ENERGY EFFICIENCY AND DECARBONIZATION IN INDUSTRIAL HIGH TEMPERATURE PROCESSES

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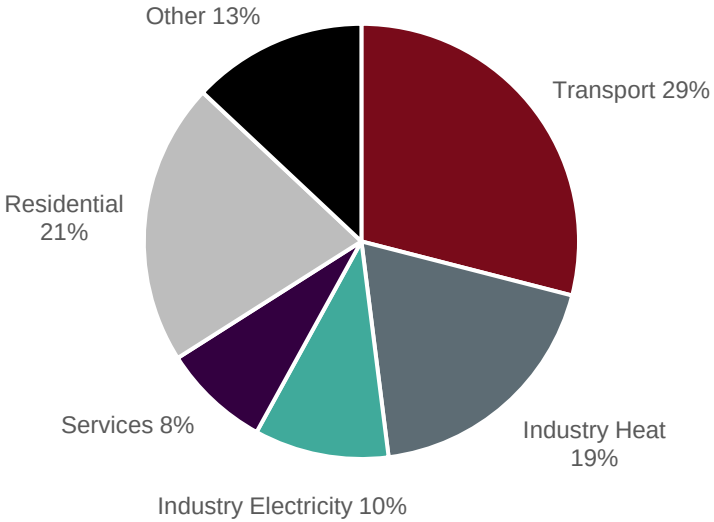
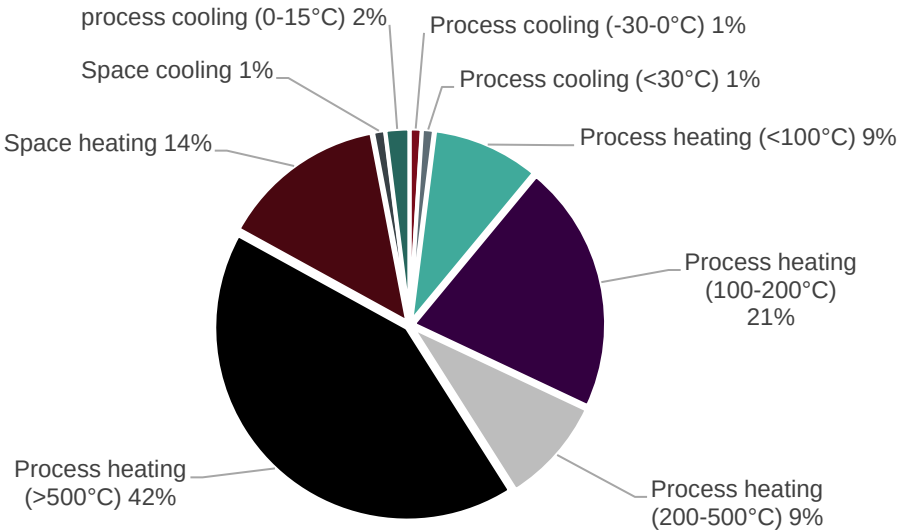
MOTIVATION

Worldwide final energy demand per sector



International Energy Agency IEA, Energy Balances 2020

Final energy demand in industry



Heat Roadmap Europe, Heating and Cooling - facts and figures (2017)

TECHNOLOGY OPTIONS & INFLUENCING FACTORS TO DECARBONIZE YOUR PROCESS

Technology options

- Thermal, electrical and chemical storage
- Direct electrification: electric arc, electric boiler, etc.
- Heat pumps + steam recompression
- H_2 gas engines & turbines
- Hydrogen & renewable gases
- 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

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

STEPS FOR DECARBONIZATION

STEP 1: ANALYSIS

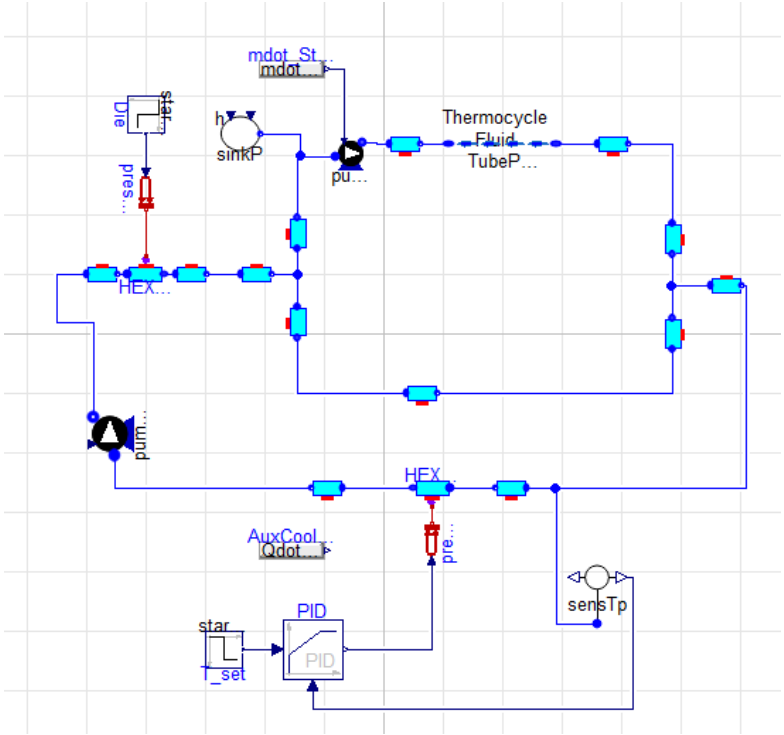
DECARBONIZATION STEP 1

Analysis of status quo / modelling

- Closing mass & energy balance
- If necessary / possible additional measurements (gas consumption, temperatures, mass flows)

- Understanding of process requirements
- Energy flow diagrams (Sankey)
- Identifying measures to
  - Save energy
  - Use access heat
  - Replace fossile fuels

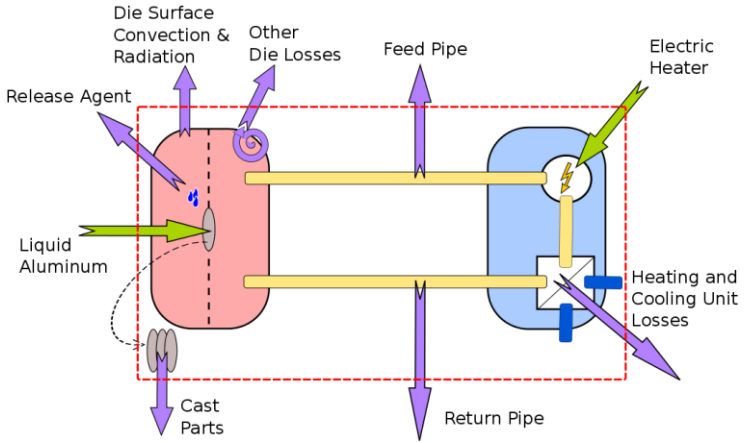
- Simple model of all energy flows and processes

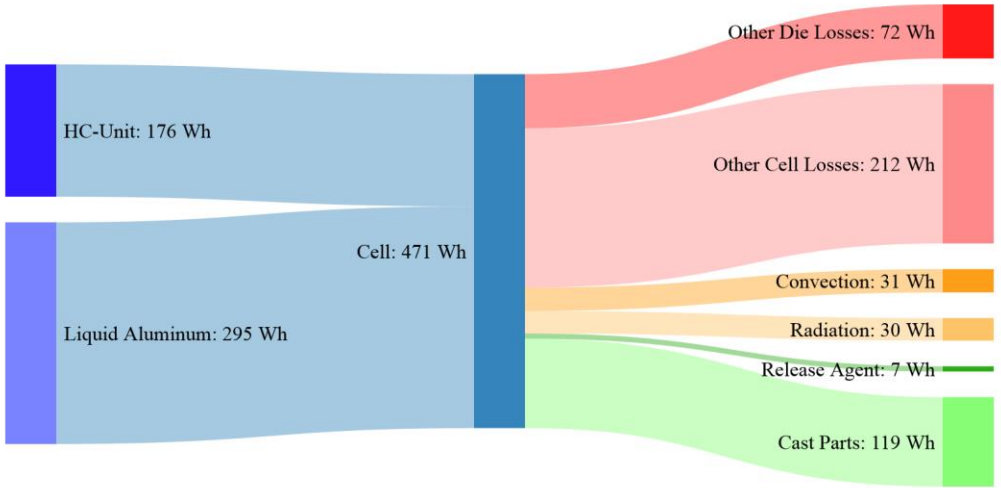


DECARBONIZATION STEP 1

Exampe: Aluminium die casting

- Main energy consumer is melting furnace
- Enormous losses: Die-casting machine is large radiator / spraying: little energy / cooling basin: much energy
- Often heating/cooling units even have to heat up, although the molten aluminium releases energy during solidification





STEP 2: REDUCE HEAT LOSSES

DECARBONIZATION STEP 2

Reduce heat losses

Physical framework conditions

Radiation

- Temperature
- Emission / Absorption
- Geometry

$$P \sim F_{1\to2}\ \varepsilon(\lambda)\alpha(\lambda)(T_1^4 - T_2^4)$$

Convection

- Temperature
- Velocity
- Geometry

$$P \sim Nu(v, \lambda, geo)(T_1 - T_{Luft})$$

Heat conduction

- Temperature
- Heat conductivity
- Geometry

$$P \sim \lambda(T_1 - T_2)(geo)$$

Technical possibilities

Radiation

- Therm. insulation
- „low-e“ / „low a“ coatings
- Radiation panels

Convection

- Therm. insulation
- Noble gases (Argon)
- „Knudsen Effect“ (Aerogel)
- Vacuum-insulation

Heat conduction

- Therm. insulation
- Hot surfaces and contact surfaces

STEP 3: WASTE HEAT RECOVERY

DECARBONIZATION STEP 3

Waste heat recovery

- At present, "insufficient insulation" is often used to cool the machines and heat the halls.
  - Increasingly uneconomical with higher energy prices in the future
  - Production halls are often too hot in summer

- After thermal insulation → need for more re-cooling in some cases → Find heat sinks!

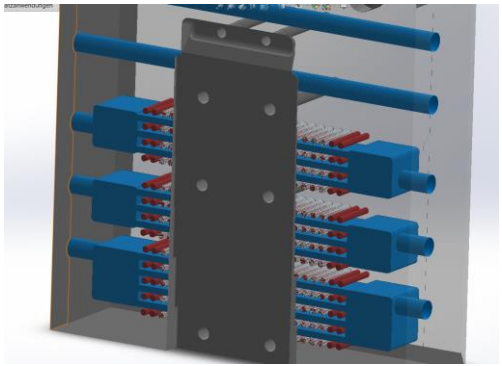
- Hall heating, shower rooms and the like are obvious, but only suitable to a limited extent (no heating in summer, showers use practically no energy, etc.).

- In many processes, goods must be heated from room temperature to processing temperature and then cooled back to room temperature.
  - Preheating is very often a good potential sink with a high energy requirement.
  - Ideally, the heat from the cooling process can also be used for this purpose.

DECARBONIZATION STEP 3

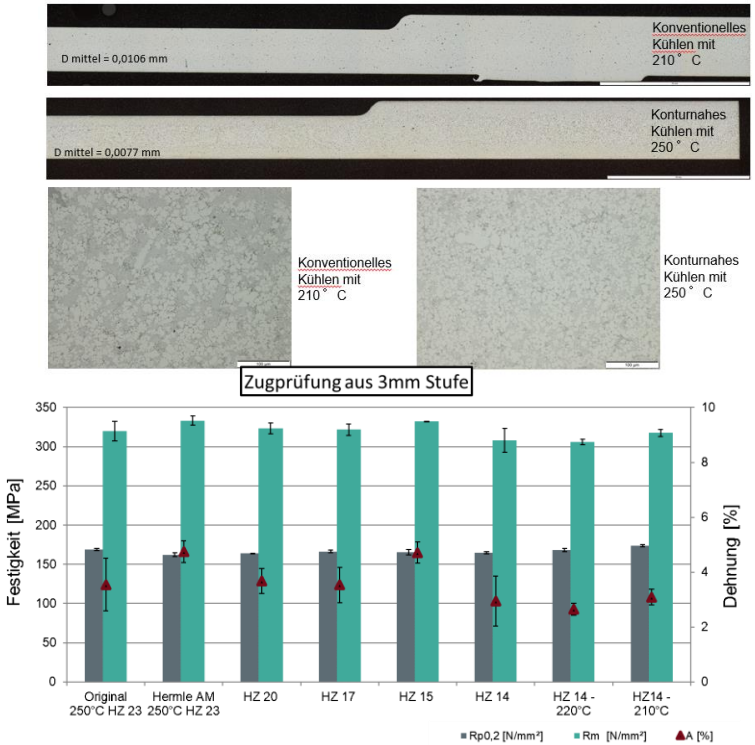
Example: Aluminium die casting

Cooling close to the contour with copper elements
mass flow control to outlet temperature



AIT, Hermle

- Higher cooling temperature
  → Waste heat can be used
- Less material stress
  → longer service life
- Better component quality, shorter cycle times



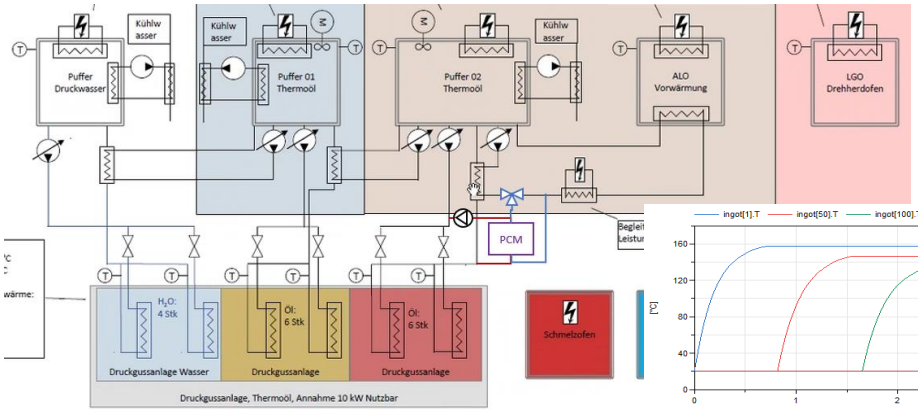
DECARBONIZATION STEP 3

Example: Aluminium die casting

- Castings with approx. 300 °C are cooled in water bath with approx. 20 °C → insulated, warm water bath → Waste heat available at T >> 20 °C
- Improved cooling → Waste heat available at 200-300 °C
- Sinks:
  1) Preheating aluminium ingots for melting furnace
  2) Preheat casting tool
  3) age-hardening furnaces

30 % reduction in energy consumption

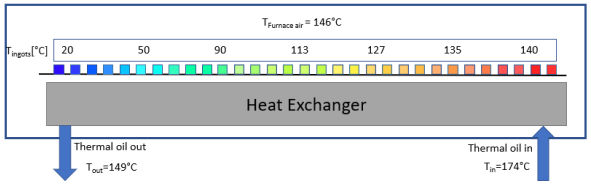
LKR Demo Factory under construction (completion 2023)



HOFMANN Wärmetechnik

Ph. Moser et al.,

IRES 2022



STEP 4: CO_2-NEUTRAL ENERGY CARRIERS

DECARBONIZATION STEP 4

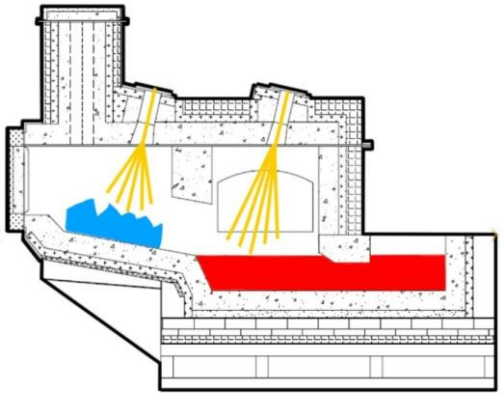
CO_2-neutral energy carriers

Electrification

Example resistive heating element

- Electric heating elements in various geometries and materials. Geometries and materials available
- < 1000 ° C metallic heating elements suitable
- > 1000 ° C more expensive materials, low durability
- Atmosphere is oxidising instead of reducing
- Heat transfer by radiation can be complex in large furnaces
- Less convection Temperature homogeneity Sometimes active circulation necessary
- Retrofit may be impossible
- Sufficient supply of green power local generation (PV, wind, hydro), PPAs, grid

Furnace products — Kanthal®



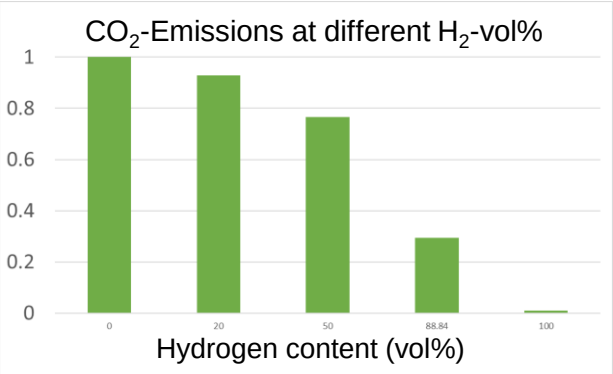
https://dynamofurnaces.com

DECARBONIZATION STEP 4

CO_2-neutral energy carriers

Hydrogen

- Decarbonization only possible with high volumetric share of H_2 (in natural gas) 20 vol-% H_2 corresponds to only 7 % CO_2 reduction.
- For (almost) 100 % H_2 gas supply, burner, refractory, exhaust system (recu, blower, HEX)?
- Increased adiabatic combustion temperature
- NOx emissions “Flameless combustion”
- First burners tested up to 100 % H_2



Danieli HYDRO MAB to take a step ahead in green steel ‹ Danieli

DECARBONIZATION STEP 4

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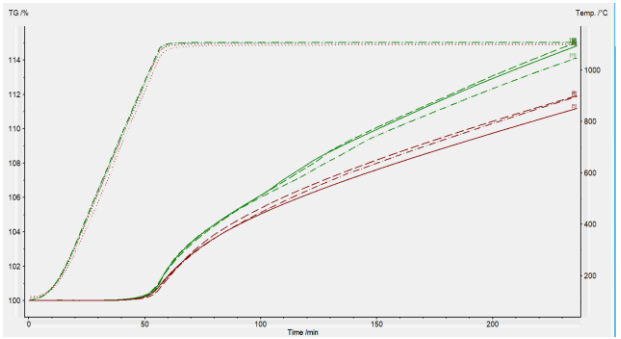
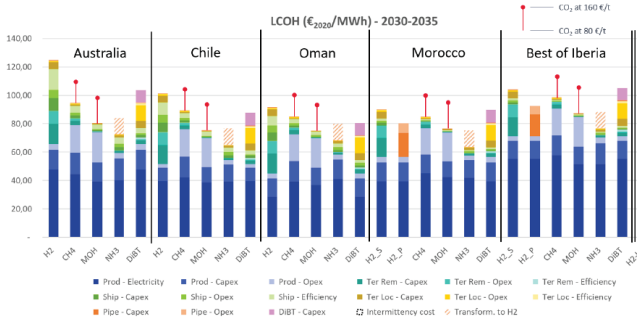
- Increased adiabatic combustion temperature
- NOx emissions “Flameless combustion”
- First burners tested up to 100 % H_2
- Heat transfer changes (radiation, convection)
- Conversion in large furnaces not trivial in terms of heat technology
- Possible negative influence on the product
- Possible re-certification necessary
- Where does the hydrogen come from (local vs. import)?



Thermogravimetry Steel for 100% H2 and 100% CH4 flame



Hydrogen Import Coalition

DECARBONIZATION STEP 4

CO_2-neutral energy carriers

„green methane“

- No conversions and no process changes necessary ("1:1 natural gas substitute")
- Biomethane from fermentation, thermal gasification

Schmack Biogas - Komplettanbieter für Biogasanlagen (schmack-biogas.com)

BEST (best-research.eu)

DECARBONIZATION STEP 4

CO_2-neutral energy carriers

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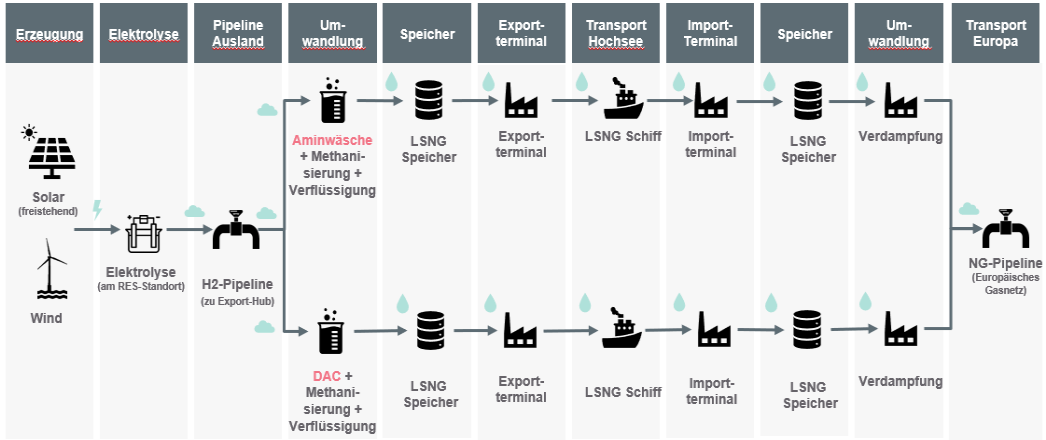
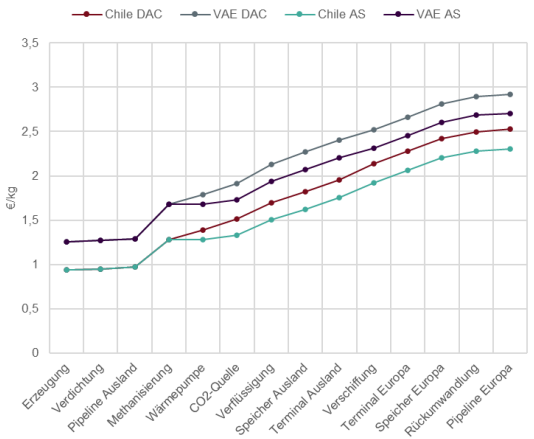
- No conversions and no process changes necessary ("1:1 natural gas substitute")
- Biomethane from fermentation, thermal gasification
- Methanisation of flue gas on site (via carbon capture) and/or
- Import of "synthetic natural gas" from wind- and sun-rich regions





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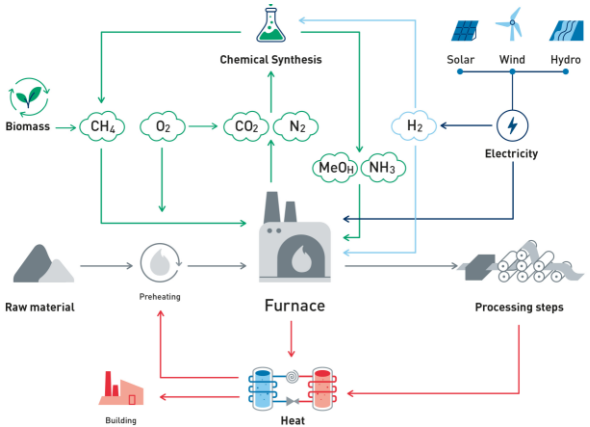
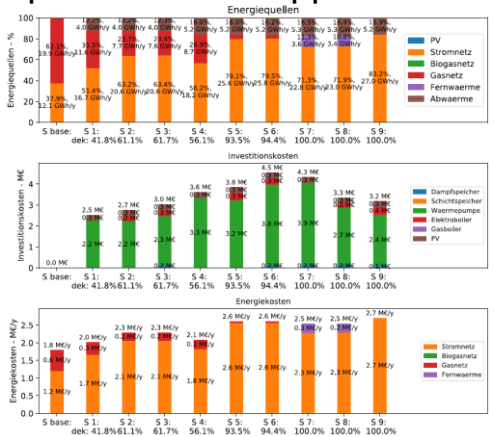
- Overall site concept, techno-economic assessment, implementation support





SOME ONGOING PROJECTS AT AIT

All projects are funded by the Climate Energy Fund

Greenbricks

Brick production

Wienerberger

Greensteel

Steel processing

Aichelin

voestalpine
ONE STEP AHEAD.

Energy

AUSTRIAN INSTITUTE OF TECHNOLOGY

Energy
LET / LKR

Hy2Wasp

Asphalt and concrete

STRABAG

envIoTcast

Aluminium die casting

MAXAN AUTOMATION

HOFMANN Wärmetechnik

business upper austria

THANK YOU!

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