Energy
National Research Programmes 70 and 71

Project

Heat utilisation with solid sorption technology

Reusing heat offers great potential

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A great deal of thermal energy currently goes unused upon being released into the air, for example the waste heat from factories and computer centres. This energy could be utilised better than has been the case to date – with so-called adsorption heat pumps. As part of a joint project, researchers have now developed new concepts for highly efficient heat pumps and drafted scenarios for their implementation in practice.

The prototype of the newly developed adsorption heat pump. Such systems could in future use waste heat from factories, for example. *Source:* Institut für Solartechnik

At a glance

- The energy for the heating and cooling of buildings and industrial processes still primarily originates from fossil sources or from electricity that has to a large extent been produced using nuclear energy. The better use of waste heat could provide an alternative.
- With this in mind, researchers from IBM Research and the University of Applied Sciences Rapperswil (HSR) have developed an adsorption pump that is much more efficient than existing systems.
- If heat pumps such as these were used in Switzerland in specific heat-utilisation scenarios examined as part of the project, emissions of greenhouse gases would fall by up to 5 %.

Generating heat requires a great deal of energy: half of Switzerland's total energy consumption can be attributed to the heating of our apartments and offices, the production of warm water and the drying or melting of materials as part of industrial processes. This energy still primarily originates from fossil sources. If we look at electricity consumption alone, 40 % is used for the heating and cooling of rooms or materials – around half of this electricity is currently still produced by nuclear power plants.

This has to change in future as Energy Strategy 2050 states that CO_2 emissions should be reduced and nuclear power should disappear as a source of electricity. Bruno Michel, a computer engineer at IBM Research, therefore states that "we need to start using our resources more efficiently". He views heat pumps, which utilise energy from previously unused waste heat, as an option here. Together with his colleagues at IBM Research and the University of Applied Sciences Rapperswil, he has further developed so-called adsorption heat pumps as part of a joint project.

Using heat instead of electricity

Adsorption heat pumps work in a similar manner to the compression heat pumps commonly seen today – with one difference: they require heat for their operation but almost no electricity.

Today, conventional heat pumps can already extract heat from their surroundings at low temperatures as low as minus five degrees Celsius and multiply this. This works as follows: the environmental heat is initially used to evaporate a refrigerant. This is a chemical substance that has a low boiling point and is used in, for example, refrigerators. The steam then enters a compressor that is operated electrically. This compresses the steam, heating it further. The additional heat is finally fed into a heating circuit.

In contrast to this, an adsorption heat pump contains a so-called adsorption heat exchanger instead of a compressor. This is not driven by electricity, but rather by heat. However, the entire process only works from a driving heat of 50 to 60 degrees Celsius. Similar to a compressor, an evaporated refrigerant is fed into the heat exchanger – water is often used here as an environmentally friendly refrigerant. Inside the heat exchanger, the steam is then condensed in a sorption material, which in turn generates heat. The system now requires a little extra thermal energy in order to release the warmer steam once more. As usual, the upgraded heat can then be routed into a heating circuit.

Although this technology would be perfect for capturing and reusing waste heat that has not been utilised to date, for example the waste heat from factories, computer centres and thermal solar systems, it has yet to prevail in practice. Project manager Michel says there are chiefly two reasons for this: firstly, there had until now been no well-thought-out scenarios that showed in which existing heating infrastructures the systems could be best integrated. Secondly, the heat pumps were still relatively inefficient and expensive.

Realistic scenarios

The research work of Michel and his colleagues has now overcome these obstacles. They initially drafted four detailed application scenarios for the future use of heat pumps:

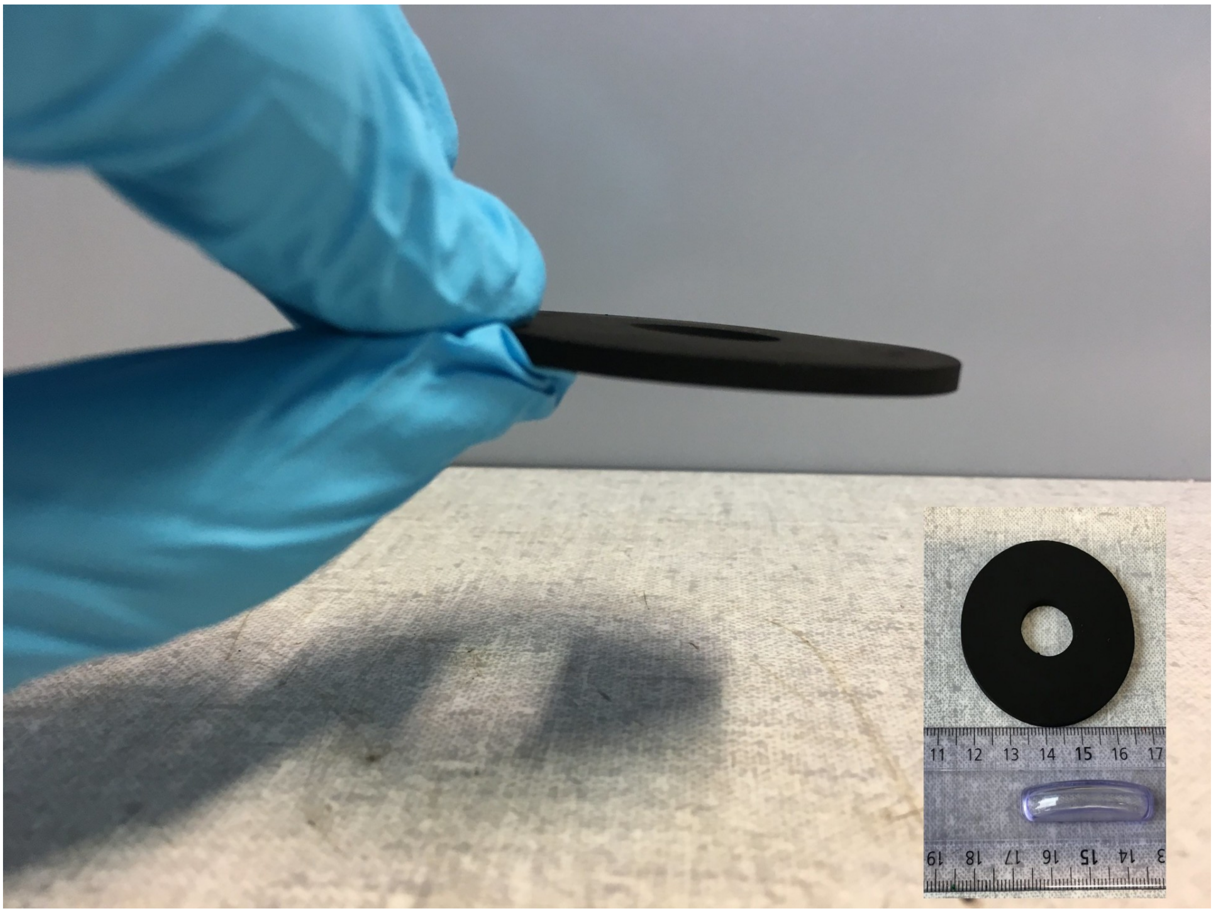
- The use of waste heat from industry for heating via district heating pipelines.
- The transformation and distribution of heat for more energy-efficient heating via district heating pipelines.
- The strengthening of wood pellet heating systems.
- The cooling of a computer centre. This is because just like conventional heat pumps, adsorption heat pumps can also work in the opposite direction for cooling.

The objective for each of these scenarios was to make optimal use of the available heat. The effect: if just these four scenarios were introduced nationwide across Switzerland by 2050, the calculations of the researchers suggest that greenhouse gas emissions would fall by up to 5 %.

On the basis of the scenarios, the researchers subsequently determined which technical requirements the corresponding systems would have to meet. These requirements served as a basis for the further development activities.

Required: great efficiency

Firstly, they began searching for a more efficient sorption material – the heart of an adsorption heat pump. To this end, they tested various production methods for new materials based on carbon. With a so-called sol-gel synthesis, they finally obtained a substance – a so-called carbon monolith – that is both stable over extended periods and also efficient. They adsorb and desorb steam twice as efficiently as the materials used until now.



The newly developed sorption material. Such carbon monoliths condense steam in an adsorption heat pump and thus generate thermal energy. Lukas Huber, Empa

Secondly, the researchers improved the heat transfer within the machine. To do so, they specially developed a new characterisation process with an infrared camera as part of a sub-project. Using this, they identified where and why heat is lost within the system. This allowed them to ascertain that the mircostructure of the sorption material plays a major role. By trying out new structures and conducting successive tests, they developed the optimal structure step by step. Result: the efficiency of the material increased once more by a factor of three.

Visible heat: an infrared camera shows the temperature differences during an adsorption process.
Institut für Solartechnik, HSR

Decision-making aid

Finally, the computer engineers conducted a sustainability and cost analysis in order to determine the environmental impact and the economic viability of their adsorption heat pump over its entire service life. They compared these values with other systems, for example heating systems that are fuelled with wood pellets or natural gas or a conventional heat pump that draws heat from the ground. In doing so, the researchers calculated the environmental impact of each of the different systems as well as their economic and social effects on the basis of various criteria – for example, the emission of greenhouse gases, energy consumption, the costs of the systems and how well the technologies are accepted by the population.

The adsorption heat pump came out best in all respects and especially when it came to siphoning off heat from large plants – for example, factories or solar thermal power stations. However, the adsorption heat pump also fared better than conventional compression heat pumps or wood heating systems in the case of smaller, decentralised systems, such as the heating system of a multi-family home.

The researchers view their results as a decision-making aid for the industrial sector and for funding institutions in the energy sector. “The potential offered by the advanced adsorption heat pump is enormous” is the conclusion of project manager Bruno Michel. The calculations show that if just the four projects examined during the project were implemented in Switzerland by 2040, energy consumption for heating and cooling would decline by up to 9 %. CO_2 emissions would fall by around 5 % – this corresponds to a million tonnes of CO_2 that would not be emitted into the atmosphere.

Produkte aus diesem Projekt

- Adsorption heat pumps for datacenter coolingand study of transport rate limitations in adsorbers
  Date of publication: 01.01.18
- THRIVE: Thermally driven heat pumps for substitution of electricity and fossil fuels
  Date of publication: 01.01.18
- Heat utilization with adsorption heat pumps: Concept & applications
  Date of publication: 01.01.18
- Project THRIVE: Heat utilisation with solid sorption technology
  Date of publication: 01.01.18
- Flickr picture gallery
  Date of publication: 01.01.18
- IBM Research - Zurich project website
  Date of publication: 01.01.18
- Das grosse Potenzial der Abwärme
  Date of publication: 01.01.18
- Neuartige Wärmepumpe nutzt Abwärme effizienter
  Date of publication: 01.01.18
- Nutzen statt wegwerfen – Neues Forschungsprojekt nimmt Abwärme ins Visier
  Date of publication: 01.01.18
- Mit Abwärme betriebene Wärmepumpe bald Wirklichkeit?
  Date of publication: 01.01.18
- IBM Research and industrial partners are working on more cost-effective heating and cooling pumps
  Date of publication: 01.01.18
- Wenn das Rechenzentrum Gebäude heizt und kühlt
- How to stop data centres from gobbling up the world's electricity
  Date of publication: 01.01.18
- Converting heat from data centers into air conditioning for cooling data centres
  Date of publication: 01.01.18
- Addressing Climate Change at a Major Source: Buildings
  Date of publication: 01.01.18
- Datacenters zuiniger dankzij zwarte kool
  Date of publication: 01.01.18
- IBM wants to cool data centers with their own waste heat
  Date of publication: 01.01.18
- Abwärme zum Heizen und Kühlen
  Date of publication: 01.01.18
- Aus warm mach kalt
  Date of publication: 01.01.18
- Wärme statt Strom als Antrieb
  Date of publication: 01.01.18
- Adsorption heat pump principle
  Date of publication: 01.01.18
- Wärme – Rückgewinnung
  Date of publication: 01.01.18
- Sustainable Data Centers and Energy Conversion Technologies
  Date of publication: 01.01.18
- Wärmerückgewinnung – Nutzen statt wegwerfen!
  Date of publication: 01.01.18
- Wenn das Rechenzentrum Gebäude heizt und kühlt
  Date of publication: 07.09.15
- Abwärme zum Heizen und Kühlen
  Date of publication: 28.07.15

Date of publication: 01.01.18

- Adsorptionswärme soll Industrie kühlen
  Date of publication: 01.01.18
- Waste Heat: Innovators Turn to an Overlooked Renewable Resource
  Date of publication: 01.01.18
- Đánh thức nguồn năng lượng từ nhiệt thải
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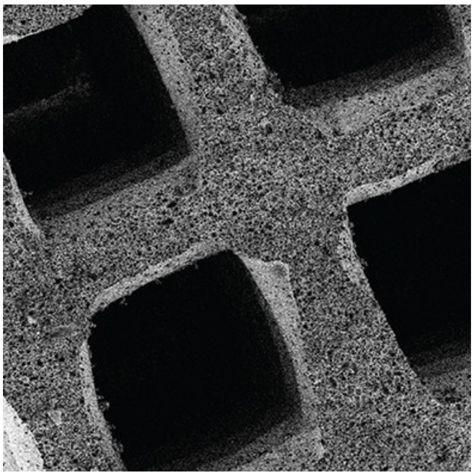
Connected projects

Materials for adsorption heat pumps

A new material uses waste heat more efficiently



Materials for adsorber heat exchangers

From the 3D printer: more efficient materials for adsorption heat pumps

Compact adsorption heat pumps

A new type of heat pump helps to use heat more efficiently

Pilot of adsorption heat pump

Where waste heat can be better utilised

Sustainability of adsorption heat pumps

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

All information provided on these pages corresponds to the status of knowledge as of 05.06.2019.