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Seasonal storage: using the summer sun to warm a neighbourhood in winter

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Abstract

The developers of real-estate projects in Geneva's Florence and Champendal neighbourhoods want to heat the 61,050 m^2 of floor space in their new residential buildings and produce domestic hot water using a minimum of fossil-fuel energy. The solution, for which a feasibility study is now underway, provides for storing summer heat on site for use in winter. It incorporates thermal solar collectors, daily storage in water, a seasonal ground storage reserve, and about 0.5 km of remote heating network. The goal is to have solar energy cover 75% of the heating needs. The buildings meet Minergie® standards. Each uses solar energy to produce domestic hot water, and has a backup gas boiler. So the buildings can operate independently, or connect to the neighbourhood's solar heating system. Additional collectors are located on the flat roofs of a neighbouring school. The estimated cost for the solar facility is 135 CHF per m² of heated floor surface. To provide heat at a cost equivalent to that of a gas boiler at current prices, a subsidy equal to 40% of the investment is needed. If the cost of energy doubles, the subsidy will be unnecessary.

Keywords: Building Heating Seasonal Solar Storage

Objective

The developers of the Florence and Champendal neighbourhoods want to provide heat and hot water for their new residential buildings with a **minimum of fossil-fuel energy,** while at the same time keeping costs at a customary level. The new structures will contain 393 housing units with a gross heated floor area of 61,050 m². The first buildings are already occupied; the others are under construction.

Wood heating results in microparticulate emissions in quantities incompatible with the legal limit, which current emissions—primarily from automobile traffic—have nearly reached already. Heating with a heat pump, with compensation for its electrical consumption through photovoltaic solar production, implies dependence on distributors and producers of electricity who store energy between summer and winter. The solution, which is now at the feasibility study stage, provides for storing summer heat on site for use during winter.

Figure 1 Configuration: Florence (9 buildings), Champendal (5 buildings), solar collectors on the flat roofs of the school located near the oval ground storage

Facilities

Thermal System

The thermal system comprises:

- 45,000 m³ of seasonal ground storage,
- a 300 m^3 daily thermal reserve in water,
- 4,500 m² of thermal solar collectors distributed over the roofs of the buildings connected to the system and a neighbouring school,
- the buildings being provided with heat for heating and hot water production, and
- a remote heating network linking these components.

There are gas boilers in each building to supplement solar production at the end of winter, thus ensuring each building's autonomy during construction—which will be done in stages—and reassuring the owners that heat will always be available.

Ground storage

The ground storage is a cross section of land 45 m in diameter and 30 m thick, covered with an insulating layer 1 m thick. Heat exchange with the ground is made possible by vertical bored tubes or exchangers every 4 to 5 m², analogous to the ground collectors in heat pumps. Each of the boreholes contains four tubes forming two parallel circuits in which heating water circulates. Multiple tubes are connected in series to achieve radial stratification of the heat reserve, from the colder edges to the warm centre. During the recharging period, the water circulates from the centre towards the outside; during discharge it circulates from the outside towards the centre. Compared to a tank of water, ground storage is a poor accumulator due to the difficulty of thermal exchanges and leakage at the reserve's uninsulated edges and bottom. On the other hand, it is inexpensive.

Hydrogeological analysis of the site is essential to ensure there is no groundwater flow that would carry off the heat. The hydrogeological, thermal, and thermomechanical properties of the clay soil were determined through boring and testing.

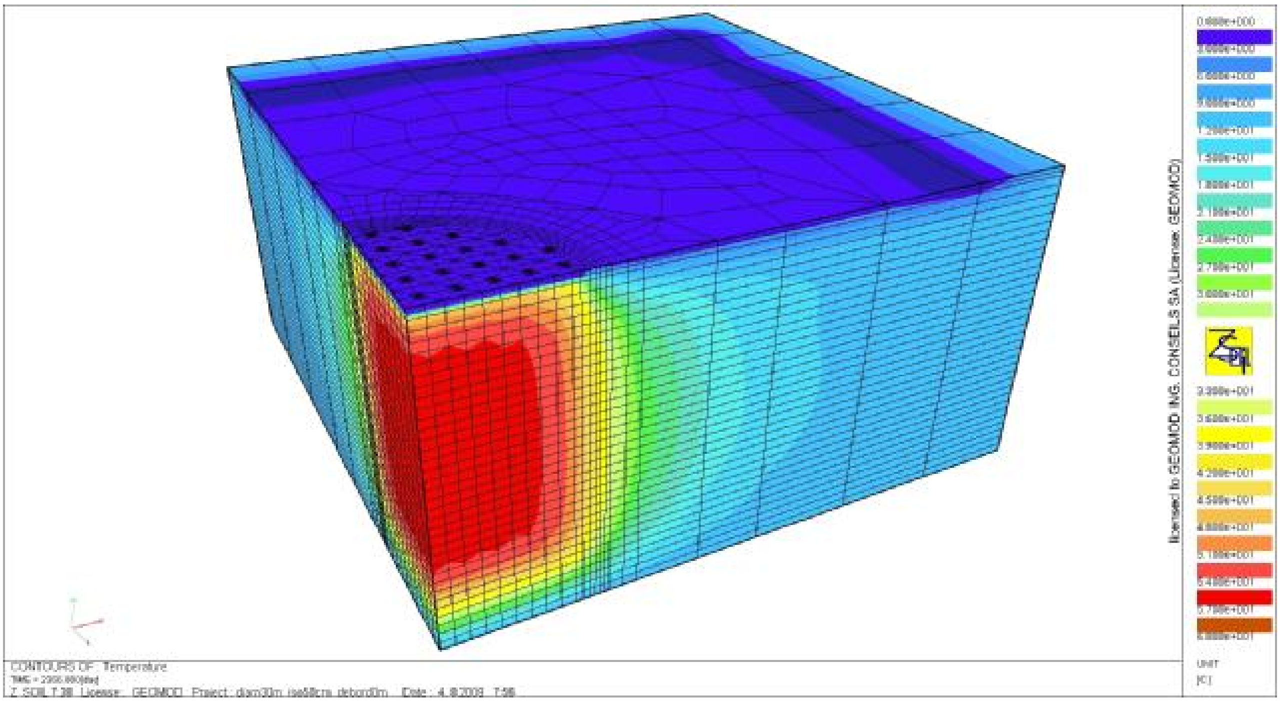


Figure 2 Simulation of the thermal behaviour of the ground reserve

Daily reserve accumulators

The daily reserve has two purposes. First, when the sun is shining, it supplies heat for hot water as a first priority, and if necessary, heating. Second, especially in the summer, it accumulates the heat captured by the solar panels during the day and transfers it to recharge the ground reserve through a thermal exchange spread over 24 hours. So the daily reserve makes it possible to reduce the power of the exchange with the ground reserve, and therefore the length of the buried tubes, which reduces their cost.

The daily reserve is contained in the buildings' domestic hot water tanks and in a main reserve buried in the ground nearby.

Optimisation

The goal of optimisation is to adapt the heat users to the solar resource. The ground reserve's efficiency, i.e., the heat density accumulated and the proportion of energy recovered in winter compared to the amount stored in the summer, is improved by the project's size and low operating temperatures.

Size of reserve

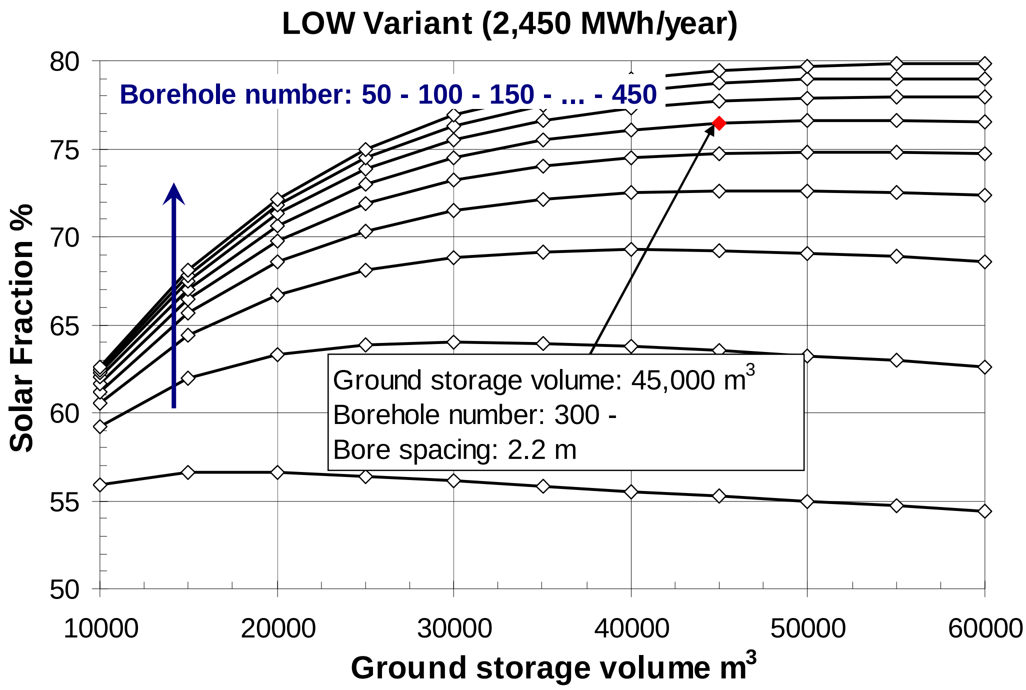
The depth of penetration by the thermal wave around the reserve is on the order of 3 m, with annual periodicity. In addition, there is a continual component corresponding to the reserve's multi-year average temperature, which is higher than that of its cradle. It takes six to ten years to stabilise the ground reserve's thermal range.

If the reserve is too small, it cools before winter due to thermal losses. The larger the reserve, the smaller the losses from it in proportion to the energy flows. The minimum size for such a solution is on the order of 20,000 m³. So this technology is applicable on the scale of large building complexes or neighbourhoods. For example, consolidating service to the buildings of the two developments of Florence and Champendal allows for a seasonal ground storage reserve of some 45,000 m³.

Digital simulation of the thermal system

Digital simulation enables us to specify the most profitable options while respecting, for example, the technical limits of overheating. The simulation of the complete system takes into account the users' temperature and power needs, solar input, the climate, and automatic adjustment functions.

LOW variant– without dissipation and overheating with a 4,500 m² total collector area



Best system design to avoid overheating and heat dissipation in the collector field:
45,000 m³, 300 borehole heat exchangers. Maximum temperature in collectors: 99°C
Solar fraction: 76.5%   solar cost: 234 CHF/MWh

Figure 3 Optimisation of entire system

Low temperature

The lowest possible nominal temperature is selected for the buildings' heating facilities. The buildings have underfloor heating with non-insulating floor coverings of ceramic or wood. Triple-pane windows are used in small spaces with many windows to reduce the installed surface power density. The operating temperature of the heating system is progressive, with the water distributed varying from 20°C for an outside temperature of +20°C, to 30°C for an outside temperature of -6°C. At the same time, domestic hot water is produced using highly efficient exchangers that make it possible to greatly cool the heating water that preheats the cold potable water supply—which is distributed at about 10°C in the winter—to 12°C. The aim of these mechanisms is to cool the ground reserve as much as possible in order to extract maximum energy from it. The reserve's temperature varies between 60°C when it is fully heated at the end of summer, and 25°C when it has been discharged by the end of winter. The heat is used directly, with no heat pump. The gas backup was selected for its low cost.

Insulation versus solar

These buildings meet Minergie® requirements. The optimisation analysis shows that, in terms of Minergie® to Minergie®-P performance, the additional non-energy cost, i.e., the additional investment needed to reduce consumption, is on the same order of magnitude or even less than the investment for a larger solar installation. Moreover, the limited surface area available for installing collectors is an incentive to make the buildings consume very little energy.

Architecture and solar collectors

In the case of this particular project, the buildable perimeter for new buildings is vertically defined by two sloping sections. Attic storeys with terraces and set-back facades use this upper volume, reducing the roof's surface area. The solar panels installed there contribute mainly to producing hot water, whereas the collectors needed for heating are installed on the flat roofs of a nearby school, which the public authorities kindly made available in support of this project.

As a rough estimate, a flat roof completely covered by solar collectors can supply most of the heat needs of the seven to ten storeys of the highly energy-efficient building it covers.

Implementation

Third-party investor

This type of project, which is handled on the neighbourhood scale, involves multiple investors. Naturally, their specific interests and objectives are not all the same. The constraints of economic competitiveness always weigh heavily. Coordinating heat buyers is problematic. So it is efficient to delegate the completion of such an infrastructure to a contracting company. In this case, *Services Industriels de Genève* (SIG) undertook to finance, complete and operate the solar heating facilities in this neighbourhood.

Financing was shared among SIG for the major portion, Federal and Cantonal subsidies, and modest participation by the developers, who buy heat. SIG is paid through the sale of heat to the heat buyers.

Staggered construction

The buildings are not all built at the same time. The heating and hot water production facilities are designed for staggered completion of the buildings and to allow them to operate independently or connected to the neighbourhood's solar infrastructure. To meet Minergie® requirements, each building has its own solar heating to produce domestic hot water. This independence is reassuring for the developers. Even though there will be connection easements and heat supply contracts, each developer will maintain control of its own investment and will be free to market its building.

Hydraulic schematic for the buildings

The heating and hot-water-producing facilities allow the building to operate independently or be connected to the neighbourhood's solar heating system.

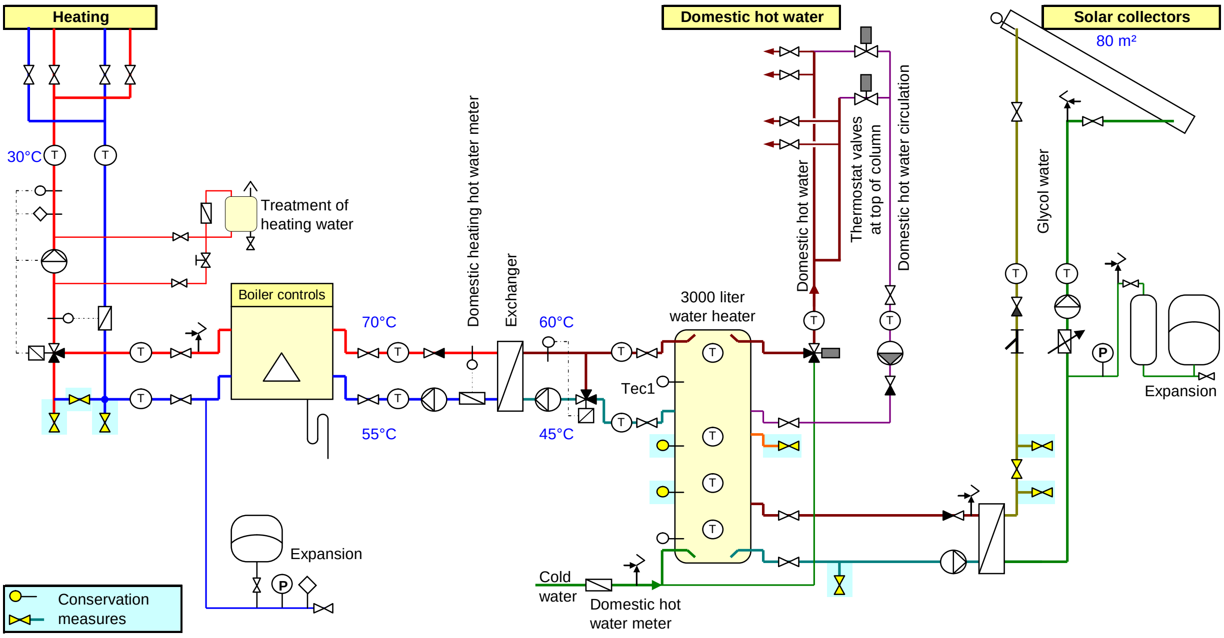


Figure 4 Schematic for buildings without remote solar heating

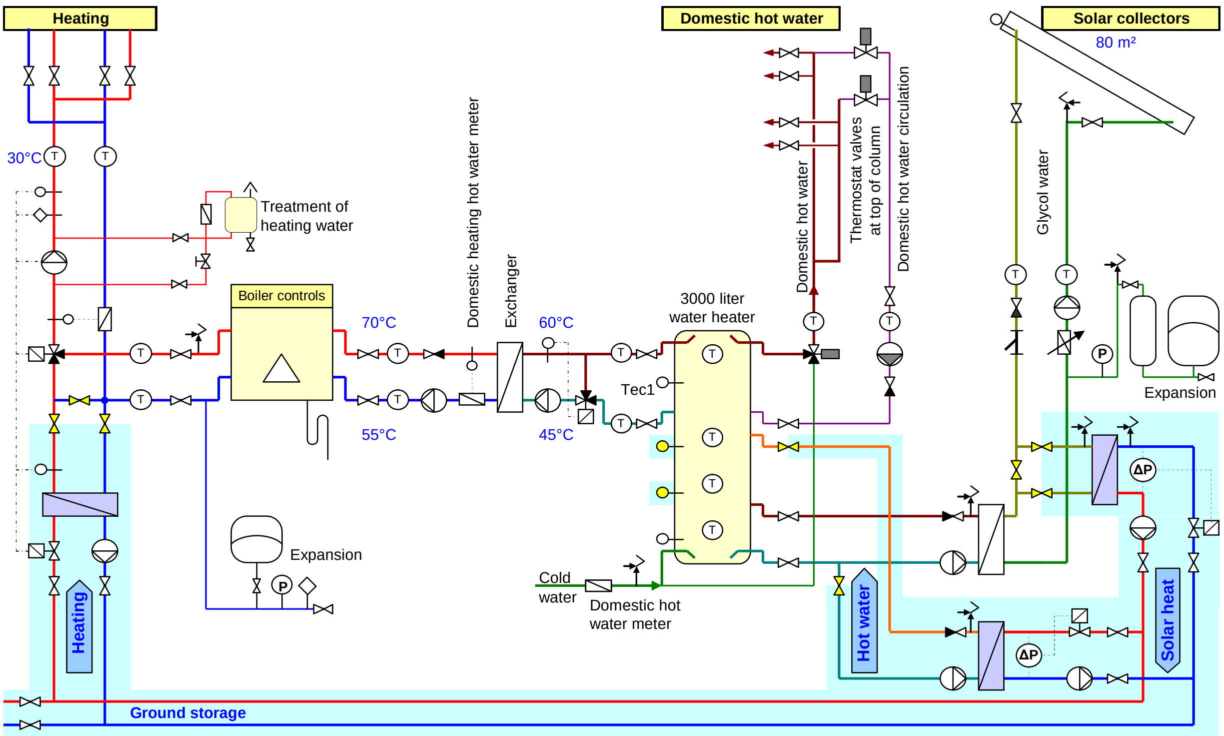


Figure 5 Schematic for buildings with remote solar heating

Costs

As a rough estimate, collecting solar heat represents about 60% of the total investment, the ground reserve about 20%.

Outlook

Buildings

Since best practices, the state of the art and regulatory requirements have changed in four years, today the buildings would certainly be designed to meet Minergie®-P requirements. Triple-paned windows are less expensive, narrower frames favour solar heating, and heavier-duty insulation is becoming a matter of course. Energy considerations are intruding more into the architect's realm: balconies are being replaced by glass walls that bathe the windows in sunlight and favour passive solar heating, interior anti-glare solar protection avoids the need to use outside protection in the winter, and solutions for thermal bridges have been improved.

Seasonal water reserve

This alternative is costlier than the ground reserve, but it applies at the building level rather than the neighbourhood level. Coordination and decision-making processes are simplified. The built volume contains the reserve, so regulations should be adapted to prevent the tank from reducing the usable floor space. The water reserve, as an accessory to the building's heating system, is financed by the developer. This financing is less expensive than financing by a third-party investor, which includes a risk/benefit margin for completion of a neighbourhood infrastructure.

Regulation

Buildings with low energy consumption are heated mainly by the free heat from people, appliances, lighting, and especially the sun. It becomes essential to turn off the usual heat sources as soon as the free sources become sufficient. An additional investment in automatic control is now necessary to keep pace with the progress in architecture and the building's envelope and facilities.

Progress

In buildings with low energy consumption, the energy required to produce hot water is greater than that needed to heat the premises. The demand for heat for hot water production is distributed over the entire year, through temperatures ranging from 12 to 62°C. So direct solar heating of hot water covers a major portion of the annual needs. The ground reserve can be used to preheat hot water in any season, even if it is too cold to supply the heating system. Additional heat is required especially at high temperatures.

It is interesting to note that the heating energy in buildings with low energy consumption becomes less than the electrical energy used for appliances and lighting, as well as the building's embodied energy.

Results

The setup theoretically provides for coverage of 75% of the 2,500 MWh of heat needed to heat the buildings and produce hot water, after five years of operation (preheating of the reserve). We used 70% as the probable value, given that observed consumption was slightly higher than the theoretical value.

To ensure that heat is provided at a cost equivalent to that of a traditional gas solution at current prices, a subsidy equal to about 40% of the total investment is needed. If the cost of energy were to double, the subsidy would become unnecessary.

Conclusion

The technology used for heating is simple. Storage is not outsourced to the "electricity suppliers." Constraints are the availability of sites with non-flowing groundwater, and sufficient roof surface area for the collectors. With the help of public authorities, the project will be completed. So energy policymakers will be able to test the technical and economic feasibility of such solutions that are achievable on an urban scale.

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