SWK
Hochschule Niederrhein
University of Applied Sciences
SWK E²
Institut für Energietechnik und Energiemanagement
Institute of Energy Technology and Energy Management

Appendix to the Short Study: Energy-Efficient and CO_2-Free Process Heat

Explanations and Practical Examples

| As of July 2024 |

Authors: Meyer, Jörg | Zaubitzer, Louisa | Alsmeyer, Frank| Madsen, Marius

Courtesy Translation

1. Study Explanations

1.1 Methodology

1.1.1 How were environmental heat, geothermal energy, solar thermal energy, etc., considered in the study?

The study adopts the perspective of energy procurement within enterprises. Consequently, energy that is freely available, such as environmental heat, is not classified as final energy. The authors acknowledge that this approach deviates from other balance sheets, which often have different objectives.

A heat pump uses technical work to absorb thermal energy from a lower-temperature reservoir, often comprising environmental heat, geothermal energy, or waste heat. Combined with the drive energy (alt. terminology motive power) (typically electricity), this thermal energy is provided as useful heat at a higher temperature for space and process heating. In this study, only the drive energy is considered as final energy because it must be purchased.

1.1.2 Did the study differentiate between fuel quantities for material conversion in industry and the actual utilization of process heat?

The study only accounts for energy quantities used for energy purposes. Quantities used for non-energy (material) purposes, which are listed in a separate column in GENESIS, were not considered.

1.1.3 Process heat is already being supplied by electricity. Would it not be more practical to focus solely on fuels?

Electricity was not excluded from the study because potential savings through insulation and optimized regulation exist even with electric heat provision (e.g., electrolysis, electric arc furnaces). Moreover, this inclusion allows for better comparability of overall figures. However, it is accurate to state that the majority of savings in process heat arise from fuel use. Comparatively, savings in already electrified processes are minimal, with only 8 percent of process heat generated by electricity in the reference year.

1.1.4 Were infrared applications considered in the electrification analysis?

Yes, infrared heaters were considered alongside electric or electrode boilers, heat pumps, and induction furnaces. The economic viability of these technologies is highly dependent on individual electricity and fuel prices and specific conditions (e.g., material properties). While some intriguing infrared solutions exist for space heating, this was not within the scope of the study.

1.1.5 To what extent was biomass usage considered?

Currently, biomass or heat from renewable energies (e.g., contributions within district heating networks) accounts for approximately 7.8 percent of the industry. The study assumes this share will increase to around 15 percent by 2060, with the absolute amount only rising by about 50 percent from today. Biomass availability is limited, and we have adhered to the principle of cascading use (prioritizing material use before thermal use).

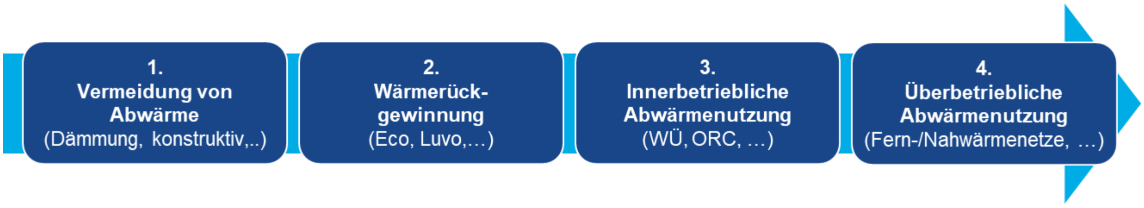
1.1.6 What data formed the basis for determining savings?

The authors had access to nearly 1,000 energy audit reports encompassing several thousand measures across almost all sectors. Additionally, evaluations from DENA (Energy Efficiency Networks) and BAFA (compilations of measures) were reviewed, along with numerous guidelines and industry-specific studies. Repeated audits—either annually or biannually for EnMS or every four years for EDL-G audits—provided a reasonable estimate of the implementation rate of these measures.

1.1.7 What is the difference between heat recovery and waste heat utilization?

In some studies, the terms "heat integration" and "waste heat utilization" are used interchangeably, but our study differentiates between them in the energy analysis of the heat sector.

The energy cascade for waste heat begins with assessing whether waste heat can be avoided (e.g., through insulation). Next is heat recovery, where the waste heat from Process A is redirected back into the same process (e.g., economizers in steam generators). Lastly, we consider waste heat utilization, where waste heat from Process A is used in another process, Process B (e.g., using exhaust air from a compressed air system to heat a hall) or outside the facility.



1.1.8 What is the potential for waste heat utilization in neighbouring industrial facilities or properties if there are no internal applications?

This aspect was not considered in the study. However, there is likely substantial potential, particularly for process heat with temperatures exceeding 200°C.

1.2 Industry-Specific Considerations

1.2.1 The steel industry has already established a decarbonization pathway. How was this factored into the study?

The measures from published studies were included in our assessment. In addition to steel production, related processes (e.g., coating plants) were also considered, though these are often not detailed in existing studies.

1.2.2 In the cement and lime industries, "Carbon Capture and Storage" (CCS) is an integral part of their decarbonization strategy. How was this addressed in the study?

CCS is not an efficiency measure—higher efficiency results in less CCS. The study only examined the reduction of energy consumption for process heat provision.

1.2.3 In many chemical industry processes, energy savings are challenging. Was this adequately addressed in the study?

Yes, this was sufficiently considered. The study initially classifies process heat by temperature levels. This classification is based on a study commissioned by the German Federal Environment Agency. Energy consumption is broken down by temperature ranges and industry sectors, enabling the estimation of savings potentials considering specific applications/processes and corresponding reference technologies.

In the chemical industry, many processes occur within the 100–500°C range, and potential savings in this range were included. For basic chemicals, processes exceeding 500°C exist, and, as with the steel, cement, and lime industries, results from other studies were considered. The authors are aware of the challenges associated with high-temperature processes, which is why significantly less potential was indicated in these areas.

1.3 Economic Considerations

1.3.1 Were increases in energy carrier prices and taxes considered?

The basis for electricity price determination was the average EEX front-year base values from 2025 to 2028, as of March 4, 2024 (70 €/MWh), plus 50 €/MWh for grid fees, 15 €/MWh for charges and levies, and 20.5 €/MWh for taxes (excluding VAT). The "vbw/Prognos Electricity Price Forecast 2023" [30] was then used to project prices from 2028 to 2060. The authors are aware that, for example, the electricity tax for 2025 has been partially reduced to 0.5 €/MWh, but an extension of this reduction had not been decided at the time of writing (June 2024). Such minor changes do not significantly impact the fundamental conclusions of this study due to the inherent uncertainty of price forecasts.

A similar approach was taken for natural gas price determination. The average THE front-year base values from 2025 to 2027, as of March 4, 2024 (31 €/MWh), were used, plus 10 €/MWh for grid fees and 35 €/MWh for charges, levies, and taxes (including CO2 charge of 10 €/MWh, also excluding VAT).

1.3.2 Are all fuels assessed based on the natural gas price?

No, the industrial fuel mix comprises natural gas, heating oils, coal, waste, and biomass. This was accounted for when calculating the heating price. However, natural gas is dominant, currently representing 47% of the final energy demand for process heat, with an upward trend (displacing oil and coal). Therefore, the determination of the future natural gas price was explained separately.

1.3.3 Were investments assessed for individual plants or overall system integration?

Investment costs were evaluated based on the overall integration into existing systems, which can significantly exceed the cost of individual units.

1.3.4 What does additional return without production restrictions mean?

This term highlights the attractiveness of energy efficiency measures as investments, emphasizing that production remains unaffected since most measures pertain to ancillary systems (heat provision).

1.3.5 Is electrification feasible in every facility, or are the necessary power lines lacking?

The study did not account for infrastructure investment costs (e.g., transformers, and grids). A lack of sufficient capacity can be a significant barrier, with substantial investments having a major impact on the economic evaluation.

1.3.6 Have companies with established energy management systems already implemented most of the economically viable final energy-saving potentials?

No, the extent to which an Energy Management System (EnMS) is integrated into business processes and the level of automation is critical. A well-established EnMS can facilitate the implementation of measures, provided there is support from management.

1.3.7 Can all facilities reduce process heat consumption by nearly 50 percent?

Certainly not. Savings depend heavily on the processes and, particularly, the temperature level of the process heat. Figure 3 of the study clearly shows that savings potential is much lower in processes with temperatures exceeding 500°C. A significant portion of energy consumption, such as in metal melting, is unavoidable.

2. Practical Examples

2.1 Temperature Range up to 100°C

2.1.1 Insulation of Process Hot Water Pipes

- **Measure**: Insulation of warm water network pipes (production) in the unheated basement with PUR pipe insulation (12.3 W/m).
- **Savings**: Natural gas: 502 MWh/year (OLD) – 106 MWh/year (NEW) = 416 MWh/year
- **Economic Viability:** Investment cost: 19,000 €, Return: 34,270€/year, Payback period: under 6 months.
- **Additional Information:** Implementation of the measure in 2021.

2.1.2 Optimised Control of Process Hot Water Tanks

- **Measure:** Heating the four hot water tanks for the emulsion as late as possible. Installation of a timer. Avoidance of radiation losses of approximately 5.2 kW due to the lower temperature.
- **Savings:** 41,795 MWh/a (OLD) – 30,788 MWh/a (NEW) = 11,007 MWh/a (-26%) or €2,077/a.
- **Economic Viability:** Investment cost: a few hundred euros, Payback period: <1 year.
- **Other Information:** Implementation of the measure in 2021.

2.1.3 Heat Recovery and Optimised Control of the Paint Booth

- **Measure:** Installation of a cross-flow heat exchanger in the paint booth to preheat the supply air using the heat from the exhaust air. Additionally, different air volumes in the sections of the booth.
- **Savings:** 2,124 MWh/a (OLD) – 654 MWh/a (NEW) = 1,470 MWh/a (-69%) or €117,600/a.
- **Economic Viability:** Investment cost: €408,072, Payback period: 3.47 years.
- **Other Information:** Implementation of the measure in 2023. The other two paint booths do not yet have heat recovery.

2.1.4 Hydraulic Balancing of the Hot Water Network (Production)

- **Measure:** Conducting hydraulic balancing in the hot water network (production).
- **Savings:** Natural gas: 580 MWh/a (OLD) – 498 MWh/a (NEW) = 81 MWh/a (-14%) or €9,332/a | Electricity (Pump): 6.8 MWh/a (OLD) – 5.4 MWh/a (NEW) = 1.4 MWh/a (-21%) or €450/a.
- **Economic Viability:** Investment cost: €27,521, Payback period: 2.9 years.
- **Other Information:** Implementation of the measure in 2023.

2.2 Temperature Range 100 - 200 °C

2.2.1 Heat Recovery on the Steam Generator | Economiser

- **Measure:** Retrofitting an economiser for feedwater preheating.
- **Savings:** Natural gas: 43,097 MWh/a (OLD) – 42,903 MWh/a (NEW) = 194.2 MWh/a (-0.5%) or €15,613/a.
- **Economic Viability:** Investment cost: €38,410, Payback period: 2.5 years.
- **Other Information:** Implementation of the measure in 2019.

2.2.2 Optimised Control of the Steam Generator

- **Measure:** Retrofitting an automatic blowdown control system (conductivity measurement).
- **Savings:** Natural gas: 43,097 MWh/a (OLD) – 42,980 MWh/a (NEW) = 117.0 MWh/a (-0.28%) or €9,406/a.
- **Economic Viability:** Investment cost: €12,280, Payback period: 1.3 years.
- **Other Information:** Implementation of the measure in 2019.

2.2.3 Conversion of Process Hot Water from Steam to Hot Water

- **Measure:** Steam is used in production, although only hot water at 70 and 80 °C is needed. The boilers need to cycle frequently, resulting in relatively poor efficiency and high heat losses. Conversion to an existing hot water system.
- **Savings:** Natural gas: 362 MWh/a (OLD) – 79 MWh/a (NEW) = 283 MWh/a (-78%) or €12,443/a.
- **Economic Viability:** Investment cost (replacement investment): €59,225, Payback period: 4.9 years.
- **Other Information:** Implementation of the measure planned for 2024.

2.3 Temperature Range 200 - 500 °C

2.3.1 Insulation

- **Measure:** Annealing furnace: Enclosure of the transport chain beneath the furnace to reduce heat loss from the chain.
- **Savings:** 351 MWh/a (OLD) – 92 MWh/a (NEW) = 259 MWh/a (-73%) or €25,300/a.
- **Economic Viability:** Investment cost: €38,274, Payback period: 1.51 years.
- **Other Information:** Measure planned for March 2023. Further measures on the furnace are possible.

2.4 Temperature Range 500 - 1,000 °C

2.4.1 Heat Recovery

- **Measure:** Annealing furnace: Substitution of standard industrial burners with recuperative burners.
- **Savings:** 2,171 MWh/a (OLD) – 1,715 MWh/a (NEW) = 456 MWh/a (-21%) or €44,685/a.
- **Economic Viability:** Investment cost: €124,300, Payback period: 2.78 years.
- **Other Information:** Measure planned for March 2023. Further measures on the furnace are possible.