

## Welcome

Welcome to the second issue of **MESSIB News**, a newsletter for all interested in energy storage technologies.

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### MESSIB ... at a glance

- four-year EU project, begun in January 2009
- pan-European consortium
- drawn from 9 EU countries
- eleven work packages
- MESSIB run under FP7 program
- influences EU member country policies
- see [www.messib.eu](http://www.messib.eu)



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## Leadership in technological innovation

*Technological innovation will be pivotal for Europe to achieve its 20-20-20 climate action targets and for Europe to complete its 2020 Agenda for smart, sustainable and inclusive growth.*

*Innovation will be needed to develop efficient technologies and low carbon technologies (renewable energy, **energy storage**, energy efficiency including digital technologies, CCS, and research on new generation nuclear production and safe disposal of nuclear waste).*

*The level of public and private spending on research and development in energy technology innovation must be drastically increased.*

Source: **Stock taking document**  
Towards a new Energy Strategy for Europe 2011-2020  
page 14

[http://ec.europa.eu/energy/strategies/consultations/doc/2010\\_07\\_02/2010\\_07\\_02\\_energy\\_strategy.pdf](http://ec.europa.eu/energy/strategies/consultations/doc/2010_07_02/2010_07_02_energy_strategy.pdf)

Overview and progress report:

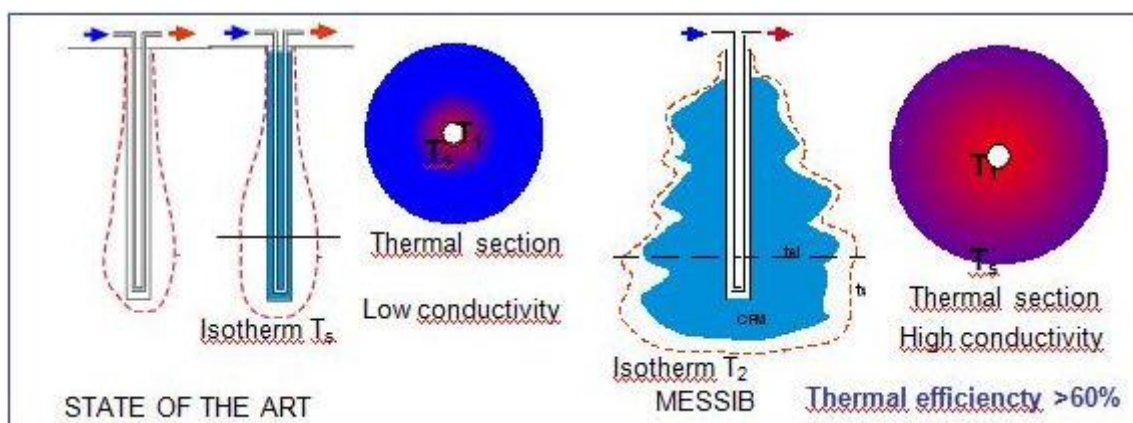
WP2

## “Thermal energy Storage technologies for buildings: PCMs and Ground Storage.”

WP 2 LEADER: FHG

The overall objective is to design, develop, evaluate and manufacture a new Thermal Energy Storage System based on PCMs and ground storage, taking into account life cycle, safety and energy efficiency.

- To develop suitable energy storage materials in the form of micro-encapsulated and polymeric hydrate PCMs and Fluids (slurries) containing PCMs (PCS).
- To integrate these PCM developments in a building's envelope, floor, ceiling and walls.
- To develop and evaluate of new PCM activated gypsum-boards systems with slurry throughcirculation to improve energy storage efficiency
- To develop simulation software tools to facilitate and evaluate system design and integration at building level.
- To develop an advanced Thermal Ground Storage System based on new concepts such as heat exchange and new materials for piping. Its combination with phase change and radiant heating and cooling systems will improve the overall energy performance of the building.
- To optimize the manufacturing processes for cost reduction.



## Phase Change Slurries

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Phase Change Slurries (PCS) are mixtures of a Phase Change Material (PCM) and a carrier fluid. As PCM we use paraffin as it is insoluble with water which is used as carrier fluid. The target of this development is to increase the heat capacity of water within the melting range of the PCM. In the MESSIB project we use paraffin as PCM which melts between 10 and 17°C. So this PCS can be used as heat transfer and storage fluid for cooling application e.g. a chilled ceiling system e.g. with a cold storage buffer in the cellar and the chilled ceiling in offices. In the given temperature range we reach a storage capacity which is two time higher than that of pure water.

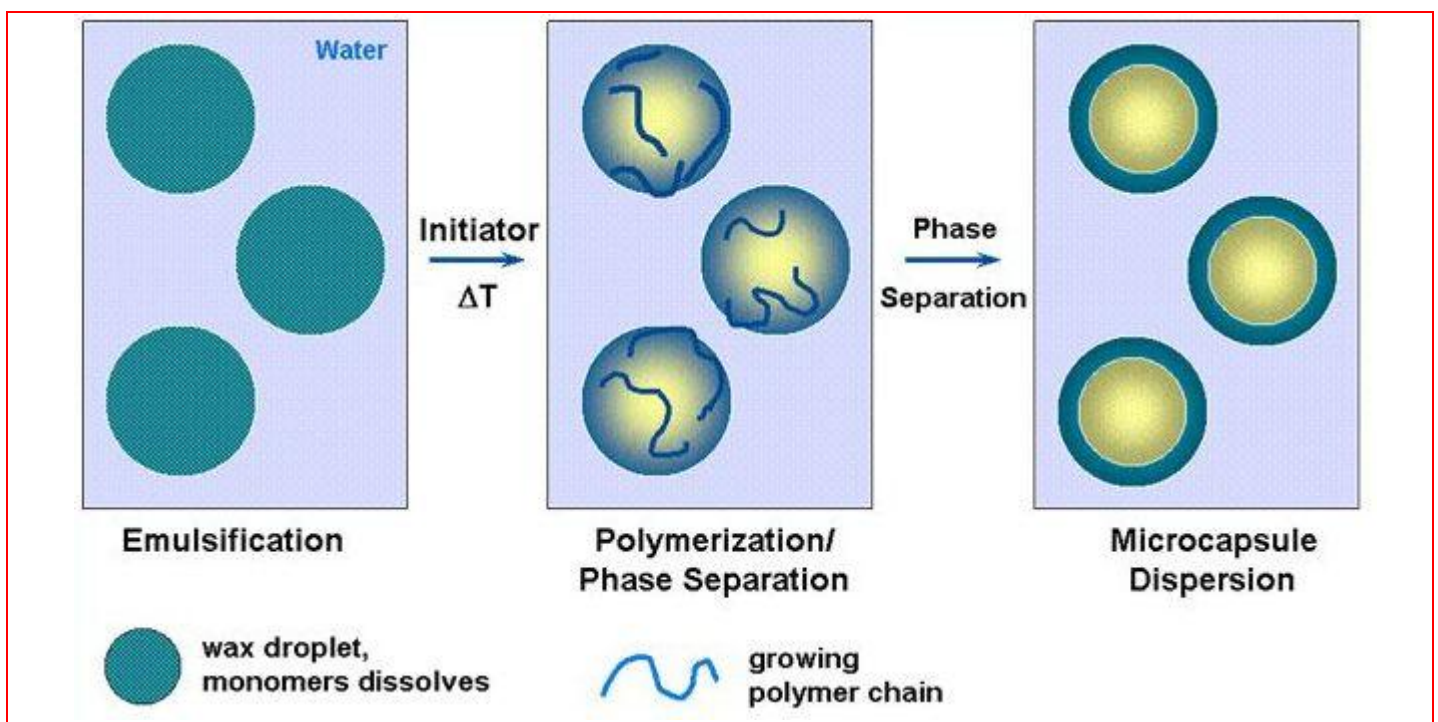


Image 1: Production of Phase Change Slurries (PCS) as it is done by BASF

The PCM is emulsified in water then the polymerization of the shell is started by an initiator. The shell is built at the surface between the paraffin droplets and the water. The slurry contains 30 wt.-% of these encapsulated paraffin and additives to prevent separation.

The slurry was characterized and tested at Fraunhofer ISE. The PCS appears as white fluid which shows a viscosity in the ranges between 40 and 80 mPas and a heat capacity of 60 kJ/kgK when operated between 10 and 17°C. The slurry shows a very good stability when applied to hydraulic cycles. It was tested to withstand 20000 cycles in a testrig containing flat plate heat exchangers and centrifugal pumps.

## Microencapsulation of salt hydrates

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Compared to paraffin salt and salt hydrates show a much higher volumetric heat capacity, they are non-flammable and therefore they are well suited to be applied to buildings. But as they are hydrophilic and contain a very well defined water fraction (salt hydrates) the requirements to the shell is much higher as for shells used to encapsulate paraffin or other organic materials.

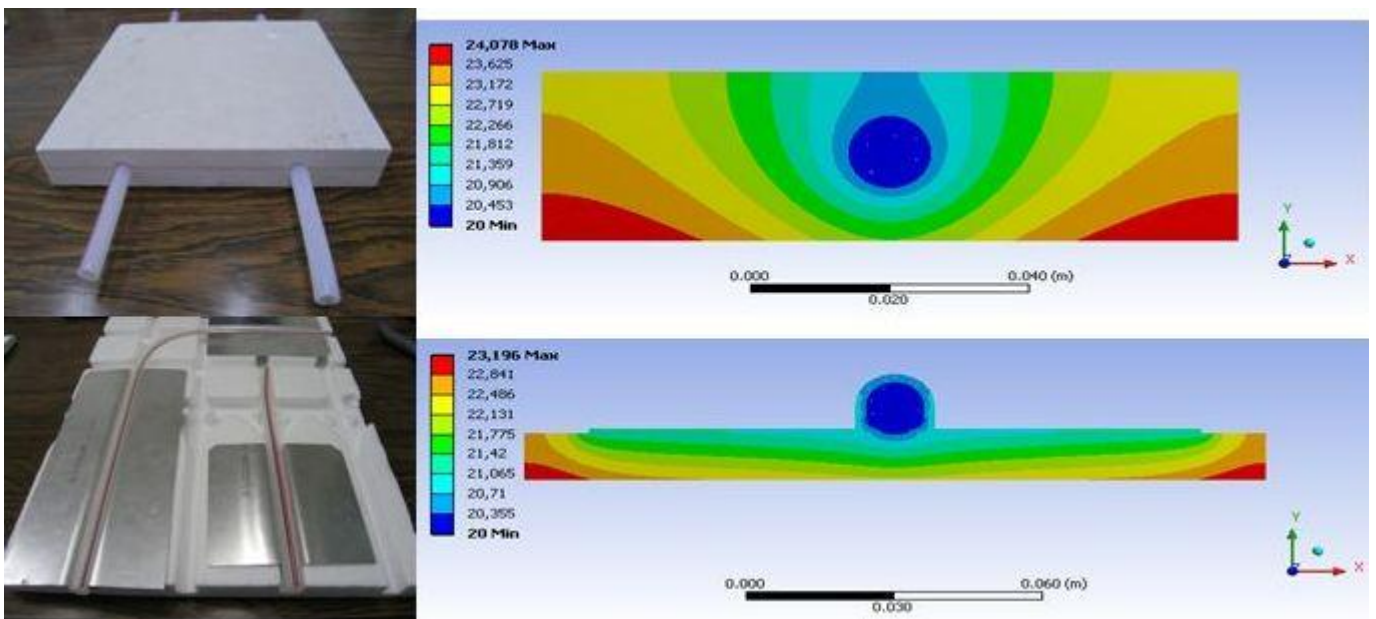


Different groups of the MESSIB consortium developing the microencapsulation of salts and salt-hydrates. The picture above shows one example of Fraunhofer ISC. Here a salt hydrate is dropped in to a solution of ORMOCER® which builds a shell around the PCM. The SEM images show examples of encapsulated salt hydrate. So far the encapsulation of salt hydrate was successfully done but the shells are not water tight and stable enough to be applied to construction materials like plasters or to mix them into water.

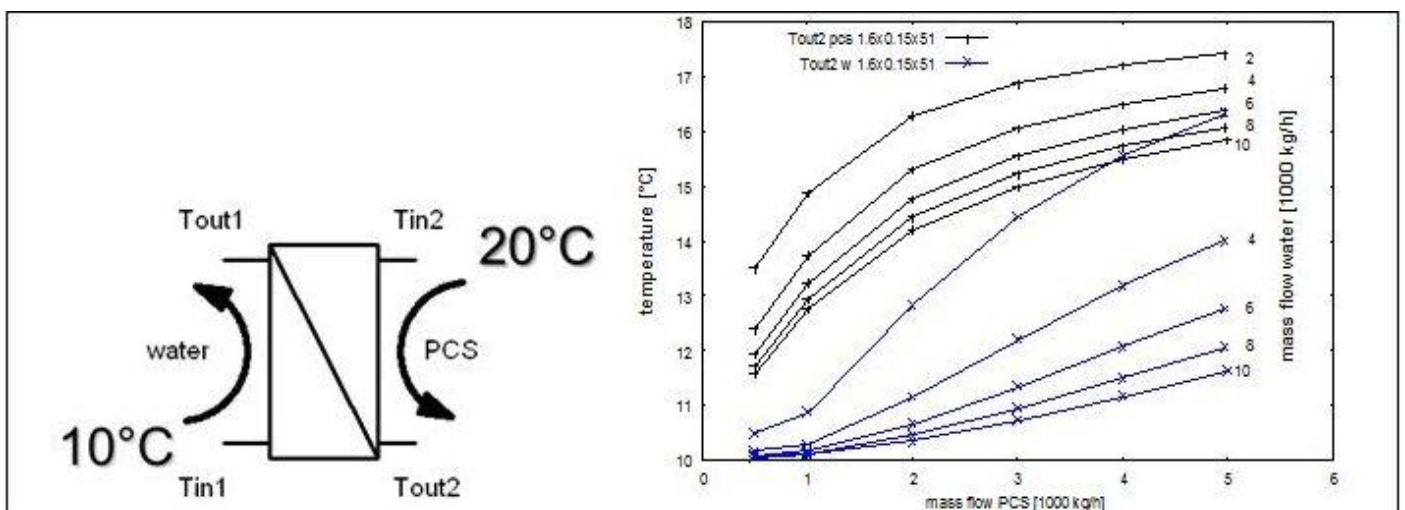
# Simulation of PCM-construction materials, phase change slurries and ground storages

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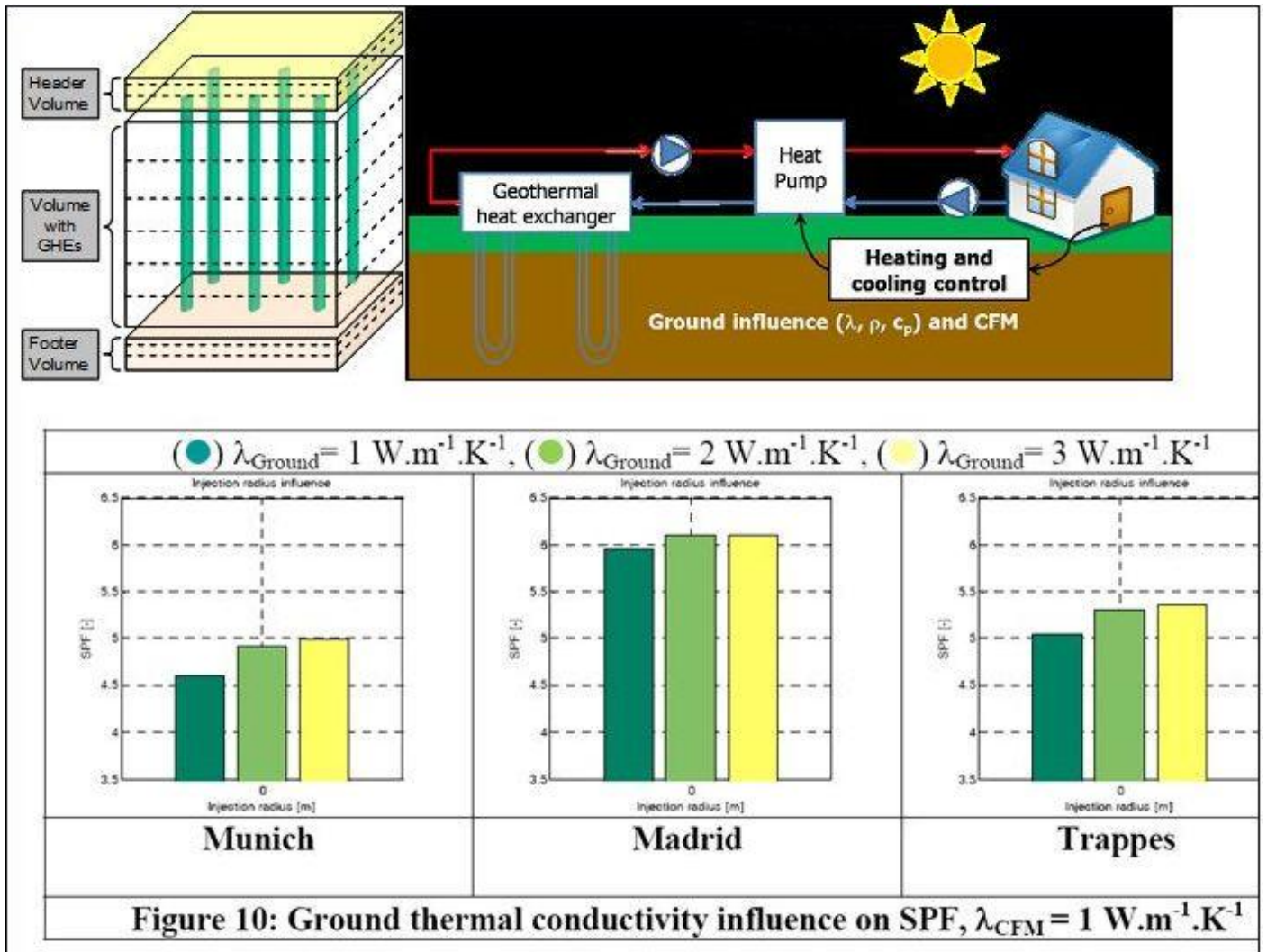
Different simulation models were developed to evaluate the effects of PCM when applied to different applications. The image below shows one example of this simulation for a chilled ceiling with different placement of the pipes.



Simulation using HETRAN for two designs of a chilled ceiling system done by partner NTUA. The result shows that a thick layer of plaster board can not sufficiently cooled by the pipe placed in the center.



If using a PCS heat exchangers are necessary to charge or discharge the slurry. The graph above shows one example of a simulation that was done at Fraunhofer ISE to compare a flat plate heat exchanger when operated water or a PCS. It can be seen, that when the heat exchanger is operated using water on the PCS side the temperature is deeper ( $T_{out2}$ ) then with PCS. This is due to the higher viscosity of PCS. As a result the heat exchangers have to be designed with a larger exchange area.



Simulation of ground storages processed by CSTB. The graph shows a comparison of different thermal conductivities of the ground for different locations and the impact on the seasonal performance factor SPF.

## Advances in ground storage

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Ground Storage is considered a powerful solution for supplying thermal energy for H&C of buildings. MESSIB Project has tackled the development of this technology in order to enhance the current status of the technology and integrate those systems into buildings together with other energy solutions considered in the project. Ground Storage can mainly supply thermal energy to be used for H&C of the buildings and SHW covering the energy demand of buildings by means of extract or inject heat in the ground. The behaviour of the ground in those systems is considered as a thermal reservoir, and, subsequently the thermal characteristics of the ground will determine the efficiency of the geothermal systems.

### **MESSIB project has been focused on different aspects to assure the enhancement of the ground storage:**

1. Design and development of new methods for measuring the soil conditions in order to facilitate the understanding of the ground as a thermal reservoir. The temperature conditions of the ground and the thermal conductivity determinate the heat transfer from the heat exchangers to the ground and vice versa. Those parameters are usually inferred from thermal response tests but can be completed using the techniques developed within MESSIB Framework using temperature sensors and measuring the thermal conductivity of the different lithologies using the cores and cuttings extracted during the drilling stage.
2. Optimization of the ground for thermal storage purposes by means of inject inert mineral materials which could enhance the thermal conductivity of the grounds. The development of those materials has been obtained within the development of the project and the thermal conductivity of the grounds has been increased from average values of 2 to 4 w/mK. The enhancement produces a better transfer of the heat from the exchangers to the ground. It also permits to increase the effective area of heat transfer with a positive repercussion on the efficiency of the installation. The efficacy of the actuation will be tested and demonstrated in a pilot plant which will be placed at Paterna (Spain).
3. Development of new enhanced pipelines systems to increase the performance of the geothermal systems. This system will permit a better exchange process between the exchangers and the ground.

## BTES (Borehole Thermal Energy Storage)

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Ground Energy Storage can be implemented in different ways depending on the ground conditions. If there is a natural ground water flow so called Aquifer Thermal Energy Storage can be implemented. However mostly the ground conditions is not suitable for ATES and so called BTES (Borehole Thermal Energy Storage) is the only viable way to go when a ground energy storage is going to be implemented. Already during the oil crises during the 70's different projects started to investigate the possibilities to realize seasonal energy as storage for solar energy. In Sweden some projects ended up with some promising results but when the oil crises ceased the interest disappeared. Later on during the 80's and the 90's ground couple heat pump emerged as an attractive technology in Sweden because electricity prices was pretty low and oil and other heating technology started to be expensive again. However, ground couple heat pump only makes use of the natural ground temperature and upgrade the temperature to desired temperature with the compressor. In some big installation several ground heat exchangers are used and the heat waves from the different boreholes start to interfere with each other, which is preconditions when implementing a BTES if we are going to increase temperature in the ground above the natural temperature. However, when configure many different borehole together with a certain distance between the bore hole it is necessary to charge and discharge the ground with the same amount of heat, otherwise the ground temperature will change during the coming years. The ultimate installation requires the same amount of heat during winter and cool during the summer, that is, a so-called balanced BTES. There are reports of such a BTES but very little real seasonal energy storage has been implemented despite many people call some big installation as BTES even if they only use the ground as a heat source or heat sink (for cooling).

It seems there is a lack of knowhow regarding BTES in the commercial community but also in the academic world. UPONOR has studied the old reports from the 70's and according to these reports there is a need for an improved GHEX (Ground Heat Exchanger) to really exploit the potential to use the ground as a seasonal BTES. Uponor has developed one ground heat exchanger called G12 based on this research report results. The G12 has been installed in two bore holes during the summer 2010 and measured by fiber optics along the length of the G12 to get temperature profile along the vertical bore hole. The results are all found to be in line with theoretical assumptions and have been presented in scientific papers as;

- Acuna et al, 2011. Distributed Temperature Measurements on a Multi-pipe Coaxial Borehole Heat Exchanger. 10<sup>th</sup> IEA Heat Pump Conference. Tokyo, Japan.
- Acuna et al, 2011. First Experiences with Coaxial Borehole Heat Exchangers. IIR Conf. on Sources/Sinks alternative to the outside Air for HPs and AC techniques. April 5<sup>th</sup>-7<sup>th</sup>. Padua, Italy.

The G12 offers higher heat transfer per length compared to conventional U-loop. The performance is about 80-100 % better than U-loops depending on operation conditions. With the characteristics that G12 offer it is expected to obtain seasonal ground energy storage with lower heat losses and hence, make it more efficient to store heat from summer to winter. If there is no need for space cooling during

summer the BTES has to be charged with other green energy. Such a green energy can be solar energy from cheap low temperature solar collectors. It might even be interesting to store surplus electricity as low grade heat in the ground. Normally it must be considered as waste to store high Exergy (quality) energy as electricity as low grade (20-40 C) thermal energy. However, the more the intermittent renewables are introduced into the large electric grid the more periods of surplus electricity that cannot be utilized immediately. For instance a wind power unit can produce electricity during summer when there is no need for the produced electricity. The electricity can be stored in electric batteries for later use but electric batteries have a limited life time and have to be replaced, which implies high capital cost. The surplus wind electricity can also be charged in hot water accumulators for shorter periods. But if neither one of the alternatives with electric batteries or the hot water accumulator is not a viable choice it could be justified to charge a BTES with surplus electricity rather than loose it away, even if it means conversion from electricity to low grade heat.

## WP3

### “Electrical energy Storage Technologies for Buildings: Flywheels and Batteries.”

WP 3 LEADER: ZIGOR

The overall objective is to design, develop, evaluate and manufacture a new Electrical Energy Storage System composed by:

- A new lightweight and high strength orthotropic composite wheel for FW system in buildings with improved kinetically storage capabilities and electrical performance
- An improved and compact VRB in buildings for long term electrical storage.
  - To design the Flywheel system.
  - To design the manufacturing process on nano-composite wheel.
  - To design and test the electronic part of the flywheel.
  - Complete flywheel development.
  - To manufacture the Flywheel
  - To select materials (membranes, electrodes and flowfields) for VRB cell components.
  - To design single cell vanadium redox-flow system to demonstrate its functionality.
  - To compare of the redox flow system with a commercial battery at lab scale
  - Development of simulation model for the prototyping of flywheels and control strategies for the VRB

## Redox flow batteries

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### Introduction

Redox flow batteries are excellently suited for intermediate storing of electricity in hybrid PV and wind mini-grids and grid connected applications like in buildings. With their advantageous properties, they present a promising alternative to conventional battery-based storage units or also hydrogen storage via combined electrolyser and fuel cells. Particularly the so-called all-vanadium redox flow battery (VRFB) features essential advantages compared to conventional electric storage units: Separation of the conversion and storage units, high electric efficiency, good cycling stability and thus long lifetime, and no degradation effects in the electrolyte arising from cross-contamination via the membrane.

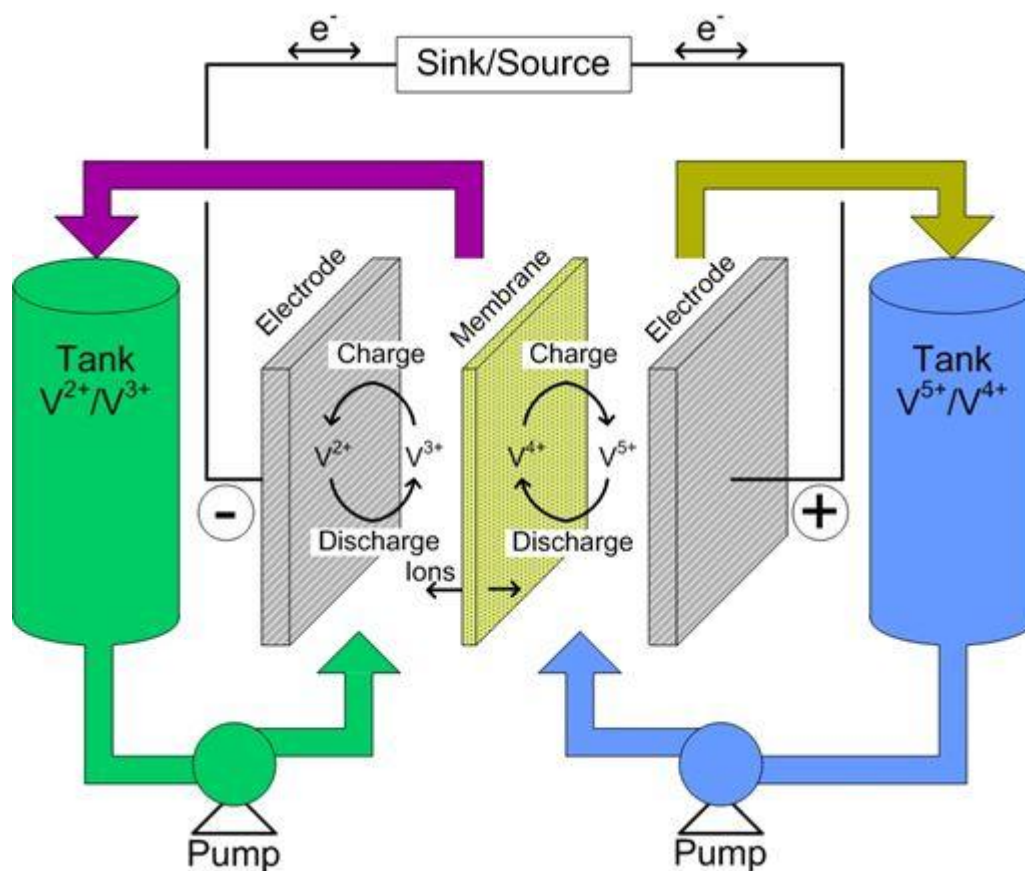


Image 1: Principle of a vanadium redox flow battery

Within the European project MESSIB, potential of the all-vanadium redox flow battery is investigated, starting from system concepts for different applications, cell and stack design, fluid simulations, component development and construction, development and implementation of optimised operating control strategies within a "smart redox flow control", stack and system characterisation as well as simulation of these storage units. The final result will be the installation in the "solarhaus" in Freiburg to show the advantages of the MESS technology.

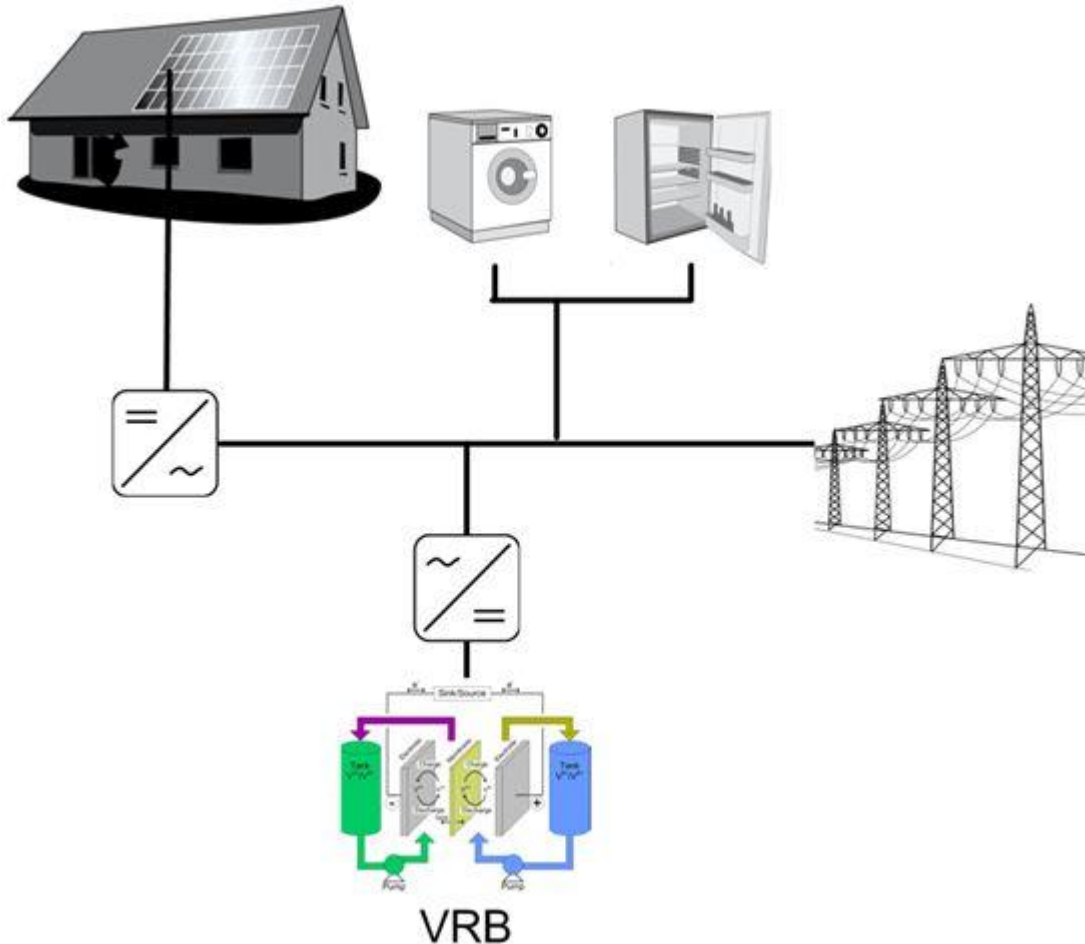


Image 2: Overview of the system integration into „solarhaus“ in Freiburg

### System and stack design

The redox flow battery is very interdisciplinary battery technology. This is because the power and the storage are decoupled and it is a flow battery the system. Which means it is a mixture of system engineering, the construction of the stack and electrochemical engineering for the materials. On the top the battery has to be connected to a grid or a sink and source.

To understand the behaviour of the redox flow system with a stack thirst a single cell was constructed and tested. Out of these results a small stack (5 cells 250cm<sup>2</sup>) was build up to learn more about the stack and system behaviour. This system was tested in a test site at the Fraunhofer. The test side was special manufactured for the stack and several measuring values were measured, like the pressure drop, temperature, state of charge, single cell voltage, stack voltage, stack current and pump consumption. An analysis of the influence of the flow rate to energy efficiency of the stack was carried out. Defined cycles were driven to analyse the interrelationship from the stack voltage to the state of charge and the current density. The energy efficiency was analysed according to the current density.

With the results and experience of the small stack a system design was made for a 1 kW 6 kWh redox flow system, which is the redox flow system for the “solarhaus” in Freiburg (WP6). The system was layout to the required power of the stack and the capacity of 6 kWh of the system.

This means the electrolyte volume was adjusted. Also the geometric design of the stack was analysed considering that it would connect to the AC Grid with a standard inverter. The pumps were selected in terms of the maximal flow rate and the ability to control the flow rate of the electrolyte. The SoC range was adjusted through the higher energy efficiency and the flow rate of the pumps.

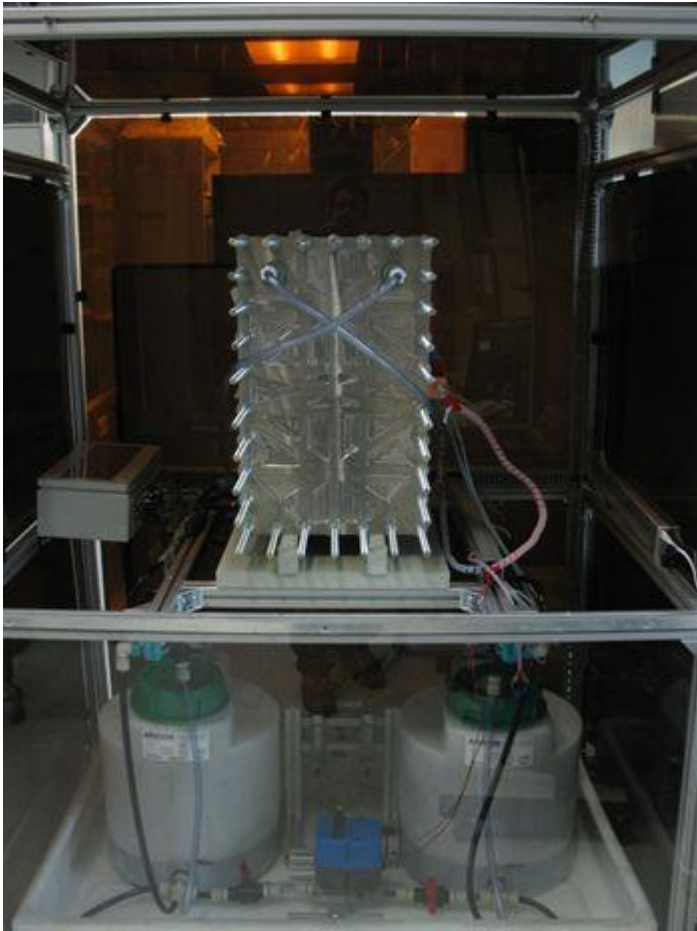


Image 1: 1 kW - 6 kWh redox flow battery

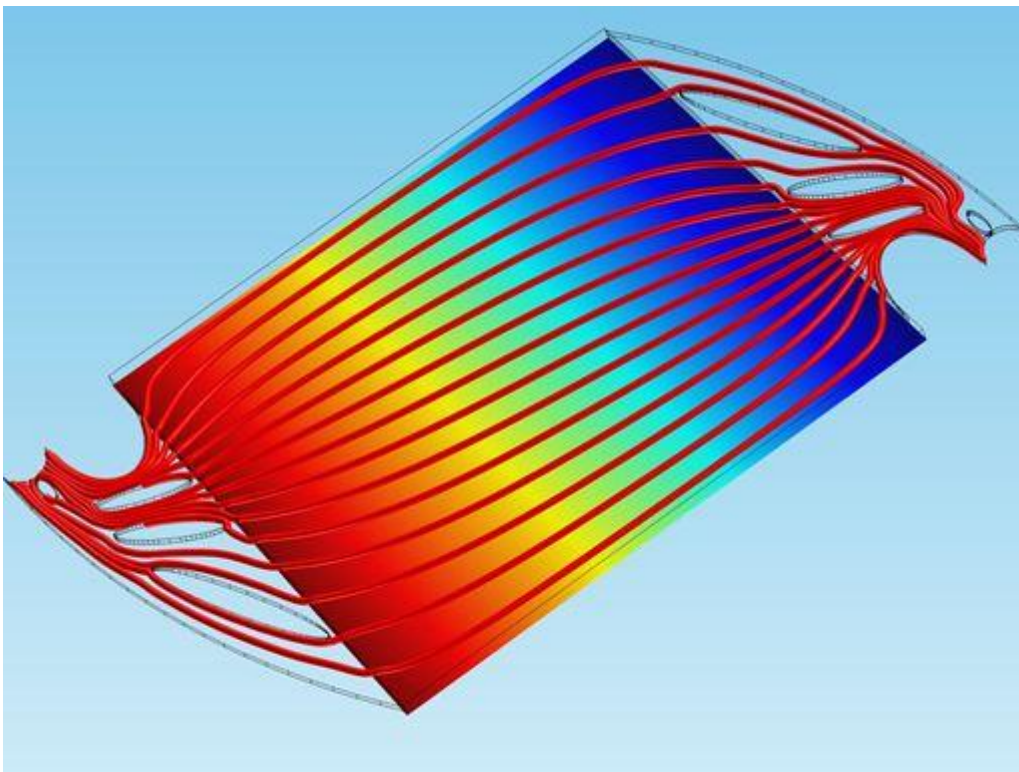


Image 2: Computational Fluid Dynamics simulation of a single cell.

## Simulation Model and operation strategies

The redox flow battery is a quiet complex storage technology which consists of the core component stack, the periphery and the inverter for grid connection. Because of the interconnection of these different technical fields a system model is essential to understand the characteristics and the operation behavior.

In the modeling language modelica the model was developed. Modelica was chosen because it is a suitable language for chemical, electrochemical, electric and fluid dynamic modeling. An advantage is that modelica is an object oriented modeling language. Every component of the battery was modeled separately and connects to each other to build up a system model. So it is easily possible to create different setups of the battery, like 2 Stacks instead of one. Although a parameter variation is quite easy and allows understanding characteristics of the battery.

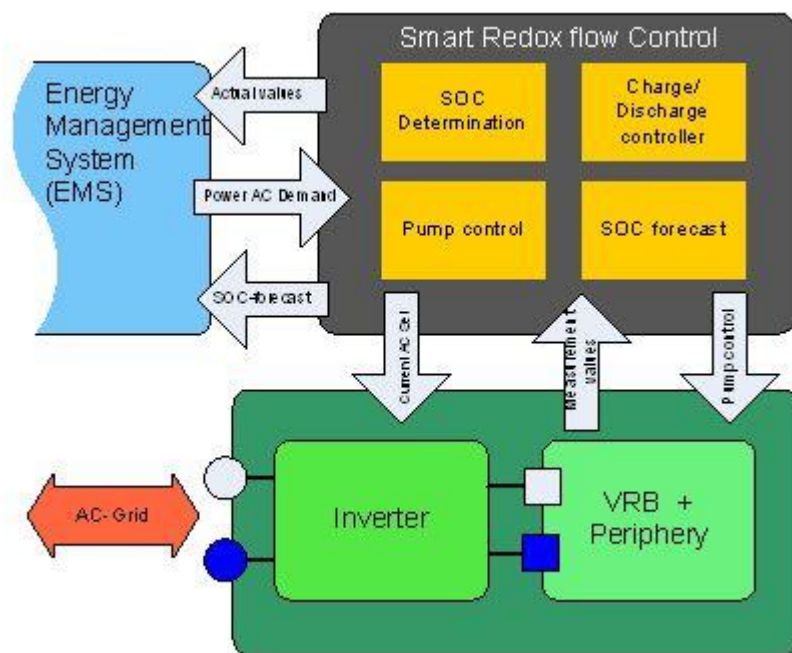


Image 1: Scheme of the control unit for redox flow batteries “smart redox flow control”

Because of the different technologic fields the operation strategies of redox flow batteries are quite complex. The operation strategies for the battery will be controlled by a controller. In this case the controller is a model based controller, the “smart redox flow control”. The “smart redox flow control” has the tasks to communicate with the EMS, to give a SoC prediction in according to demand profile from the EMS, to determine the SoC from the system and to assure an optimized and sure operation of the system. The operation strategies of the redox flow battery are hereby a difficult task. The battery have to be ready always, also the energy efficiency has to be high so the pump have to run in optimized working point.

For the different tasks different models with different model depths were modelled for the development of a controller. The dynamic of redox flow battery was modelled with simplified model. With this model and the simulation tool P-Spice it was possible to simulate the inverter with the battery characteristics before installation.

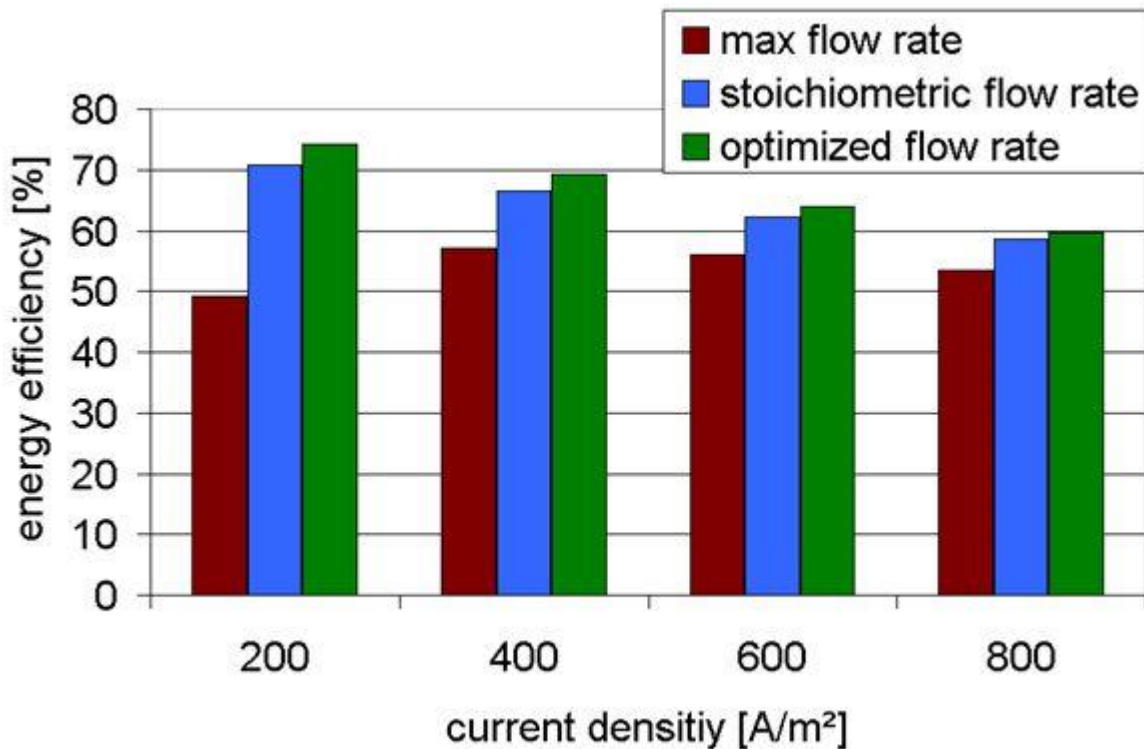


Image 2: Benefit of the smart redox flow controller in terms of energy efficiency

### ***Electricity storage in the power sector: Technology Information Sheet***

*Electricity generated by renewables, such as wind and solar, is based on variable resources. Electricity storage can optimise the energy flows between supply and demand and therefore enable a higher contribution of renewable energy in our electricity mix. Renewables may also not be fully available at the moment when demand is higher or they may supply an excess when the demand is lower, thus creating an imbalance.*

*Electricity storage can overcome the mismatch between output and demand (the so-called time-shifting) and it can smooth out fluctuations in supply without calling on other back-up capacities. It can also save a supplier from penalties when forecast supply cannot be met (the so-called forecast hedging). The principal electricity storage technologies include hydropower with storage, compressed air energy storage, flow batteries, hydrogen-based energy systems, secondary batteries, flywheels, super capacitors, and superconducting magnetic energy storage.*

Source: <http://setis.ec.europa.eu/newsroom-items-folder/electricity-storage-in-the-power-sector-technology-information-sheet/?searchterm=None>

## Flywheel

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A flywheel is a mechanical device with a significant moment of inertia used as a storage device for rotational energy. Flywheels resist changes in their rotational speed, which helps steady the rotation of the shaft when a fluctuating torque is exerted on it by its power source such as that caused by a piston-based (reciprocating) engine, or when an intermittent load, such as the motion of a piston pump, is placed on it.

Flywheel energy storage works by accelerating a rotor-flywheel to a very high speed and maintaining the energy in the system as rotational energy. When energy is extracted from the system, the flywheel's rotational speed is reduced as a consequence of the principle of conservation of energy; adding energy to the system correspondingly results in an increase in the speed of the flywheel.

MESSIB advanced flywheel energy storage systems have rotors made of high strength carbon filaments, suspended by magnetic bearings, and spinning at speeds up to 50,000 rpm in a vacuum enclosure. Such flywheels can come up to speed in a matter of minutes – much quicker than some other forms of energy storage.

The design parameters which had the greater influence on the FW configuration were:

- the working/maximum angular speed;
- the FW dimensions;
- the rotor material.

The speed influences the energy storage, as higher speed means higher energy stored but it is limited by vibration problems, system performance and materials strength.

The high energy to be stored in the FW is one of the primary goals of the project, that could be achieved increasing the dimension of the wheel, its angular speed or its density. Energy constraints, FW dimensions and maximum angular speed are strictly related: high angular speed and big rotor height mean a little outer diameter and so vibration and eccentricity related problems are lower. On the other hand, big rotor dimensions (outer diameter and height) mean low angular speed with a consequent reduction of safety related problems and less strict requirements for the mechanical performance of the rotor material.

Summarizing, the energy to be stored influences the dimensions and the angular speed of the FW rotor and in turn it is limited by the mechanical characteristics of the material used.

According to the Description of Work, the FW for the MESSIB project should be able to store 300MJ. This energy requirement would lead to a high rotational speed and a big rotor if stored in a single FW, which means problems in terms of safety, materials choice, vibration and eccentricity of the wheel as, well as instability of the shaft. To avoid all these problems, during the Steering Committee it was decided to design a FW system in series constituted by FW of 4÷30 MJ each.

## WP4 “Integration of the multi-source Storage technologies with conventional installations.”

WP 4 LEADER: ACCIONA

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WP4 general objective - the different MESSIB storage technologies aim to solve the problems represented by the oversizing of power generation systems (thermal and electrical), the discontinuity in generation of renewable energy systems and the application of intelligent energy saving strategies into new and existing buildings. Main challenges are: the definition of new methodologies in design, identification of effective ways to physically integrate the equipment in HVAC and power generation facilities, implementation from energetic points of view.

Integrated system sizing - traditional methodologies are based on static calculation of power facilities, without taking into account specific storage systems, except for water tanks, more for hydraulic than energetic purposes. Active storage systems can help to reduce the nominal power of traditional generators and increase their efficiency by: integration of RES, shifting of production from utilization, reduction of peak of running. Through dynamic software simulation is possible to size storage systems and generation units instantaneously and during longer period, taking into account weather variation along year period, matching building loads with combined and discontinuous energy production. TRNSYS based simulation highlighted significant improvement brought by new storage systems.

Building integration - MESSIB storage systems, because of their physical characteristics and magnitudes, need to be integrated into domestic environment from different points of view: architectural, electromechanical and energetic. All these aspects are equally important in the final balance of the choice of the client, which aims to obtain energy savings, with respective cost reductions, without giving up the comfort represented by traditional systems. Furthermore the introduction of new technologies must be effective from the cost point of view as well as the integration/installation point of view, which must be the easiest and less invasive as possible. Depending on the national country regulations and future changing in energy policies, storage systems must allow “stand alone” (If-sustainability) or “net metering” connection to/from thermal and electrical networks. Safety issues have been considered as well as aesthetical problems and comfort (noise, vibrations).

### MESSIB

Multi-source Energy Storage System Integrated in Buildings  
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If you wish to inform us of events, related energy storage, don't hesitate to contact us.

**In the next issue:  
progress in the MESSIB work packages.**

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