Centre for Research and Technology Hellas (CERTH)
Chemical Process and Energy Resources Institute (CPERI)

Waste Heat Valorization in the Roof Tile Industry through the Integration of a High-Temperature Heat Pump



Demonstrator 2 of the EEETHOS project
Horizon Europe

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World Summit for Decarbonized & Sustainable Industry
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About us

CERTH/CPERI

01 CERTH
- Founded in 2000
- 5 research institutes
- 1600+ personnel

02 CPERI
- Formed in 2012 (ISFTA + CPERI)
- 250 specialists in clean energy and process technologies

03 Active portfolio
- >200 active projects
- ~€60M total budget

MULTIDISCIPLINARY TEAM MODEL

Research disciplines connected around industrial impact

CFD High-fidelity flow, heat transfer and reaction modelling

PROCESS System models and process integration

LCA Life-cycle and environmental assessment

ENERGY Smart grids, buildings and energy systems

EU policy

Clean Industrial Deal



01 LOWER ENERGY COSTS

21.3% → 32%
electrification by 2030
100 GW renewable capacity added annually





02 BOOST CLEAN DEMAND

40% domestic share for key clean-tech components



03 SECURE MATERIALS

24% circular material use by 2030
Joint purchasing for critical raw materials

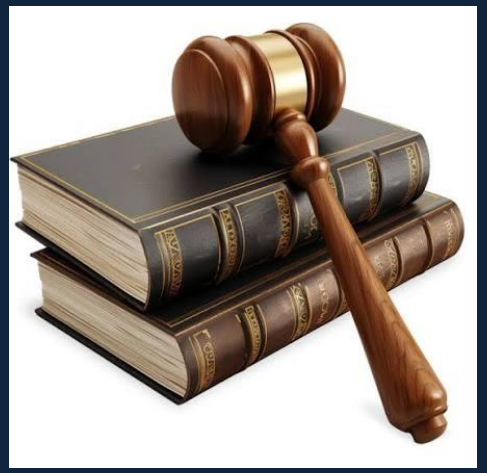


04 MOBILISE FUNDING

More than €100B through InvestEU, Horizon Europe and state-aid frameworks

Greek Policy

Greece has translated climate ambition into binding milestones



LAW 4936/2022
Annual measurement and reporting link policy directly to industrial action

55%
Net GHG reduction by 2030

80%
Net GHG reduction by 2040

2050
Climate neutrality

UPDATED NATIONAL ENERGY & CLIMATE PLAN

58.6% GHG reduction by 2030 • 77% renewable electricity consumption by 2030

COMPLIANCE OBLIGATIONS

Article 19 Calculate installation emissions verify an annual carbon-footprint report

- Article 20 Prepare and

Implementation

Decarbonizing industry with high-temperature heat pumps (HTHP)

- Roof tiles production line
- Preheated air thermal upgrade (from ~180°C to 300°C)
- Reverse-Brayton Cycle ~1 MW_{th}
- Heat recovery from exhaust gases
- Demonstration: Mar 2028

Industry: KEBE

Technology: PSYCTOTHERM

Coordinator: DANISH TECHNOLOGICAL INSTITUTE

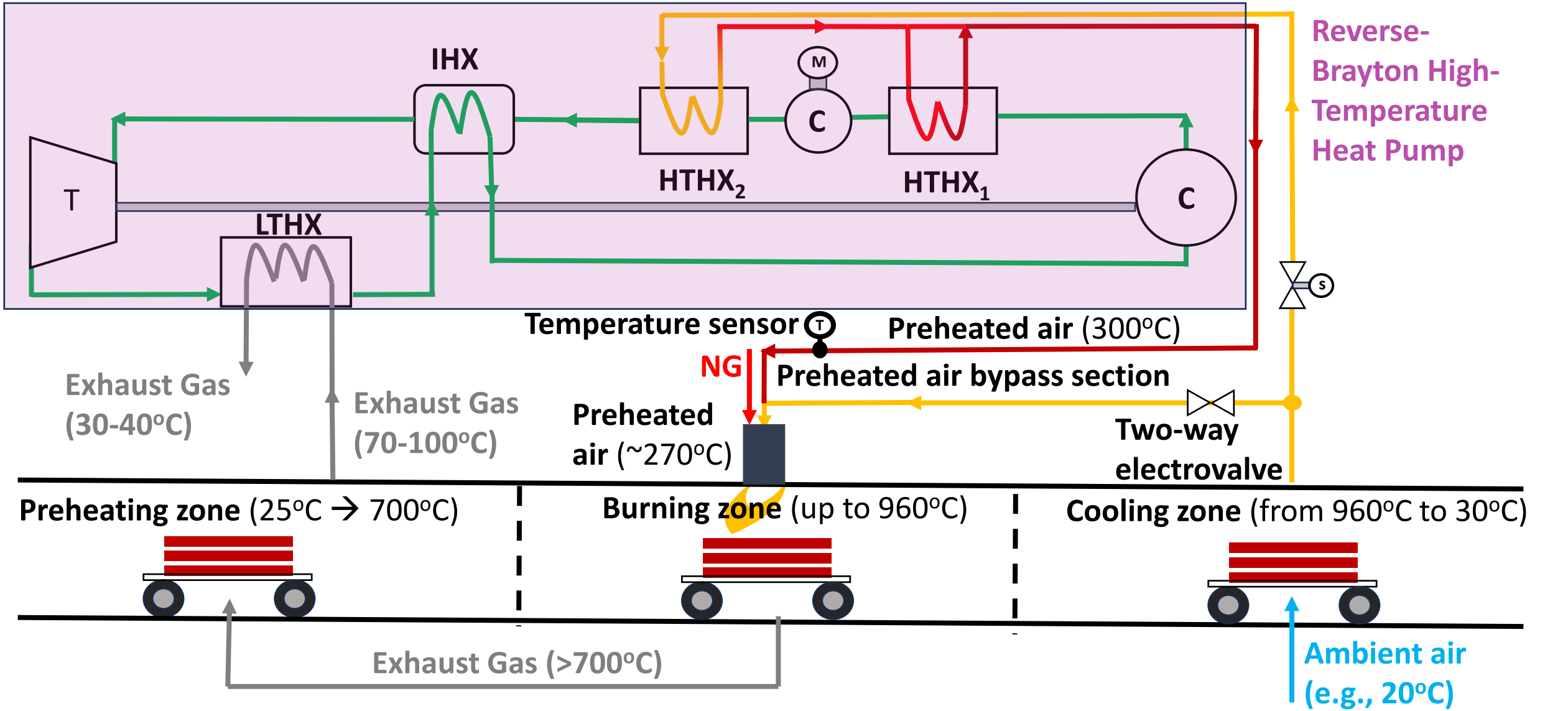
Knowledge: CERTH CENTRE FOR RESEARCH & TECHNOLOGY HELLAS; DLR

eeethos

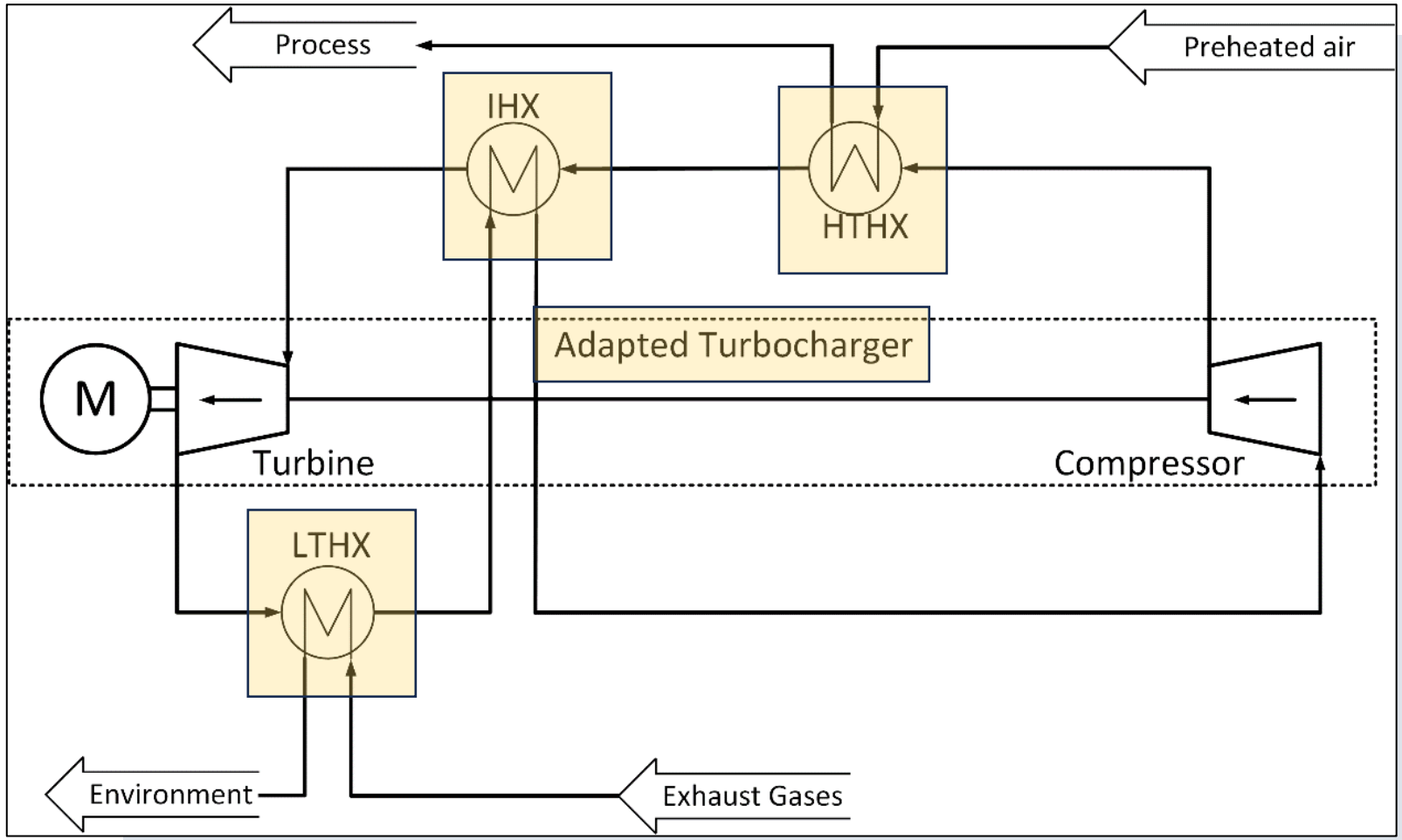


Integration

Kiln waste heat upgraded to 300 °C



Design step 1: Initial concept



Early-stage design: first feasible heat pump arrangement

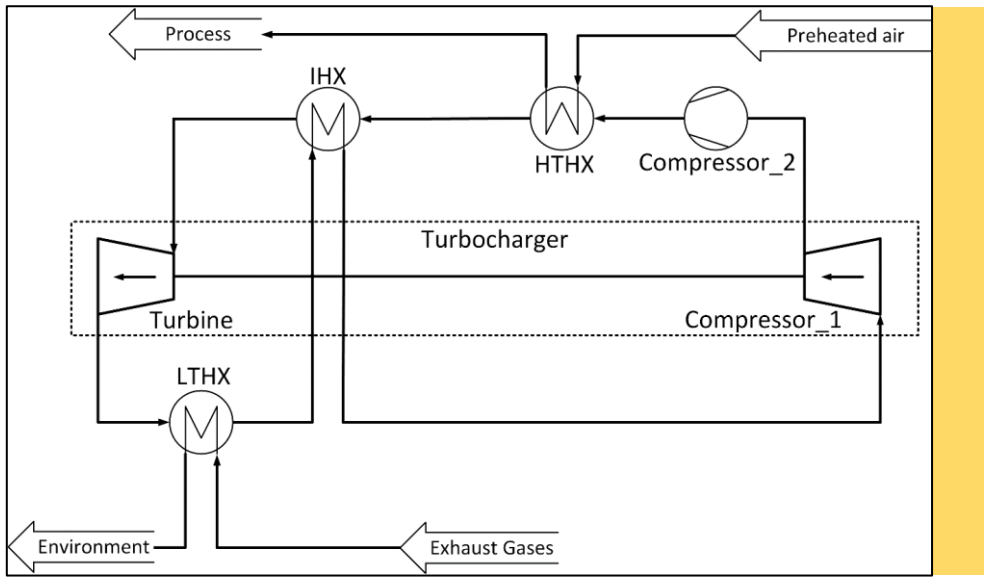
Estimates of component performance and preliminary **assumptions**

Tool: EBSILON® Professional 17 simulations performed by **DLR**

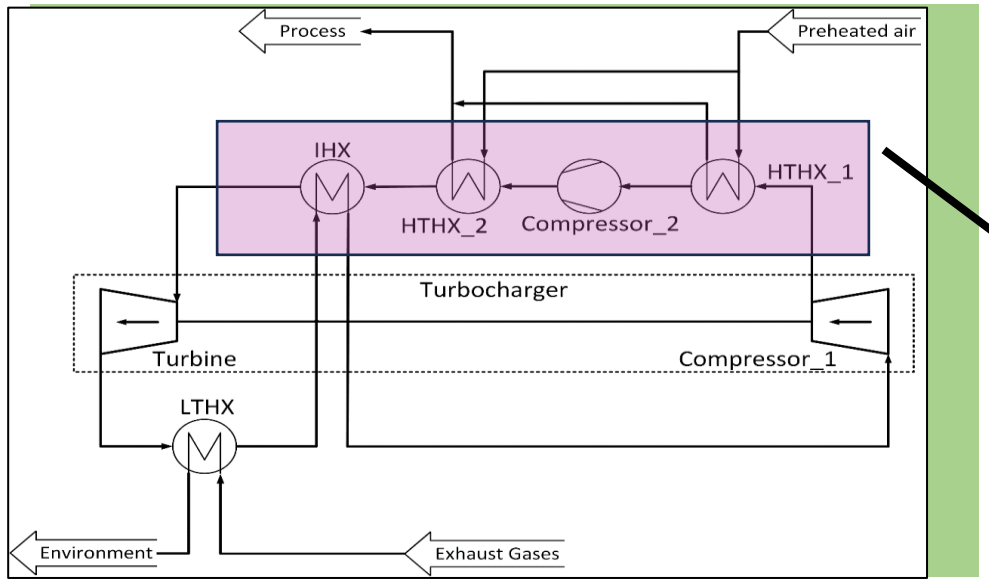
Result: COP ≈ 1.42

Design step 2: Supplier gap and revised concept

Option 1



Option 2



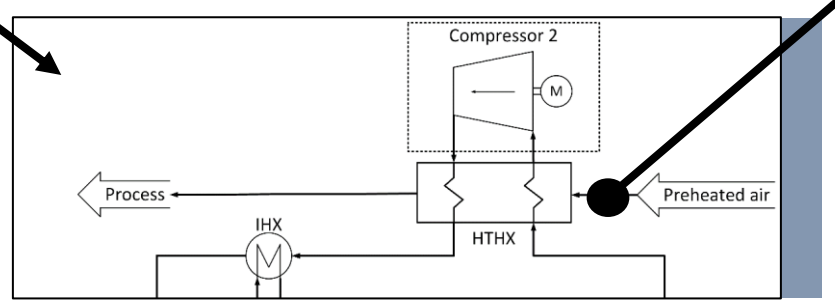
No supplier identified to provide suitable equipment within the **required capacity** range and within the **timeframe** of the project

Two HTHX modules in **one** construction

Off-the-shelf turbocharger with a **secondary** compressor

Result: COP ≈ 1.45

Revised concept

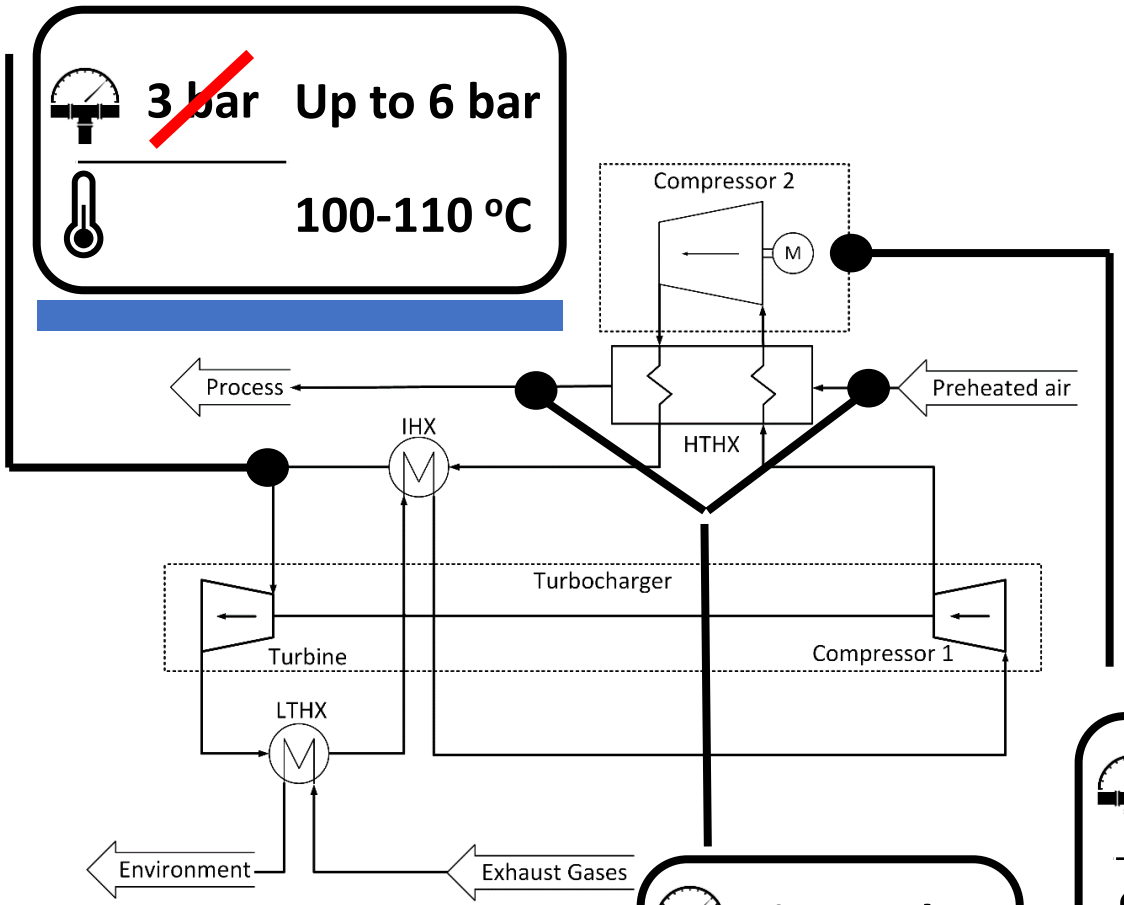


Pin=1.0 bar

Tin=230 °C

Tout=300 °C

Design step 3: Fitting an off-the-shelf turbocharger



Turbine inlet temperature for **off-the-shelf turbochargers** is generally quite high (>600 °C)

Assumption: 10% combined **efficiency losses** in the motor and gearbox

Result: COP ≈ 1.24

Parametric investigation to evaluate COP vs temperature lift

Design step 4: COP vs temperature lift

Case	Inlet Temperature (°C)	Temperature lift (°C)	COP_1 (-)	COP_2(-)
Ref	180	120	1.24	
1	180	100	1.26	1.40
2	180	70	1.29	1.43
3	150	80	1.33	1.48

COP1: electrical power input to the complete system

COP2: mechanical power at the compressor shaft

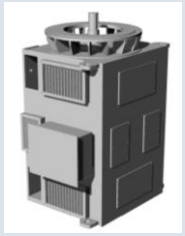
Pressure losses across the heat exchangers will be recalculated once their design is final

Pressure losses in the piping have not yet been included

Other factors affecting system COP may become apparent during **commissioning phase**

Best compromise: air heated 180 → 250 °C, COP1 = 1.29 (electrical basis) vs. the 1.5 target

Main components of the heat pump



AC motor



VSD



Gearbox

Turbocharger (off-the-shelf)

Expands the air and drives the first compression stage, without modification

Electric compressor (purpose-designed)

Second compression stage, designed by DLR for this operating point

Motor (~0.9 MW) and variable speed drive (VSD)

Motor speed sets the hot-air temperature

High-speed gearbox (prototype)

Single-stage, speed-increasing: from ~3,000 to ~24,000 rpm

Four air-to-air heat exchangers

Finned-tube coils (LTHX, IHX, 2 × HTHX), preliminary design by PSYC

Safe and compliant by design



Air as working fluid: no flammable or toxic refrigerant

HAZOP and control: surge protection takes priority over temperature control; safety functions are independent of process control

EU compliance: Machinery Directive 2023/1230, PED 2014/68/EU, LVD and EMC, with notified bodies where required

Tests: factory tests at PSYC (pressure, leak, electrical, I/O), then performance tests at KEBE

Value

Beyond energy cost: where the value for the end-user lies

01 OPERATIONAL INSIGHT

First-hand data from real industrial operation

02 PIONEERING POSITION

One of very few EU companies with such a system

Today, gas is still cheaper than electricity per unit of heat

so the value lies elsewhere

03 MARKET READINESS

Experience in place as price ratios and carbon costs evolve

04 NO DISRUPTION

Operates when required, without affecting daily production

Direct electrification

A more efficient route than resistance heaters

1 kWh of electricity gives

1.00 kWh of heat
with a resistance heater

1.29 kWh of heat
with this heat pump (simulated)

COP 1.29
simulated, 180 → 250 °C

+29%
more heat per kWh

–22%
less electricity

VS RESISTANCE HEATERS

About 22% less electricity per unit of heat, hence ~22% lower emissions at any given grid carbon intensity

VS NATURAL GAS

CO_2 savings vs. natural gas grow as the grid decarbonizes; substantial with green PPA or on-site renewables

Conclusions and next steps

1. **First of its kind:** a ~1 MWth reverse-Brayton heat pump on air, not demonstrated before at this scale, is engineered for a roof-tile kiln
2. **Supply-chain lesson:** no supplier could adapt a turbocharger in time; an off-the-shelf unit plus a purpose-designed compressor closes the gap
3. **Performance:** COP 1.24–1.33 on an electrical basis (1.40–1.48 on shaft basis); best compromise 180 → 250 °C at 1.29, to be confirmed in operation
4. **Value today is not energy cost:** it is operational insight, a pioneering position and readiness for changing price ratios and carbon pricing
5. **More efficient electrification:** 29% more heat per kWh than resistance heaters; savings versus gas grow with a decarbonized grid
6. **Next:** deliver the main components, finalize the heat exchangers and P&ID, prepare integration during the KEBE shutdown

Thank you for your attention



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Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the EU or HADEA.

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