SOLAR THERMAL ENERGY WITH STES - KREMSMÜNSTER

PITAGORAS (sustainable urban Planning with Innovative and low energy Thermal And power Generation frOm Residual And renewable Sources) is a research project co-funded by the European Commission framed into the "FP7 – Smart Cities program".

The project focuses on the efficient integration of city districts with industrial parks through smart thermal grids. In particular, the project developed a system concept based on industrial integration of solar thermal energy in combination with a seasonal thermal energy storage (STES), including the possibility of solar heat delivery also to the district heating network. The plant is planned for a specific site in the city of Kremsmünster (Austria) and in an industrial area of an oil and gas industry. The developed system concept is formed by a solar field of 9377 m², which is expected to produce around 4547 MWh of useful solar heat per year. The idea of reconverting an existing oil tank of 60,000 m³ of storage volume (that is no longer been used) into a STES allows to store the surplus solar heat in summer and its use later on in winter months, which significantly increase the solar production capabilities, system performance and energy savings. The challenge was to develop a reconversion solution for the oil tank into a STES that is technically and economically feasible.

Test field of 2500 m² located in Graz for different solar collector's testing and selection of most suitable one for the large scale solar plant to be built in Kremsmünster. Source: Solid

Existing system

Kremsmünster is an Austrian town with a population of 6.500 inhabitants approximately. Currently 65% of the thermal energy consumed in the city is covered by district heating (DH) (≈20 GWh/year). The main heat sources for the district heating are the followings:

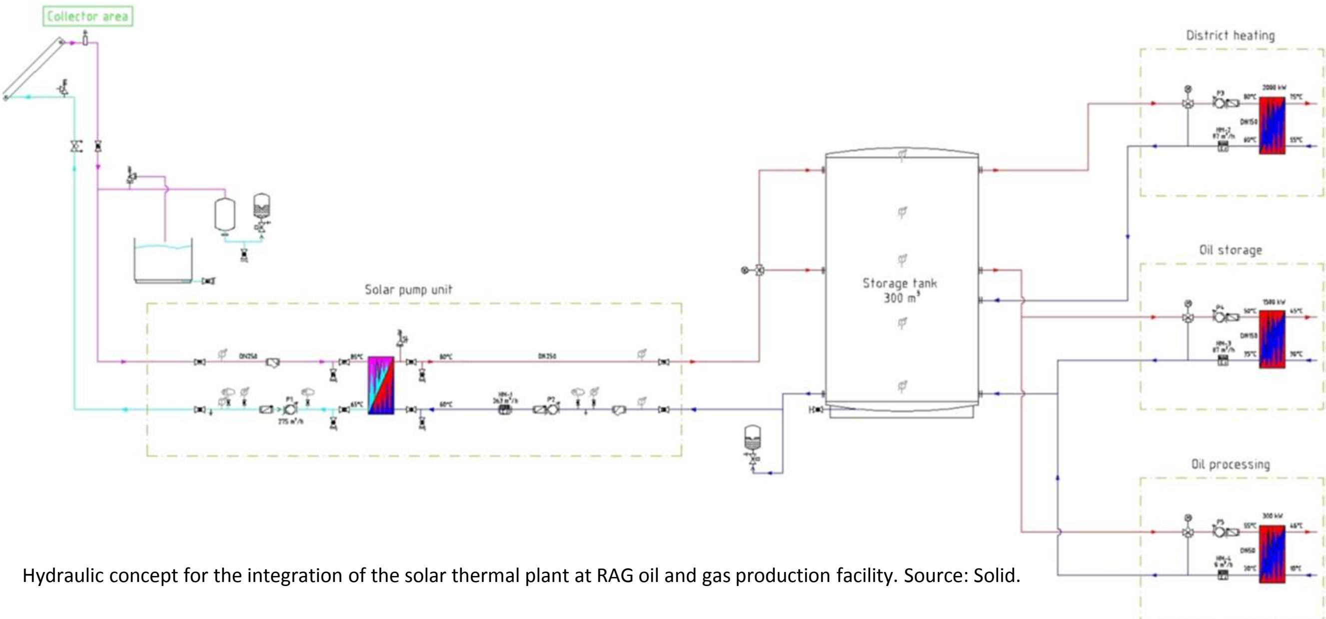
- CHP plant for electricity supply of an oil and gas company (RAG)
- Biomass heating plant
- Waste heat from a glass manufacturer

RAG is the Austrian oldest oil and gas company. Its core areas of business are oil and natural gas exploitation, production and storage. 5 km south of Kremsmünster, RAG operates an oil and gas production facility, which is indeed the site for the PITAGORAS pilot plant.

To cover the electricity demand of their facilities, they operate a gas fired CHP plant with a maximum power of 2.400 kW_e and 2.650 kW_{th}. The thermal output of the CHP plant (15 GWh/year) covers around 75% of the district heating supply of the city of Kremsmünster and it is as well partly used for self-consumption (oil production station and preheating of the oil storage tanks). In addition, there is a gas boiler for peak loads in winter time.

Layout for the Pitagoras plant

The schematic of the system layout is shown in the following figure. The energy produced by solar thermal collectors is delivered via pipes to a solar heat exchanger by a variable mass flow pump. The heat transfer fluid in the primary loop is a mixture of water and glycol in order to protect the system from freezing. In the secondary loop on the right side of the solar heat exchanger pure water is used for the heat transfer. A variable mass flow pump runs the mass flow of the secondary loop in order to meet the temperature requirements of the heat load. The produced heat is stored in a buffer tank, which feeds the three loads according to the specific requirements in each case.

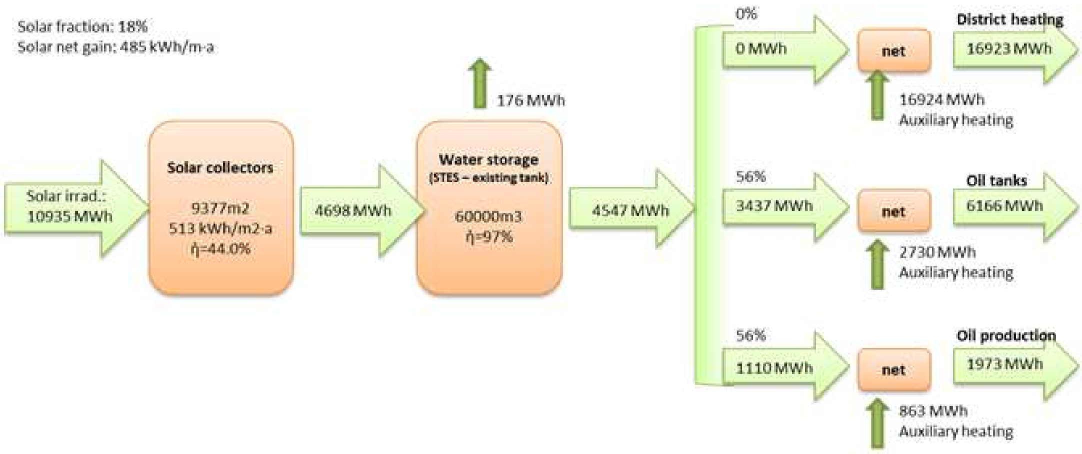


Hydraulic concept for the integration of the solar thermal plant at RAG oil and gas production facility. Source: Solid.

According to the initial calculations a preliminary layout with a total aperture area of 9.377 m² of solar collectors (10.000 m² of gross area) and 300 m³ of buffer storage was defined. The solar collector field is ground-mounted. The collectors are facing south with a slope of 30º. Due to the fact that the solar energy has to be used to a main part during summer time for district heating purpose, the high flow temperatures of the district heating net reduces the possible solar energy gain to a high extend. This raised the idea to store the solar heat from summer to winter so that it can be used for heating purposes inside the oil and gas production facility, that needs very low heating temperatures. To store the solar heat from summer to winter, a STES is needed.

System performance

Realizing a STES enables the entire system to store a lot of solar energy through summer to use it for low-temperature heating purpose in winter. The system layout asks for mean operation temperatures in the collector field that are so low that the yearly solar net gain rises to 485 kWh/m^2 even the STES has higher heat losses than the 300m^3 water storage. However, the impressive high solar net gain can be obtained by focusing the solar energy on the heat sinks with the lowest temperatures. As it can be seen in the following figure, for this variant no solar energy is fed into the DH net to avoid the high supply temperatures this heat sink asks for. Thanks to the STES, for the two other loads a solar fraction of 56% of their yearly energy demand can be obtained.

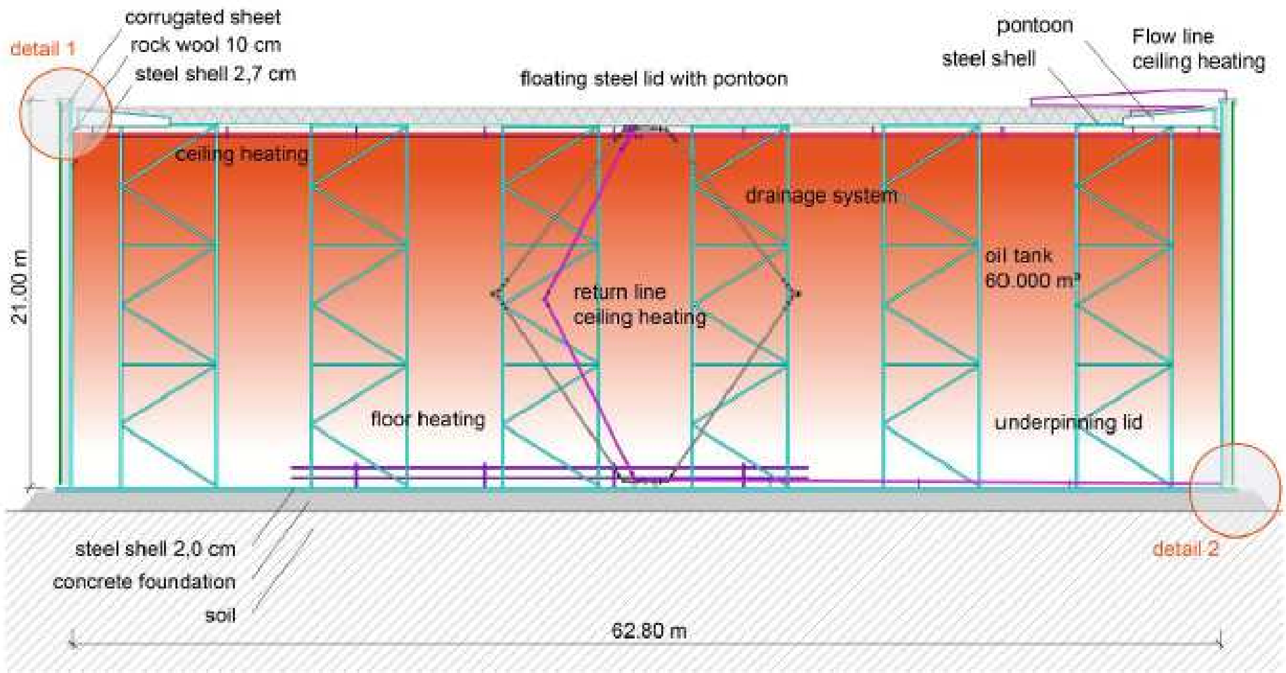


Simulation results for the variant with a reconversion of one of the oil tanks into a STES. Solar system heat balance including a STES with 60.000 m³ (one of the existing tanks) and reduced set point temperatures for the collector circuit. Datasource: Solites, Grafics: Tecnalia

Reconversion of existing oil tank into a STES

One of the most important issues when considering the reconversion of an existing tank into a STES is to check if the detailed construction and statics of the existing tank fits to a usage as a STES. When using the tank as a STES, the water inside the STES will stratify so that high temperatures are on top and the lowest ones on the bottom. This leads to static stress especially on the tank walls because the top parts will be on a higher temperature than the lower parts. The temperature lengthening of steel with rising temperature will cause static stress for the wall construction. It has to be proven that the entire storage construction can withstand that temperature stress on a long-term. A detailed statical calculation has to be carried out to prove the suitability of the existing tank construction to be used as a STES according the existing EU building standards. In addition to the static stress that may be occurred due to water stratification inside the tank when working as a STES, the particular construction of the tank under study has an additional challenge to be overcome, which is related to the floating lid. The existence of a gap between the tank wall and the lid can cause quite problematic difficulties when working as a STES, in addition to the heat and water vapour losses through the open gap. The only feasible alternative that has been concluded therefore for this specific case so that the tank can be used as STES is to fix the lid on top of the storage volume.

The following figure shows the solution with the best economics for the reconversion of the existing oil tank.



Reconversion solution for the existing tank of 60,000 m³ to be used as STES. Source: Solites.

A simple prolongation of the existing underpinning is not possible because they are too thin compared to the end height for avoiding possible buckles. But if the single underpinnings would be connected to each other to realize a kind of a vertical trussed girder, the construction would be very cost effective and easy to realize. The lid that rests on its underpinnings would be lifted step by step by hydraulic lifts that are mounted inside the tank. With every step the next part of the trussed underpinnings can be mounted. Because the trussed underpinnings consist of small steel beams, it is quite easy to transport them inside the tank. These steel beams for realizing the trussed underpinnings can be prefabricated totally, the mounting can be done by screws, welding o.e. Step by step the lid will be lifted by the hydraulic lifts with the trussed underpinnings growing into the inner height until the end height is reached. No scaffold is necessary and the amount of steel that is needed for the construction is minimized, due to the fact that the carrying construction is trussed. After that the roof can be heat insulated and closed by a watertight plastic liner.

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