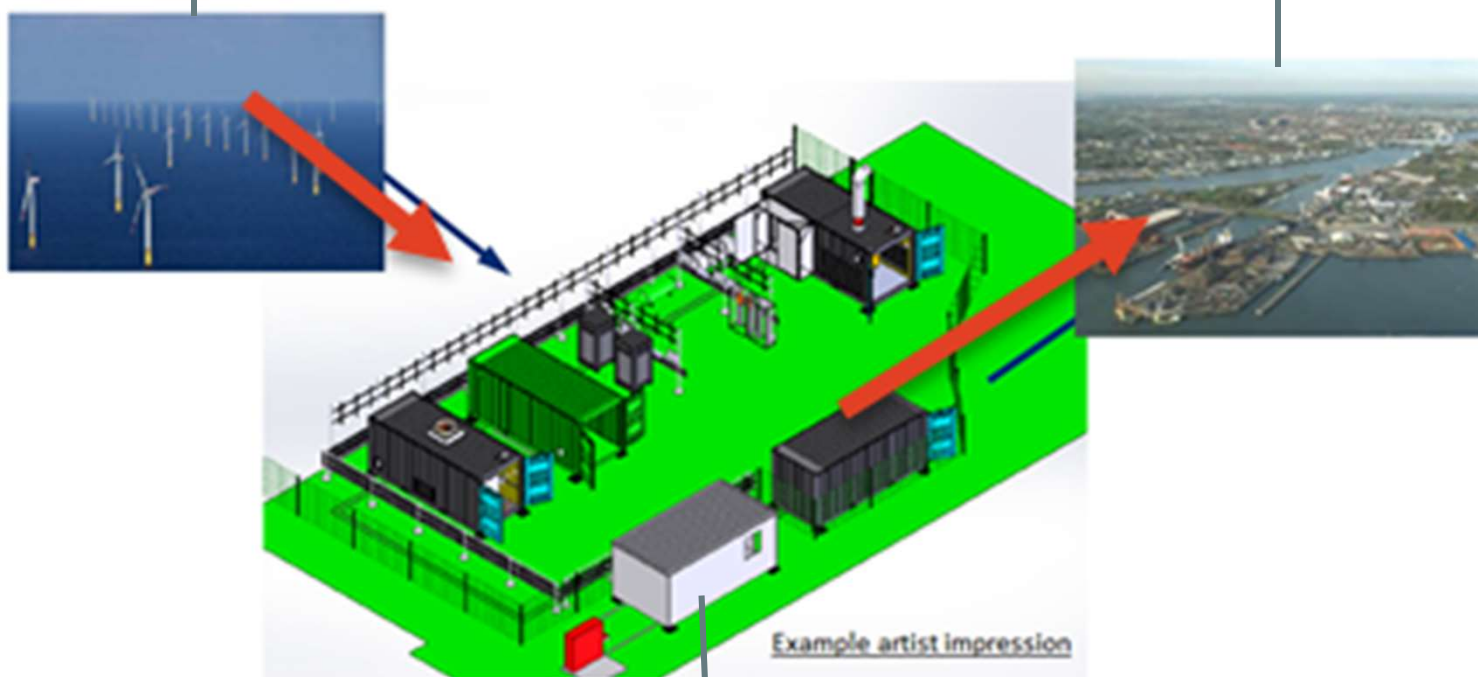
Further program development



Next step: An industrial fieldlab

Future proximity of renewable energy
Need for storage & flexibility

Large Dutch Energy & Industry cluster
Serious decarbonization objective



Industrial Demonstration & Implementation *Power-2-Heat/-Hydrogen*.
Pre-competitive Development & Piloting *Power-2-Chemicals*.



Electrification of the Chemical Industry

**More results, ideas and plans at
posters, breakouts & networking!**

**... and become member of our VoltaChem Community
for being involved on a regular basis in 2018!**