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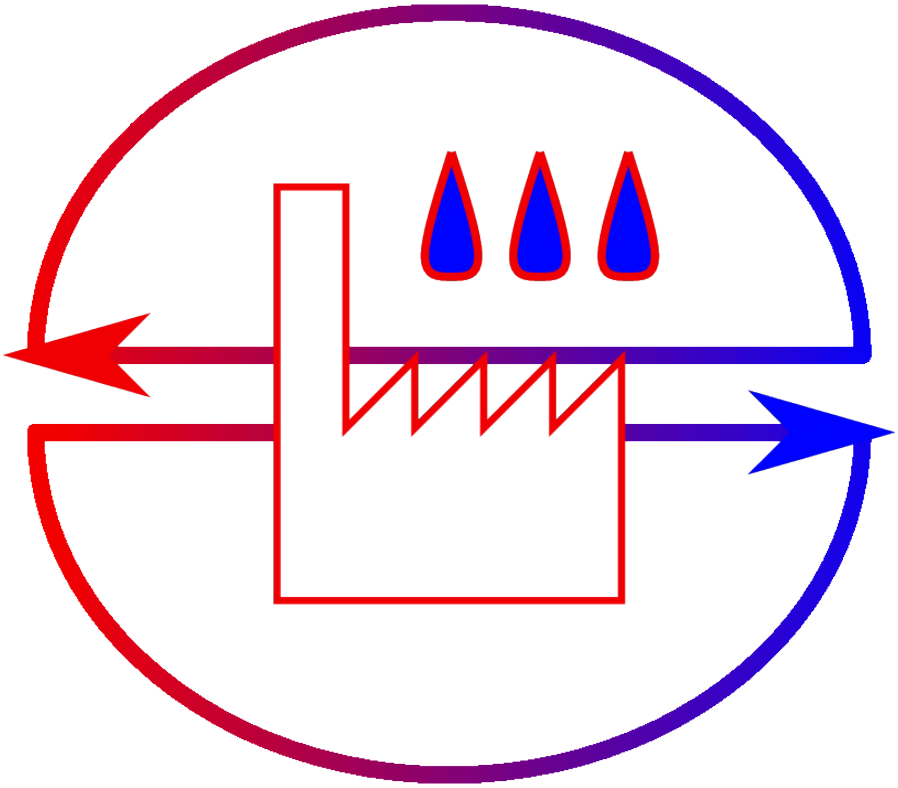
INTERNATIONAL ENERGY AGENCY
TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING



SUMMARY FOR NON TECHNICAL AUDIENCES

MEMPHIS 2.0

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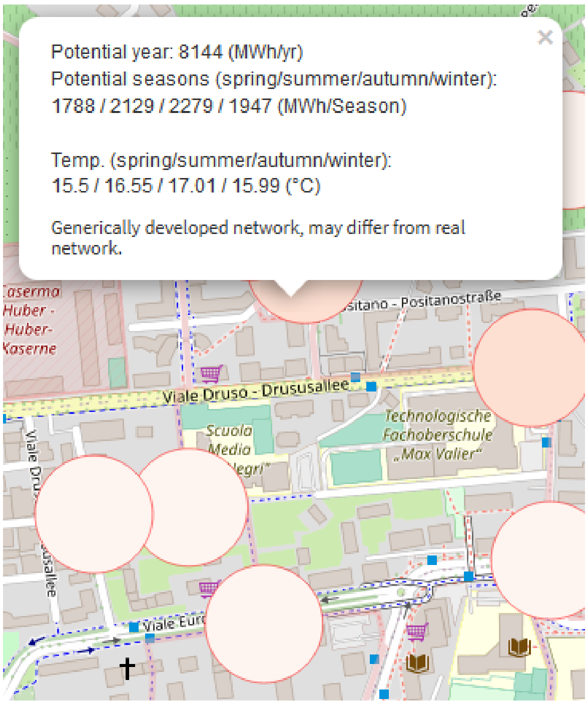
EXECUTIVE SUMMARY

Limiting global warming requires the decarbonization of energy supply through increased use of renewable energy and improved energy efficiency. Moreover, synergies between energy systems and waste heat sources and sinks must be utilized. In particular, existing district heating generation must be converted from the use of surplus heat from fossil fuel power generation to renewable energy sources such as solar thermal, geothermal, and waste heat sources from industrial processes or from sewers.
Various research results prove that renewable energy systems such as solar thermal systems, geothermal systems and power-to-heat can provide a stable heat supply throughout the year. In particular, district heating systems can be meaningfully supplied by waste heat or surplus heat as it is a basic principle of district heating systems, and consequently it makes sense to also utilize waste heat from industrial processes or sewage channels through district heating systems.

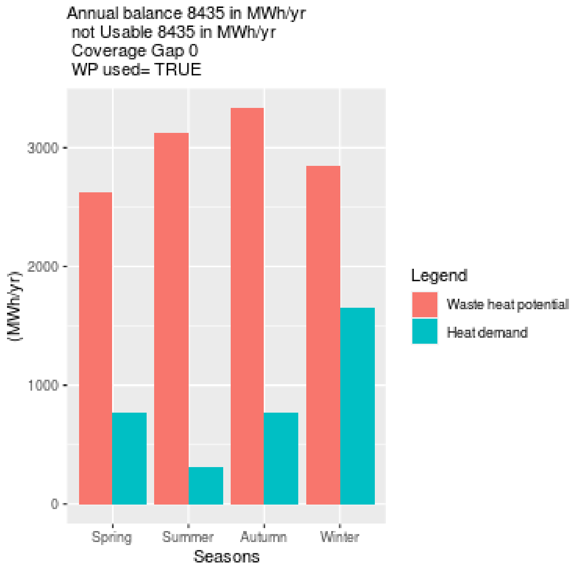
However, there are some obstacles to utilizing low grade waste heat from commercial or industrial processes as well as sewage channels: the unknown location of the waste heat source, its energy quantity and temperature level; the seasonality of the heat demand and the possible mismatch with the waste heat availability; and the long payback periods due to potentially high investment costs, together with rather low revenues from heat sales especially during summer. However, the cost competitiveness of heat supply plants is one of the essential elements for analysing the business potential of a planned technology. Generally, only investments that meet the minimum profitability required by the investor are considered for realization.

The IEA DHC project MEMPHIS 2.0 addresses these issues and promotes the availability of waste heat sources while stimulating the creation of synergies between waste heat sources and heat demand. MEMPHIS 2.0 deals with the challenges associated with low-grade waste heat, such as unknown locations of waste heat sources: energy content, temperature, seasonality, potential mismatch between availability of low-grade waste heat and heat demand and long payback periods. MEMPHIS 2.0 has addressed these issues through the following activities.

The algorithm for determining the wastewater flows within the city limits of the predecessor project MEMPHIS was supplemented by a mathematical model. This allows the wastewater sources and temperatures to be determined at each location of the sewer network. Based on the model, optimization is also possible, which was developed for potential determination.
Several scenarios are studied, differing in ground temperature and power range of the heat pumps



(a) Waste heat potential and its temperature levels



(b) Seasonal distribution of waste heat potential and heat demand

Fig. E-1 *Example of a location of waste heat extraction from wastewater given the ground temperatures of the four seasons in the city of Bolzano.*

to be installed. An example of an extraction point of waste heat from sewer is given in **Fig. E-1a**. In the cities studied, it was shown that the use of heat pumps in the low-power range of 10 kW allows a higher potential use of wastewater waste heat, but the average temperature at the extraction point is lower than the temperature at the collector of the wastewater treatment plant. However, if heat pumps with higher power extraction of more than 400 kW are installed, the usable thermal power decreases a little, but the temperature at the extraction points increases significantly.

Overall, it was found that significantly more waste heat from wastewater can be recovered with waste heat extraction within the city. Thus, with waste heat extraction within the five cities, on average 51 % of the heat originally discharged by wastewater can be tapped; with waste heat extraction at the collector of a sewage treatment plant, this value is reduced to 31 %. By extracting waste heat from sewers within the five cities, waste heat from 95 MW up to 108 MW can be tapped from the originally discharged waste heat of 212 MW. The temperature at extraction points ranges from 15.5 °C up to 18.6 °C.

The economic potential of wastewater heat utilization was investigated based on a sensitivity and profitability analysis. The dependency of the levelized cost of heating and heat prices on various parameters, in particular the electricity price, was analysed and the limits for a profitable operation were illustrated.

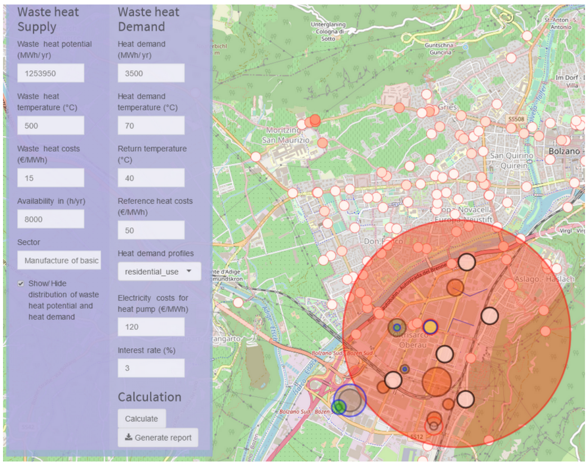
The results show that changes in the operating hours of a heat pump have the greatest influence on the levelized heating costs. The investment cost of the heat pump has the second largest impact on

the levelized cost of heating, and the electricity price follows directly after. A weaker effect is shown by the temperature lift from source to sink, the interest rate and the investment costs of the heat exchanger.
The results also illustrate the extent to which electricity prices may increase without making the wastewater heat utilization plant uneconomical to operate if heat prices remain unchanged. Based on current electricity prices, the heat price must not fall below 152 €/MWh, if a minimum profitability of 10 % is expected.

Within the project the data set on industrial waste heat was improved by including time-resolved waste heat availability and detailed information on temperature levels. As the waste heat potentials from the industrial sector might be impacted by the transition to innovative technologies and fostered decarbonization, a qualitative assessment of the effects has been conducted, combined with a quantitative assessment for the iron and steel and the cement sectors. The assessment indicates that electrification of former combustion processes and utilization of high-temperature heat pumps would reduce externally available waste heat.

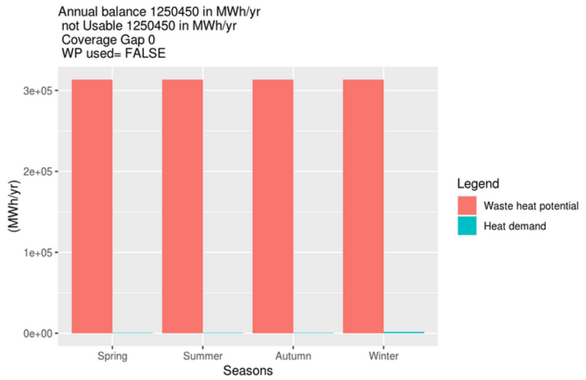
Furthermore, a comprehensive assessment was carried out to identify new and upcoming waste heat sources, with particular emphasis on data centers and electrolyzers.
Utilizing heat from data centers presents mutual benefits for both the data center operator and customers requiring heat. Successful implementations of waste heat recovery in data centers can already be found in Nordic countries and Austria.
With hydrogen playing a critical role in decarbonizing various parts of the energy system, waste heat from electrolyzers could significantly increase the overall efficiency of these installations, with projects demonstrating a system efficiency of 84 % to 90 % by utilizing waste heat.
The assessment also explores additional waste heat sources, such as supermarkets, cooling of buildings, tunnels, and transformer/converter stations, each offering significant waste heat potential that is expected to increase in the future.

Additionally, a methodology for conducting rapid techno-economic evaluations has been established and tested through a generic case study. Various scenarios were assessed, revealing that the levelized cost of heat is primarily influenced by waste heat costs, piping costs, and seasonal storage expenses. Seasonal storage is necessary to bridge the gap between waste heat availability and heat demand, but scenarios that include seasonal storage were found to be more expensive than those using heat from a reference system to cover the demand coverage gap.
Additional parameter variations were conducted, including waste heat temperature, pipe length, and waste heat potential. As waste heat temperature decreases, the need for a heat pump increases, leading to a higher levelized cost of heat. Conversely, increasing waste temperature above the heat sink supply temperature has no impact on the levelized cost of heat. In the case of limited waste heat potential, individual component costs increase as the delivered heat decreases.

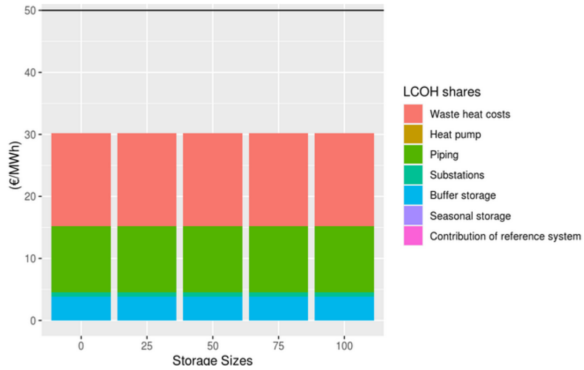


(a) *Input parameter of the economic evaluation*

(b) *Overview on the economic evaluation*



(c) *Seasonal distribution of waste heat potential and heat demand*



(d) *Levelized cost of heat (LCOH) for full coverage of heat demand and different seasonal storage sizes*

Fig. E-2 *Techno-economic assessment of the utilization of waste heat from an industrial process in the city of Bolzano reported by the economic assessment through the Waste Heat Explorer under http://cities.ait.ac.at/uilab/udb/home/memphis/.*

The findings and newly developed methodologies were implemented into the Waste Heat Explorer, an online tool to visualize information on waste heat sources from industries and the sewage network. The online tool is accessible via *http://cities.ait.ac.at/uilab/udb/home/memphis/*. An example output of the newly implemented feature is given in **Fig. E-2a** to **E-2c**.

To enable the techno-economic evaluation, the Waste Heat Explorer has been adapted to include land use data as a base map for calculating pipe costs. The tool also features a route drawing function that allows users to connect waste heat sources with the respective site of the heat sink. Furthermore, an automatically generated evaluation report provides more detailed information such as a feasibility assessment, as seen in the example given in **Fig. E-2a** to **E-2c**. Displaying the seasonal potentials of waste heat from industrial and service sectors as well as sewage networks with spatial resolution, helps to clarify aspects of waste heat sources such as seasonality, locations and temperatures of the waste heat source. The tool has been expanded to cover three Italian cities namely

Ospitaletto, Bolzano, and Trento, and new sewage data has been integrated.

With respect to the previous MEMPHIS project, the Waste Heat Explorer was further improved. The procedure to retrieve the needed data is thoroughly described in the report and could be quickly replicated for other municipalities. The Italian cases were also used to validate the estimated waste heat recovery coefficients on a few selected industrial sectors. Though significant deviations were observed in some cases, the available data generally confirmed the predicted orders of magnitude.
The Waste Heat Explorer can help to map the seasonal potential of waste heat from industrial and service sectors and wastewater networks with spatial resolution. With its functionality to manually connect heat sources and heat sinks and generate techno-economic reports on the given connection design, the results can be used for preliminary energy planning purposes.
Due to the increasing relevance of waste heat in the future energy system, it might hence be worth discussing policies where data collection is made more automated and easily accessible, as the information needed does not exhibit a significant confidentiality level.