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FROM REGIONAL POTENTIAL TO VALUE CHAINS

Showcases, methodology and preliminary results

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One question, asked at three levels of zoom

GEOGRAPHIC REACH

LEVEL OF DETAIL

1 REAL PLANT

Pre-feasibility study

A coal-fired CHP unit in Łódź, Poland, taken apart in detail.

- Process model on plant data
- CFD of the boiler
- Cost and life-cycle footprint
- Risks and investment path
- Guidelines and recommendations

● **Submitted October 2026**

3 REGIONAL SHOWCASES

Generic plants, real regions

V4 countries, Iberian Peninsula, Nordic countries.

- Full-chain process modeling and simulation
- Aligned cost and environmental life-cycle assessment

● Defined and public; simulations and analysis are running

1 EUROPEAN SHOWCASE

The CHP fleet as a whole

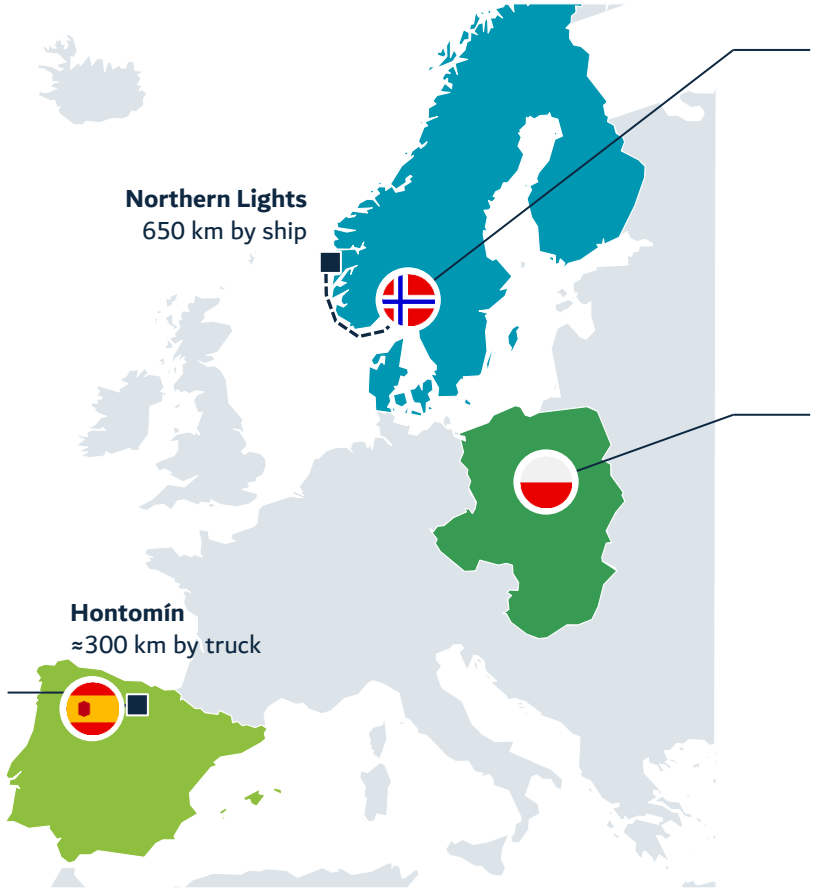
Potential, fuel limits, social acceptance, risks.

○ In progress

Does oxy-fuel bio-CHP with CO_2 capture hold up as a complete value chain, in a real region?

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Three regions, three routes to negative emissions



NORDIC Øra, Fredrikstad, Norway

New-built chemical looping CHP on forestry residues

≈52 MWth heat · ≈5 MWe to grid · ≈150 kt CO_2/y

Tests: can a novel plant design lift performance and still deliver removals?

V4 Łódź, Poland

Oxy-MILD retrofit of a pulverised-coal CHP unit, fired on pellets

108 MWe · 180 MWth · district + industrial heat

Tests: how far can an existing unit be retrofitted?

IBERIAN Cubillos del Sil, Spain

Bio-oxy-CFB with oxygen from a 27 MWe electrolyser

15 MWth · ≈29 kt CO_2/y · ≈3 kt H_2/y

Tests: does integrating the oxygen supply chain improve the whole?

Source: BioNETzero D4.1, Definition of regional showcase studies (public, 2025)

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Each showcase is a complete chain, from residue to rock

	BIOMASS	OXYGEN	CONVERSION	CAPTURE	TRANSPORT	STORAGE
NORDIC Norway	**Forestry residues** branches and tops, ≤300 km	**Oxygen carrier** ilmenite, plus a small ASU	**New CLC-CHP** whole new-build CHP plant	**Liquid CO_2** ≥95% capture target	**Ship** 650 km	**Northern Lights** offshore, Norway
IBERIAN Spain	**Pine and poplar chips** ≤100 km, ≈15 kt per year	**27 MWe electrolyser** H_2 by-product, cryogenic ASU as sensitivity	**Oxy-CFB retrofit** switch from air-mode + existing turbine	**Liquid CO_2** ≥ 90% capture target	**Truck** ≈300 km	**Hontomín** saline aquifer, Spain
V4 Poland	**Black or white pellets** milled, fired as dust	**Cryogenic ASU** electrolysis as sensitivity	**Oxy-MILD boiler** boiler retrofit + existing turbine	**Dense-phase CO_2** ≥90% capture target	**Pipeline**	**Onshore, Poland** pre-selected site, saline aquifer in central Poland

Same six stations, three different answers. The differences are what the showcases are for: how the oxygen is made, and how the CO_2 leaves.

Source: BioNETzero D4.1 (public) and D4.2 (draft)

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Each showcase tests one hypothesis, question by question

NORDIC new-built CLC

A novel plant design can lift CHP performance and still deliver negative emissions.

- **What does CLC do to the cost and performance of a CHP plant?**
  → CLC plant model vs. amine reference
- **How much fuel pre-treatment does CLC need?**
  → Pelletised vs. milled residues
- **How do impurities in residues affect performance?**
  → Fuel composition varied in the surrogate

IBERIAN oxy-CFB + electrolyser

Integrating the oxygen supply chain improves the performance of the whole plant.

- **What do the electrolyser upstream and CO_2 use downstream do to the plant?**
  → Full flowsheet, operating point varied
- **How flexible is oxygen made from renewable power?**
  → Variable profiles; oxygen buffer sizing
- **Which oxy-mode suits a CFB boiler?**
  → Wet vs. dry flue-gas recirculation
- **What must be known before writing operating procedures?**
  → Sensitivity ranking of key parameters

V4 oxy-MILD retrofit

An existing unit can be retrofitted and keep satisfactory performance and efficiency.

- **What do recirculation rate and oxygen ratio do to performance and cost?**
  → Parametric sweeps of both
- **How fuel-flexible is a pulverised-fuel boiler in oxy mode?**
  → 2–3 biomass fuels through the surrogate
- **How do power-to-heat ratio and industrial heat demand shape the result?**
  → Off-design cycle with varied extraction

Source: BioNETzero D4.1 (public); model experiments from D4.2 (draft)

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One method for every showcase, so the answers compare

WP1 regional residues, pre-treatment

WP2 pilot tests, flue-gas cleaning, CPU

WP3 full-scale CFD, surrogate models

Operators plant data, audits

Scenarios today, 2030, 2050

1

Showcase definition

Site, fuel, heat demand and CO_2 route: one dataset per region.

2

Reference plant model

Today's plant, rebuilt in gPROMS Process or Aspen HYSYS and checked against plant data.

3

Concept plant

Oxy-MILD, CLC or oxy-CFB enters as a surrogate model, with oxygen supply and CO_2 processing around it.

4

Performance KPIs

Efficiency, capture rate, energy penalty, materials use.

5

Cost and footprint

TEA and LCA on one shared inventory.

Each showcase is run three ways

Reference plant

Reference + amine capture

BioNETzero concept

Source: BioNETzero D4.2 and D4.3 (drafts)

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How a furnace gets into a flowsheet: surrogate models

A FEW PHYSICAL INPUTS

Oxy-MILD

V4 showcase

O_2 excess ratio | flue-gas recirculation | fuel composition

Fitted on full-scale boiler CFD and bench tests; runs in gPROMS Process

CLC

Nordic showcase

reactor temperature | carrier circulation | particle size

Calibrated on SINTEF's 150 kWth pilot and the CHEERS demonstration unit; runs in Aspen HYSYS

Oxy-CFB

Iberian showcase

O_2 concentration | recirculation, wet or dry | boiler load

Calibrated on CIUDEN's oxy-CFB operating data; runs in Aspen HYSYS

WHAT THE PLANT MODEL RECEIVES

At the system boundary

- Flue-gas composition
- Temperature and pressure
- Mass flows
- Combustion efficiency

Feeds the steam cycle, flue-gas cleaning and CO_2 processing models.

Fast enough to run every showcase scenario, which a CFD model is not.

A surrogate does not copy the CFD. It collapses the CFD variables into a few physical groups, keeps the non-linear sensitivities, and stays inside the range it was fitted on.

Already in use: the oxy-MILD surrogate built for the Łódź study condenses 63 CFD runs into 252 local response planes (median R^2 0.9995).

Source: BioNETzero D4.2 (draft); Łódź example from D4.4 and D3.4

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One plant, two services: energy and removal, counted apart

ENERGY SERVICE

1 MWh

of net useful heat and electricity, at the plant gate

REPORTED AS
Levelised cost of heat and of electricity
Climate impact per MWh delivered

one shared inventory

CLIMATE SERVICE

1 t CO_2

net, permanently removed and stored

REPORTED AS
Levelised cost of CO_2 removal
GHG abatement cost against the regional benchmark

LIFE-CYCLE GREENHOUSE GAS BALANCE



Regional benchmark CHP | GHG-emission-reducing | **carbon-neutral** | **carbon-negative: a net sink**

Negative only if the CO_2 is biogenic, it is stored permanently, and life-cycle emissions stay below what the biomass took up. Checked for today, 2030 and 2050.

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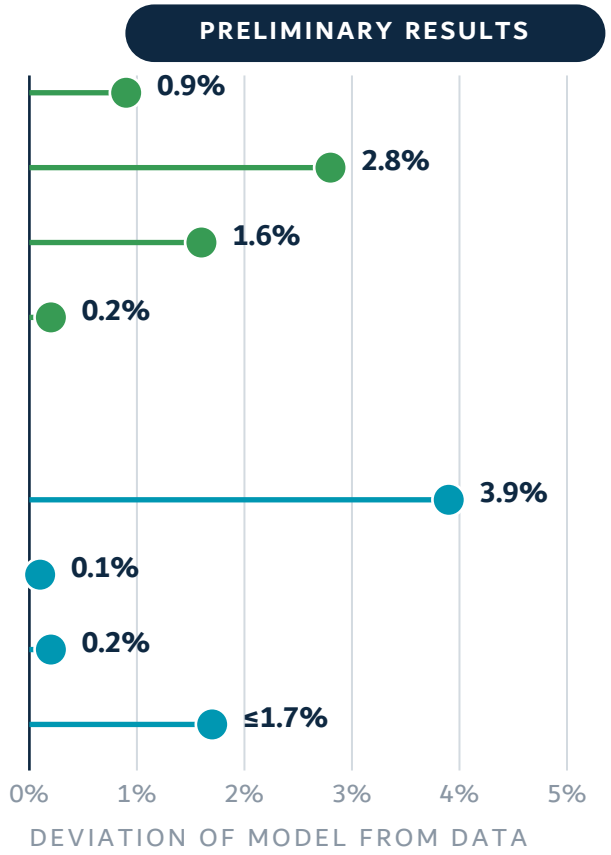
The reference plants are reproduced within a few percent

V4 Łódź unit, gPROMS Process, against plant reports

Boiler heat output	308 → 305.1 MW
Live steam flow	430 → 417.8 t/h
Live steam pressure	13.5 → 13.72 MPa
District heat supply temperature	86 → 85.8 °C

NORDIC Øra steam cycle, Aspen HYSYS, against design data

Gross electrical power	13.20 → 13.72 MWe
Heat to the steam network	30 → 29.98 MWth
Heat to district heating	26 → 26.05 MWth
Full system, 11 load points	largest deviation



Amine capture model

Within 6% of published data on lean flow, temperatures and regeneration heat.

Iberian showcase

Validation against CIUDEN's oxy-CFB test data is under way.

Still being tuned

V4 feed-water train: some temperatures are up to 13% off.

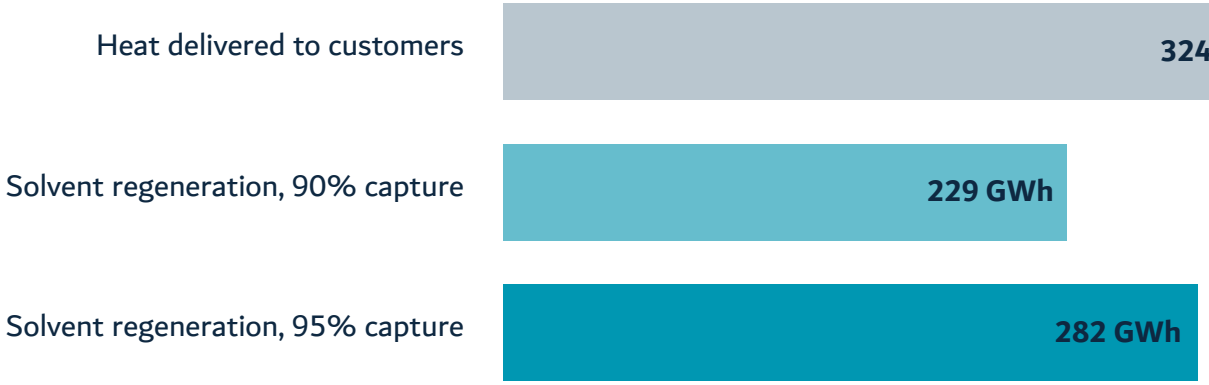
Source: BioNETzero D4.2 (draft, November 2026). Preliminary.

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The benchmark CLC has to beat: amine capture at Øra

HEAT PER YEAR, GWh Nordic reference case, 7,800 h/y

PRELIMINARY RESULTS



The last five points are the expensive ones. From 90% to 95% capture the plant stores 5.6% more CO_2 (226 → 239 kt/y) and needs 23% more reboiler heat (3.7 → 4.3 GJ per tonne).

These are preliminary results. Model status November 2026; the figures will move as the reference model is refined for D4.2.

Why this is the benchmark

The Nordic reference case keeps today's waste-fired boilers on the showcase duty and adds MEA post-combustion capture: 251 kt CO_2 a year before capture. The reboiler then asks for most of the heat the site sends to industry and the district.

What chemical looping changes

CO_2 leaves the fuel reactor already concentrated: no solvent, no reboiler. The concept-plant simulation, due in December, will show how much of this heat stays with the customers.

Source: BioNETzero D4.2 (draft). Gross reboiler duty, before heat recovery. Preliminary.

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What a real plant in Łódź already tells us

Pre-feasibility study of a 55 MWe coal-fired CHP unit, submitted October 2026. The report itself is for the consortium only due to sensitive nature.

Capture decides what the plant gives up

	HEAT TO THE NETWORK	NET ELECTRICITY
Amine capture	↓	↓
Oxy-MILD	— nearly all kept	↓

So the choice depends on what heat and power are worth locally, and on who covers the winter peak.

1 Switch the fuel first

Black pellets in a pulverised-coal boiler are technically simple, and leave the unit ready for capture later.

2 Running hours decide the economics

A unit that only runs in the heating season needs a new role: baseload, heat storage, summer operation.

3 Expect a new boiler, not a burner swap

MILD conditions need a different furnace shape. A new oxy-MILD boiler on the existing turbine is the realistic route.

4 Removals have to be paid for

No capture route pays without a price on stored biogenic carbon. Transport and storage, not capture, set the schedule.

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The Łódź study answers the V4 questions for one real plant

THE V4 SHOWCASE ASKS	THE ŁÓDŹ PRE-FEASIBILITY STUDY FOUND
HYPOTHESIS **Retrofit works, with satisfactory performance**	**For the unit, yes. For the furnace, no.** Turbine, heat network and grid connection stay. MILD conditions need a different furnace shape, so the route is a new oxy-MILD boiler on the old turbine set.
QUESTION 1 **What do recirculation rate and oxygen ratio do?**	**Recirculation is the lever; oxygen excess hardly matters.** On black pellets, doubling the recirculated flue gas shifts about 5% of the furnace-wall heat towards the furnace exit.
QUESTION 2 **How fuel-flexible is a pulverised-fuel boiler in oxy mode?**	**Black pellets behave like coal. White pellets do not.** White pellets react more than twice as strongly to the same settings (about 12% against 5%), give two to three times the NO, and need their own mills and burners.
QUESTION 3 **How do power-to-heat ratio and heat demand shape the result?**	**Oxy-MILD keeps the heat and gives up power. Amines do the reverse.** Oxy-MILD captures about 96% of the CO_2 and nearly doubles the heat-to-power ratio. Amine capture reaches about 89% and costs about 30% of peak heat output.

What the V4 showcase adds. A unit about twice the size, with an extraction-condensing turbine and industrial steam customers, so the heat-to-power split becomes a design variable. Generic prices and three scenarios replace one operator's plan.

Sources: D4.1 (public) for the questions; D4.4 (consortium report), technical findings only

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Next: concept plants, then cost and footprint, then Europe



WHAT WE WILL BE ABLE TO ANSWER

How much of the capture penalty do oxy-MILD, CLC and oxy-CFB take away in CHP service – and how it compares with reference post-combustion amine-based capture?

At what price for stored CO_2 does each chain break even, today, in 2030 and in 2050?

How much of Europe's CHP fleet could follow, and on which biomass?

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THANK YOU

Questions are welcome in the Q&A

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