DECARBONIZATION OF INDUSTRIAL PROCESSES AND DIGITALIZATION

Green Industry Summer School 2022

July 26- July 29, 2022 | Virtual

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CONTENT

- Industrial Sectors
- Decarbonization Technologies
- Heat Pumps: steam and drying
- Digitalization: method for decarbonization
- Final Statements

Decarbonization = decarb. Electricity + decarb. Heat + decarb. feedstock

Many technologies already available

INDUSTRIAL SECTORS

- Pulp & Paper: drying with steam and gas firing, milling
- Chemical Industry: steam for heating and drying, cooling, feedstock
- Food: steam/hot water for heating, drying, cooling
- Iron & Steel: redox reaction (blast furnace), arc furnace, gas for metal forming
- Cement: burning, milling
- Non-ferrous metals: burning, steam for Bayer process, electrolysis

TECHNOLOGY OPTIONS & INFLUENCING FACTORS TO DECARBONIZE YOUR PROCESS

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Technology options

- Thermal, electrical and chemical storage
- Direct electrification: electric arc, electric boiler, etc.
- Heat pumps + steam recompression
- H_2 gas engines & turbines
- Hydrogen (some processes require methane)
- Geothermal, deep storage (gas, heat).

Influencing factors

- Temporality of processes: Seasonal, continuity
- Process temperatures: $T < 200\ °C < T$
- Process atmosphere: H_2O, O_2, N_2, etc.
- Load profiles
- Energy prices and CO_2 price
- Existing facilities: load ramps
- Plant inventory: replacement investments
- Technology costs
- Infrastructure stock: electricity, gas, district heating, costs
- Geography & Topography

FOCUS

- Heat Pump Technologies
  - General
  - Steam
  - Drying

- Thermal storages
  - Bayer Process

- Geogenic emissions & CCU vs. CCS

Who is familiar with heat pump technologies?

Industrial Heat Pumps

INDUSTRIAL HEAT DEMAND IN THE EU

EU 28:

~ 1950 TWh of process heating in industry

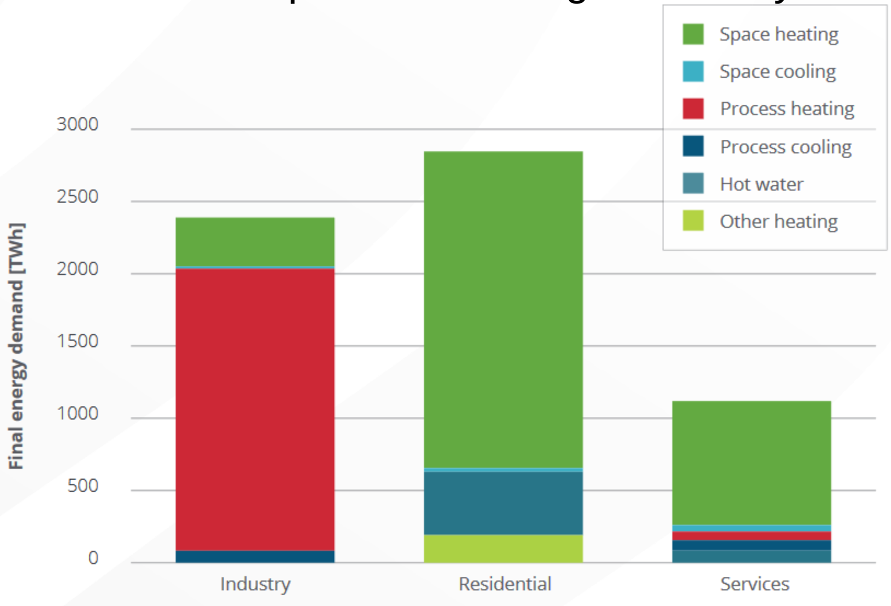
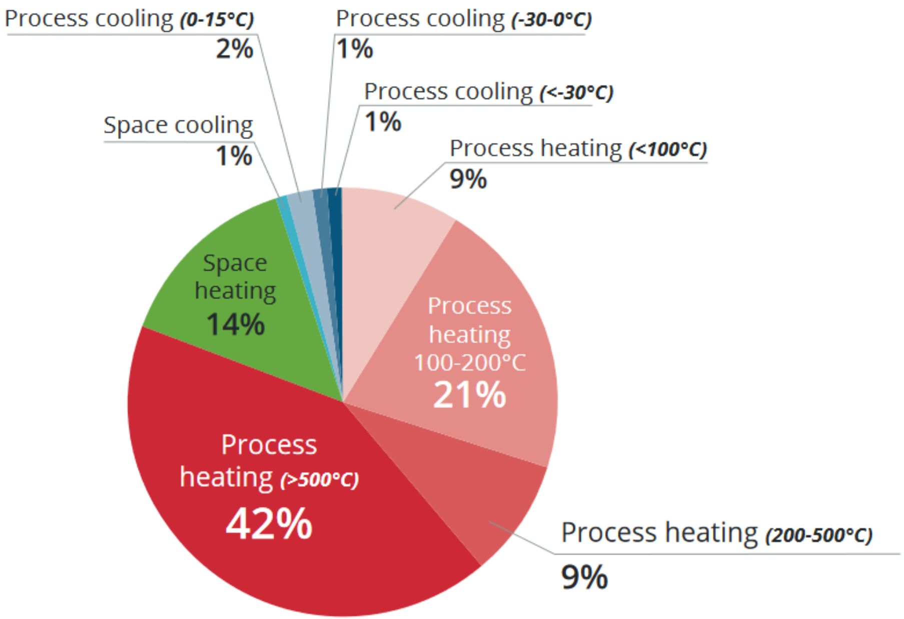


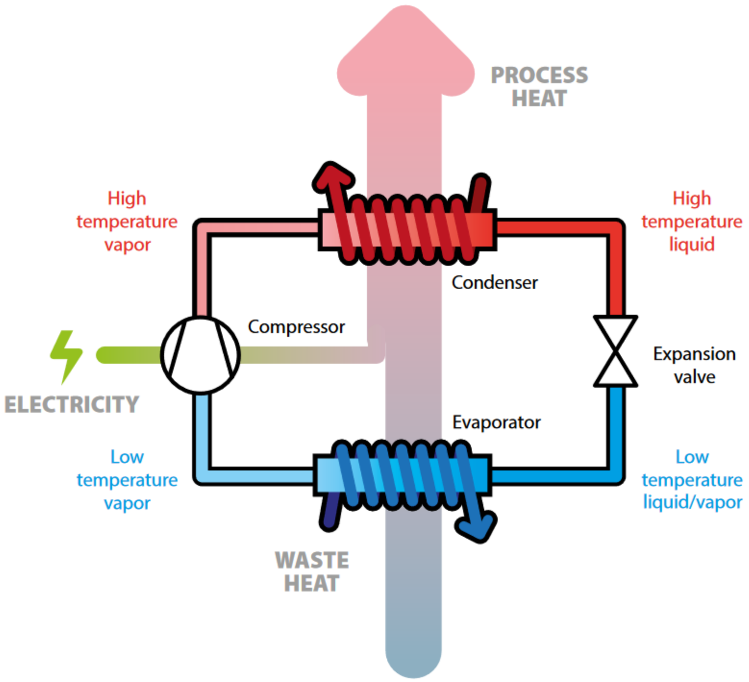
Figure 5: Sectors: final energy demand overview (EU28, 2015)

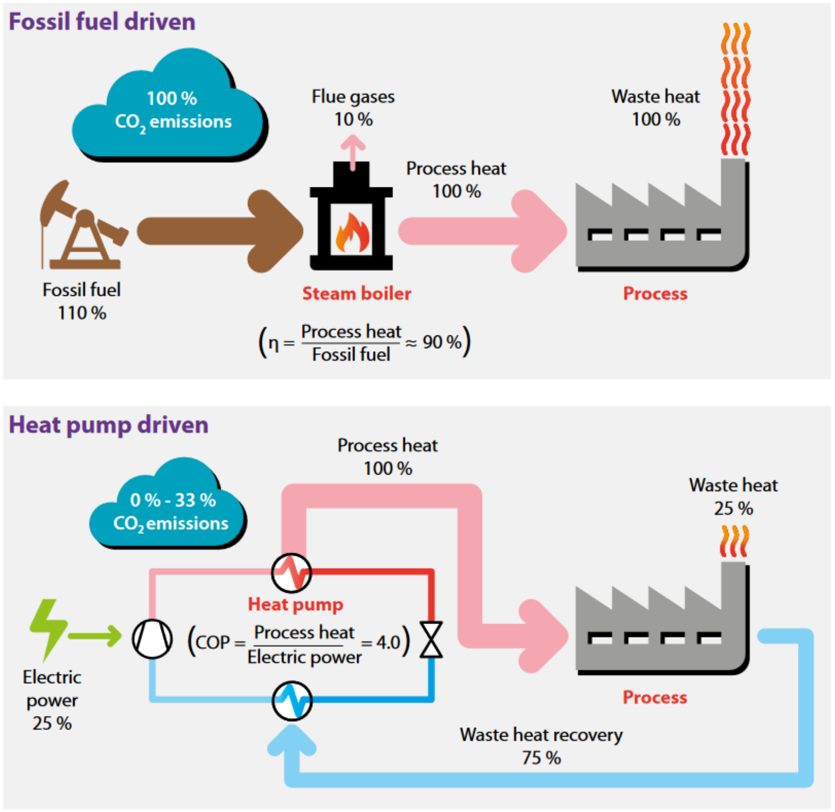
~ 30% of process heat at up to 200°C



Heat roadmap Europe – heating and cooling – facts and figures; https://heatroadmap.eu/wp-content/uploads/2019/03/Brochure_Heating-and-Cooling_web.pdf

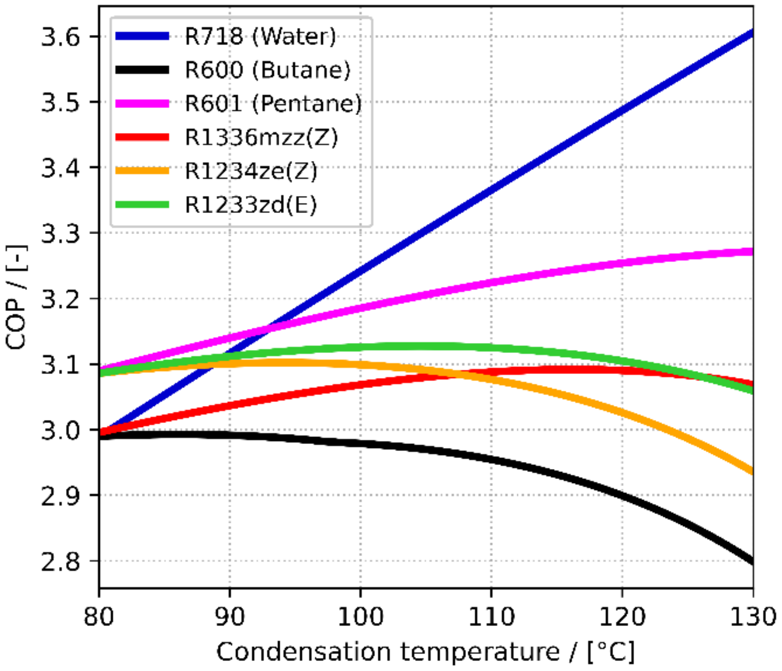
BASICS OF INDUSTRIAL HEAT PUMPS
CLOSED LOOP HEAT PUMP

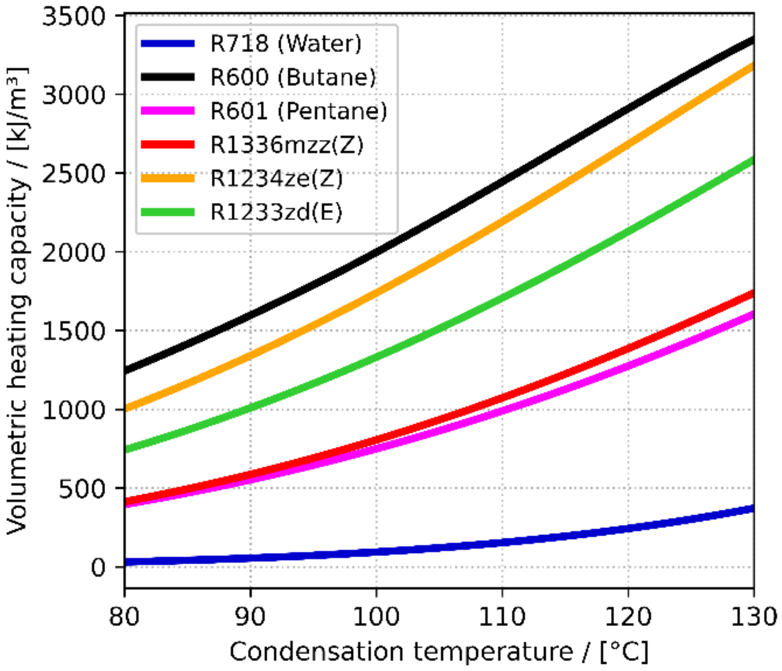




Source: https://www.ait.ac.at/fileadmin/mc/energy/News_Artikel/2020-07-10_whitepaper_IHP_-A4.pdf

BASICS OF INDUSTRIAL HEAT PUMPS

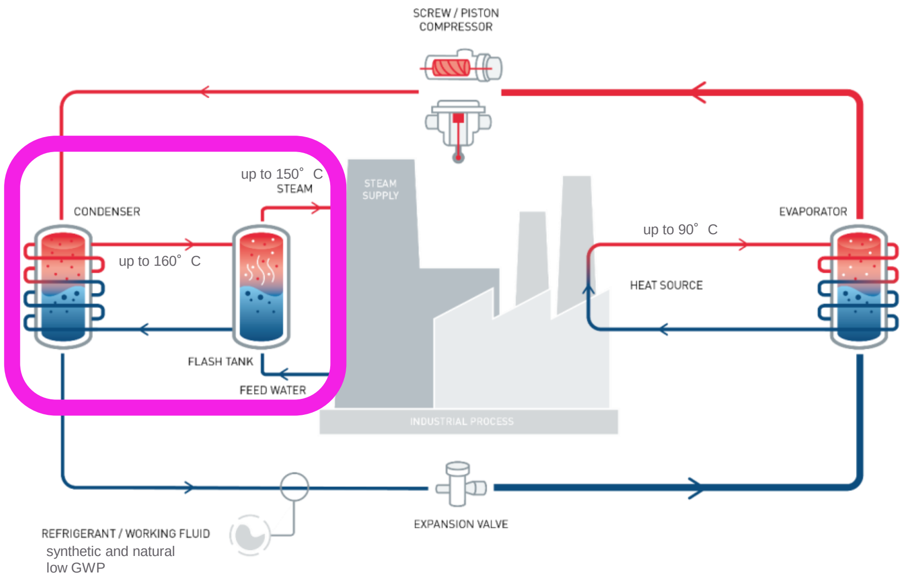


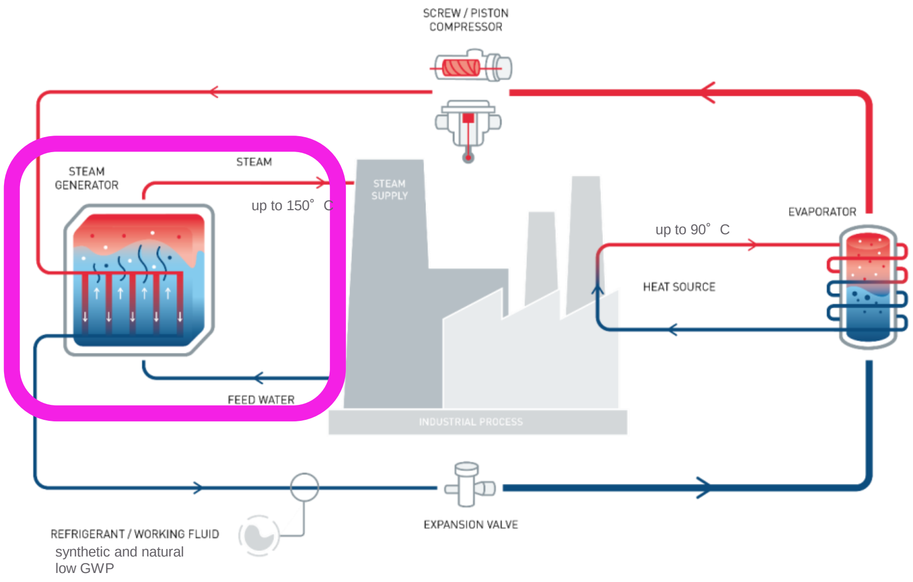


Boundary conditions: temperature lift = 70K; isentropic efficiency = 0,7

Steam generation without fossil fuels

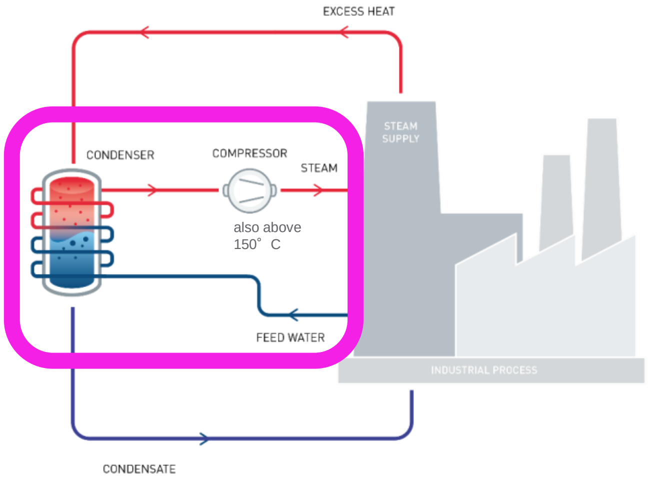
Closed loop steam generating heat pumps



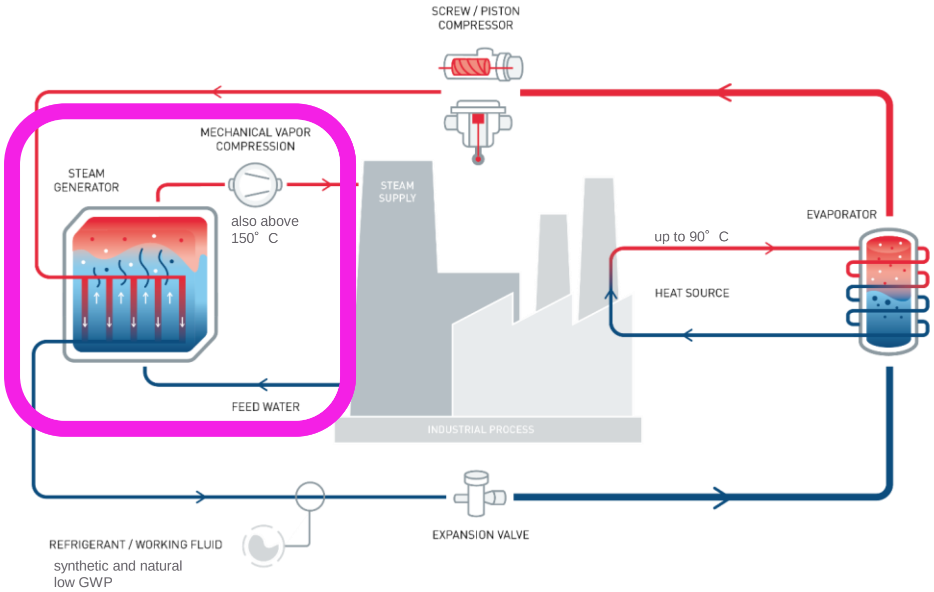


TYPES OF STEAM GENERATING HEAT PUMPS

Open loop steam generating = MVR



Combination of types



MARKET OUTLOOK
IMPACT ON EU LEVEL – GENERAL

- Based an energy audit data
- Limited to max. 200°C supply temperature
- Limited to max. 100°C temperature lift
- Also sizes in sense of heating capacity of industrial heat pumps

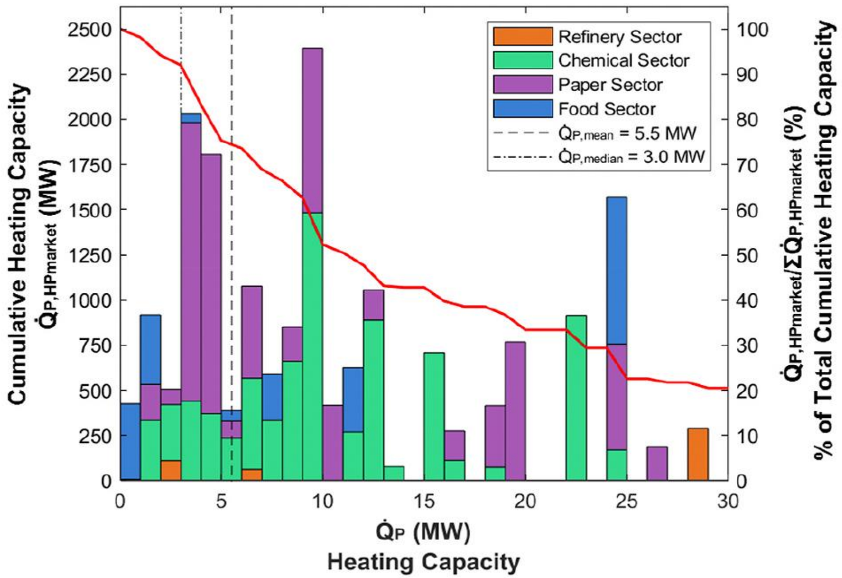


Fig. 11. Distribution of heating capacity (<30 MW) for the cumulative heating capacity of heat pump units which make up the EU28 industrial heat pump market.

Marina A. et al: An estimation of the European industrial heat pump market potential; Renewable and Sustainable Energy Reviews; Volume 139, April 2021, 110545

MARKET OUTLOOK
IMPACT ON EU LEVEL – GENERAL

Estimated **reduction of CO2 emissions**

Current energy system

37,3 mio t/year

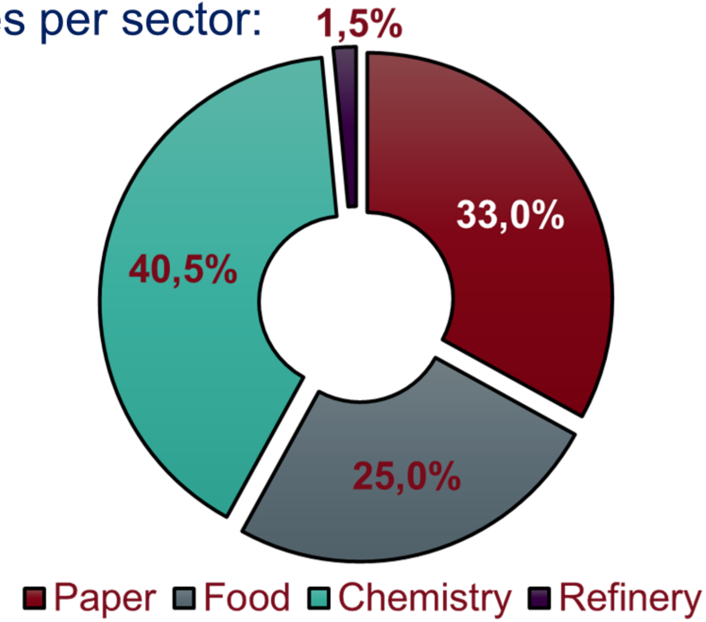
Fully decarbonized electricity system

52,6 mio t/year

Estimated **necessary investments**

4,6 to 11,5 billion €

Shares per sector:



Marina A. et al: An estimation of the European industrial heat pump market potential; Renewable and Sustainable Energy Reviews; Volume 139, April 2021, 110545

28.07.2022

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MARKET OUTLOOK
IMPACT ON EU LEVEL – STEAM GENERATION

Current energy system

Fully decarbonized electricity system

Low pressures steam (<150°C)

significant share of

Future heat pump market - about

3,5 to 8,6 billion €

Reduction of CO_2 emissions - about

21 to 35 mio t/year

Marina A. et al: An estimation of the European industrial heat pump market potential; Renewable and Sustainable Energy Reviews; Volume 139, April 2021, 110545

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ACKNOWLEDGEMENT

- H2020 project Bamboo (GA No. 820771)
- development of technologies for the valorization of waste streams and electrical flexibility
- 4 demonstrations in resource and energy intensive industries (steel, petrochemical, mineral, paper)
- heat pump steam generator for 5 bara steam

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BAMBOO

www.bambooproject.eu

In BAMBOO EDF and AIT are working with various partners to increase the use of industrial heat pumps with a focus on steam generation.

amt Kälte + Klimatechnik

ArcelorMittal

eDF

Partners: CIRCE, TU Braunschweig, AIT, IKERLAN, CERTH, EI-JKU, N-SIDE, Turboden, AMT Kältetechnik, Électricité de France, RINA Consulting, COSMO TECH, ARCELOR MITTAL, TUPRAS, Grecian Magnesite, UPM, SIDENOR, Magnesitas Navarras, ICONS

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RESEARCHER TEAM

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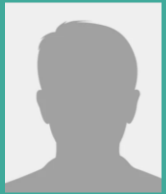
Yannick Beucher



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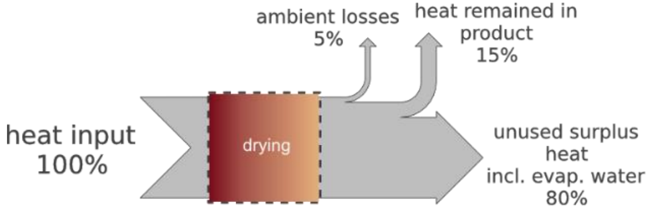
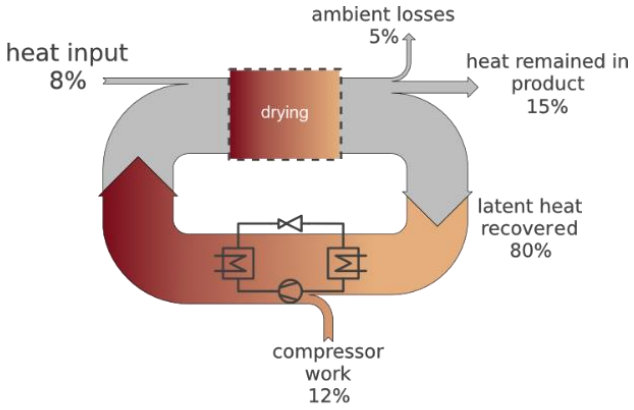
The project has received funding from the European Union’s Horizon 2020 programme for energy efficiency and innovation action under grant agreement No. 820771.

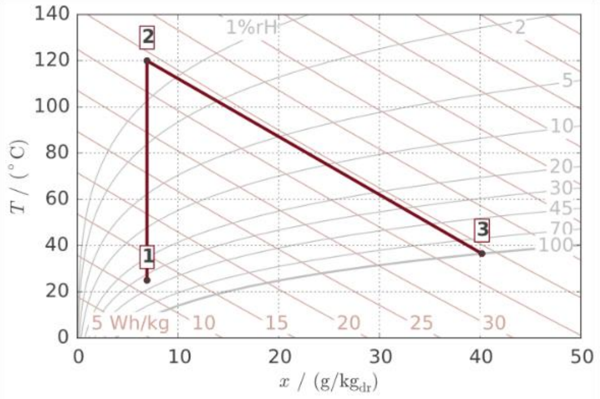
Dieses Projekt wurde durch die Europäischen Union im Forschungs- und Innovationsprogramm “Horizon 2020” (Grant Agreement Nr. 820771) finanziert.

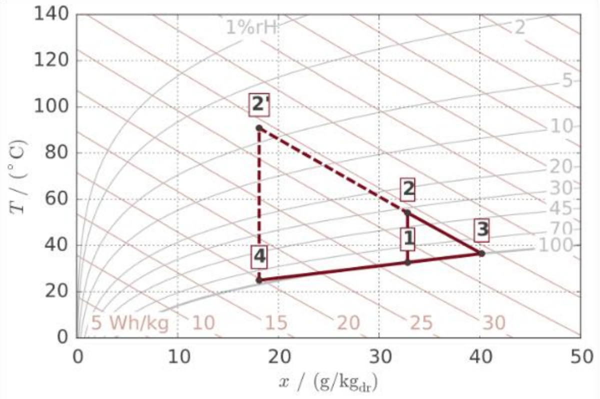
Drying without fossil fuels

CONVENTIONELL VS. HEAT PUMP









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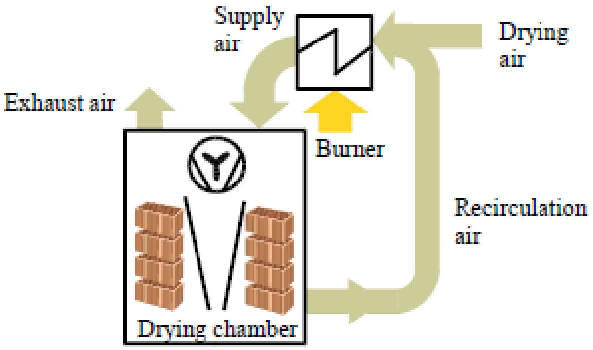
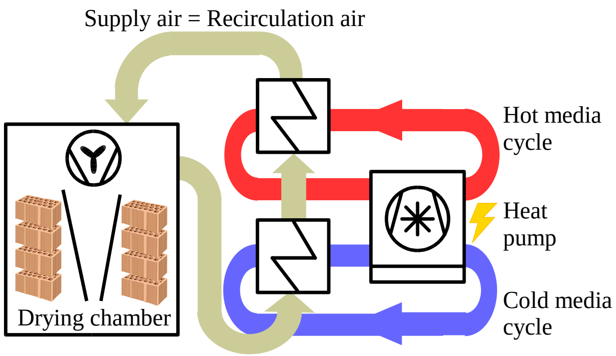
PRELIMINARY PROJECT ON BRICK DRYING





powered by klima+ energie fonds

https://energieforschung.at/projekt/effiziente-trocknung-mit-kompressionswaermepumpen/

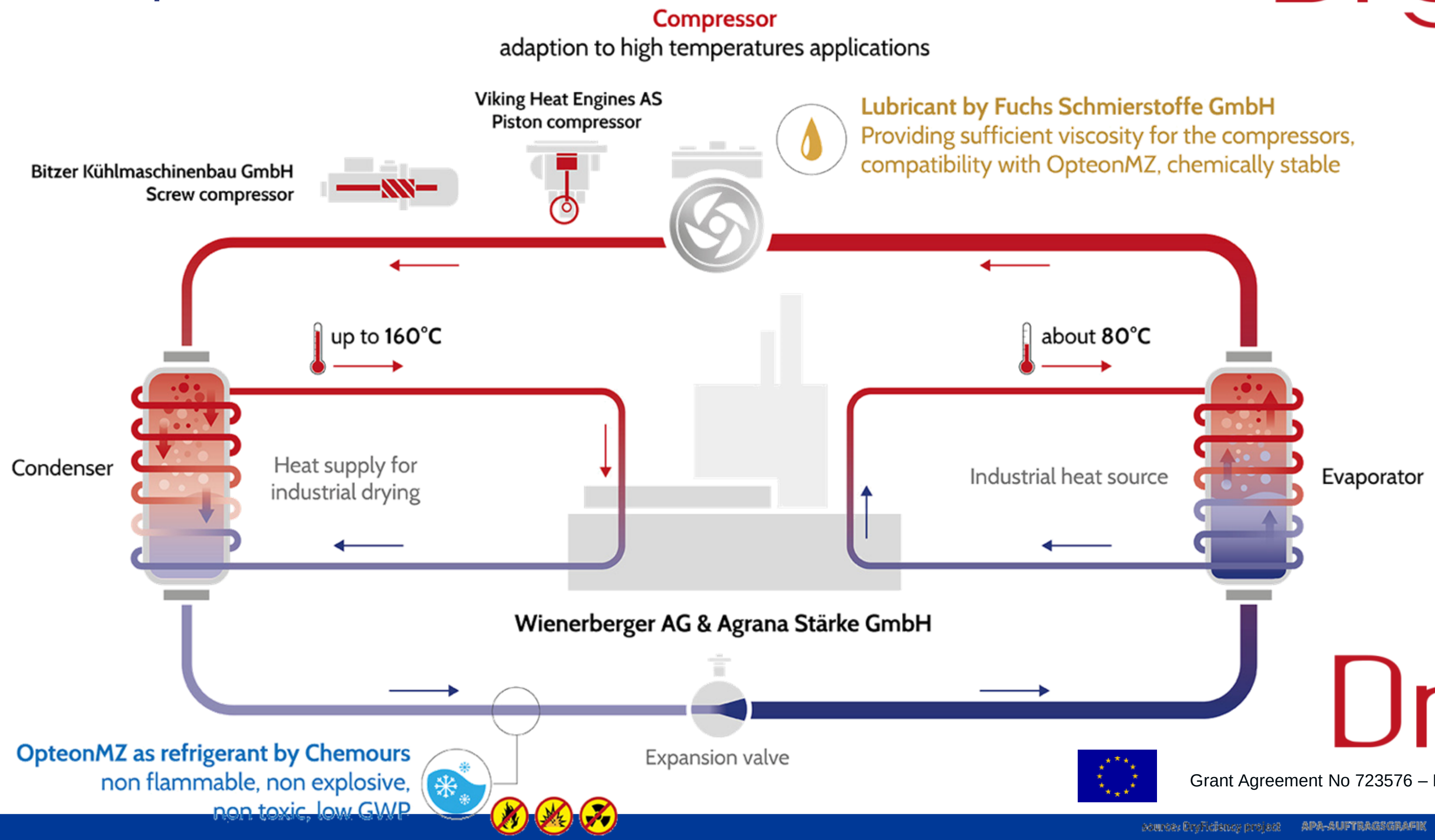
Closed loop heat pumps

DryFiciency: Industrial Heat Pump

V. Wilk, B. Windholz, F. Helminger,
M. Lauermann, S. Kling, J. Riedl,
A. Sporr, A. Schneeberger, T. Fleckl

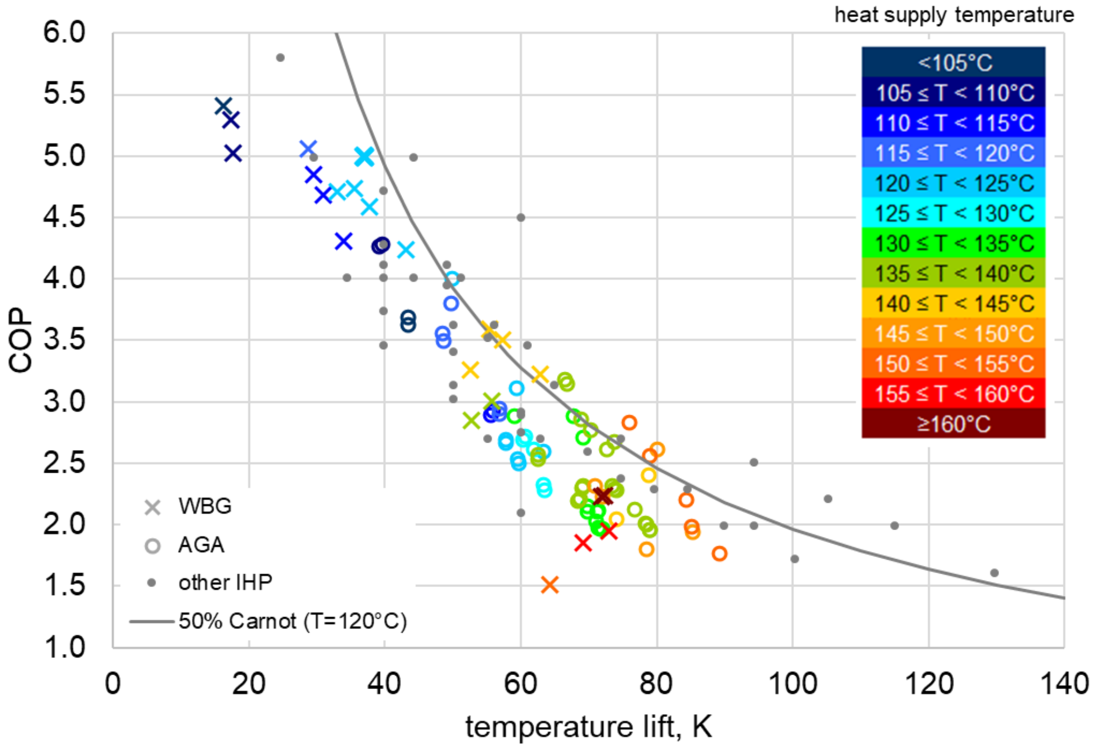
AIT Austrian Institute of Technology

Closed loop HP



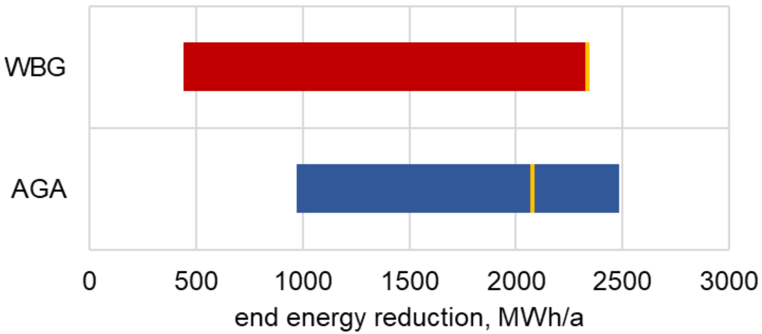
Grant Agreement No 723576 – Energy Efficiency

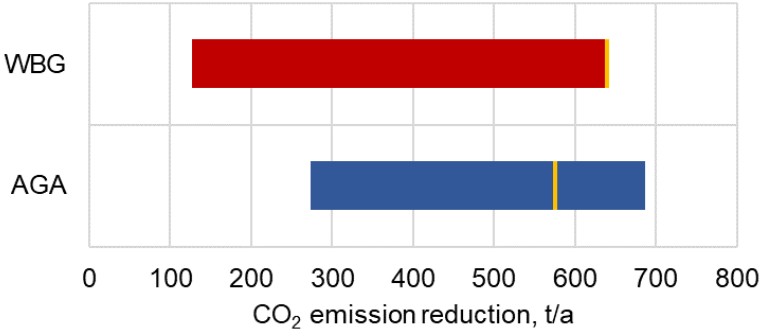
Overview on COP



other IHP from Arpagaus et al. High temperature heat pumps: Market overview, state of the art, research status, refrigerants, and application potentials, Energy (152), p.985-1010, 2018.

Environmental impact: End energy and CO_2 emission reduction



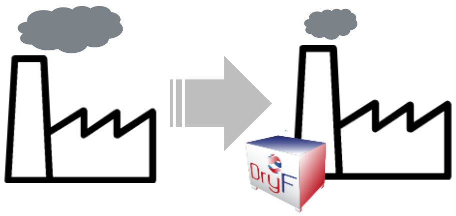


Comparison to a natural gas burner
(90% efficiency, 8400 h/a)

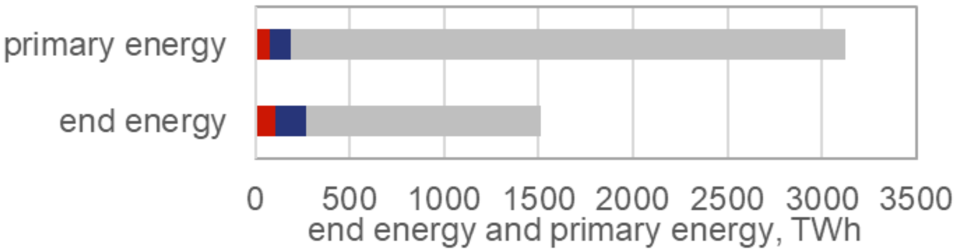
CO_2 emissions natural gas:
271 g/kWh

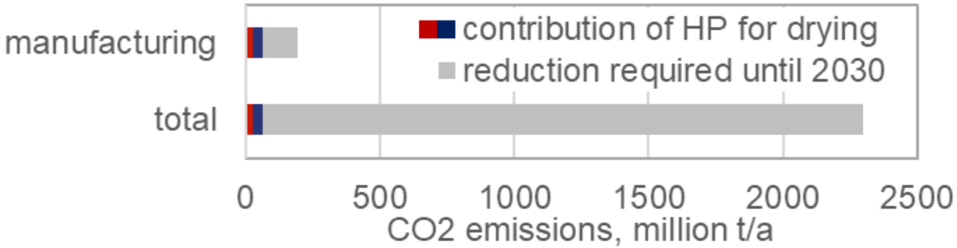
CO_2 emissions electricity:
258 g/kWh

Outlook



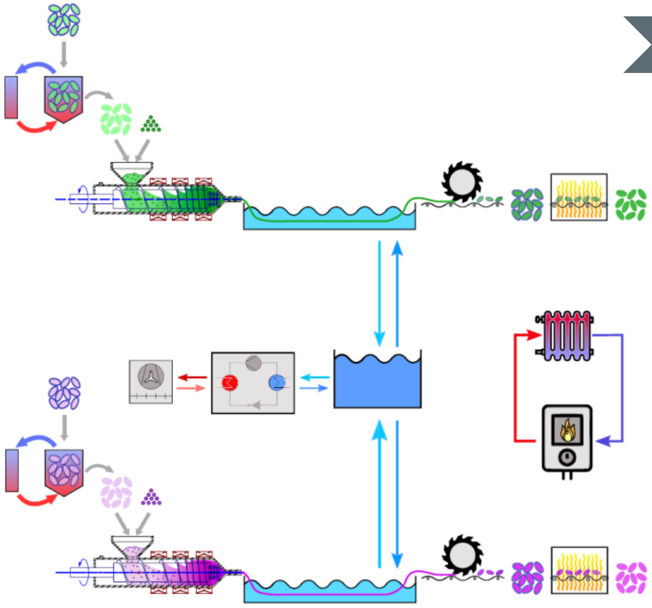
- assume that 50% of all drying processes in Europe are equipped with a DryFiciency heat pump
- replace natural gas burners
- impact on end energy consumption, primary energy and CO2 emissions



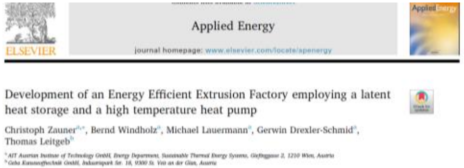


PLASTICS: EXTRUSION AND DRYING

Actual status



Heating capacity 50 kW
Source temperature 60 °C
Sink temperatures (i/o) 100/130 °C
Condensation temperature 127 °C
Evaporation temperature 55 °C

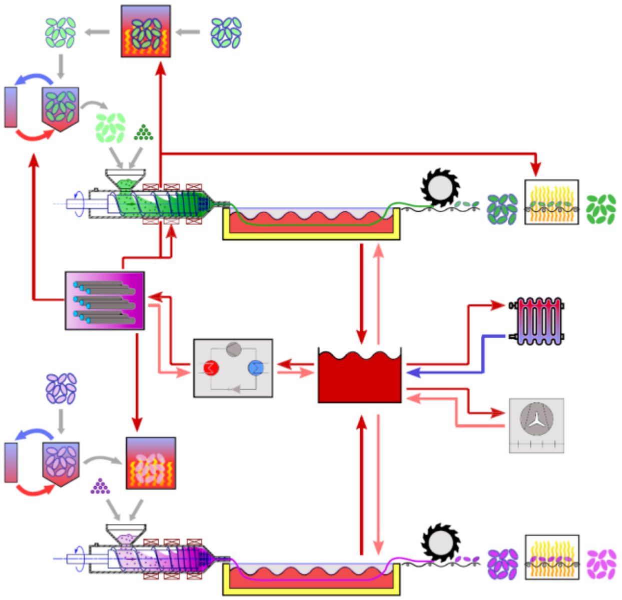

Applied Energy
journal homepage: www.elsevier.com/locate/apenergy

Development of an Energy Efficient Extrusion Factory employing a latent heat storage and a high temperature heat pump

Christoph Zauner, Bernd Windholz, Michael Lauermann, Gerwin Drexler-Schmid, Thomas Leitgeb

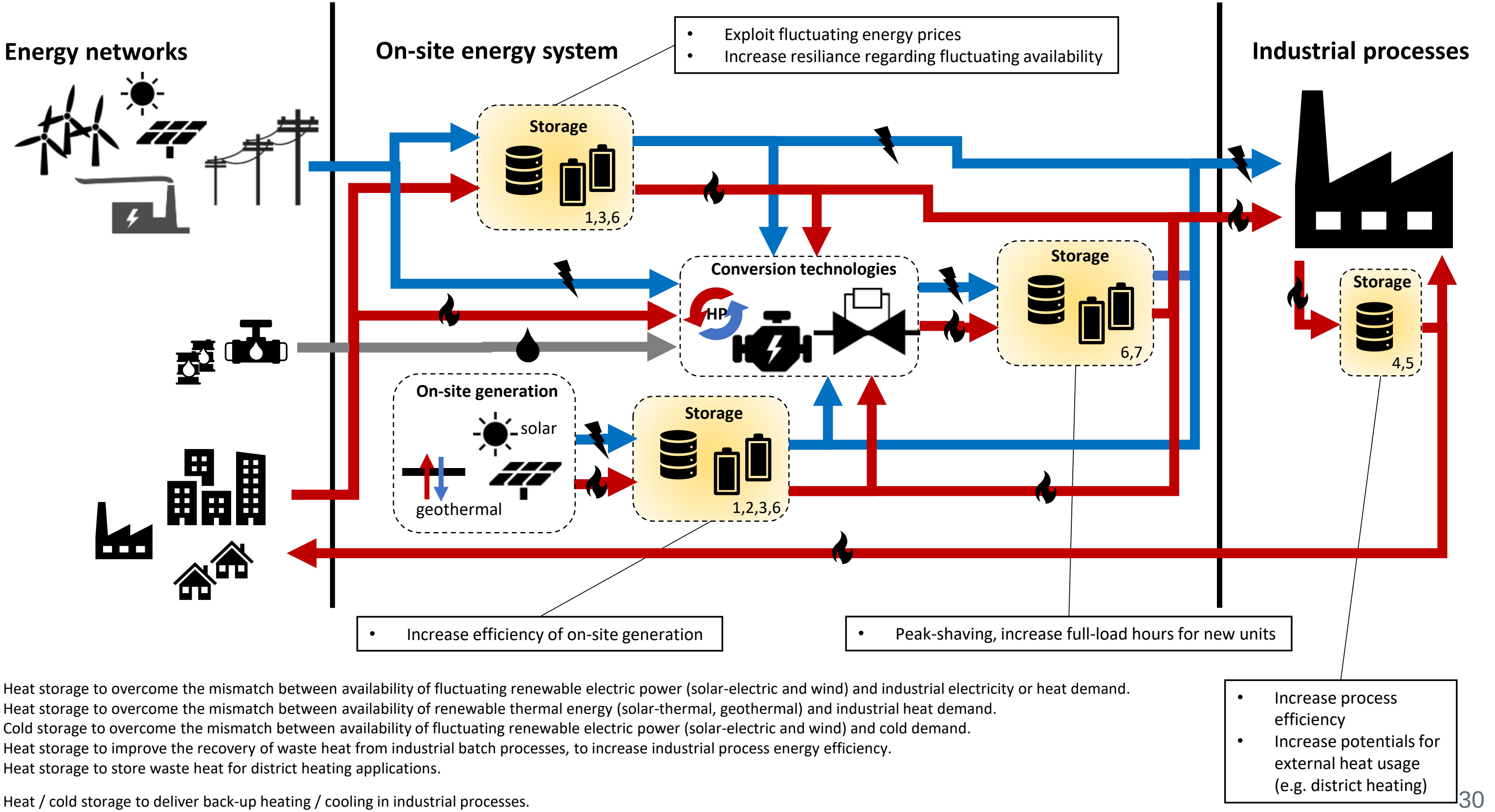
Integration HTWP and TS

fehlt



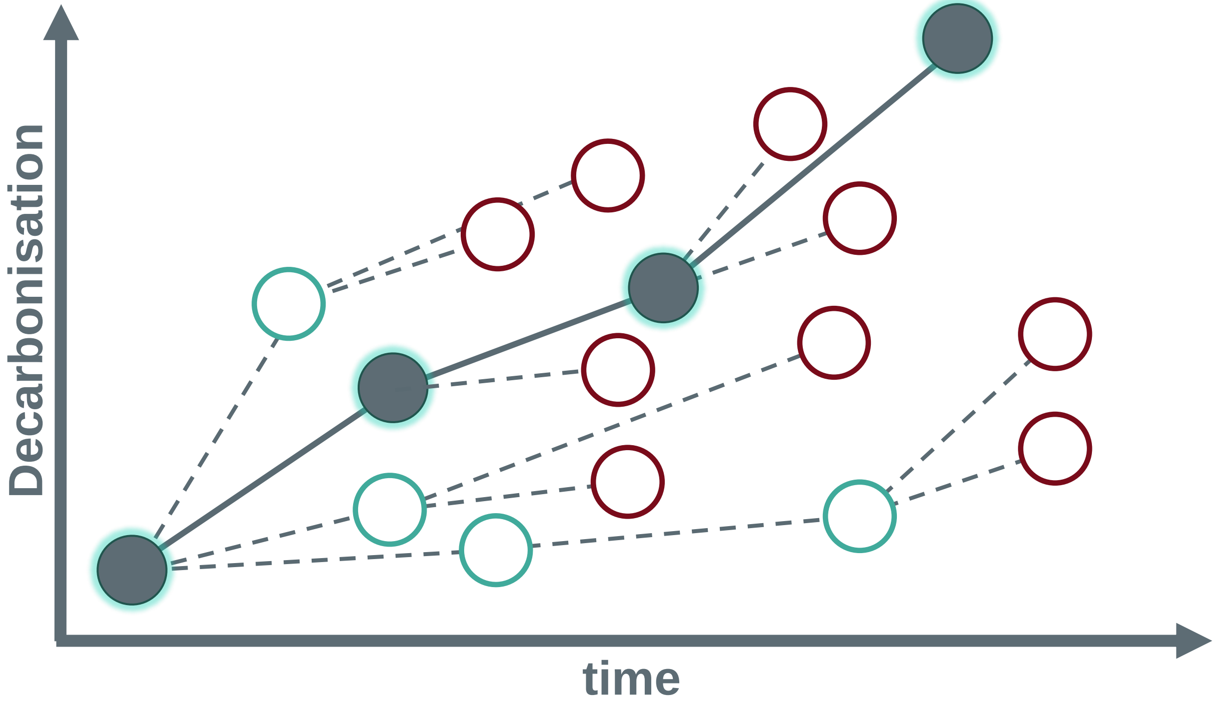
Digitalization – Methods for Decarbonization

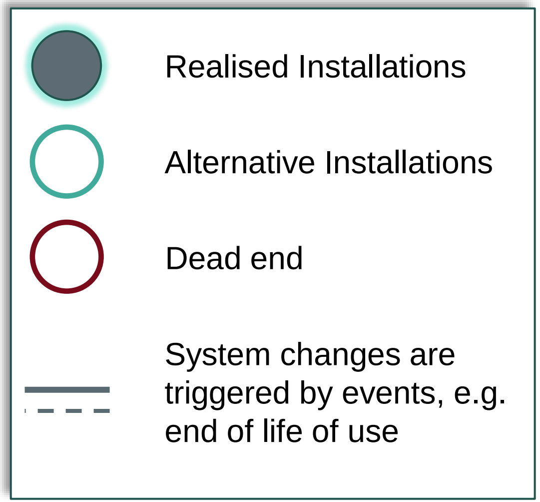
COMPLEXITY OF FUTURE INDUSTRIAL ENERGY SYSTEMS



1. Heat storage to overcome the mismatch between availability of fluctuating renewable electric power (solar-electric and wind) and industrial electricity or heat demand.
2. Heat storage to overcome the mismatch between availability of renewable thermal energy (solar-thermal, geothermal) and industrial heat demand.
3. Cold storage to overcome the mismatch between availability of fluctuating renewable electric power (solar-electric and wind) and cold demand.
4. Heat storage to improve the recovery of waste heat from industrial batch processes, to increase industrial process energy efficiency.
5. Heat storage to store waste heat for district heating applications.
6. Heat / cold storage to deliver back-up heating / cooling in industrial processes.
7. Peak-shaving

DEKARBONISATION PATHFINDER





ECONOMIC DESIGN OF DECARBONISED STEAM GENERATION – IN A NUTSHELL

AIT Austrian Institute of Technology
Gerwin Drexler-Schmid

ECONOMIC DESIGN OF A DECARBONISED STEAM GENERATION

- Steam demand
- Varying energy prices
- Steam generation
  - Electric boiler
  - High temperature-HP
- Storage technologies
  - Ruths, latent, concrete, molten salt


applied sciences

MDPI

Article

Optimal selection of thermal energy storage technology for fossil-free steam production in the processing industry

Anton Beck [1], Alexis Sevault [2], Gerwin Drexler-Schmid [1], Michael Schöny [1] and Hanne Kauko [2,*]

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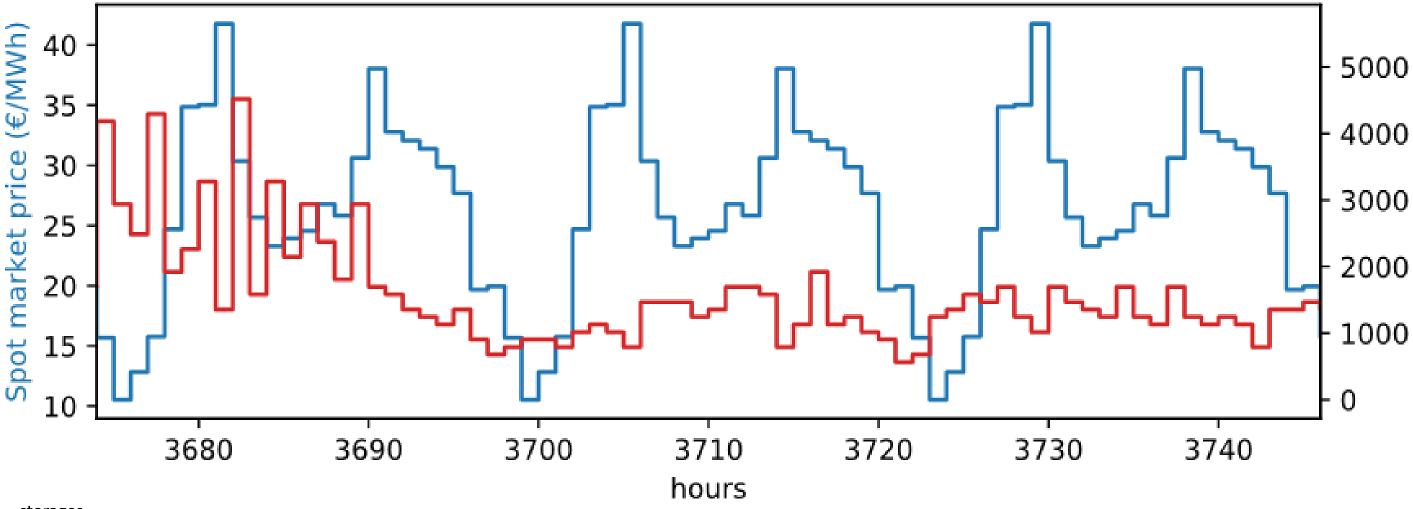

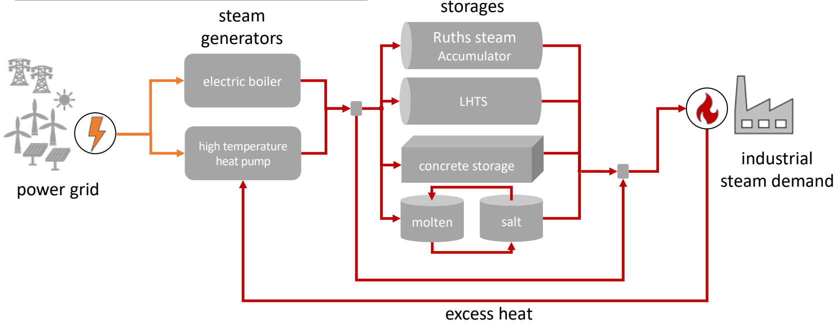

ECONOMIC DESIGN OF A DECARBONISED STEAM GENERATION

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SINTEF

- Steam demand
- Varying energy prices
- Steam generation
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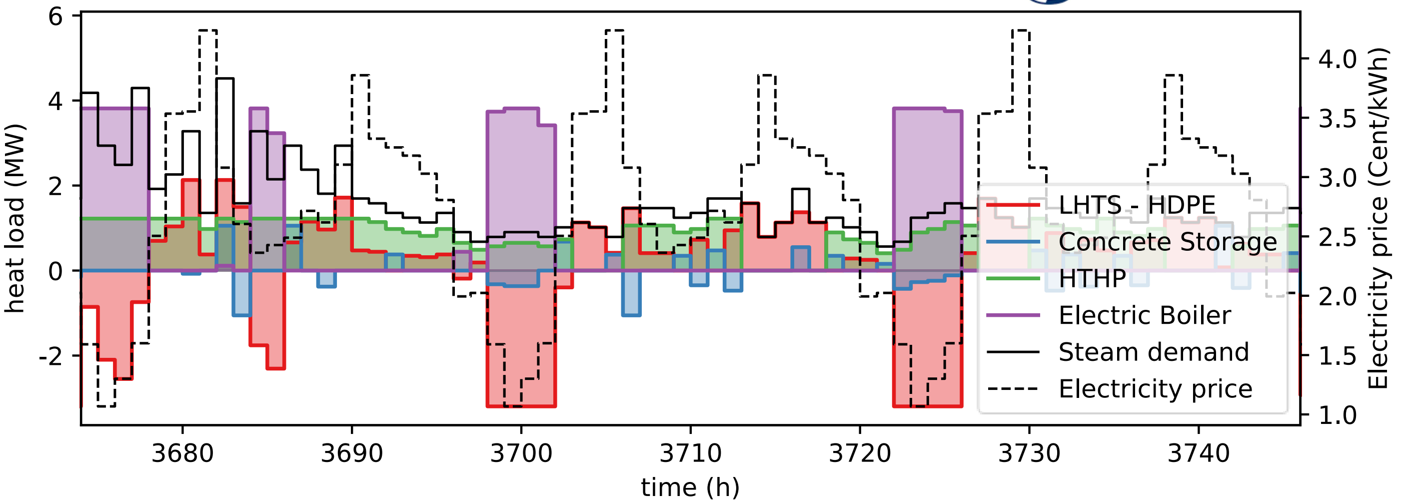


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Optimal selection of thermal energy storage technology for fossil-free steam production in the processing industry
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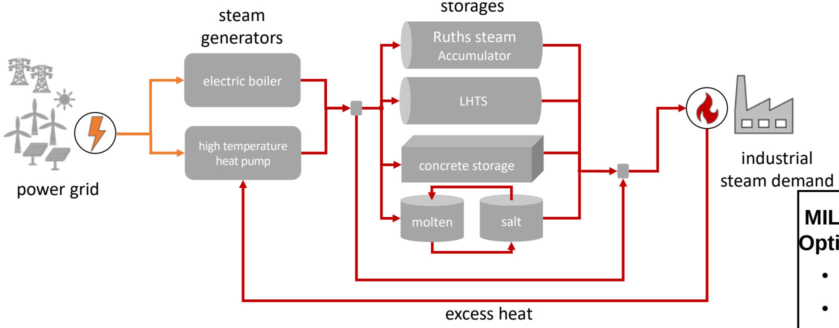

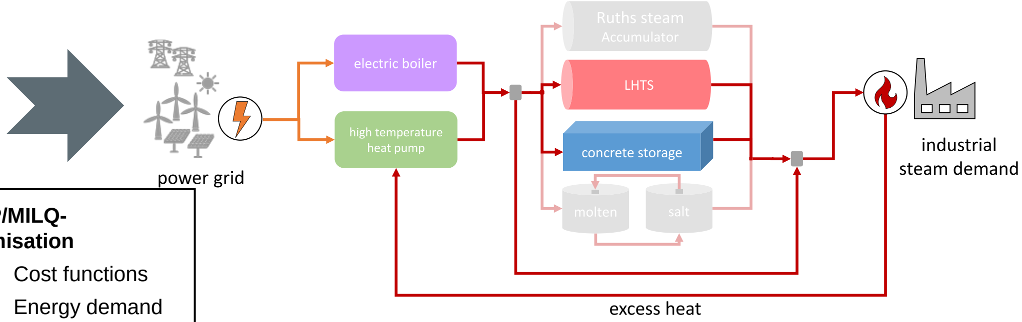

MILP/MILQ-Optimisation

- Cost functions
- Energy demand
- Energy prices

PROJECT CETES - COST EFFICIENT THERMAL ENERGY STORAGE

- Cooperation of Sintef and AIT as spin-off project in the HighEFF framework
- Project Team (alphabetical order):
  - Anton Beck (AIT)
  - Alexis Sevault (SINTEF)
  - Gerwin Drexler-Schmid (AIT)
  - Michael Schöny (AIT)
  - Hanne Kauko (SINTEF)
- Links
  - HighEFF (sintef.no)
  - Paper in Applied Sciences

DIGITALISATION - WHAT IS NEEDED?

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- Monitoring of all major **electricity** consumers on hourly basis

- Monitoring of major energy
  - Input
  - Utilization
  - Waste heats
  - On hourly basis

Decarbonization Example: Pharmaceutics

PHARMACEUTICS – SINCE 2019

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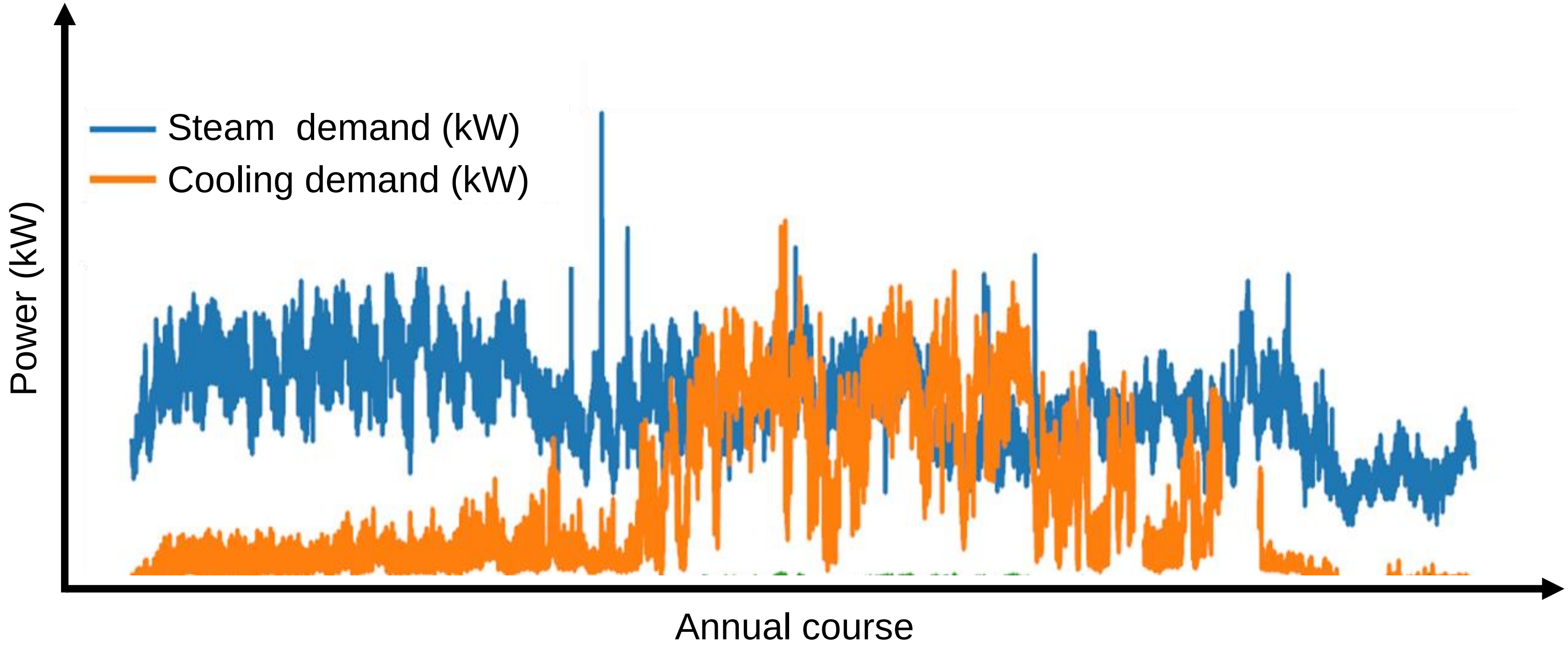
- Intermittent production (various batch processes)
- Small-scale industry (< 10 MW steam)
- Limited area for PV / Solar thermal available

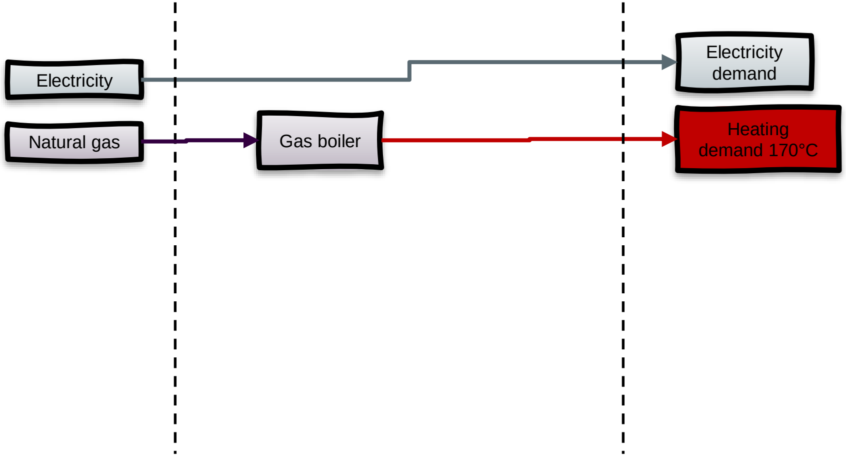
- Current energy supply units
  - Gas boiler for steam production
  - Electricity powered refrigeration system (excess heat potentials)

- Electricity price: 10 c/kWh, fixed
- Gas price: 8 c/kWh, fixed

DEMAND:
STEAM AND COOLING



PHARMACEUTICS



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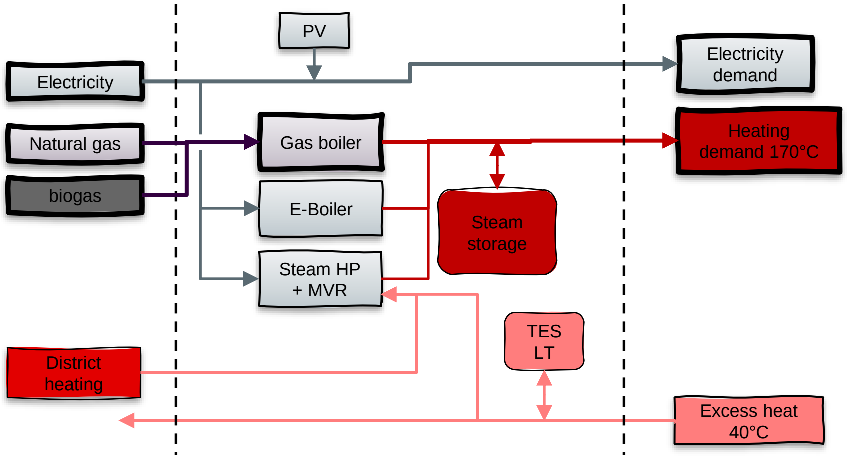
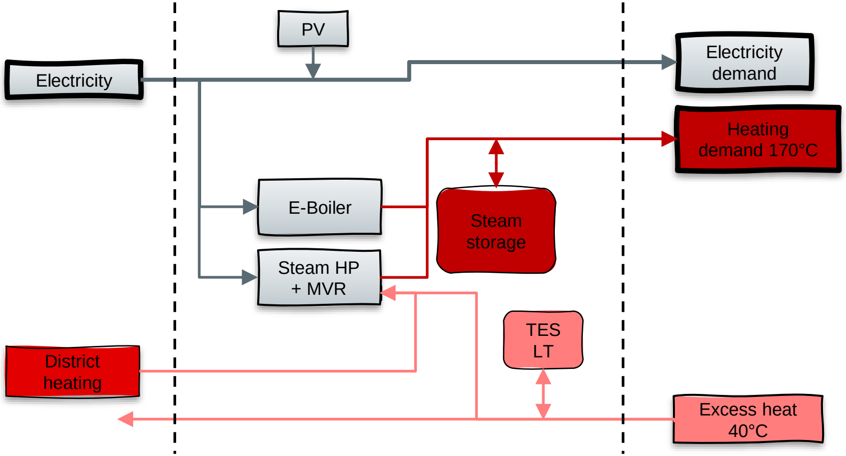


PHARMACEUTICS



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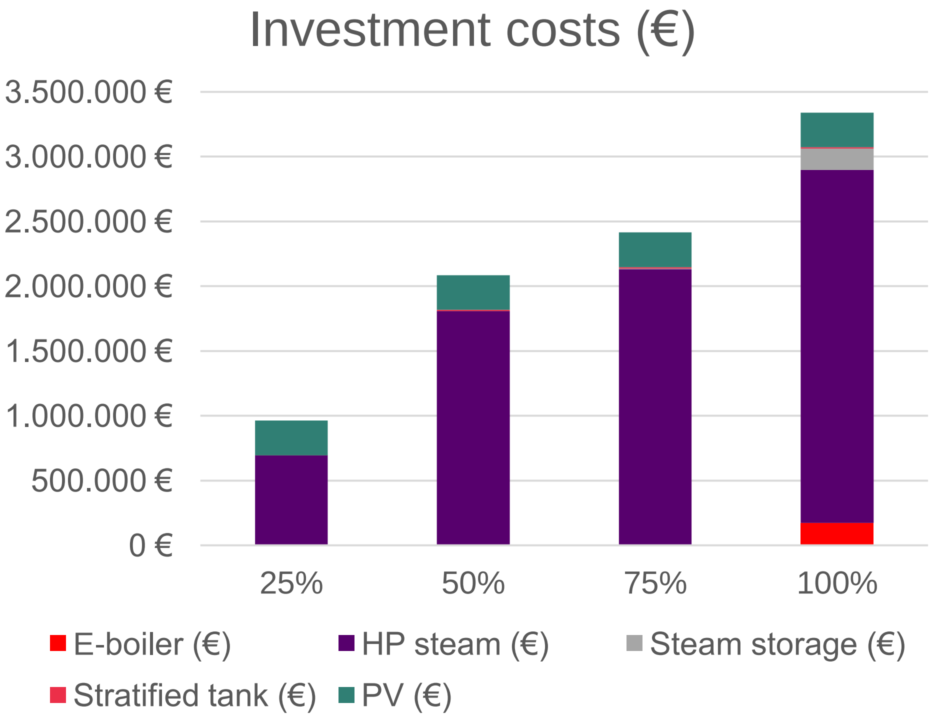

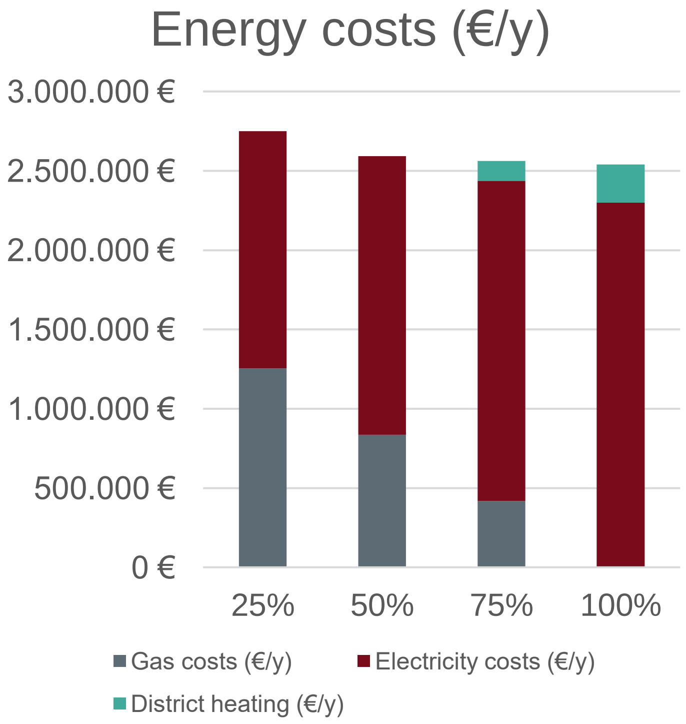

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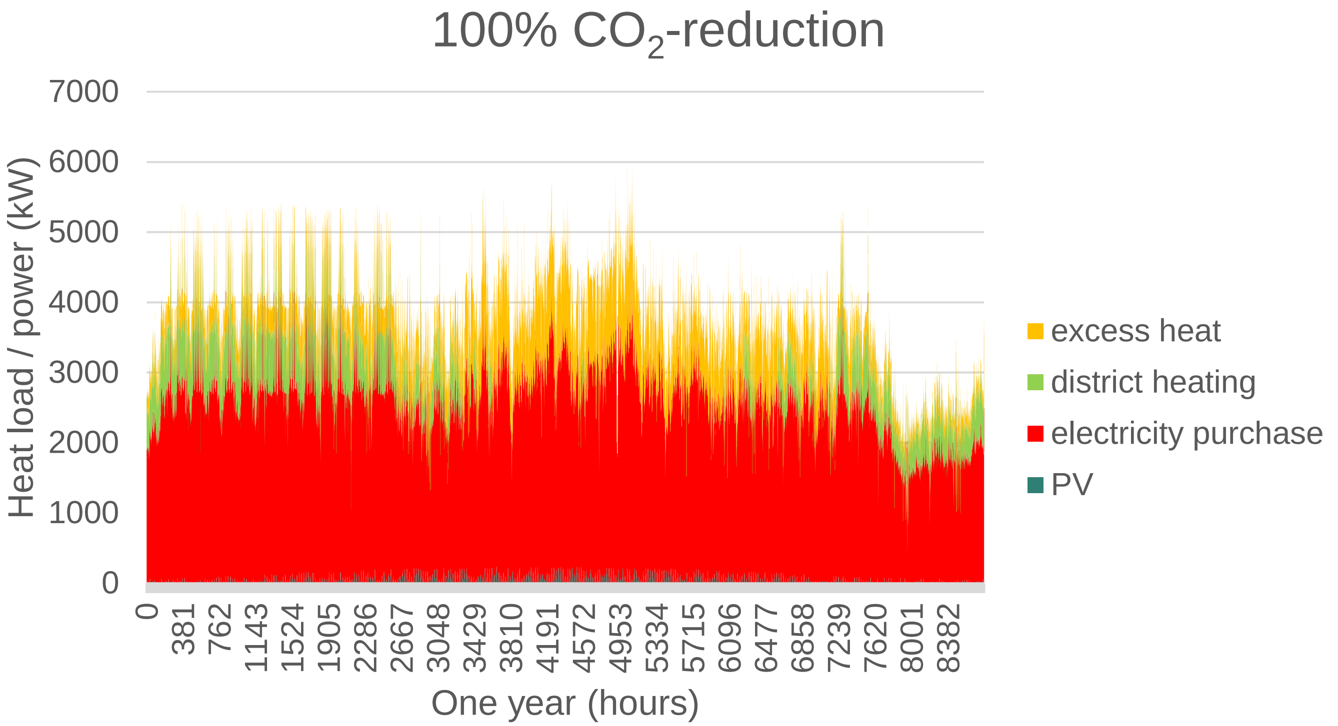
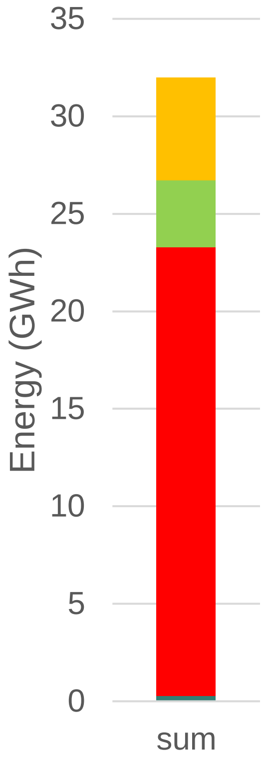




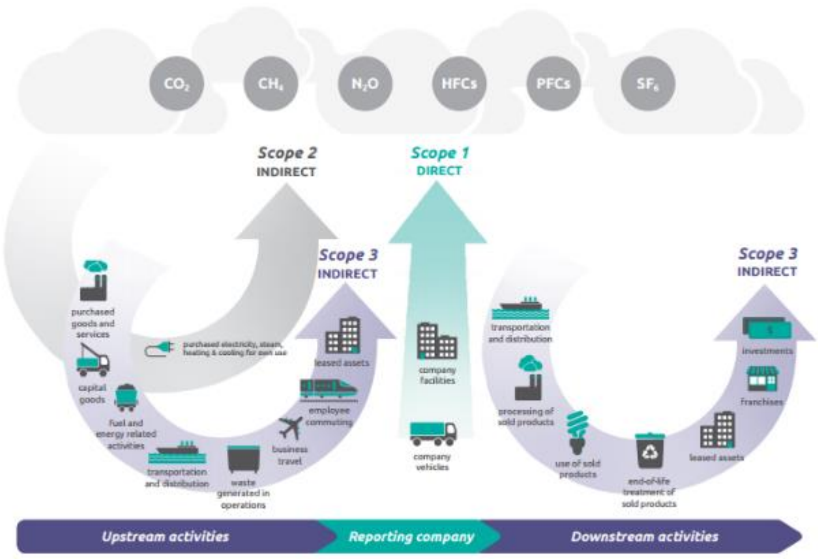
Carbonates - Calcination

CARBONATES, GEOGENIC EMISSIONS

- Cement: $CaCO_3 \rightarrow CaO + CO_2$
- Magnesium: $MgCO_3 \rightarrow MgO + CO_2$

- CCU shifts direct emissions (scope 1) to indirect emissions (scope 3)
- 80% of current Austrian plastics demand could be covered with CO_2 emissions from cement industry, at a current recycling rate of only 8%
- Possible future recycling rate 80% would lead to an 60% overproduction
- Use CCS for geogenic emissions (trees)

Green House Gas Protocol



Conclusio

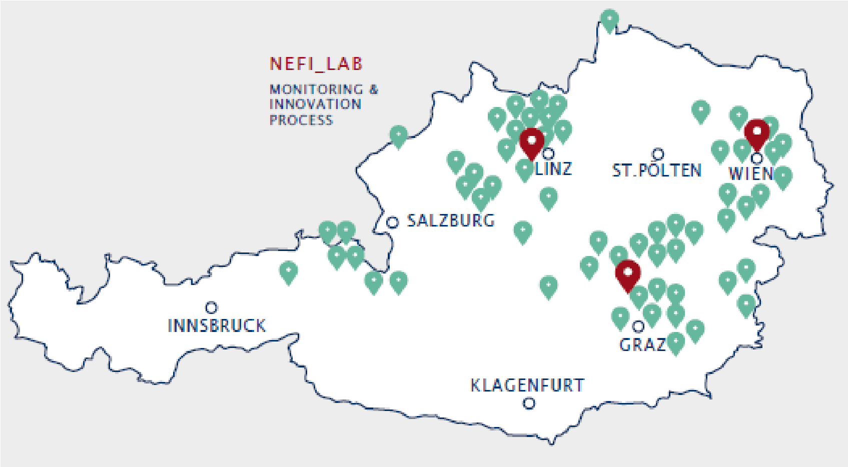
STATEMENTS

- Approx. 50 % of primary energy can be saved, sometimes more, sometimes less
- Decrease process temperature if possible – rethink the process
- Increase cooling temperatures
- Use heat recovery!
- Avoid to burn stuff!
- Look at the whole system! – Every investment must be puzzle piece for an 100 % decarbonized systems

NEW ENERGY FOR INDUSTRY

NEFI PROJECT MAP

Geographical distribution of projects and industrial sites



BC4I – Biochar for industry

Clean Energy for Tourism – Load Management in the field of power grids

DSM_OPT - Demand Side Management: Operation Optimization of Industrial Energy Systems

EDCSproof – Process flexibility and efficiency in the food industry

EDDY – Enhanced drying in the agricultural commodity and food industry

ENVIOTCAST – environmentally friendly casting

GmundenHTLink – High temperature waste heat utilization in the cement industry

Heat Highway – Interregional heat transfer networks

HyStEPs – Hybrid steam storage in the steel industry

Industrial Microgrid – Energy exchange between industrial companies

Industry4redispatch

LEAP – Low Pressure Steam Heat pump

Oxysteel – Energy efficiency through oxygen input in steel production

SANBA – low temperature waste heat utilization from food industry

SBM_IND – demand-oriented and network-related marketing of industrial flexibility potentials

TCP_to_Industry – Thermal cracking process for energy recovery to industry

FURTHER INFORMATION:
www.nefi.at/projects

THANK YOU!

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