SAFR PROJECT
Layman's Report

The SAFR project is a collaboration between Trianel GmbH and Carbon-Clean Technologies GmbH.

The SAFR project is supported by the EU LIFE+ Programme. LIFE is the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU. Since 1992, LIFE has co-financed some 4 171 projects, contributing approximately €3.4 billion to the protection of the environment and climate.

About

The **S**torage **A**pplication **F**or **R**enewables project (SAFR) aims to develop **energy storage** to help integrate green, renewable energy sources into our electricity supply.

SAFR has developed and validated an innovative **thermo-electric energy storage technology**. The technology allows large quantities of renewable energy to be stored, like a giant battery, so that we can make better use of the renewable energy we produce.

The development of this technology contributes towards Europe's goals of providing clean, renewable energy for all its citizens.

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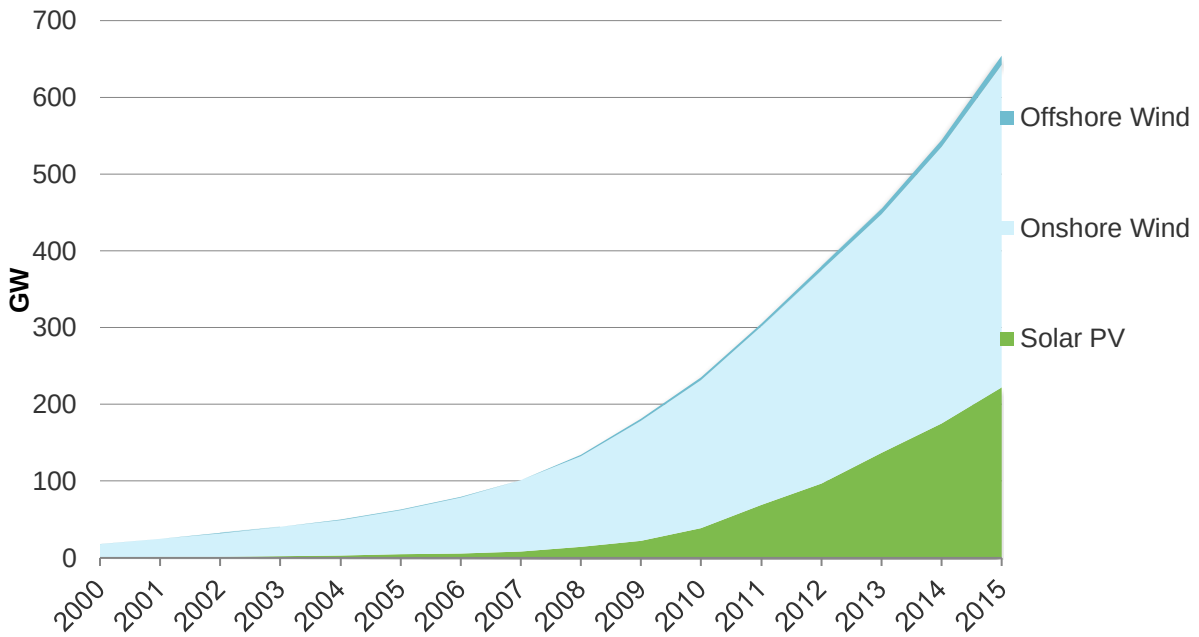
Introduction

In order to combat climate change, countries across the world are moving away from generating electricity from fossil fuels (like coal and gas). Instead, they are quickly building renewable electricity sources. These include wind and solar. Wind turbines and solar panels generate electricity from the wind and the sun, so don't generate the greenhouse gas emissions which drive climate change.

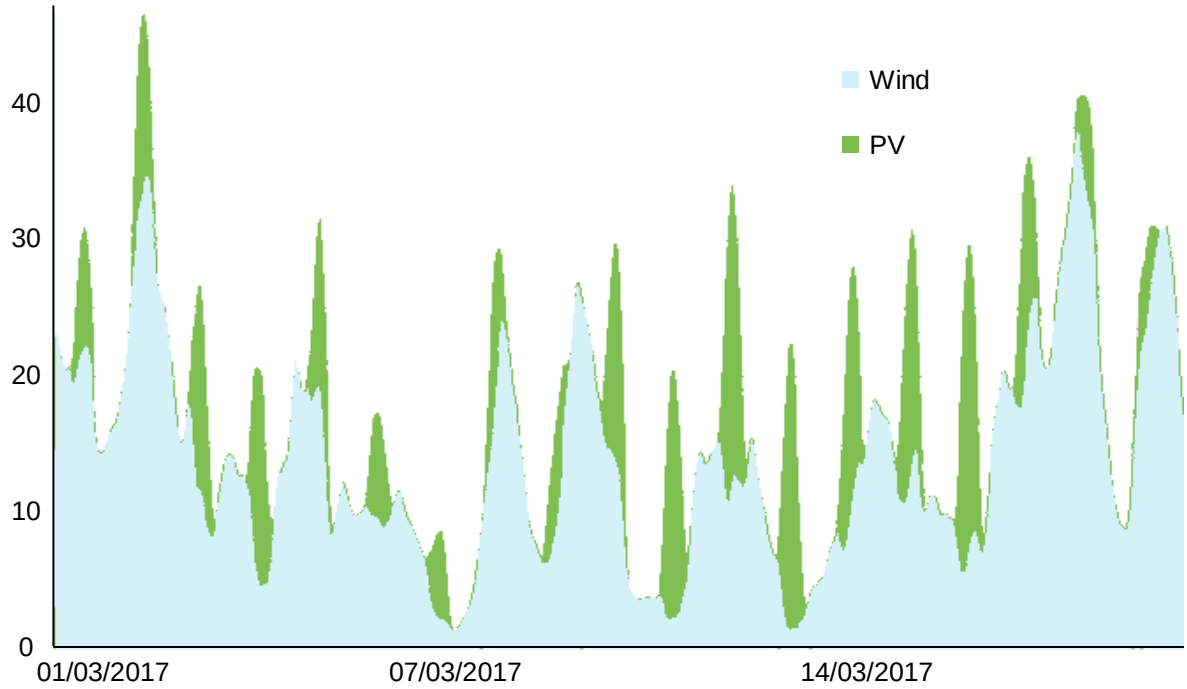
Globally installed capacity of renewable power



The amount of wind and solar installed has dramatically increased. Today, 700 gigawatts (GW) of wind is installed globally. This is equivalent to roughly 350 nuclear power plants.

There is one problem with renewables – they are not predictable and they are not always available.

Electricity production (GW) in Germany from renewables over two weeks



When the wind is blowing, and when the sun is shining, they produce electricity. In Germany, **wind and solar combined sometimes provide as much energy as Germany can use**. But, when there is no wind, and it is cloudy, then these renewables are unable to provide any electricity at all. This was the case, for example, on 7th March 2017. On this day, there was **virtually no electricity generated from wind or from solar**.

The **big question** facing us is:

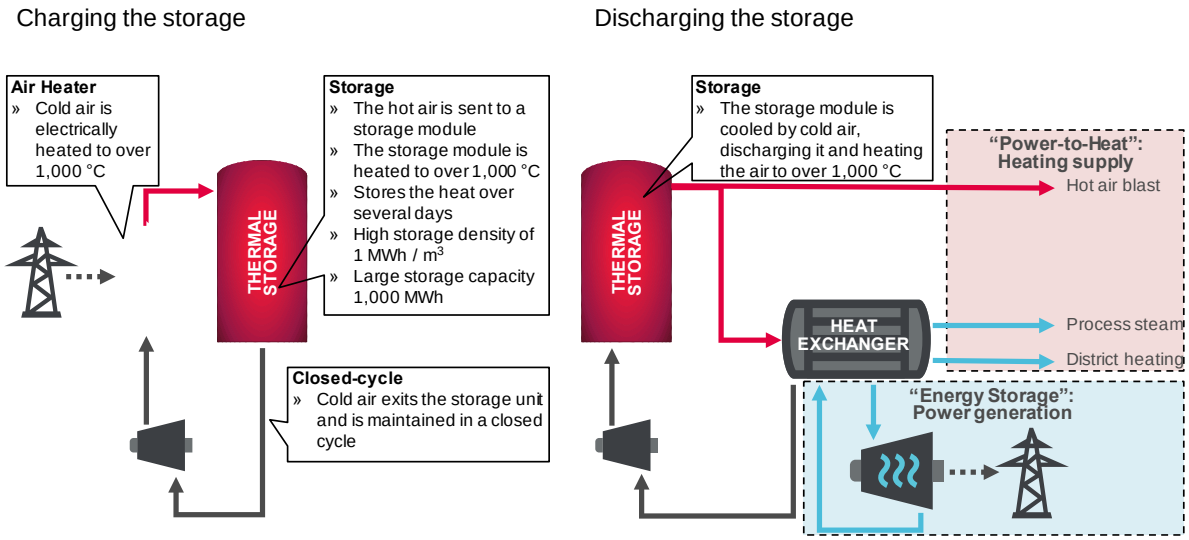
How do we use the fluctuating wind and solar power to generate an electricity supply which is reliable and stable?

The answer is to use **energy storage**. Energy storage can **store energy** during times when there is too much, and **release energy** when it is needed again.

Technology

The SAFR project has developed a thermo-electric storage technology, which stores energy in the form of high-temperature heat. The energy storage system can store 500 MWh of energy, as much energy as three hundred European citizens use in one year.

Thermo-electric energy storage technology



The energy storage system is operated in two phases. It is charged by using electricity to heat air to extremely high temperatures. The air deposits its heat in a storage module, heating special temperature resistant ceramic material to temperatures over 1 000 °C. To discharge the system, cold air is pumped into the storage module. The air heats up, carrying the energy out of the storage module. This extremely hot air can then be used to drive highly efficient steam processes to regenerate the electricity. At the same time, the hot air can be used to generate hot water for district heating or for industrial processes.

The technology has been developed by Carbon-Clean Technologies GmbH, an innovative company based in Cologne, Germany.

Results

Requirements Analysis

A model-based tool was developed to simulate how an energy storage system would operate under current conditions in the German electricity market. Two options were considered, a stand-alone storage system, and the integration of the storage system into the existing machinery of a conventional power plant. The simulations showed that the storage system should be able to store approximately 500 MWh of energy and be charged with 50 MW.

Process Engineering

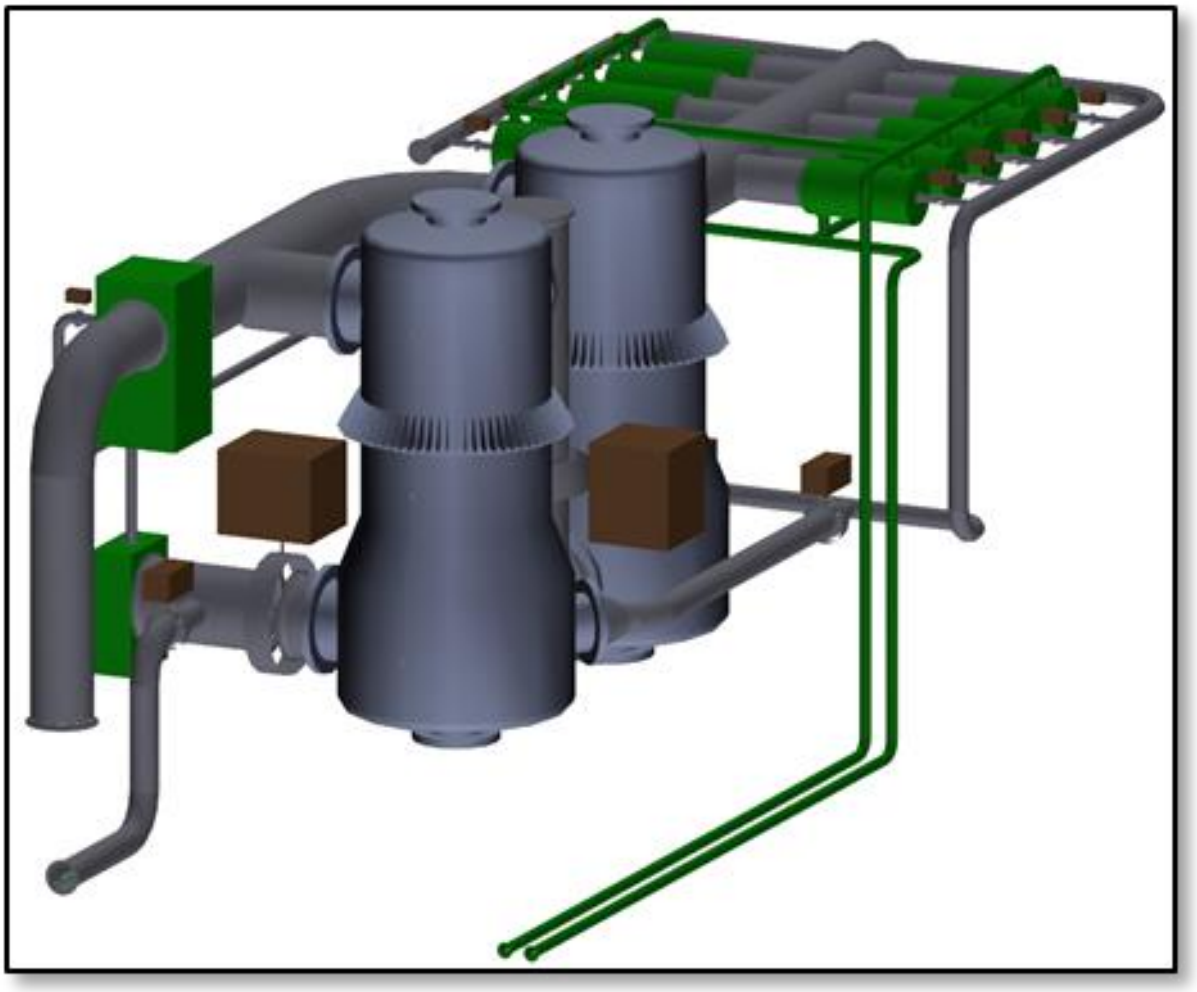
The process engineering built on the specification, to design a technical system which could achieve the necessary storage capacities and efficiencies. Since a storage system is repeatedly charged and discharged, the process engineering considered a dynamic cycling process. Extensive state-of-the-art computer simulations were performed to optimise this dynamic cycle.

The process engineering determined the type of thermodynamic cycle needed, and specified process temperatures and pressures in order to achieve the highest possible storage density and efficiency in the system.

Engineering the Storage Module

The design of the storage module was performed, selecting materials and insulations which could withstand both the high temperatures and the repeated cycling of the system. The designs of the storage module were incorporated into a computer-aided-design (CAD) model of the entire storage system, as shown below.

CAD model of the 500 MWh storage system



Engineering the Air Heater

To reach the high temperatures required for the storage system, a special air heater is required, which is not commercially available. This system was designed, and three prototypes have been tested in order to demonstrate its function and to improve the design.

Engineering the Power Generation System

The power generation system converts the stored high temperature heat back into electricity via an air and steam turbine cycle. Three concepts for this system were studied in detail through computer simulations, optimising the design of this system.

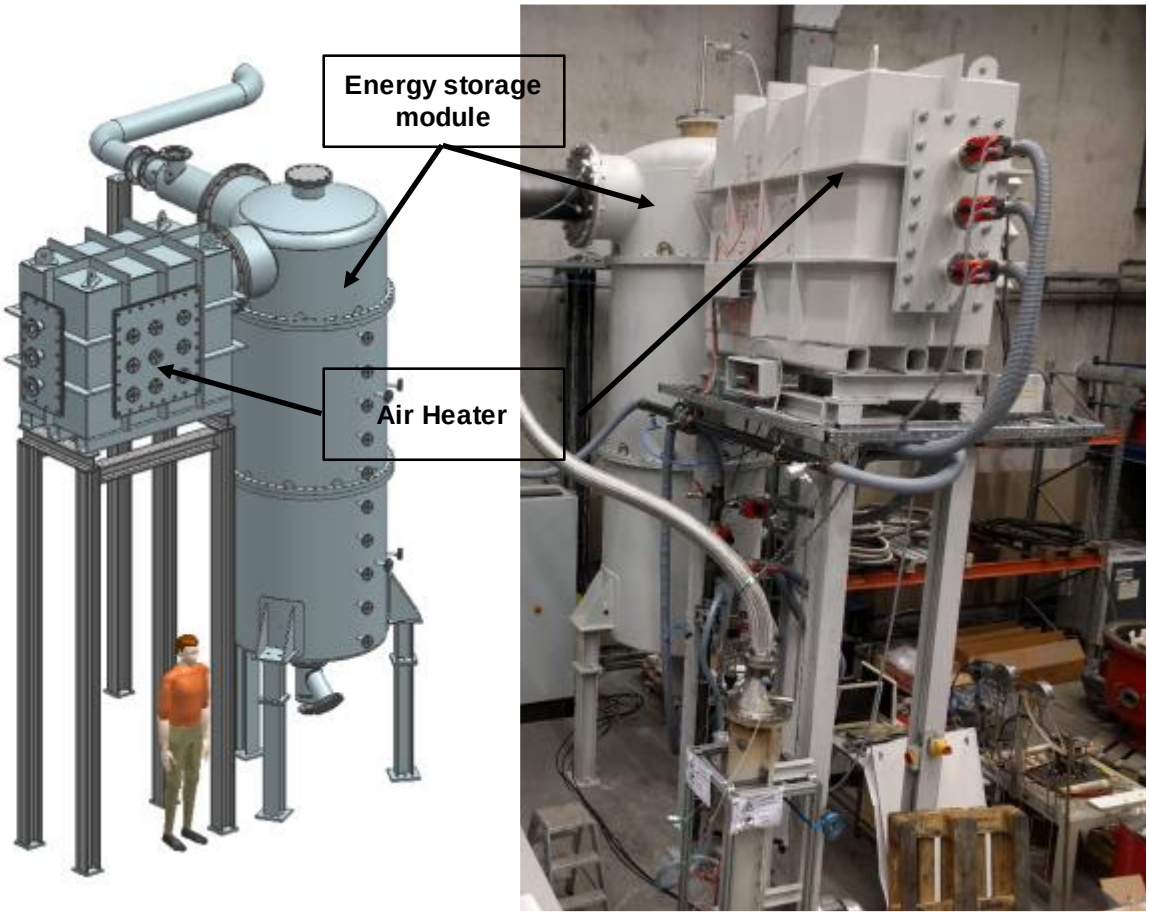
Engineering the Electrical Systems

A complex electrical system is required to achieve the high powers required for charging the storage system and to accurately control the multiple air heaters. Several concepts for the electrical systems were studied, and the best option was selected.

Laboratory testing of modules

In addition to designing the full-scale system, the SAFR project constructed a laboratory-scale demonstrator to prove that the system functions as our designs suggest. In collaboration with the Technical University of Darmstadt, a 1 MWh storage module was designed and constructed, as shown below.

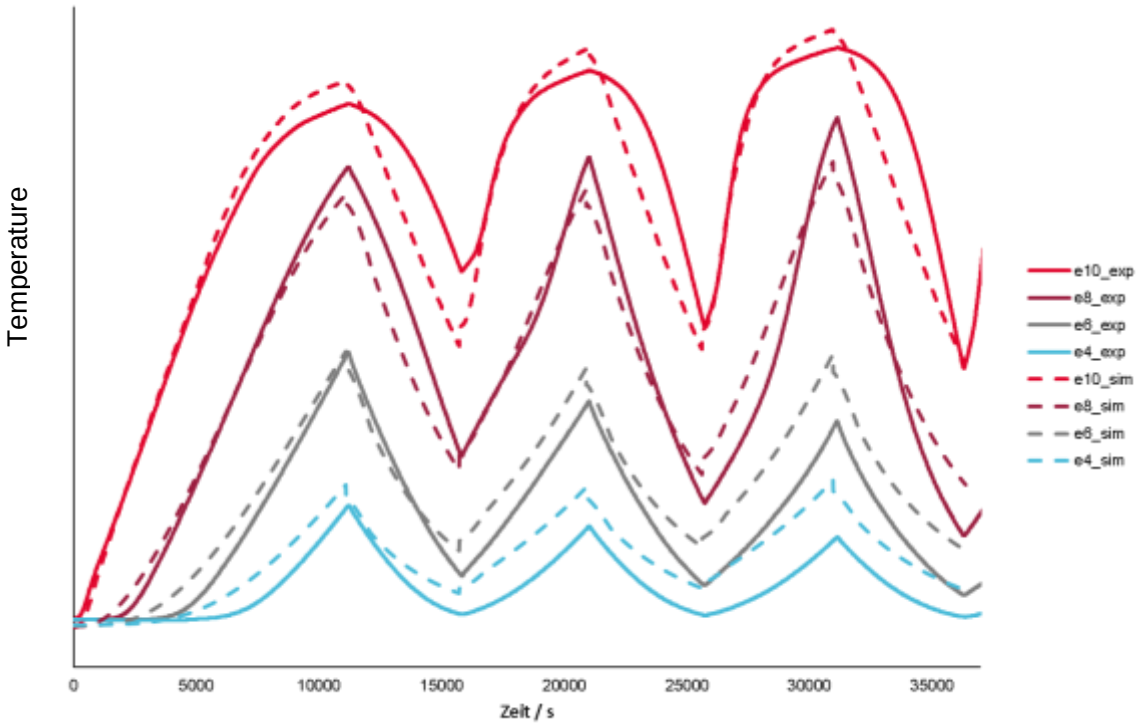
Laboratory test system



The 1 MWh of energy stored is almost as much energy as one person uses as electricity in a year.

The system was operated, testing multiple charging and discharging cycles. A sensor suite monitors the temperature along the storage module and in the thermal insulation. Extensive computer simulations were performed to compare the results of the practical tests to the designs for the full-scale system. The results of one of these tests is shown below.

Results of operation



The experimental results (solid lines) for how the temperatures at different points along the module vary through multiple charging and discharging cycles fit extremely well with the results of our computer simulations, validating our model of how the storage system operates. This result allows us to be confident that the full-scale system will work according to our design.

Conclusion

The SAFR project has developed and validated an innovative **thermo-electric energy storage technology**. The technology allows large quantities of renewable energy to be stored, like a giant battery, so that we can make better use of the renewable energy we produce.

The project designed the full-scale system, built and operated a laboratory demonstrator. The results from the laboratory demonstrator were used to prove that the full-scale system will work as we plan.

This storage technology will now be applied on an industrial scale to help buffer renewable electricity generation in Europe and help Europe to make the transition to clean, renewable electricity generation.

Project Information

Project website: www.safr-project.org

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