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Project

Sustainability of adsorption heat pumps

The best alternative for heating and cooling: the utilisation of waste heat

The best alternative for heating and cooling: the utilisation of waste heat

At present, a lot of waste heat from industrial plants still escapes into the air. This energy could be collected and used – with so-called adsorption heat pumps. Researchers at the Paul Scherrer Institute have now prepared a comprehensive assessment of the environmental influences and economic viability of such systems and compared them with established heating systems.

The heat from wood pellet heating systems can also be upgraded with the help of adsorption heat pumps – and thus used more efficiently and in a more environmentally friendly way. *Source:* iStock

At a glance

- So-called adsorption heat pumps could in future help to use heat energy more efficiently by collecting waste heat from factories or computer centres.
- Researchers from the Paul Scherrer Institute have now subjected the facilities to a sustainability assessment. Among other things, the study examined their impact on the environment, the risks for people and the associated costs. Here, adsorption heat pumps performed better than established heating systems such as gas and wood pellet heaters and conventional compression heat pumps.
- If systems such as these were used in Switzerland in specific scenarios examined as part of the project, emissions of greenhouse gases would fall by up to 5 % compared to an energy system without these scenarios.

Switzerland's CO_2 emissions must be reduced in the future – this is a requirement of Energy Strategy 2050. One step towards achieving this goal is to use the resource of heat more efficiently. The heat we need to heat buildings, produce hot water or dry and melt materials in industrial processes accounts for half of our total energy consumption. And this energy still primarily originates from fossil sources such as crude oil and natural gas.

Heat energy could now be used more efficiently by recovering and reusing more waste heat than before. This is made possible by so-called adsorption heat pumps. Similar to conventional compression heat pumps, such systems can collect and upgrade heat. In contrast to conventional heat pumps, they require almost no electricity to this end. Instead, they use the heat as a drive source. The process works from an input temperature of 35 to 60 degrees Celsius. For example, adsorption heat pumps could obtain waste heat from factories, computer centres or renewable heat energy from thermal solar plants. However, assessments of their impact on the environment and their economic viability have so far been lacking. Researchers from the Technology Assessment Group at the Paul Scherrer Institute (PSI) have now changed this and created a comprehensive sustainability assessment.

On the one hand, they have drawn up a life cycle assessment in which they analysed the entire life cycle of an adsorption heat pump – from its manufacture right through to its ultimate disposal. On the other, they carried out detailed cost calculations. “With these assessments, we have created a decision-making basis for the future introduction of the systems”, says Peter Burgherr, who headed up the project. “This allows for the advantages and disadvantages of different usage strategies to be identified. It also enables us to compare the systems with other, already established technologies”.

First step: the influence of a single system

The researchers initially determined the environmental impact of a single market-ready heat pump. As a basis, they used the technical features of a new prototype that had been developed by colleagues from the joint project. The PSI researchers extrapolated the prototype to a market-ready system and then examined it according to various criteria, such as CO_2 emissions, energy consumption, the environmental damage caused by the mining of metals – the heat pump is made of steel, aluminium, copper and brass – and the impact on human health, for example due to potential accidents. It was found that the overall environmental impact is very small. For example, there are almost no CO_2 emissions. The greatest damage is caused by the mining of the required metals, followed by electricity used throughout the production chain.

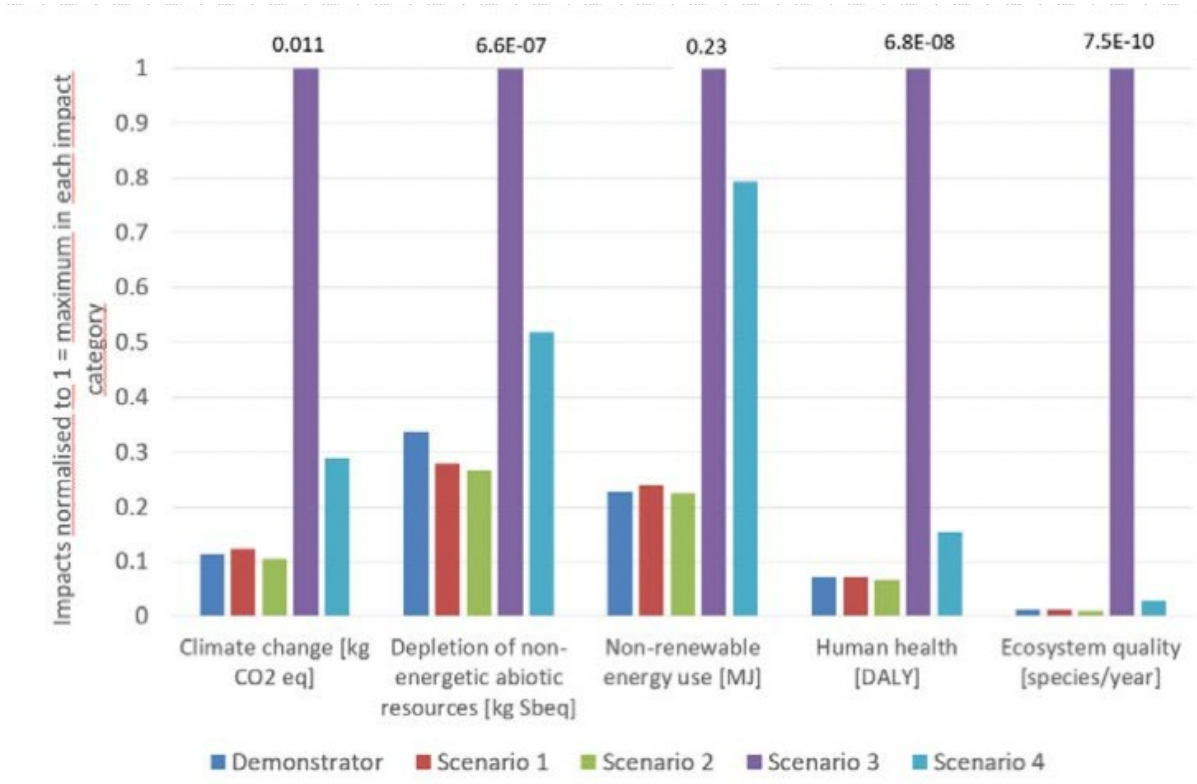
The costs of the energy produced with the adsorption heat pump are also manageable. They amount to around CHF 0.08 per kilowatt hour – provided that the waste heat used is free of charge and does not have to be purchased separately. By comparison: at present, consumers in Switzerland pay between CHF 0.05 and CHF 0.27 per kilowatt hour of electricity depending on their municipality.

In practical use

To expand their assessment to systems for practical use, the PSI research team referred to four specific application scenarios, which were developed in a further separate sub-project:

1. The use of waste heat from industry for heating via district heating pipelines. A central system upgrades waste heat from industrial plants and generates the appropriate temperature for the district heating grid.
2. The distribution of heat for more energy-efficient heating via district heating pipelines. Here, heat pumps connected directly to individual buildings regulate the temperature from the district heating grid to a suitable heating temperature, ensuring that the thermal energy is used efficiently.
3. The adjustment of wood pellet heating systems. Linked to a wood pellet heating facility, the system adapts the heat produced in line with demand: for modern buildings with underfloor heating, it lowers the heating temperature, while it can increase the heat for older buildings with radiators. A scenario that also ensures the more efficient use of heat away from centralised district heating pipelines.
4. The cooling of a computer centre. Like conventional heat pumps, adsorption heat pumps can also work in the opposite direction and cool – using their own waste heat in each case, meaning no additional energy is required.

For each of these scenarios, the PSI researchers now determined the size and output of the corresponding systems. They then extrapolated the previously determined influences onto this output. Result: in terms of environmental impacts, scenarios 3 and 4 perform slightly worse than the first two scenarios. In scenario 3, wood pellet heating is responsible for the significantly higher consumption of non-renewable energies as well as for higher CO2 emissions. In scenario 4, the higher electricity consumption causes slightly higher environmental damage than in scenarios 1 and 2.



The graphic shows the environmental impacts of the adsorption heat pumps in the four considered scenarios: the first two scenarios, in particular, are extremely environmentally friendly, as the heat pump is connected to an existing district heating grid. Burgherr et al. 2018

Best alternative

Overall, however, adsorption heat pumps perform far better than other established heating systems such as natural gas and wood pellet heaters or conventional heat pumps that draw heat from the ground. This was shown by a comprehensive comparative analysis in which the environmental influences and costs of the systems as well as social influences were taken into account – for example, how well the population accepts the technologies.

In this comparison, adsorption heat pumps are by far the most advantageous in all respects – especially when it comes to siphoning off heat from large systems such as factories for the district heating grid, as is the case in scenario 1. However, even with smaller, decentralised systems, such as a heating system for an multi-family home similar to scenario 3, the adsorption heat pump performed equally well or better in all criteria relative to all comparable heating systems.

Finally, the researchers calculated how the Swiss energy landscape would change with the spread of adsorption heat pumps. The calculations reveal significant potential: if only the four scenarios considered in the project were implemented in Switzerland by 2050, CO_2 emissions would fall by around 5 % – depending on the energy landscape, this corresponds to 500,000 to 800,000 tonnes of CO_2 that would not be emitted into the atmosphere.

Produkte aus diesem Projekt

- Poster: Heat utilization with solid sorption technology
  Date of publication: 15.04.15
- Project THRIVE: Heat utilisation with solid sorption technology
  Date of publication: 26.07.15
- Bilderfundus zum Verbundprojekt
  Date of publication: 30.11.-1
- Nutzen statt wegwerfen: “THRIVE” nimmt Abwärme ins Visier
  Date of publication: 22.07.15
- Konferenzpräsentation: K. Treyer (2019) Small adsorption heat pump – big impact in the Swiss energy system: Sustainability assessment. Life Cycle Management (LCM) Conference 2019, Poznan (PL), 02.09.2019.
  Date of publication: 02.09.19
- PSI-Fachwissen stärkt Forschung für die Energiewende
  Date of publication: 05.02.15

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