FAPESPWeek NETHERLANDS
OCT 27-29, 2026

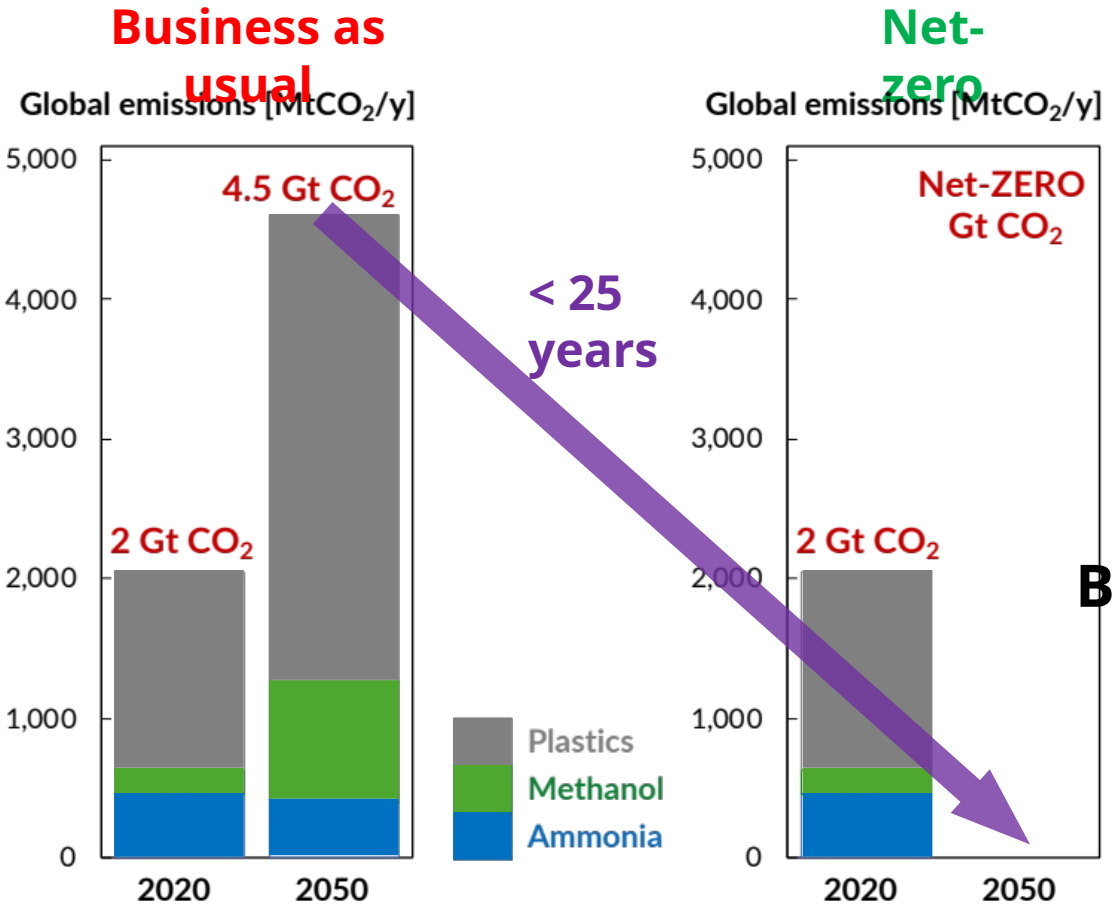
Large scale energy storage and carbon circularity

- towards net zero emissions



The Big Challenge

To reduce fossil resources' dependency we need to develop <u>entirely new process technology</u> to be deployed within <u>25 years</u>:



- **Net zero CO_2** process industry within 25 years
- Feedstock: only **circular carbon** & increase the Netherlands' **self-sufficiency** (exploit "North Sea power house")
- **Green electricity** as primary energy source

BUT: electrification <u>and</u> continuous operation of chemical plants: **not viable!**

Electrification of a 1 Mt.y^{-1} naphtha cracker in continuous operation → 37 GWh* of electric battery, > much higher than the largest battery system

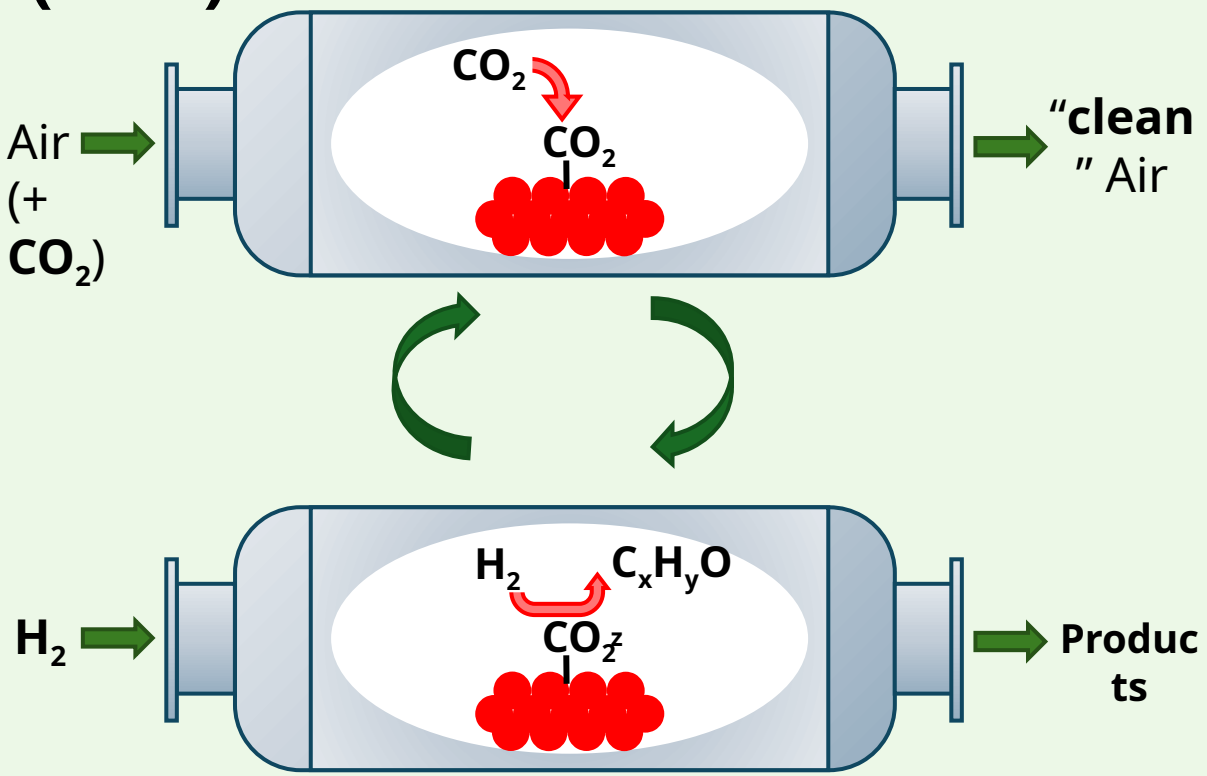
* source: Tiggeloven, J.L., Faaij, A.P.C., Kramer, G.J., and Gazzani, M. (2023) Ind.Eng.Chem.Res **62**,

The solution for coping with e-intermittency

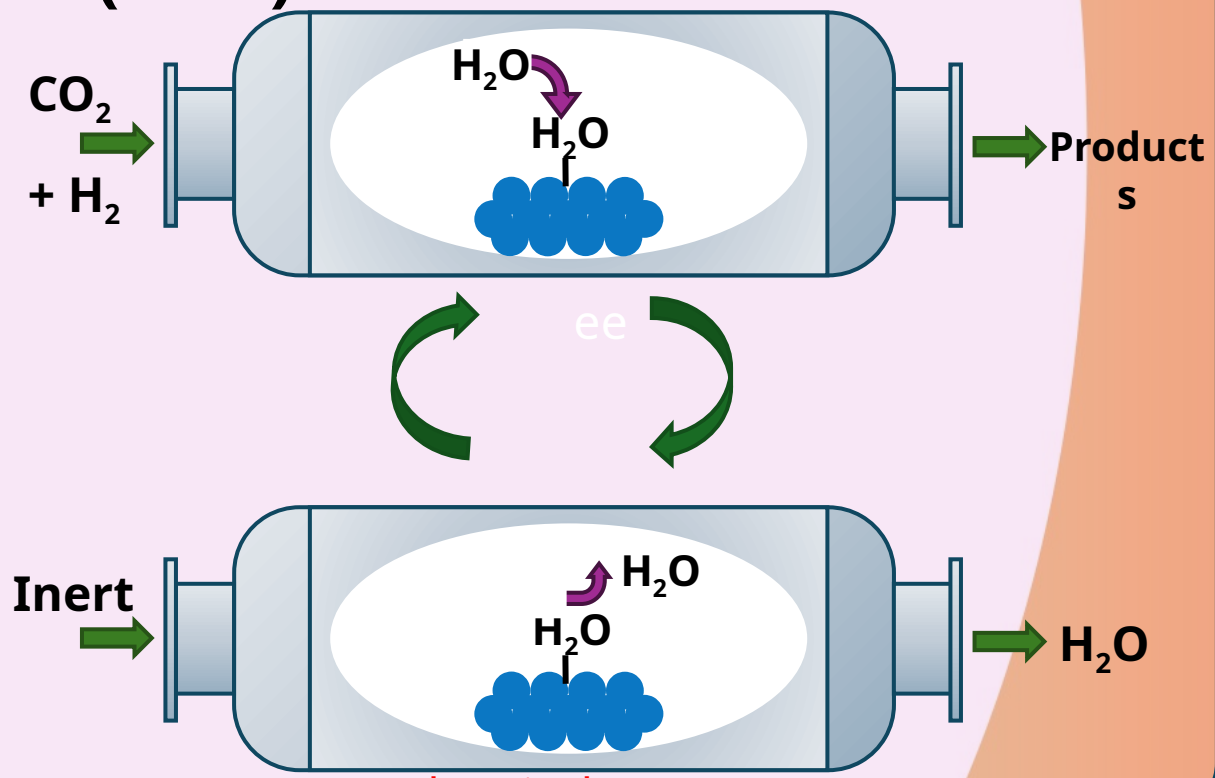
Entirely new electrified process technology for chemical and bulk key fuels to be deployed within 25 years:

$$CO_2 + 4\,H_2 \rightleftharpoons CH_4 + 2\,H_2O$$

Integrated DAC and conversion (WP1)



Sorption-enhancement (WP2)



The Solution

***Entirely new process technology** to be deployed within **25 years**:*

Integration
- Reactor
- Process
- System

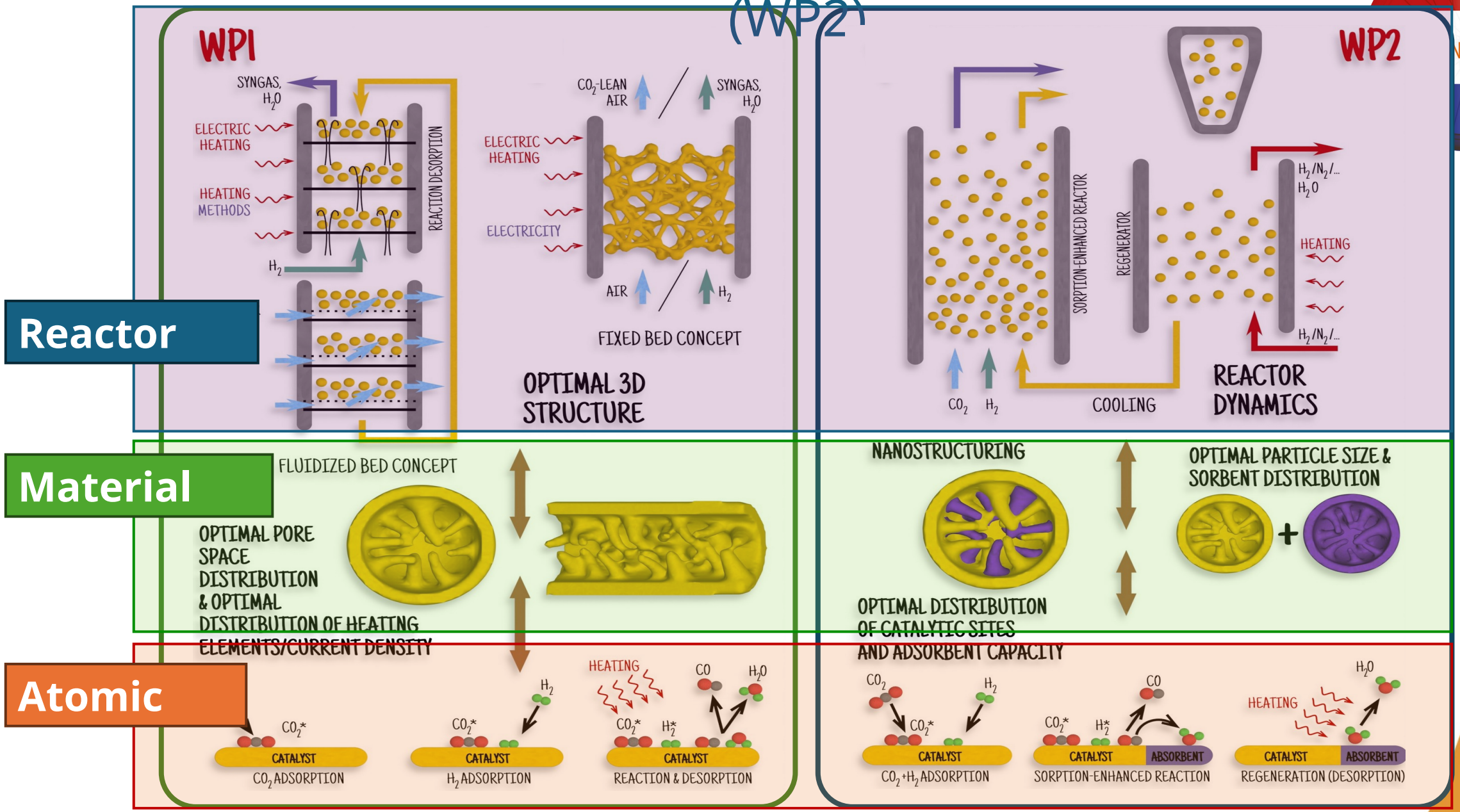


Dynamic Operatio

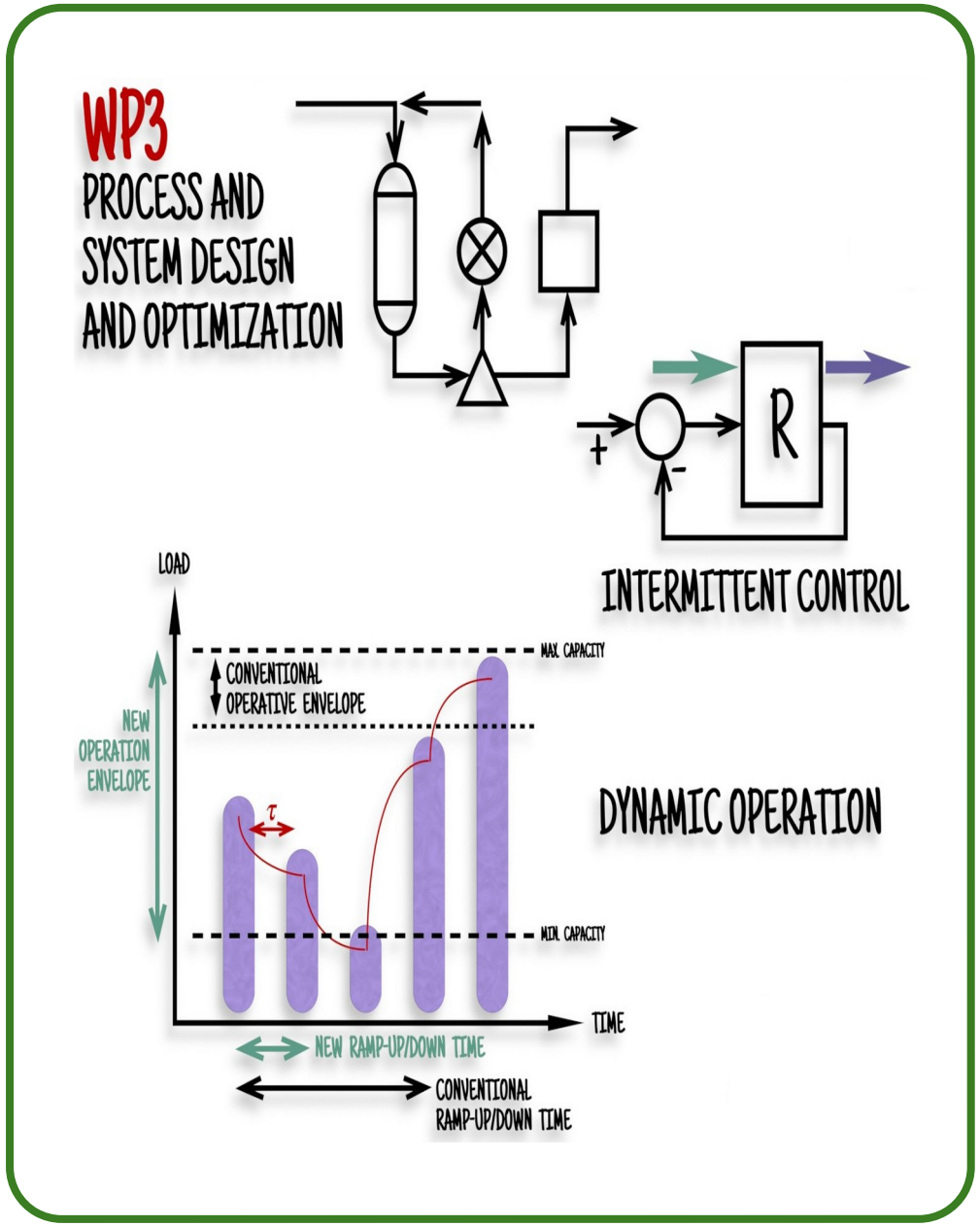


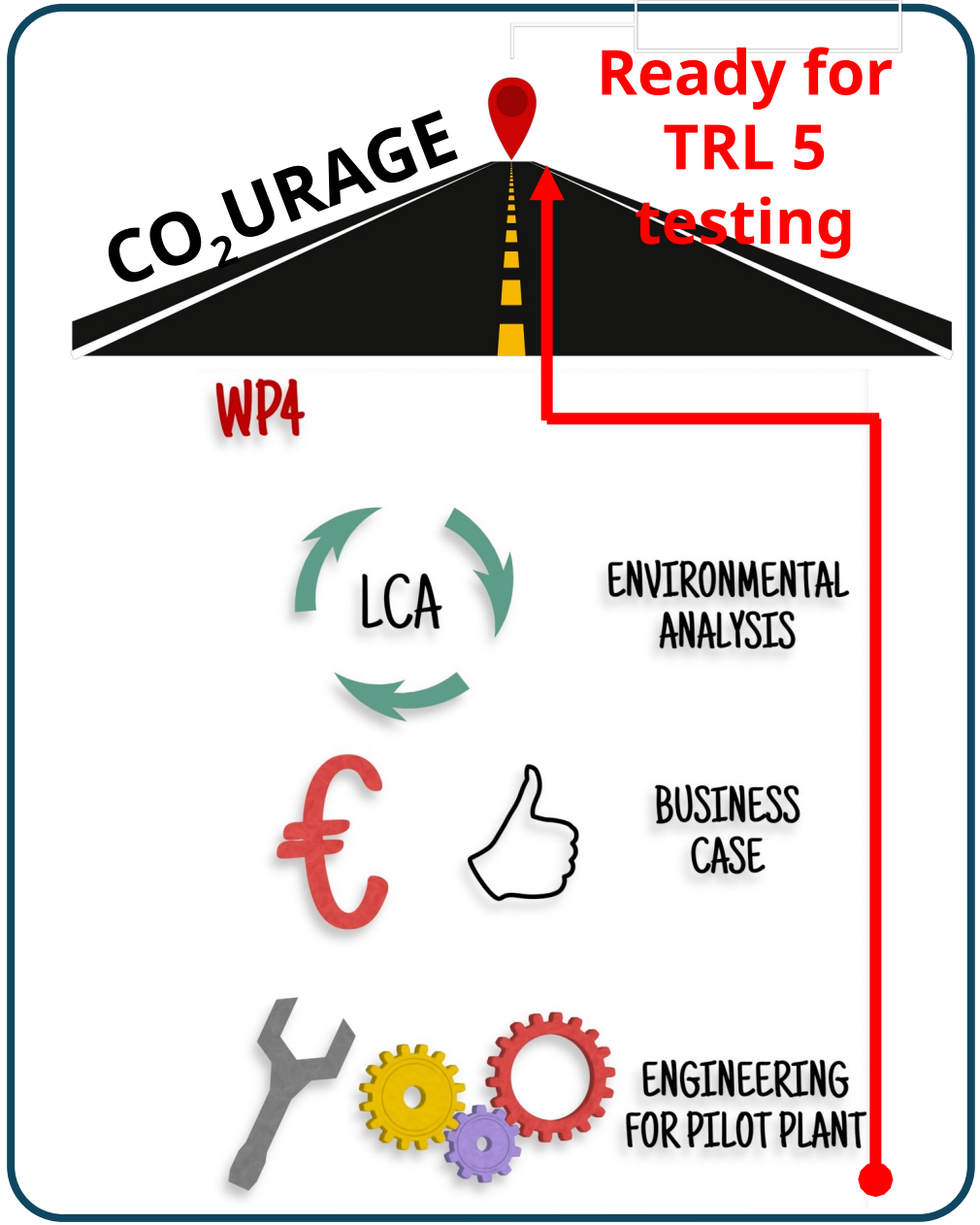
Electrificatio

WP1+2: Reactor technology development of DAC (WP1) and SEC (WP2)



WP3+4: Process System Design, Control, Optimization (TEE/LCA)





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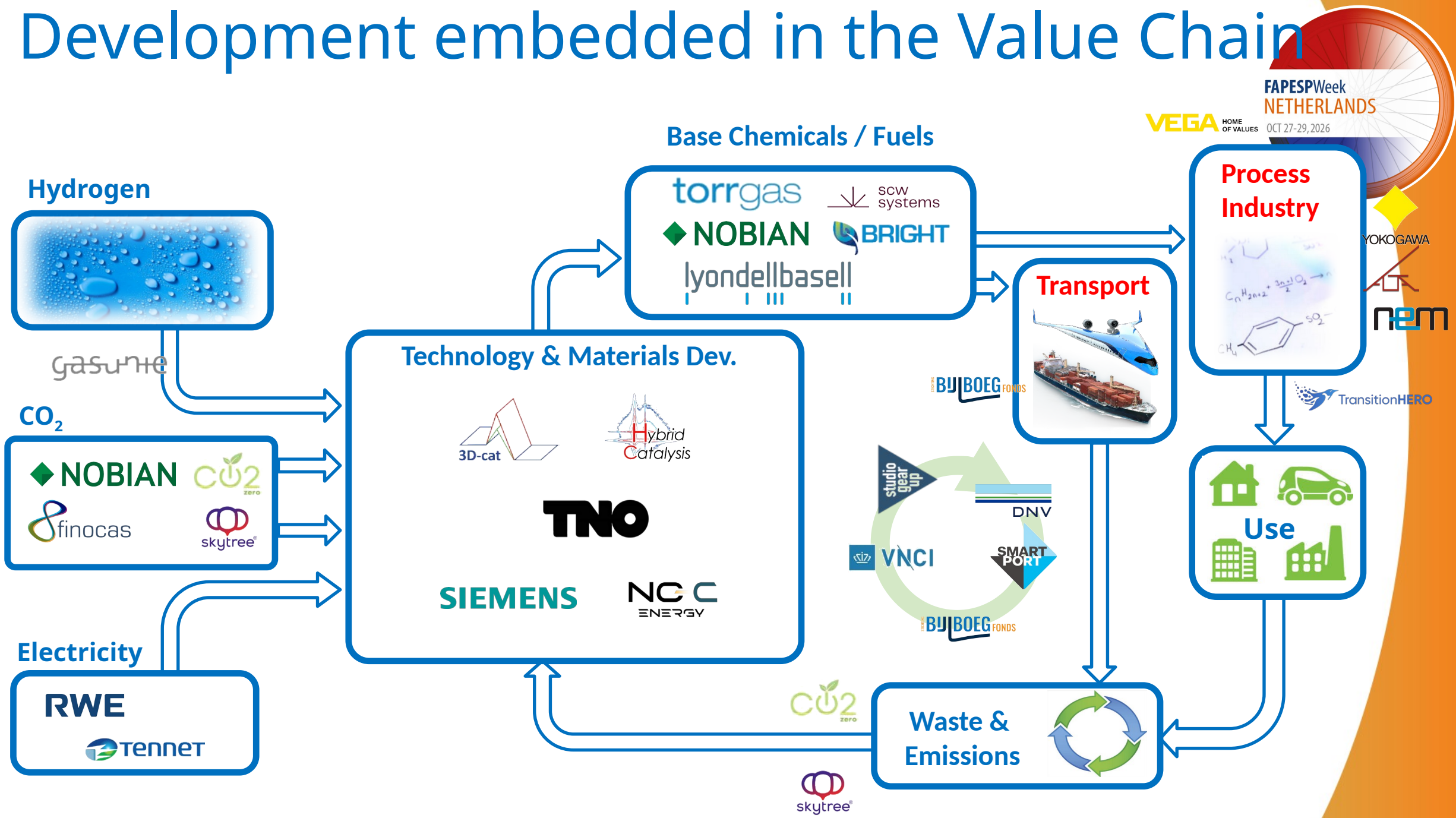
Development embedded in the Value Chain



CO_2URAGE

WP0: Project management and knowledge utilisation

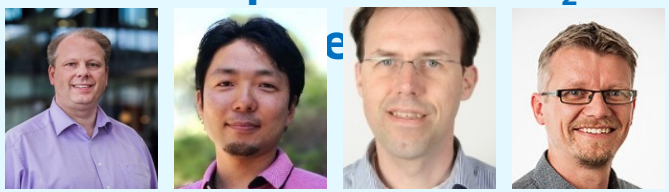
WP3: System integration & design,



WP4: Techno-economic, environmental, engineering & business case analysis



WP1: Electrification of Direct Air Capture and CO_2



WP2: Electrification of sorption-enhanced CO_2



Societ y, Futur e

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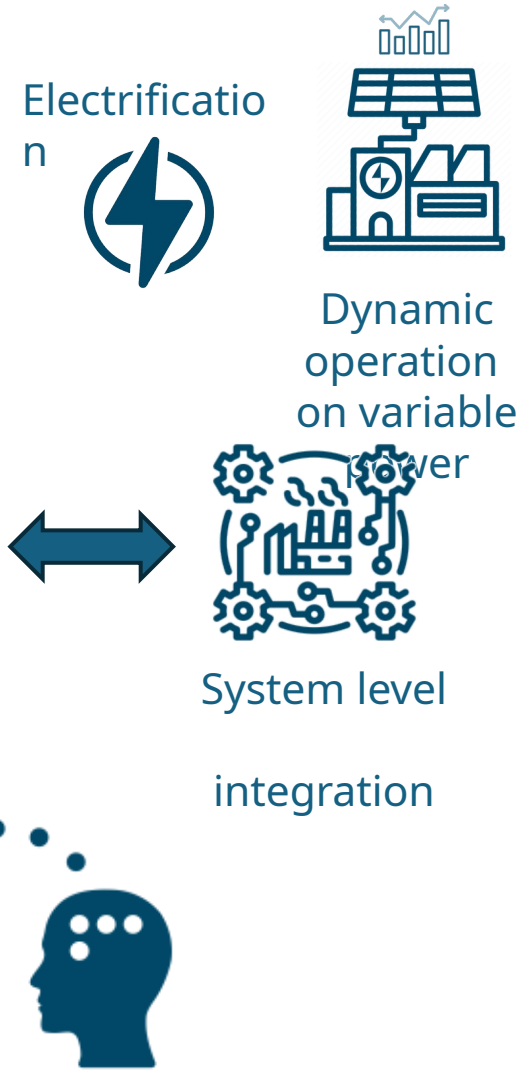
Innovativeness

- Technology development based on <u>intermittent</u> electricity (= dynamic operation)

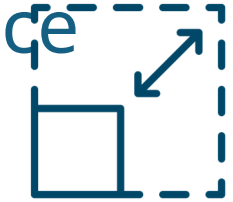
- <u>Bi-directional</u> information transfer: reactor level ↔ (process) systems level

⇒ Enabled by strong collaboration
within a <u>unique</u> ecosystem
(4 universities & 26 companies)

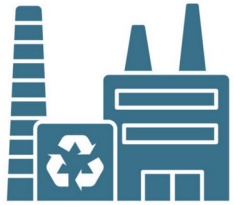


Outcomes (the follow up)

- Quantification of potential performance of the developed technologies for CO_2 point sources and DAC
  ⇒ on-site demonstration at TRL5



Scaled tests



Small pilot-plant

- Use of developed knowledge & tools in follow-up projects / future programs



New Technology Toolbox



Software, Control & Optimisation Strategies

- Create awareness & highly trained workforce



Past: Highlights 2020-2026



RELEASE

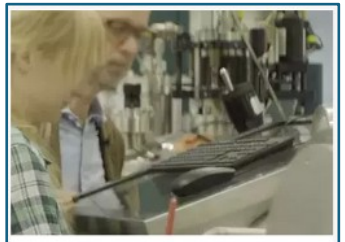
Reversible Large-scale Energy Storage

NWO Crossover 11 M€



HyCARP

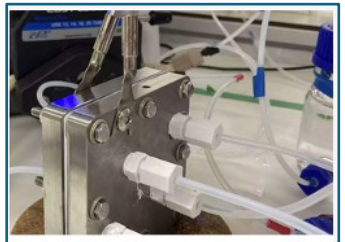
GVNL-WP4 5 M€



E2CB

Electrons to Chemical Bonds

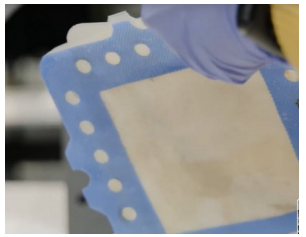
NWO Perspectief 5 M€



SELECTCO2

Selective Electrochemical Reduction of CO2 to High Value Chemicals

4 M€



ReCoVR

NWO Perspectief 4 M€



Alquion B.V.

groenvermogennl

GroenvermogeNL

NGF

Pilot & Demo 661 M€

NGF R&D 177 M€

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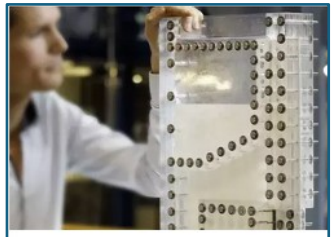


E2C

Electrons to high value Chemical products

Interreg Europe 7 M€

groenvermogennl

HyNITROGEN 5 M€

HyFINE 4 M€

COURAGE 2

CO2URAGE

NWO Perspectief 7 M€



FlexEChem

Flexible Electrochemical Plant of the Future

NWO OTP 1 M€

erc NWO Veni, Vidi, Vici

Personal Grands

ERC Vermaas

ERC Burdyny

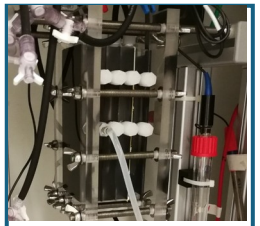
VICI Ramirez

VIDI Haverkort

VIDI Hartkamp

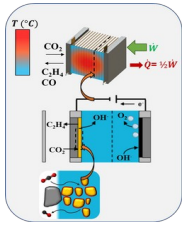
VIDI Vermaas

11 M€



C2-C6 MES

NWO OTP 1 M€



e-Heat

NWO OTP 1 M€

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