

The heat is on

An innovative project aims to develop groundbreaking materials for efficient, long-term thermochemical storage. Here, project coordinator **Professor Dr Nataša Zabukovec Logar** and investigator **Dr Alenka Ristić** explain the principles underlying this technology and how it could revolutionise future heat storage options



For those who are unfamiliar, can you define the concept of long-term heat storage?

AR: Long-term heat storage systems can store heat for at least a few months. In solar-based storage systems, long-term storage refers to seasonal storage, which means that we can store summer heat for use during winter. There are currently no efficient long-term storage systems available. To date, thermochemical storage (TCS) is considered the only storage concept with the potential for long-term, seasonal, low-temperature (up to 150 °C) thermal energy storage with high enough energy density.

Could you outline how the properties of a material affect its heat storage capabilities?

AR: Adsorbents for the long-term, large-scale utilisation of TCS heat storage systems need to fulfil three basic criteria. The first is high storage density, which is defined by the water sorption capacity of the materials and heats of adsorption. The long-term aim is to arrive at thermal storage systems that are eight times more compact than a thermal storage system using water. Second, the charging temperature of the material (drying) should be below 150 °C. Finally, adsorbents should have good thermal and chemical stability under operating conditions to enable efficient storage for many years.

With the potential of new materials to provide a 'lossless' storage option, does

inefficiency pose a significant problem in existing systems? What proportion of generated energy is currently lost?

NZL: Inefficiency, in terms of the amount of stored heat, is not the main problem for existing hot water tanks. Instead, it is heat losses over relatively short periods of time. The current state-of-the-art alternative is the 'active solar house', where a large array of solar thermal collectors (30-70 m²) is combined with large water stores (5-20 m³). Together with rigorous insulation and optimisation of passive solar gains, solar fractions of over 50 per cent are reached in final energy demand. However, high costs are associated with the construction of the system, including significant costs for the collector field and the large pressurised water tanks.

Will the results of your research be applicable on a worldwide scale?

NZL: Space heating and hot water preparation represent up to 80 per cent of the final energy demand in residential and service sectors. In general, heating and cooling account for half of the final energy demand in the EU. Therefore, there is huge interest in TCS research. The applicability of the newly developed materials to other heat transformation applications, including adsorptive heat pumping, cogeneration/waste heat utilisation and space cooling, further broadens the pertinence of our results, since there is a significant overlap in the material requirements.

What does the implementation of long-term heat storage technologies mean for the future of energy production and the shift toward more renewable options?

NZL: An important part of the International Energy Agency's programme

involves collaboration in R&D, and the demonstration of new energy technologies to reduce excessive reliance on imported oil. By 2025, the Solar Heating and Cooling (SHC) Programme envisages that solar thermal technologies will provide 10-15 per cent of the total energy demand in OECD countries. For Europe, the goal is even more optimistic, with the Joint Declaration for a European Directive to Promote Renewable Heating and Cooling calling for 25 per cent of EU heating and cooling to be supplied by renewables in 2020.

Any improvement to the performance, lifetime or costs of thermal storage will positively affect every renewable heating system, globally. Additionally, thermal storage is used in many nonrenewable heating technologies, such as electrical boilers. Improvement in the performance, lifetime or costs of thermal storage will also positively affect these systems. So, in addition to increasing the amount of renewable energy production, advanced thermal storage will also contribute to a decrease in fossil fuel consumption.

Will you be attending any forthcoming events, conferences or workshops? If so, in what capacity will you be contributing?

NZL: Members of our group regularly attend conferences on porous materials research; upcoming are the International Zeolite Conference, Moscow in July, and a symposium on Advanced Microporous and Mesoporous Materials, in Varna in September. We will also contribute at conferences about thermal energy storage (EcoMaTech, Bled in September, IEA SHC Task 42 29 meeting, Ljubljana in October), mainly presenting state-of-the-art research concerning materials investigation.

Engineering efficiency

Many heat storage systems are plagued by a combination of low storage densities and high heat losses. There are currently no efficient long-term storage systems available on the market. However, the **STOREHEAT** project's development of an energy and economically efficient storage system is set to change this situation

THE EXISTENCE OF global climate change is rarely now a topic of serious debate. Endeavours to slow the process have been long in the making, and the reduction of greenhouse gas emissions has been a serious ambition of many international governmental bodies for a number of years. Yet central to this worldwide dilemma is the inconvenient fact that few countries wish or can afford to make the necessary sacrifices. Fossil-fuelled technologies are so engrained into functioning societies that their eradication and replacement is far easier said than done. Therefore, as well as developing alternative energy resources, also fundamental to the reduction of harmful emissions is the creation of a more efficient means of energy usage. Heat storage systems are one example in which significant advances could bear extremely positive outcomes for tackling climate change.

THE STATE OF PLAY

Many existing heat storage systems are characterised by the inefficient pairing of low storage densities and high heat losses. Even in cases in which renewable energy is used, there is a very real need to mend the disparity between heat availability and heat delivery. In recent years, the drive for heat storage innovation has been characterised by trial and error; though heat storage in the form of 'sensible heat' is a widely studied area and is at an advanced stage of development, there are still flaws.

One example – seasonal heat storage – involves the use of large-scale (thousands of cubic metres) tank or pit storage systems for district heating, in which heat is stored in the form of water, or water mixed with gravel. Although showing great potential, this novel approach comes with severe heat loss and water leakage. Furthermore, such storage technology has to be inconveniently large in order to limit the total heat loss per unit volume.

Another novel concept is latent heat storage (LHS), which uses the heat of liquefaction of phase-change materials (PCM) – such as salt hydrates, fatty acids and paraffins – for storage. However, PCM systems are still inferior to hot water tanks, even with twice the energy density, because of their expense and associated considerable heat loss over time.

STOREHEAT

Currently providing some solutions to these problems is the STOREHEAT project. Focusing upon thermochemical storage (TCS) systems, the project hopes to improve the effectiveness of thermal storage. Developing heat storage systems that utilise reversible physical-chemical sorption phenomena (mostly water adsorption on solid sorbents) to store energy, STOREHEAT's current aim is to improve the effectiveness of energy conversion and utilisation technologies, by developing new materials for a 'lossless' storage option. Although this innovation could

go physically unnoticed by the masses, its impact on the amount of renewable energy consumed in a home, a town or even a country could be huge.

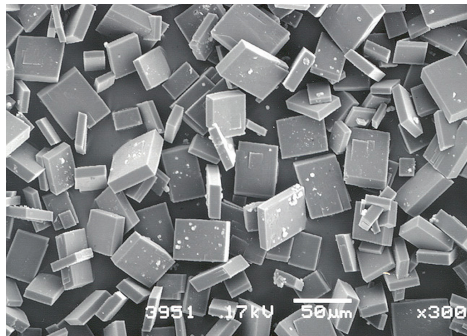
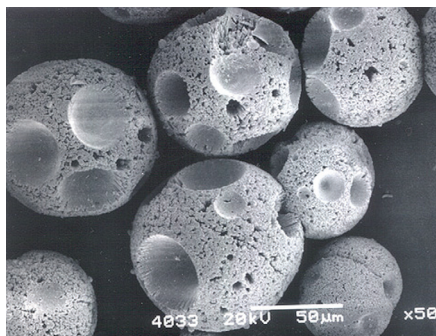
NEW HEAT STORAGE MATERIALS

In essence, STOREHEAT develops new materials for long-term thermal energy storage. The current emphasis is on a form of so-called low-temperature heat storage: solar energy storage. This technology is relevant to systems for space heating, cooling and domestic hot water. The storage principle upon which the research is based relies upon the fact that heat supply effects an endothermic phenomenon, in which water is desorbed from the material that is then stored separately. In turn, this promotes an exothermic reaction when water vapour and sorbent are put into contact, creating heat release. The proposed storage materials are hydrophilic porous adsorbents and composites, which contain porous matrices with salt hydrates.

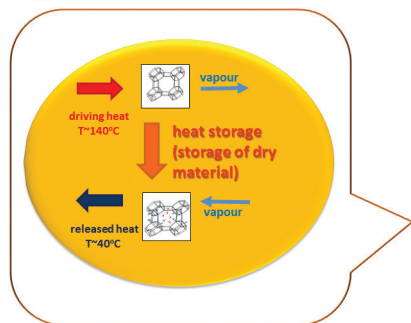
The researchers have taken a two-pronged approach: first, they will focus upon the design and synthesis of new, innovative materials which can be optimised for long-term storage; and second, they will investigate the scaling up of such materials' fabrication for further commercialisation and testing in storage systems.

VIABLE APPROACH

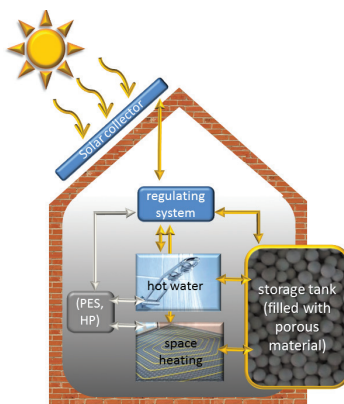
Refreshingly, the STOREHEAT team is also realistic in the scope and future of its plans. Not only is their developing technology energy efficient, it is also economically viable. With affordable fabrication in mind, the researchers concentrate on low-cost reactants and quick syntheses at moderate temperatures. It is hoped that such research will soon provide European industry with new materials for heat storage systems that are at least four times more efficient than hot water tanks. The new systems are safe and non-toxic, and boast reduced storage volumes with substantially decreased storage losses at low-to-moderate costs. Amazingly, such storage systems are



Crystallites of porous aluminophosphate materials, which have proved very suitable as heat storage materials. **Left:** aluminophosphate with a one-dimensional pore system denoted FeAPO-36. **Right:** FeAPO-TRIC.



Left: schematic representation of a heat storage system. **Right:** schematic representation of the integration of the storage system in a house.



also capable of gaining up to 70 per cent of renewable solar thermal energy and could also increase the efficiency of a number of existing heating and cooling technologies.

A DIFFICULT PROBLEM

The materials created as part of the STOREHEAT project are being advanced via a rigorous process of R&D. When developing and refining such materials, the team must take into account a wealth of properties. For example, structural and sorption properties are particularly important; the applicability of any new material is determined by the basic structure characterisation of the synthesised product. Furthermore, detailed characterisations of the active sites of selected materials are necessary, and require the employment of complex techniques, like NMR spectroscopy, analysis of texture properties and analysis of mechanical stability. Finally, a characterisation of the products' potential heat storage applications is undertaken, using breakthrough curves for temperature and humidity, kinetics studies, calculations of the differential heat of adsorption, modelling of the complete storage cycle and calculations of storage efficiency. Also taken into account is the potential for cost-effective production methods to be implemented capable of industrial-level production. This nebulous array of factors that require consideration offers an insight into the complexity of the team's R&D programme.

One essential breakthrough which is necessary for the commercialisation of the TCS storage concept under development is materials optimisation. This will involve the precise design and engineering of new sorbents with well controlled chemical composition and structural features. To succeed in this aim, the STOREHEAT team plans to employ a multidisciplinary approach, using experts in the areas of inorganic and organic synthesis, structure determination, adsorption, mass and heat transfer, numerical modelling of sorption phenomena, scaling-up of materials production and storage system engineering. The project's success relies

upon strong collaborations, involving a wide spectrum of expertise.

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FUTURE AMBITIONS

Undoubtedly, STOREHEAT has already achieved remarkable things, but their work is far from complete. The team will continue to refine the knowledge and technology it has already accrued, developing new porous materials with appropriate chemical composition and pore sizes for optimal storage systems. Additionally, the project will begin further R&D on composites with porous materials. This phase of development will involve using additives to enhance heat transfer, such as post-synthesis deposition of sorbents on various advanced support structures like silicas, clays and metals.

Next, the researchers will transpose these findings into a more practical incarnation. The researchers plan to develop, evaluate and demonstrate a system based on seasonal thermal energy storage for the space heating and domestic hot water requirements of a single-family home. This enormous research leap is contingent upon further funding, and the project coordinators are currently looking for potential industrial partners. However, if funding and partners can be found, it could truly revolutionise domestic heat storage systems, and the way in which we consider energy efficiency.

INTELLIGENCE

ADVANCED MATERIALS FOR THERMAL ENERGY STORAGE

OBJECTIVES

- To design and develop new innovative materials optimised for sorption-based long-term storage of solar or waste heat
- To scale up these materials' fabrication for further commercialisation, which is expected to have an important impact on renewable heat markets and on the efficiency of existing heating/cooling technologies

PARTNERS

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KEY COLLABORATORS

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