

Operational experience CCU

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hvc.
energie en hergebruik

Introduction
HVC

some key figures (2025)

shareholders

- **54** municipalities and **8** water boards

Renewable energy

- Total renewable energy production: **1.520 GWh** (equivalent: circa **800.000** households)
- Heat supply to **34.354** household equivalents
- Number of geothermal sources: **5**

Waste and reuse

- Collection in **27** municipalities **(629.187 households)**
  - waste separation: **83%** (source and subsequent separation)
  - **17** collection stations (**> 36** different waste streams) and **2** 'recyclepleinen'
- Organic waste: processing of **201** kton (resulting in **73** kton of compost)
- Sewage sludge: processing of **346** kton

staff

- Number of fte's: **1.418**

finance

- Operating income: € **593 mln**
- Net result € **20 mln**
- Shareholders' equity € **278 mln**

environmental efficiency

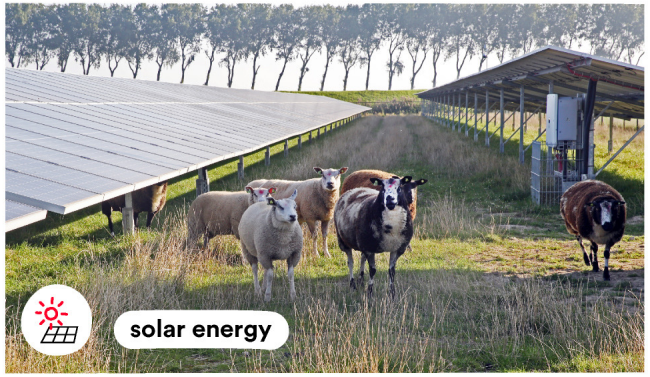
- Fossil and biogenic CO_2 emissions: **1.481** kton
- Avoided CO_2 : **1.039** kton

our activities

more sustainable heat, more renewable electricity, and more green gas















less waste, more waste separation, and more recycling









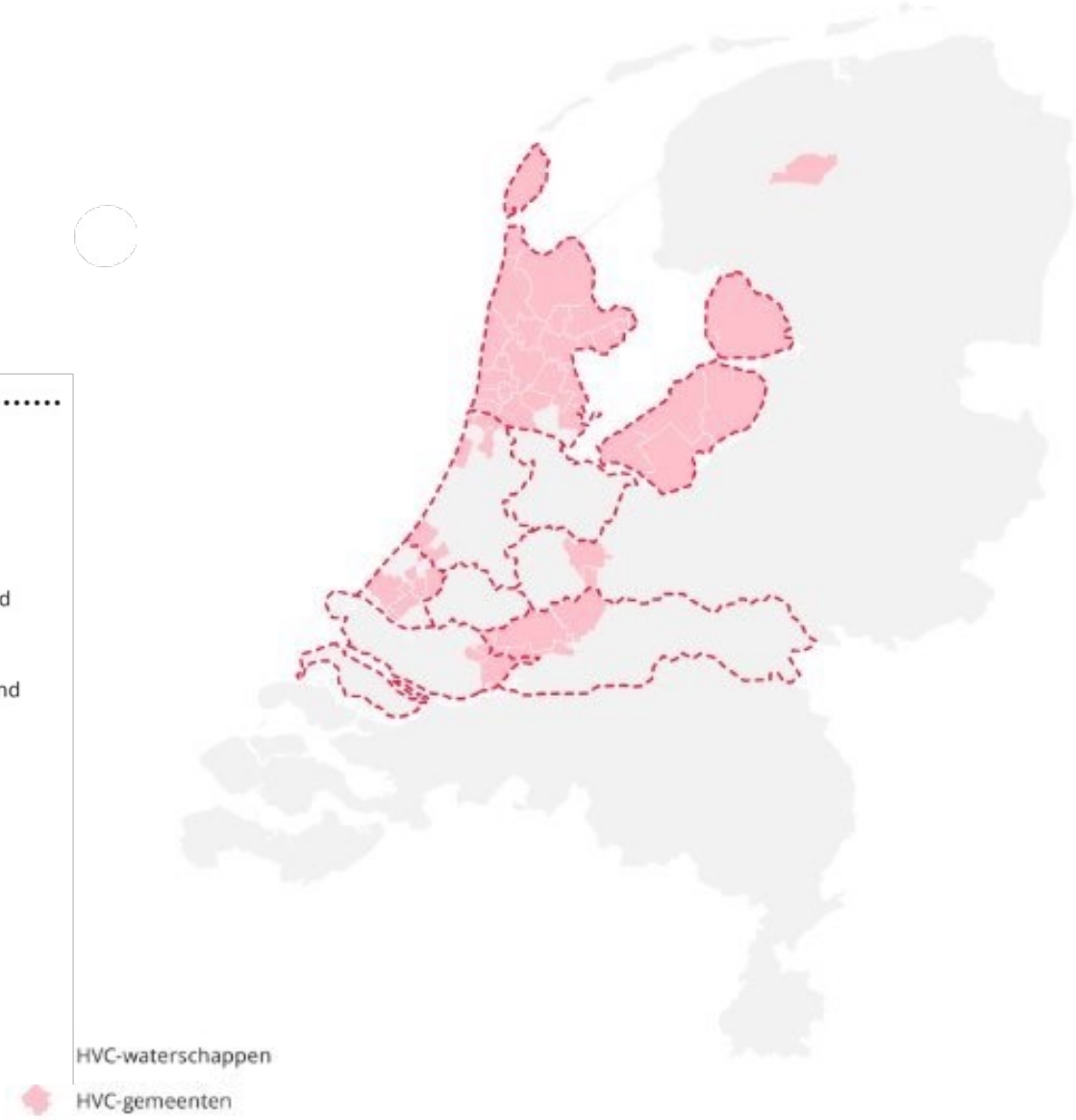
HVC working area

Gemeenten
april 2026

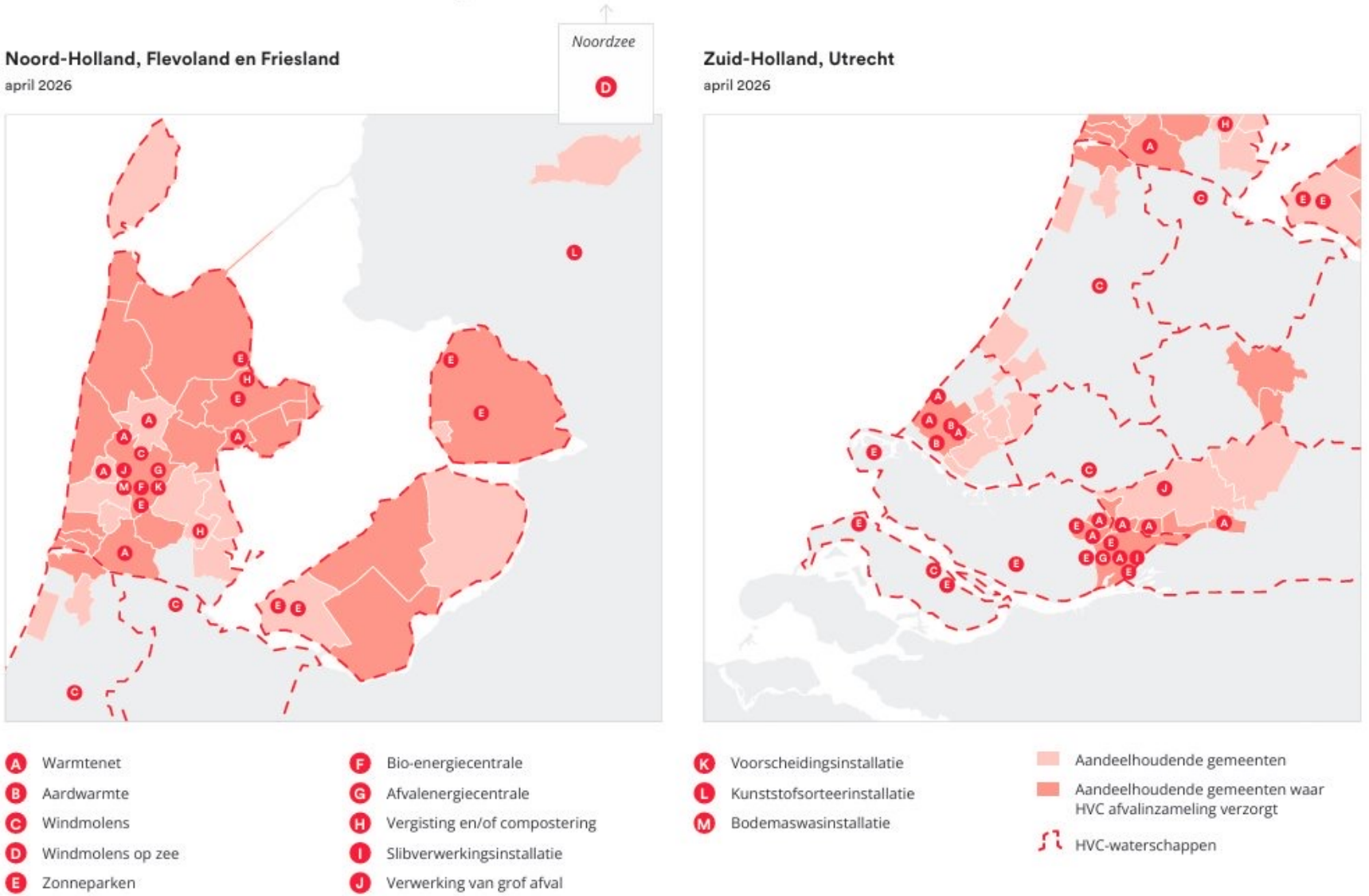
- Alblasserdam
- Alkmaar
- Almere
- Bergen
- Beverwijk
- Castricum
- Delft
- Den Helder
- Dijk en Waard
- Dordrecht
- Drechterland
- Dronten
- Enkhuizen
- Edam-Volendam
- Gorinchem
- Haarlem
- Hardinxveld-Giessendam
- Heemskerk
- Heiloo
- Hendrik-Ido-Ambacht
- Hollands Kroon
- Hoorn
- Koggenland
- Leidschendam-Voorburg
- Lelystad
- Maassluis
- Medemblik
- Midden-Delfland
- Molenlanden
- Nieuwegein
- Noordoostpolder
- Opmeer
- Papendrecht
- Pijnacker-Nootdorp
- Purmerend
- Rijswijk
- Schagen
- Sliedrecht
- Smallingerland
- Stede Broec
- Texel
- Uitgeest
- Urk
- Utrecht
- Velsen
- Vijfheerenlanden
- Wassenaar
- Waterland
- Westland
- Wormerland
- Zaanstad
- Zandvoort
- Zeewolde
- Zwijndrecht

Waterschappen
april 2026

- Waterschap Hollandse Delta
- Hoogheemraadschap van Schieland en de Krimpenerwaard
- Hoogheemraadschap Hollands Noorderkwartier
- Hoogheemraadschap van Rijnland
- Waterschap Rivierenland
- Hoogheemraadschap van Delfland
- Waterschap Amstel, Gooi en Vecht
- Waterschap Zuiderzeeland



activities in operation



Context CO_2 and position HVC

Climate impact of CO_2

WHAT IS CO_2?

Carbon dioxide (CO_2) is a chemical compound of carbon and oxygen and one of the most important greenhouse gases in the atmosphere. It is produced during the combustion of carbon-containing fuels such as natural gas, coal, oil and fossil transport fuels, as well as biological processes such as respiration and decomposition. CO_2 absorbs and reflects infrared radiation, which contributes to the greenhouse effect and climate change. Although it is an essential part of the carbon cycle, the CO_2 caused by human activity has led to a disruption of the natural balance, resulting in global warming.



DIFFERENCE BETWEEN CCS, CCU AND CDR

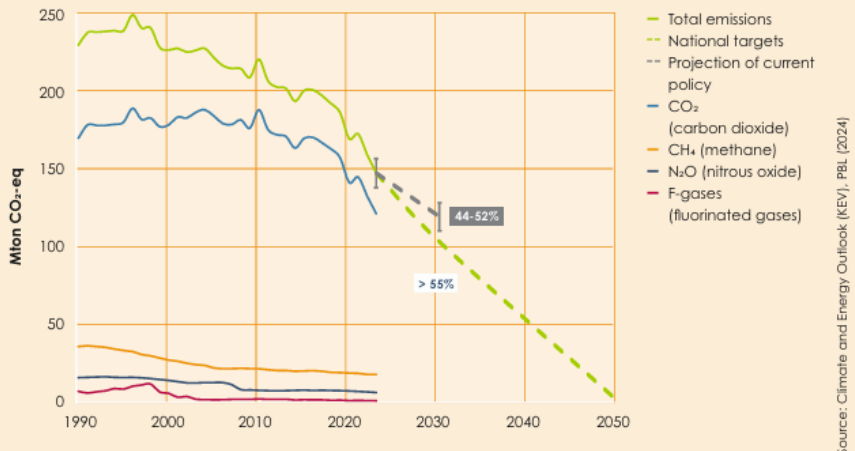
CCS – Carbon Capture and Storage
With CCS, CO_2 is captured and then stored, usually underground. The goal is to reduce emmissions by preventing CO_2 to enter the atmosphere.

CCU – Carbon Capture and Utilisation
In the case of CCU, CO_2 is captured and then reused, for example as a raw material in industrial processes or for the production of synthetic fuels.

CDR – Carbon Dioxide Removal
CDR focuses on the capture and long-term removal of CO_2 already present in the atmosphere, for example temporarily in forests and soils or permanently deep underground and in rocks.

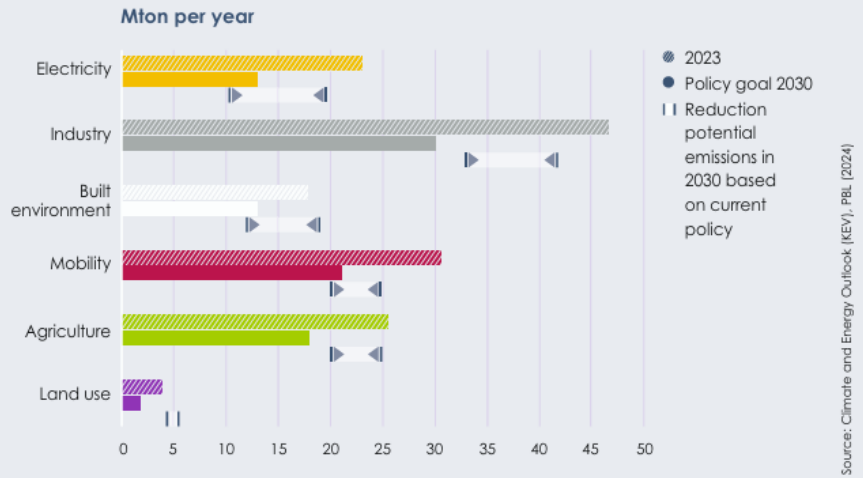
Source: "Clearing the air" advice from the Scientific Climate Council (WKR) (2024)

WHAT ARE THE DUTCH CLIMATE GOALS?



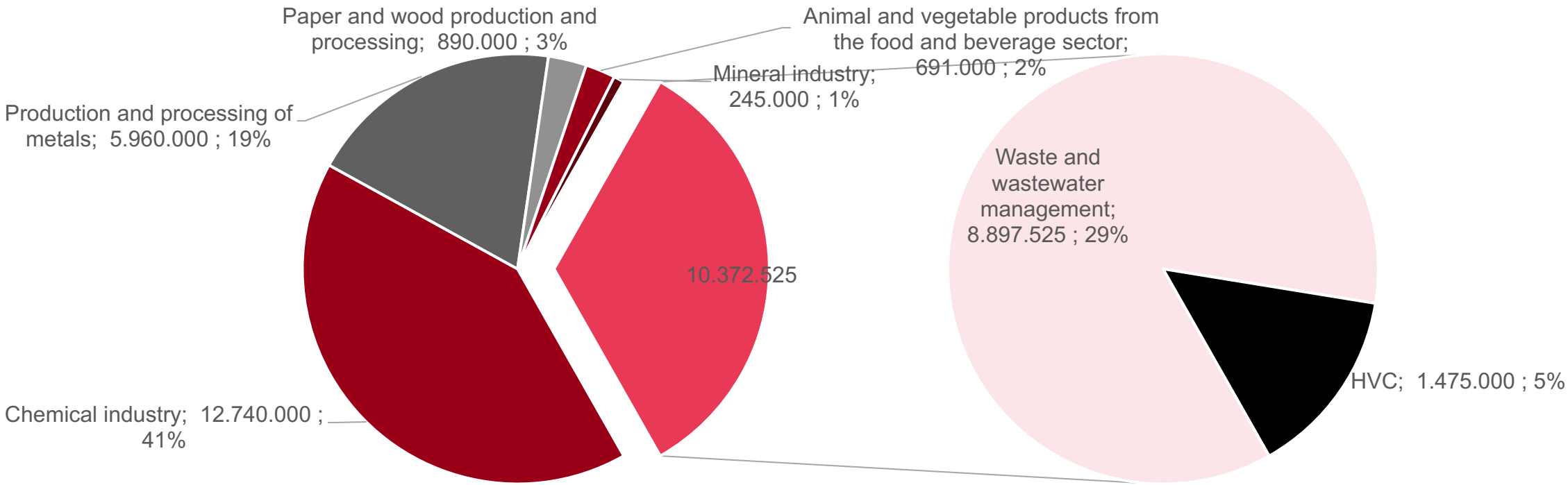
Source: Climate and Energy Outlook (KEV), PBL (2024)

EMISSIONS IN THE SECTORS: TARGETS FOR 2030



Source: Climate and Energy Outlook (KEV), PBL (2024)

CO_2 emission NL: share WtE in industry



- Share of waste processing approximately 30% of all industrial emissions
- Share of HVC in fossil + biogenic emissions approximately 5% of industry
- Share of HVC about 1% of total CO_2 emissions NL

Financial drivers for CCUS

Subsidies

- SDE++ is a production subsidy. Subsidy per ton of delivered CO2, regardless of the nature (***both biogenic or fossil***)

Tax reduction ETS

- From 2028 onwards, ETS will apply to waste incineration
- No ETS has to be paid for captured ***fossil*** CO_2 that is stored (CCS)
- This benefit will be deduced from the CCS SDE++ subsidy

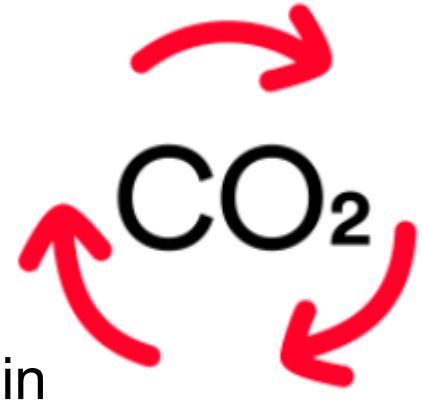
Tax reduction Dutch national levy

- For both ETS and non-ETS (WtE) companies for ***fossil*** emissions that exceed a reduction goal
- No levy has to be paid for captured ***fossil*** CO_2
- This benefit will **NOT** be deduced from the CCS SDE++ subsidy

Sales (income) or gate fees (costs)

- Farmers are willing to pay: SDE++ anticipates for that
- CCS provider requires a gate fee including ‘push or pay’ mechanism

What does HVC do with CCUS?



- **Biomass plant Alkmaar:** small pilot (capture and liquefaction) of 4 kt/y in operation. Possible large scale capture if negative emissions are rewarded
- **WtE Alkmaar:** large scale installation under development for the capture of 100kt/y at newest line 4. SDE subsidy awarded for:

  50kt / 4000 hours (summer) — CCU (delivery to green houses)
  50kt / 4000 hours (winter) — CCS (storage under the North Sea)

- **WtE Dordrecht:** Exploration of 200 kt/y capture at newest line 5 in Dordrecht
- Other smaller and older WtE lines (3 in Alkmaar and 2 in Dordrecht): No capture foreseen, uncertain future
- **Sludge incinerator Dordrecht:** thermally quite small-scale lines. Capture difficult to cost ineffective scale.

In the end..

‘Profitability’

- Each project at HVC must be profitable at the point of making the FID, unless legislation leaves us no other options
- CCUS is hardly profitable within the current tax & subsidy framework

Other options:

- Our shareholders embrace a policy of zero waste on the midterm (2040)
- We limit our CCUS project on the newest WtE lines. (50% of the throughput)
- We would prefer CCU above CCS (circularity)
- Perhaps positive FID decision, driven by policy considerations

In General:

- HVC’s company policy is to reduce the financial dependency on WtE, to be more financially robust on the long term…

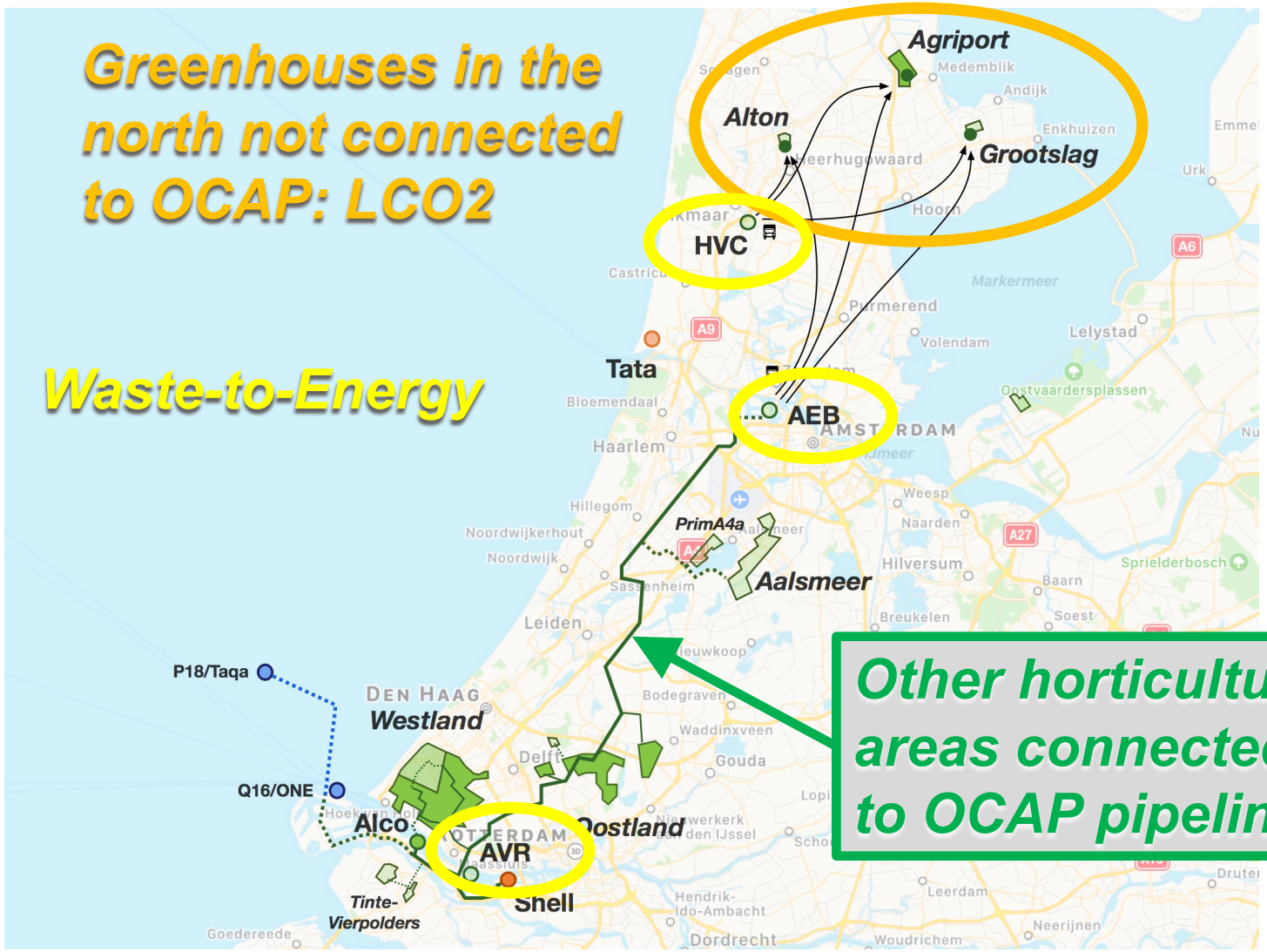
Purpose of the pilot plant: CCU

Purpose of CCU in The Netherlands



- Reducing natural gas consumption greenhouses: during summer reduced CHP use to generate CO_2
- 1 Mton/a (L)CO_2 during summer replaces 0,5 BCM of natural gas consumption in greenhouses in gas fired CHP, or worse, gas boiler
- In the long run this ratio can shift to 1-to-1, once Geothermal energy is fully implemented in greenhouses
- CO_2 from a biomass is biogenic by origin and results in ‘green’ tomatoes
  CO_2 from Waste-to-Energy is two-thirds biogenic

Geography CCU in western Netherlands



Infrastructure liquid CO_2 exists

Agriport already operates a collection station for LCO_2
(capable of handling some 10.000 tpa)

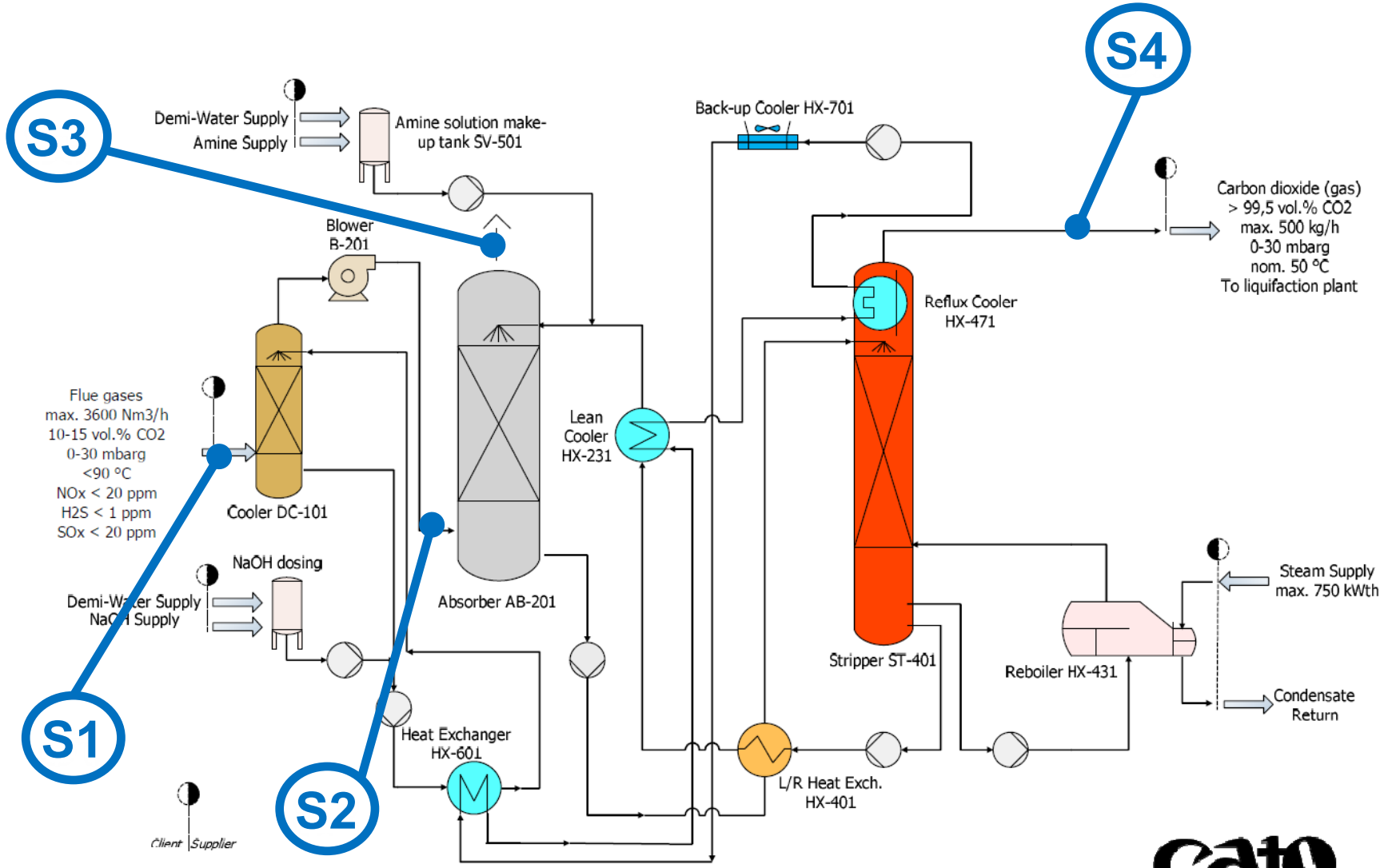


Scope of the pilot

- Practical step without large financial risks
- Amine adsorption - desorption proven technology
- ‘Nameplate’ scale 0,5 t/h capture (4.000 t/y)
- Operation during 12 years foreseen (SDE+ timetable)
- Subsequent liquefaction and sales to farmers
  Small scale allows outlet also during winter
- Some 400 t/y of the CO_2 will be delivered as a gas to the bottomash washing plant as an alternative for Soda.

Realisation
of the
pilot plant

PFD of capture plant



S0 = measuring point

Reboiler, DCC, absorber & stripper (1st floor)

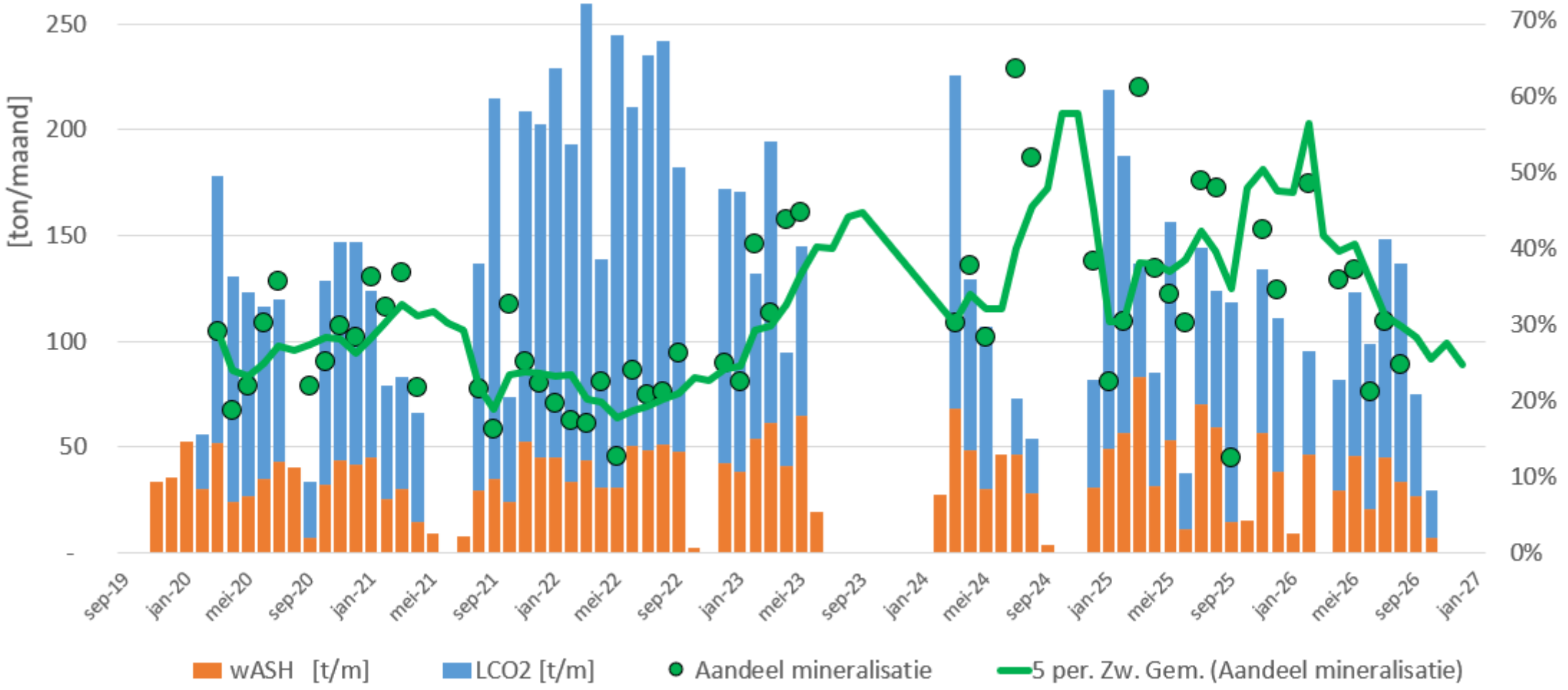


Gaseous CO_2 buffer bag (6th floor)



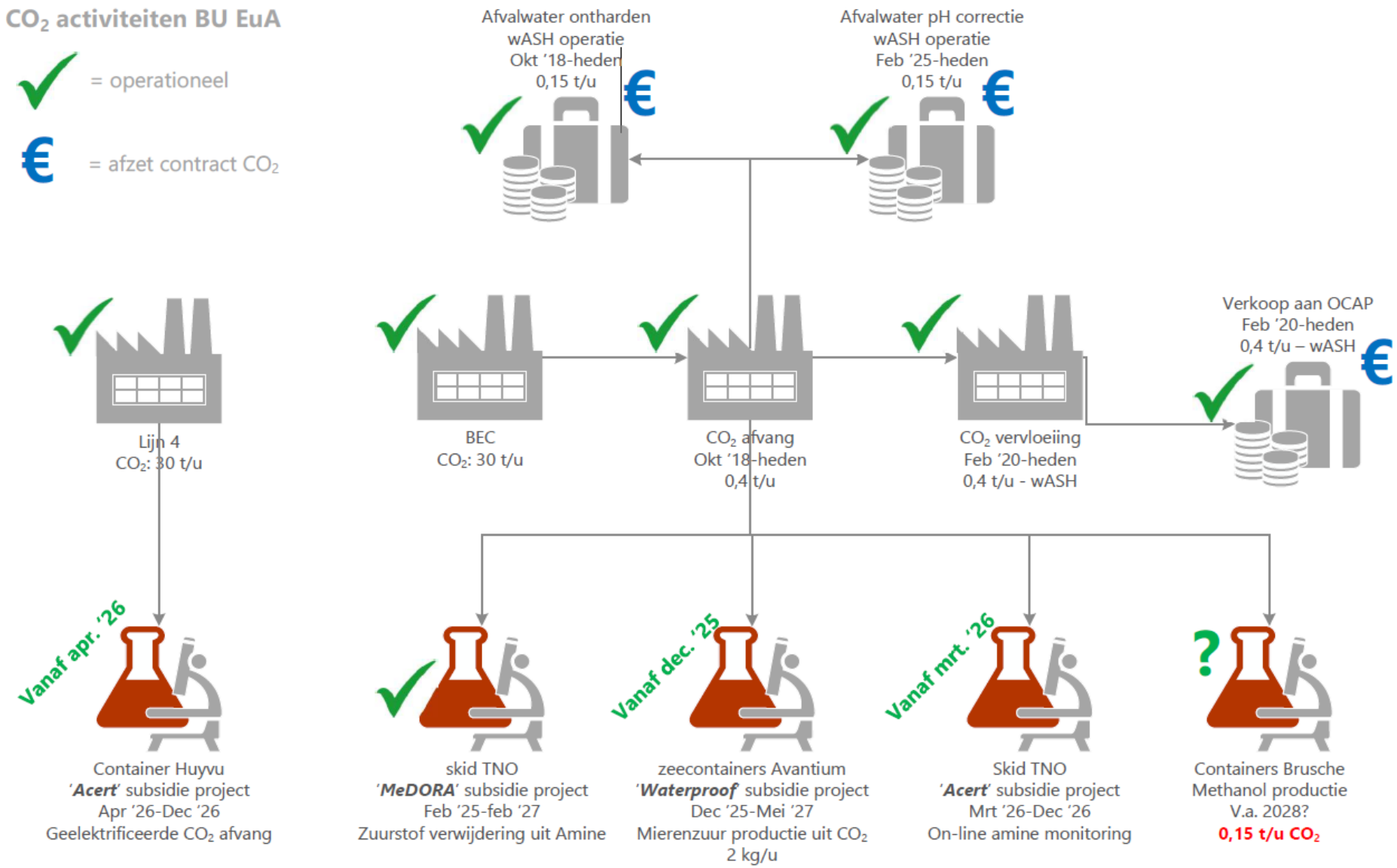
Operation
of the
pilot plant

Monthly performance pilot plant



Operational knowledge & CCU spin-off from the pilot plant

CCU spin-off at the PCC pilot plant HVC

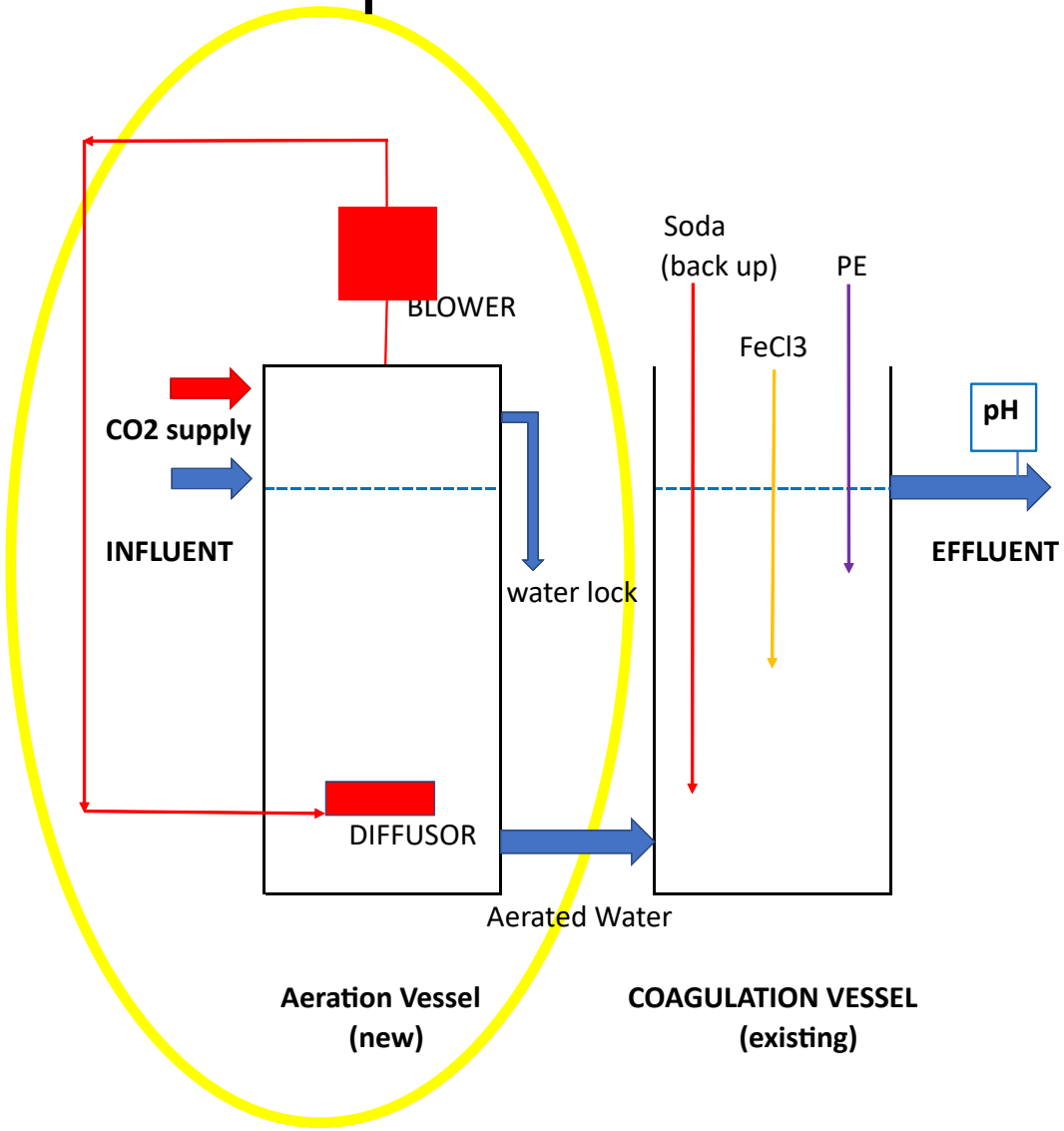


Sales of liquefied CO_2 to greenhouse farmers



Gaseous CO_2 for treating wastewater

Full scale practice at HVC since 2019





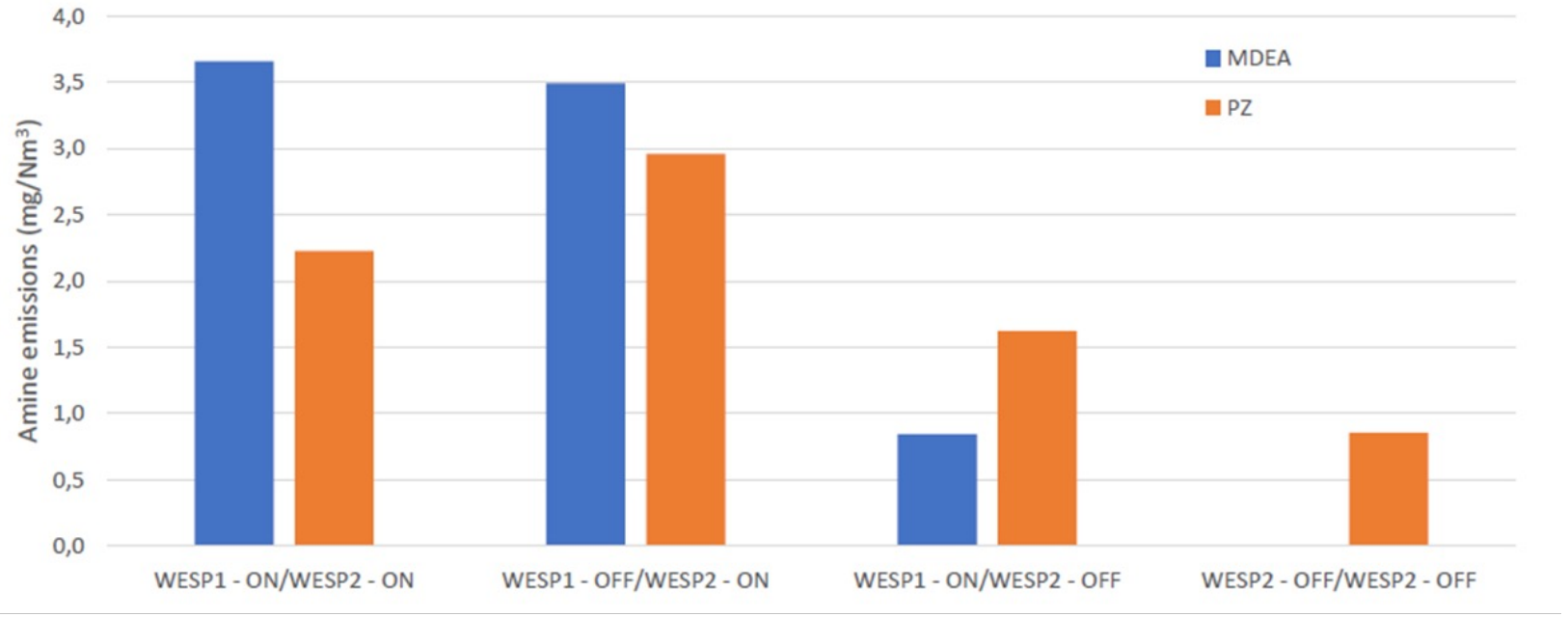
Solvent losses & Emission

1. **Evaporation & aerosols (majority of losses)**
   - Mainly in absorber (40°C) with (depleted) flue gas
   - Minor in stripper (100°C) with CO_2 gas
     (smaller flow, higher boiling point of 'loaded' amines)
2. **Degradation (minor losses)**
   - mainly by oxidation with residual oxygen in the flue gas
   - forms organic acids that are present in the solvent as a salt
   - These salts have high boiling points and accumulate in the solvent
3. **Side reactions**
   - NO_x, and particularly NO_2, reacts with secondary amines (PZ) to form nitrosamines and nitramines.
   - In small amounts, but some are notoriously toxic

SCOPE

DORA

Solvent losses & Emission *SCOPE*



- During SCOPE project TNO observed periodical drops in emissions
- HVC found out that these coincided with periodical automatic cleaning of the WESP
- A test program was performed that lead to the graph above
- Apparently, the WESP produces aerosols that lead to solvent losses
- TNO advised to install a BDU to capture aerosols
- HVC simply reallocated the intake of flue gas of the PCC upfront the WESP

Solvent degradation mitigation

Remedial action(s) foreseen:

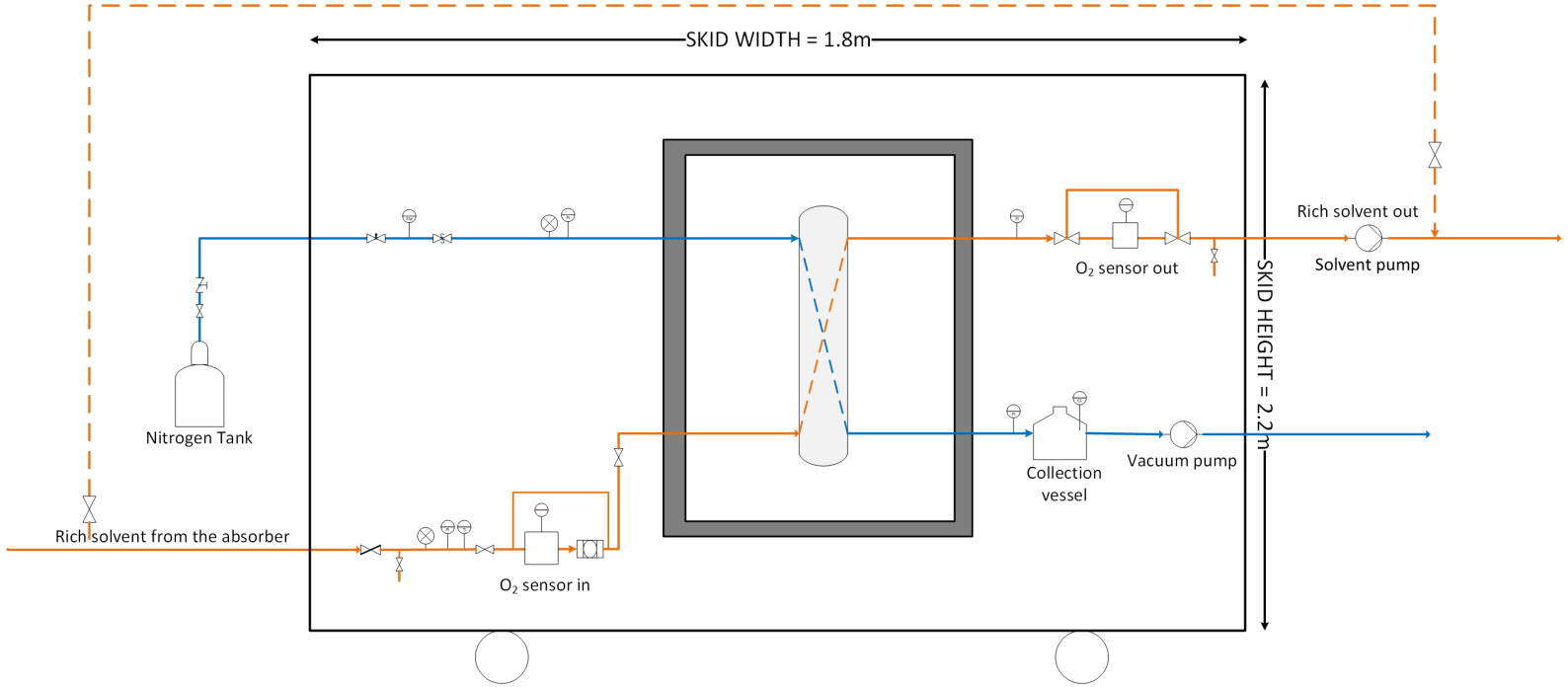
- Applying a **DORA** (Dissolved Oxygen Removal Apparatus) skid as developed by TNO to :
  - diminish the formation rate of degradation (oxidation) products
  - Reduce the oxygen content of the produced CO_2

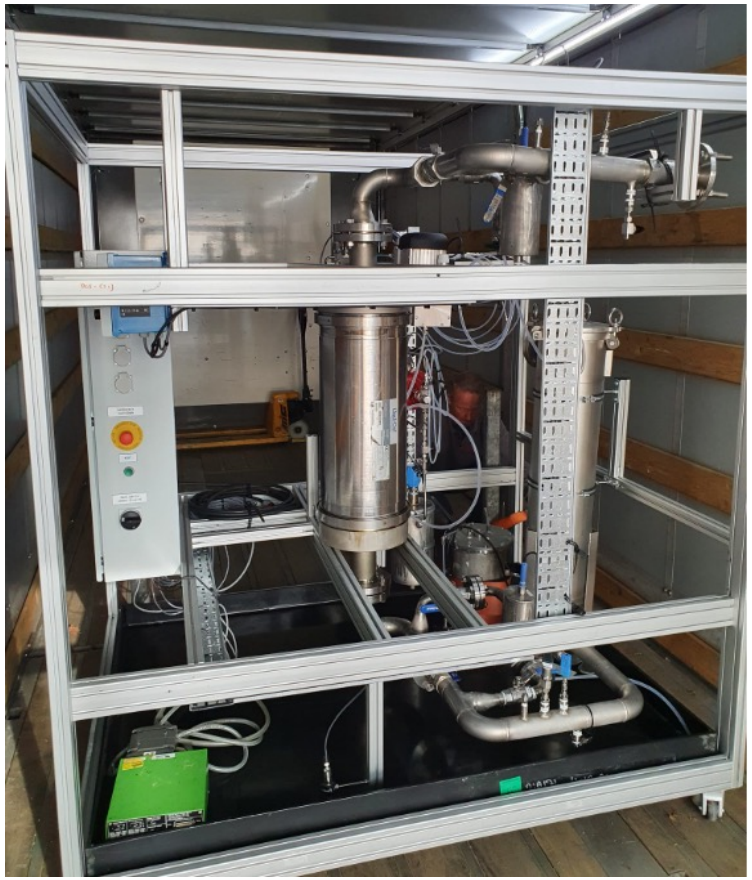
DORA skid already on site and in operation for 2 years now

Degradation mitigation

DORA (Dissolved Oxygen Removal Apparatus)

Skid to be operated for 2,5 years at HVC as a mitigation technology for oxidative degradation of the solvent. The entire flow rate of the plant will be treated.





Formic Acid production

Waterproof project

Demo plant of HVC site tot demonstrate the production of Formic Acid from CO_2.

Formic Acid used

- As such as an ingredient for (household) cleaning agent
- As ingredient for (fish) leather tanning
- As ingredient for producint a ‘deep eutectic solvent’ that is able to dessilve metals from waste matrices



conclusions

Conclusions

1. Carbon capture not as simple as one should think
2. Solvent management is the essential operational aspect
3. Site specific configuration (fuel, flue gas cleaning, residual oxygen), upstream of CCP, determines required solvent management
4. Yet, PCC is no rocket-science
   Operation & Maintenance department of a WtE plant can master this, at least once fear of solvents (chemicals) has ebbed away….
5. Running a pilot plant attracts scientists and start-up that want to demonstrate their technology on ‘live’ CO_2 from flue gas

Financial acknowledgements

- **SDE+ subsidy** biomass plant (2015)
  Opex subsidy for steam required for reboiler
- **TKI subsidy** capture plant CO_2 (2017)
  Capex subsidy, project ‘Ambience’
- **TKI subsidy** liquefaction plant CO_2 (2018)
  Capex subsidy, project ‘Ambition’
- **TKI subsidy** research de-risking pilot plant (2019)
  Research & pilot testing, project ‘Decipher’
- **Subsidy** mitigating emission
  Research & measurements, Project ‘Scope’ (2021)
- **Subsidy** Formic acid production from CO_2 (2022)
  Research and demonstration
- **Subsidy** reducing solvent degradation (2023)
  Research & pilot plant



European-Research-Area Network
(ERA-Net ACT3)



Funded by
the European Union



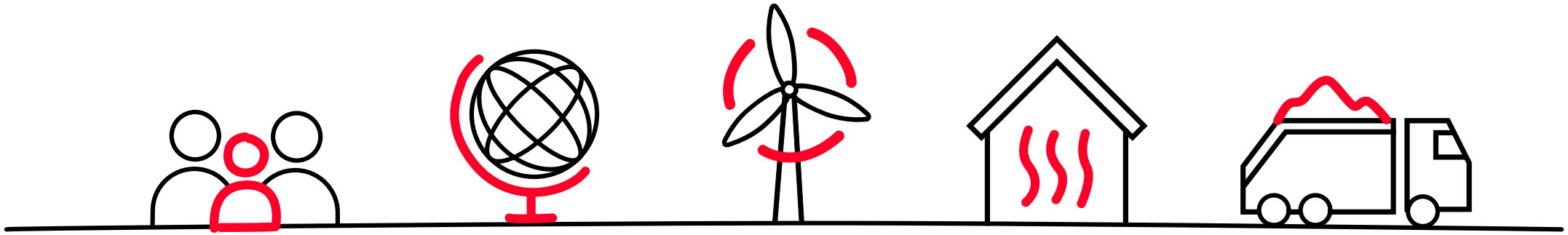
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  Research & pilot plant

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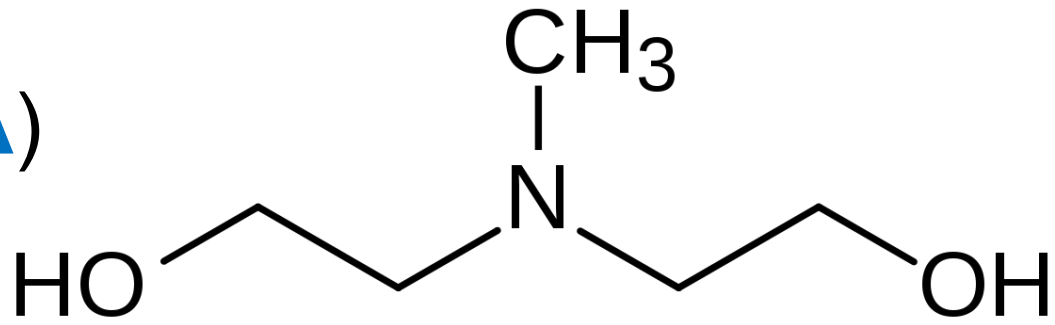
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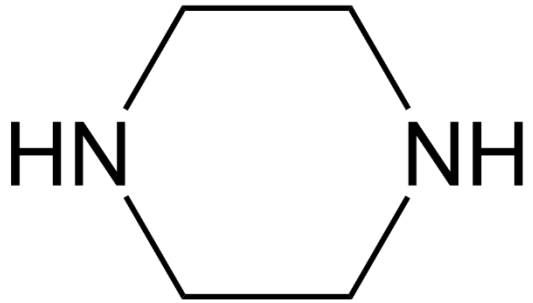
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Active solvent

Methyl diethanolamine (**MDEA**)



With Piperazine (**PZ**) as activator
(MDEA / PZ ≈ 5)



Beware: this is a Dow proprietary mixture