EXPERIENCES WITH ATES APPLICATIONS IN BELGIUM
Operational results and energy savings

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1. INTRODUCTION

Aquifer Thermal Energy Storage or ATES was introduced on the Belgian market since 1995. VITO performed research activities on the applicability of this technology, the integration in the HVAC installation, the geohydrological boundary conditions and dissemination of information. In Belgium, it still stays difficult to give ATES systems a broad implementation. Since 1998, many companies showed interest in the technology, but this isn't translated into a steady increase of realized projects. This is mainly caused by the hydrogeological circumstances. In Belgium, the Northeastern part of the country has very good technical and economical potential for the application of ATES. However, the most interesting economical and industrial areas are located outside this region. A thick clay layer covers the Western part of Belgium, the southern part mainly exists of Silurian schist and Devonian rock. At this time, ten large ATES-systems (> 300 kW) and dozens of small systems (< 50 kW) are operational. Due to the high-energy prices and new developments concerning medium sized ATES systems (between 50 and 300 kW), the technology becomes more and more interesting for other parts of the country with interesting payback periods.

A number of ATES projects are monitored within the framework of a subsidy program for the stimulation of innovative energy technologies, called "Energy Demonstration Program" (initiative of ANRE - Administration on Natural Resources and Energy - of the Flemish authorities). Enterprises can get financial support on the condition that the project is extensively monitored. These projects act as an example and the program gives a good overview on the real possibilities and limitations of the demonstrated technology. This gives interested parties a boost on the further implementation of innovative technologies.

The results of three projects are described in this paper, each with a different system configuration. It concerns a standard ATES installation for office building "ETAP" in Malle, an ATES system with reversible heat pump for the "KLINA"-clinic in Brasschaat and an ATES combined with cogeneration and a heat pump for hospital "St-Dimpna" in Geel.

2. ENERGY DEMONSTRATION PROGRAM

The Energy Demonstration Program of ANRE has been set up by the government in order to stimulate innovative investments on energy savings and use of renewable energy sources. Within this program, financial support can be provided up to 35% of the extra investment of the durable innovative investment in comparison to a traditional installation. The authorities appoint a third party for the execution of a measurement campaign for at least one year. The monitoring period depends on the demonstrated technology, for ATES system a campaign of three years was postulated in order to have representative results for steady-state performance. After a few months of operation, a first interim report is drawn up with the first operational results. At that point, small interventions or adaptation of control settings can be made if necessary. At the end of the campaign a final report is made with the results and main conclusions on the innovative installation in comparison with the conventional system. The described installations in this paper all concern projects supported within this program.

A full analysis of the ATES systems is made by retrieving data on all energy flows (flow and temperatures) of the specific energy installation. In that case, not only the energy transfer between the building site and the ATES system is measured, also fossil fuel or electricity consumption of other cold or heat providers and the total energy demand for heating and cooling of the building is monitored. Also important is the electricity expenditure for all auxiliary equipment (boilers, refrigerators, pumps,…). In order to determine the primary energy savings, the ATES system is compared with a reference installation. A comparison is made with a water-cooled cooling machine (with a COP for cooling of 3.5) for cooling and a gas boiler (with a yearly efficiency of 85%) for heat deliverance. These assumptions are based on experiences from previous monitoring campaigns. For the calculation of primary energy an efficiency of 44% for a power plant is assumed, the average value for Belgian electricity production. Furthermore, the impact of the innovative installation on the greenhouse gas emission is calculated. For the determination of the CO_2-emission a discharge of 624 g CO_2 per kWh electricity consumption and 55 g CO_2 per MJ gas consumption is postulated.

3. PROJECT RESULTS

Project "ETAP"

ETAP is a company that develops, fabricates and commercializes functional lighting. ETAP built a new "light pavilion" in order to demonstrate general lighting technology, security lighting and specific applications. The pavilion was integrated in the existing building that was extended with 3000 m^2 floor area. In this building an ATES system is installed with a capacity for cooling of 570 kW_{th}, a maximum groundwater flow of 90 m^3/h, 85 m distance between the wells and a well depth of 67 m. The company decided to implement the technology in replacement of refrigerators as high electrical consumers. The cooling load of the entire pavilion is covered by the ATES system. The thermal energy from the cold and warm well of the ATES system is used in the building by an air distribution system with air handling units (AHU's). The groundwater is separated from the secondary building circuit by means of two heat exchangers. This secondary system feeds the water coils of the AHU's which function as cooling or heating coils depending on the operating modus of the ATES system.

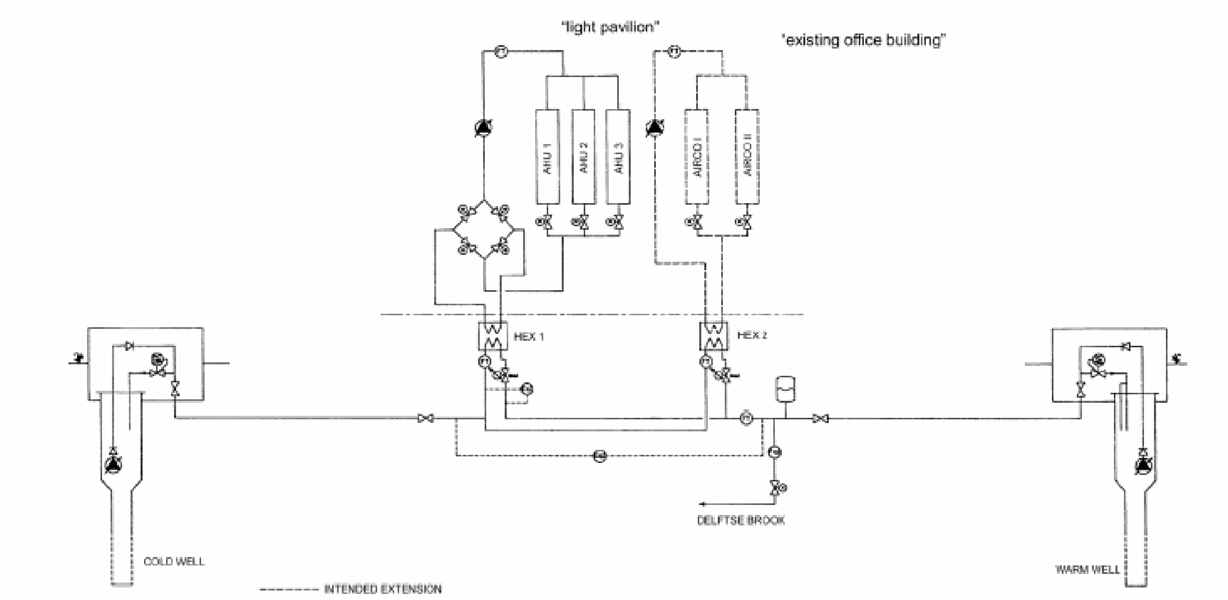

Figure 1: ATES system "ETAP"

This project was monitored from 01/01/2003 to 31/12/2005. During this period, in total 126,721 m³ of groundwater was pumped with 43,071 m³ for charging cold or delivering heat to the building (direction from warm to cold well) and 83,650 m³ for discharging cold or delivering cold to the building (from cold to warm well). Figure 2 gives the evolution of the temperature of the cold well during 2004. A rise of the cold well temperature can be noticed during the summer period. The temperature raises slow and steady from about 8°C in June to 11°C by the end of September. This proves that by the end of the cooling season the groundwater system is still active and can still provide cooling to the building system, the offered temperature is even below the natural ground temperature for this region (12°C). During the heating season, heat is extracted from the warm well at about 13°C and injected in the cold well at an average temperature of 7°C (charging of cold).

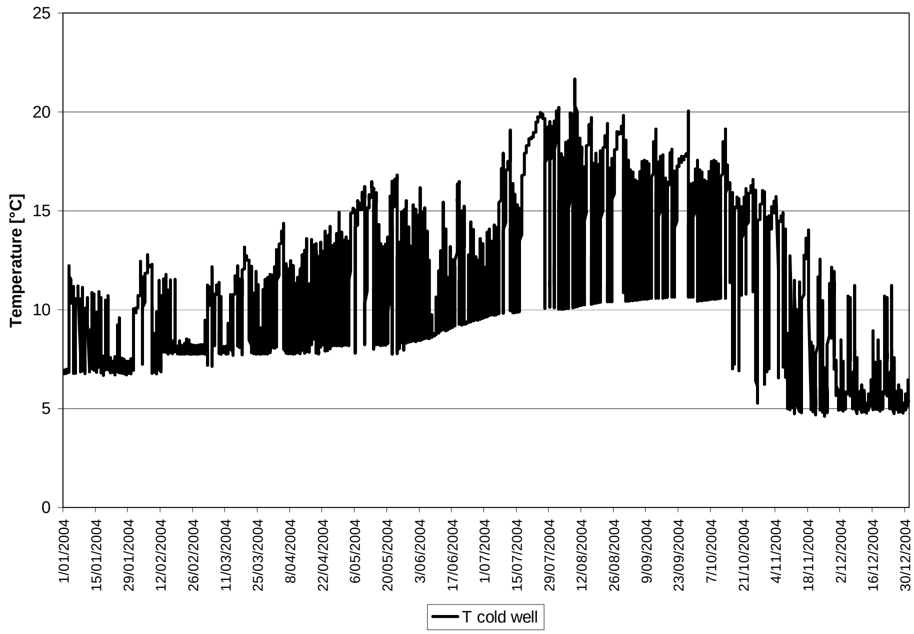

Figure 2: Cold well temperature during 2004

In fall and winter of 2004, the average injection temperature in the cold well is significant lower then during the first months of the year. This is due to a different setting of the desired charge temperature. A lower set value results in lower cold well injection temperatures. On the other hand, charging will only be possible at lower temperatures which results in a smaller total charging period and less charged energy. It's thereby very important to find a good value for the charging temperature in order to have an optimal balance between cold well temperature and charged energy amount. Considering the energy amounts of the different heating and cooling seasons over the monitoring period, it can be concluded that the balance is in a good equilibrium. Over the total period, in total 280 MWh_{th} of cold is charged and 323 MWh_{th} is discharged.

The discharged energy is completely used inside the building for cooling purposes during warm periods. At the charging process during winter time, outside air is heated by water from the warm well. However, this heat is not entirely usefully spent in the building as a lot of cold is stored during nighttime when ventilation is not essential and the heat is brought back to the environment. Measurements indicate that about 46% of the charged energy has contributed to the building heating by preheating of the ventilation air.

The total electrical input during this monitoring period is 22.6 MWh (figure 3). When refrigeration is considered separately (the ATES system has been especially meant as an alternative for cooling machines) 12.2 MWhe of electricity is necessary for providing 323 MWhth of cooling (SPF_{cold} = 27). Because the heat from the warm well is only partly usefully used, the SPF is during the heat supply lower, particularly SPF_{heat} = 12. This heat supply represents only a small share in the total heat demand of 1175 MWh, it is 106 MWh or 9%. The cooling demand on the other hand is taken entirely (100%) by the ATES system.

By application of these low-energy technology a saving on gas of 41,699 kWh/year is reached and an electricity saving of 23,232 kWh/year. Because of this 1021 GJ less primary energy was consumed during the past three years. This corresponds to an annual saving of approximately 340 GJ or 18% of the necessary primary energy of the reference installation. The application of ATES reduced CO_2-emission with more than 68 ton over the past 3 years. On an annual basis this gives a saving of approximately 23 ton or 21 %.

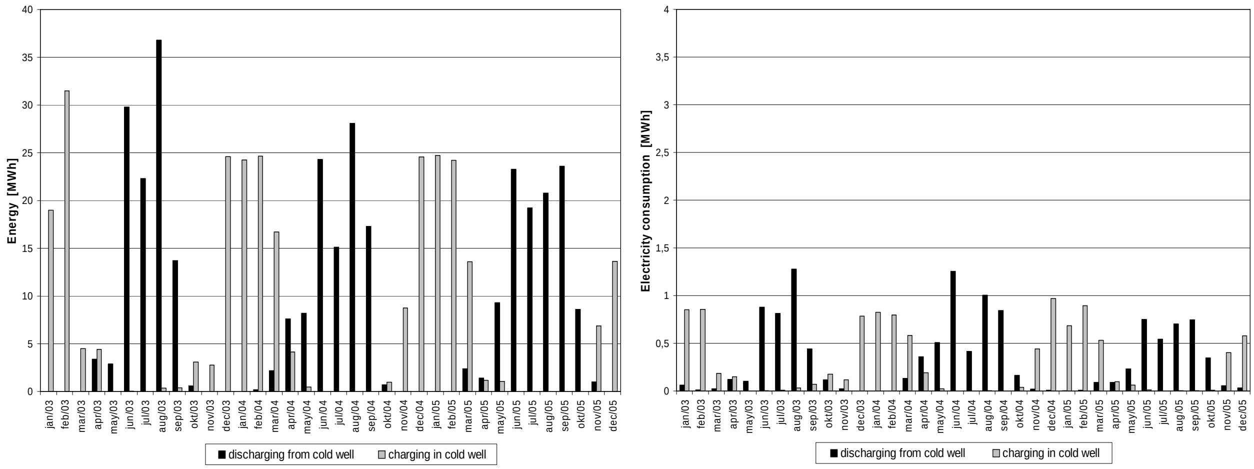

Figure 3: Energy deliverance (left) and energy consumption (right) of the ATES system at KLINA

In order to incorporate the ATES system at this application, an investment of 342,000 € was necessary, an investment of 148,000 € could be avoided (no refrigerator necessary). The reduction of the energy consumption led to a yearly saving of 13,000 €. This gives a simple payback time of 15 years. Objection at this figure concerns the only partial exploitation of the system until now, today only 40% of the capacity of the sources is exploited. At complete exploitation the payback time will more than halve. In this evaluation the financial support by the government is not taken into account.

Project "KLINA"

The clinics of Northern Antwerp (KLINA) decided to cooperate and to extend with 400 beds. For that purpose, a completely new hospital was built with full climatisation. The KLINA hospital was one of the first in Belgium to incorporate comfort cooling in the patient rooms. In order to avoid expensive cooling with traditional refrigeration a system with long term storage of cold and heat in the groundwater was installed.

An ATES system was installed in combination with two reversible heat pumps. This system contains one cold and one warm well with each a depth of approximately 65 m. (diam. drilling = 80 cm). The maximum groundwater flow amounts to 100 m^3/h for both charging and discharging of cold. The two reversible heat pumps have each a heating power of 195 kW and, depending on the season, are used for heating or cooling. The ATES system provides cooling by means of pumping up groundwater from the cold well (see also figure 4). This groundwater incorporates the building warmth and is injected in the warm source. At inadequate cooling power or if an insufficiently low temperature is reached by the system, the heat pumps are integrated. The condenser warmth is also removed by means of the ATES system to the warm well. In the winter groundwater is pumped up from the warm source with as aim preheating the ventilation air. This way the winter-cold is taken by the ATES system and injected in the cold well.

The project is monitored over the period 01/12/2002 - 30/11/2005. During this period more than 534,000 m^3 groundwater was moved from cold to the warm well and 515,000 m^3 groundwater in the opposite direction. This represents in total 4.8 GWh of heat and 3.7 GWh of cold.

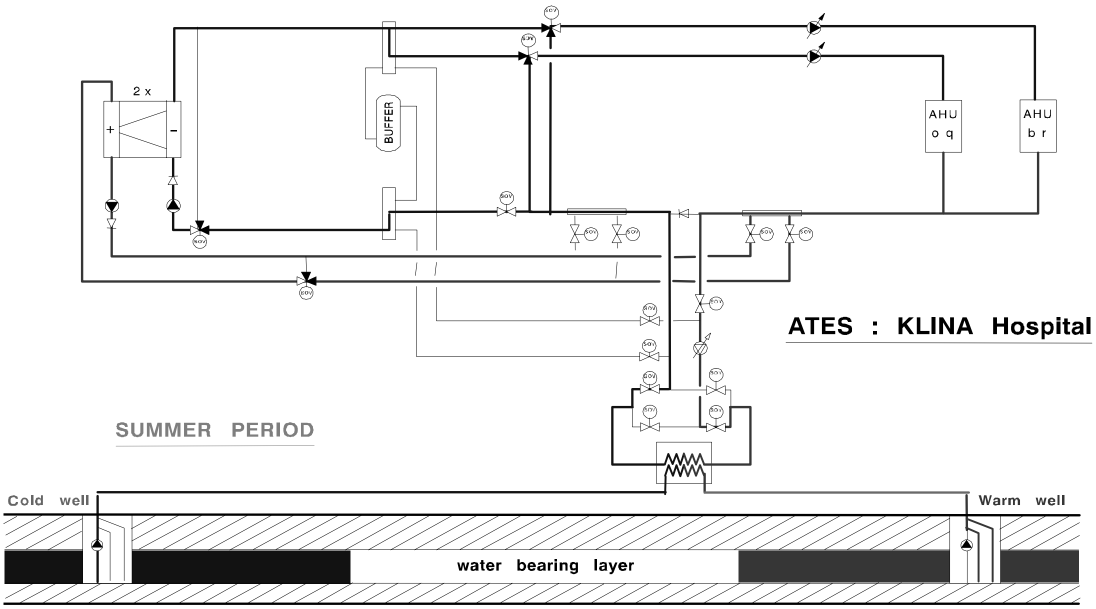

Figure 4 : KLINA - ATES operation during summer period

The energy supply by the ATES system (discharging of the cold source) for 2005 is presented in figure 5. The system provides a capacity between 100 kW and 1.2 MW. In the winter period there is a more constant but lower capacity supply with an average of 350 kW (provide heat to building or cold charge of cold source). The presence of a heat pump helps significant in the cold charging process. The number of charging hours increases and is independent of the outside air temperature. Furthermore, the injection temperature is more constant and at a interesting low value. In the summer period the provided capacity varies much more and fluctuates in function of the intensity of overheating of the building.

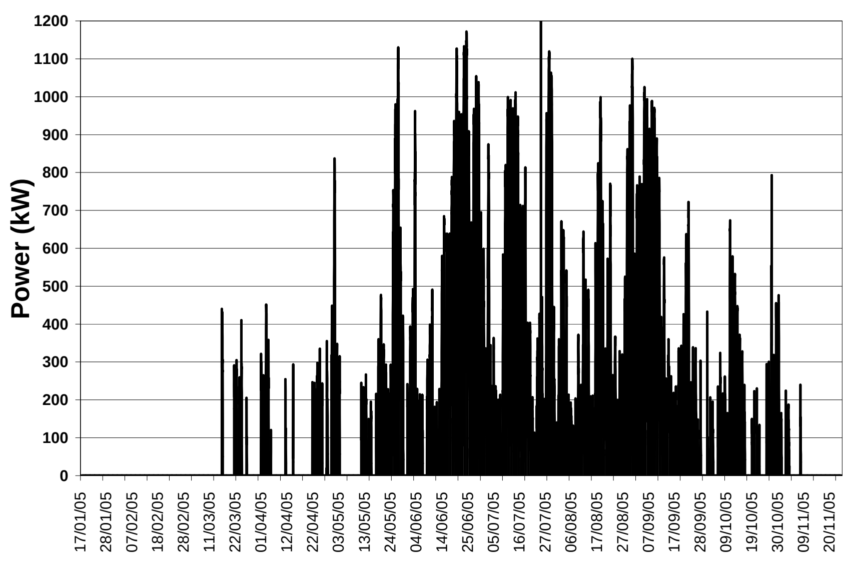

Figure 5 : KLINA - ATES power supply during cooling

Figure 6 gives a picture of the energy supply of the ATES system and the heat pump concerning the entire monitoring period (three years). The largest part (74%) of the ATES cooling is applied directly for comfort cooling of the building (incl. surgery, pharmacy,…). The remaining 26% is used for refrigeration of the condenser of the heat pump during summer situation (operating as a cooling machine). This operation is necessary for supplying cold on low temperature (for dehumidification purposes). Analogously the groundwater system provides heat, the proportion of direct heat supply to the building is rather limited (17%). Generally, the warm well will provide heat to the evaporator of the heat pump at heat demand. In this way, efficient heat supply is provided to the building and the cold well is charged. The seasonal performance factor (SPF_{cold}) for cooling amounts 29.

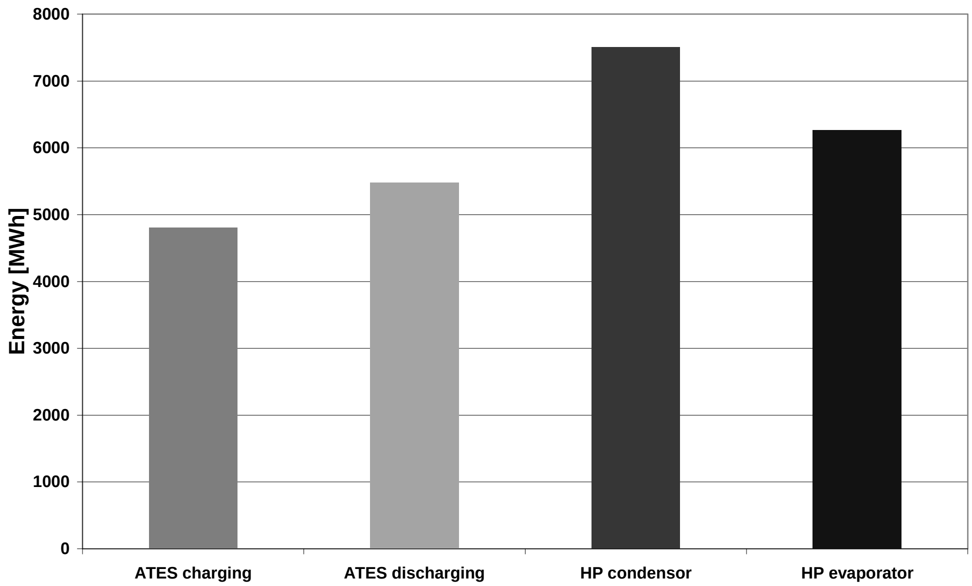

Figure 6 : KLINA - ATES energy amounts

The application of ATES reduced CO_2-production more than 1909 ton over the past three years. The gas consumption for conditioning of the ventilation air is omitted entirely and is replaced by electricity consumption of the source and heat pumps. Because the heat pumps operate very efficiently, the total electricity consumption remains under this of the reference installation. There is a total primary energy saving of 69% on the climatisation of the ventilation air with a CO_2-reduction of 67 %. On an annual basis, this installation stands for a reduction of primary energy with approximately 9,000 GJ and a reduction of CO_2 with approximately 650 ton.

It's important to point out that the total heating demand of the building also involves a static heating system with classic radiators and a boiler as heat supplier. It's typical that the ratio static / ventilation heating is about one. Recalculated to the total energy demand for heating and cooling the primary energy saving amounts 41 % for this renewable energy technology.

Project "St-DIMPNA"

The public hospital St-Dimpna has carried out a modernization and extension of the building property. The comfort within the building was raised by the application of a complete climate regulation of all rooms. In order to limit the energy use, an ATES system combined with cogeneration and reversible heat pumps as well as condensing boilers are applied (figure 7).

The ATES system has one cold and one warm well with each a depth of approximately 100 m. (diam. drilling = 70 cm). The maximum groundwater flow amounts to 100 m^3/h for both charging and discharging. The cogeneration unit has a thermal capacity of 705 kW and an electric capacity of 455 kW. The reversible heat pump has a heating capacity of 400 kW and, depending on of the season, is used for the production of heat or cold. In the summer, water from the cold well is withdrawn for refrigeration of the air in the air-handling units, condenser heat of the heat pump and cogeneration heat can be added before the groundwater is injected in the warm well. During the winter, the pumped warm water from the warm well is used for pre-heating of the ventilation air, after possible further cooling with the evaporator cold en then guided to the cold well.

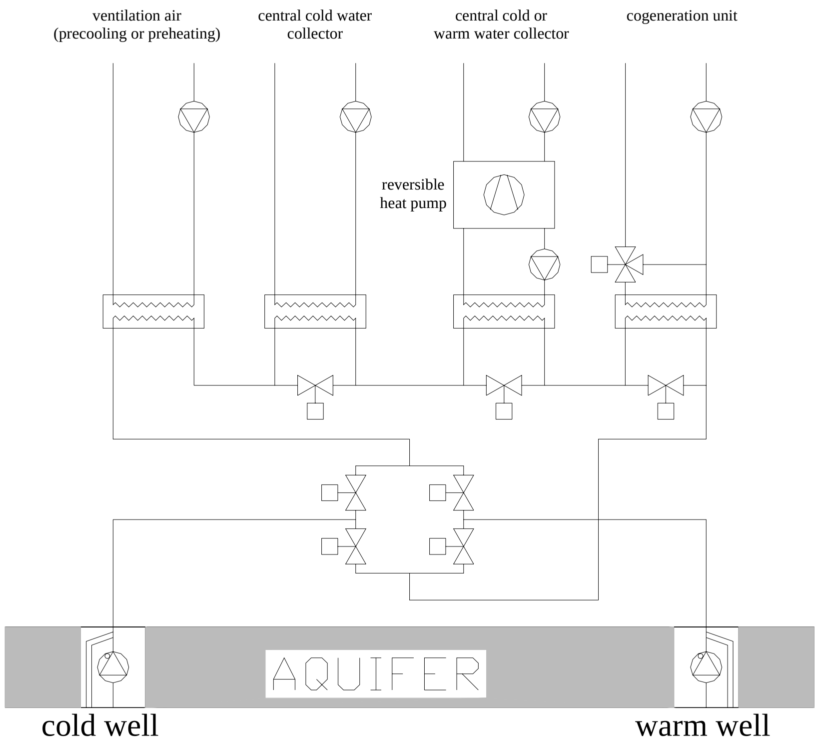

Figure 7 : St-Dimpna hospital : schematic diagram ATES system

For this installation, an interim report is drawn up after three months of operation (feb-mar-apr 2003). An overview of the main findings in this report regarding to the durable energy installation :

- In the indicated period there was a total cooling demand of 168 MWh and a total heating demand of 1167 MWh for the building (all consumers included);
- There was a durable deliverance of 22% by the ATES system; 15% of the heat demand was covered by the groundwater system against 53% by the WKK;
- The contribution of the groundwater system (ATES) situates on (pre)heating and cooling of the ventilation air;
- The average charging temperature amounts to 11°C, which is insufficient in order to become a cold well temperature significant below the natural ground temperature;
- The reversible heat pump provides 24% of requested cold to the cooling system, heat supply is impossible due to high return temperatures of the heating system;
- The cogeneration unit functions with a relatively low total efficiency of 73% (η_{th} = 42% ; η_{el} = 31%);
- The condensing boilers deliver heat with an efficiency of 95%, due to the high return temperature from the building there was very little condensation energy (only 2,5% of total heat production);
- Compared with the reference installation, energy savings of 8% on the primary energy use were reached and 25% on the CO_2-emission (for the indicated period);
- This means an effective reduction of the CO_2-emission with 123 ton.

In general, it can be stated that one quarter of the cooling and three third of the heating demand is provided by a durable / energy saving energy technology. An important reduction of the greenhouse gas emission could be realized. Yet, several suggestions were made in order to improve system performance. Main intervention concerns a separation of the hot water supply system from the main heating collector, these results in a decrease of the return temperature and thereby the performance of the heat pump and the condensing boiler improves.

4. CONCLUSION

This paper describes performance of three different ATES systems in Belgium. The installation and integration of such a groundwater system in combination with a traditional HVAC system isn't self-evident. This was proved with the installation of the first systems where some problems occurred on the integration aspects. A good cooperation between drillers, building/HVAC designers and contractors is absolutely necessary with a clear demarcation of the responsibilities.

The results show good operation of the monitored systems with huge savings between 80 – 90 % on the cooling energy offered by the ATES system. When total energy deliverance is considered, an average energy saving of about 60% can be easily reached. This is lower due to the fact that is most cases the charging process isn't combined with a 100% of heat recovery or that heat pumps are used. A comparison with the initial design parameters indicate that the main results comply very good. Due to the important increase of the energy prices, the energy savings are even higher then expected. The investment estimations on the other hand were a little bit too positive in advantage for the reference installation. The two aspects combined show that the financial objectives on simple payback time were more or less reached (payback of 6 years or less without subsidy). The bigger the project, the quicker the payback.

It's very important to have a good charging process, this can be made effective by using a heat pump. The economy of heat pump combined systems show better results then a solely ATES system. The heat pump provides high efficiency heat (KLINA shows COP = 6) while having a very effective charging process in the cold well. Another point of attention concerns the temperature difference of the groundwater circuit, all measures should be taken in order to have it as high as possible. It's therefore not recommended to have a one to one ratio between primary and secondary flow rates. A special attention point regards the control system, the common and transfer signals of HVAC and ATES system and the system settings should be defined and taken care of properly. An ATES system can be integrated in numerous applications, the St-Dimpna project however shows that it's not evident to have an optimal system when using a lot of durable and energy saving technologies together. It's better to keep the installation as simple as possible, but to have it in an optimal shape.

It's clear that well designed and installed ATES systems provide heating and cooling with spectacular efficiency. As a general conclusion it can be stated that of all renewable energy systems (and ATES can be considered as one of them) this technology can present, under good application circumstances, one of the best economical figures.

ACKNOWLEDGMENTS

The authors are grateful to ANRE for supporting this renewable technology and having the opportunity to monitor these ATES systems and to gain experience from it. The introduction of ATES in Belgium has been made possible through the exchange of knowledge and experience with other countries through Belgium's participation to IEA IA ECES.

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