Distributed vs centralized solar District systems. Study case in Mediterranean districts

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Abstract

Balearic Islands have a few renewable energy facilities in the buildings like the rest of Spain. The combination of District Heating with solar thermal centralized and decentralized systems can provide all the thermal energy for the buildings and share the excess of energy during the summer. Solar heating in a central plant and distributed in buildings has been designed to achieve different values of the solar fraction, comparing 100% centralized system and decentralized system with the Spanish Building Code and having the higher efficiency of the system with net zero energy in thermal production.

Keywords: Solar Thermal, Photovoltaic, District Heating, Solar District

1. Introduction

District heating is installed in all over the world, especially in countries with higher thermal demand all the year. Solar heating has obtained increased interest all over Europe in recent years. District heating is one major approach to increase the overall energy efficiency in urban areas, either by refurbishment of existing systems or by the introduction of new systems in existing or new building establishments. On the other hand, solar heat is available practically anywhere all over Europe. A prevailing success factor of the realized plants is the involvement of local actors and policy makers with interest and knowledge to develop and demonstrate the new technologies.

The Solar thermal energy has lost installed power lately against other technologies, like photovoltaics (PV). The electricity has a better perspective, for two reasons, the simplicity of the systems and the excess could be sent to the grid. The thermal systems need not only more support from the public administration using of Large Solar Energy Centralized plants. They need as well new concepts of energy systems with decentralized systems and sell the energy with District Heating Systems, where the bigger facilities (like hotels and building residents) can buy or sell energy according to their occupancy. Mallorca has a high amount of tourist areas where the quantity of tourists during the period when there is more solar radiation makes even more interesting to create District Heating and Cooling combined with large Solar Plants, and share thermal resources between buildings. In different countries, different concepts have been developed for solar district heating. The two main variables are:

The way the solar plant is connected to the net (distributed vs centralized). Distributed solar district heating plant: The solar collectors are placed at suitable locations and connected directly to the district heating primary circuit on site. Often these plants use the district heating network as storage.

The goals of Solar Thermal System are an energy thermal reuse, the challenge of which is how to store thermal energy in the cheapest way, the threshold of power installation between solar thermal generation and green renewable generation to obtain electric power and thermal power and the known objectives basically are energy sustainability for environment purposes and energy efficiency for saving resources purposes. The size of the heat net in which the solar thermal heat is fed-in has to be optimized before installing it. It ranges from small net systems to supply a few buildings to systems destined to supply new construction areas or villages and lastly systems to be connected to large district heating nets supplying large cities. In this paper has been studied a District heating system with several scenarios from completely centralized without solar thermal energy in the buildings to distributed systems with solar thermal energy in each building at the Balearic Islands.

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2. Description of the system

Large Solar Energy Centralized plants can sell the energy with District Heating Systems, where the tertiary buildings and residents can buy energy according to their necessities. Mediterranean towns have few heating necessities, and sometimes larger cooling necessities, only the Domestic Hot Water is the most constant throughout the year, that makes even more interesting the creation of District Heating and Cooling combined with large Solar Plants, and share thermal resources between buildings. The maximum distance considered is 5 kilometers, there will be different scenarios studied, one installing one Large Solar Plant in the center and another with distributed generation (roofs, and public areas). In all the cases flat plate collectors have been considered. We have studied different Buildings, with different necessities (Education, Hotel, Multi-family, city block, single houses, commercial, Municipal, Hospital,) for the Balearic Islands. There has been developed a simulation program from the conclusions and detailed analysis from other studies (Wolfgang Streicher 2006) using the typical meteorological year (TMY). The result will be presented with very few days of overheating, and using all the energy throughout the year for Domestic Hot Water (DHW). The solar policies are different in each country, according to the IEA Members. In our case the Spanish Technical Building Code is promoting the solar energy in two different ways. For each new building a demand limitation is imposed through simulation taking into account passive solar issues. In a second stage, the energy footprint is calculated, where active solar systems are directly involved in the simulation. In the new buildings or big upgrade, a minimum DHW contribution from 2006 is imposed and it will be revised in the upcoming years to include district heating and cooling system characteristics. This imposition requires a minimum quantity of solar panels to produce the DHW, between 0,5-1 square meter per person, to produce a solar fraction between the 30-70%, according to the solar radiation and external temperatures. At the Balearic Islands this is between the 50-70% according to the size of the system. In existing districts, the less than the 10% of the houses are made with the new code, and from the existing there is a 15% with solar energy. In new districts all the buildings will have solar energy, and in 2020 they will almost be zero energy buildings.

<u>DATA</u>

Demand of Domestic Hot Water: according to the Spanish Technical Building Code.

Demand of Heating: space of 20 m^2 24h for heating, the rest according to real simulation

Surface of FPC to cover de % of DHW: according to the Spanish Technical Building Code.

The occupancy factor has been contemplated in each building.

Simulating the whole year system we reach different solar fractions depending on the efficiency of the system and the working temperature of the storage system.

ST Collector Efficiency $\eta = 0{,}807 - 3{,}075(T_m-T_a)/G - 0{,}022((T_m-T_a)/G)^2$ (eq. 1)(e)

$Q_{DHW} = m_e \cdot c_{pe} \cdot (T_{HOT} - T_{COLD})$ m= nº people · water-person · density of water $T_{HOT} = 60ºC$ [8]

$Q_{transfer} = U \cdot A_r \cdot (\Delta T_A - \Delta T_B) / (ln\Delta T_A - ln\Delta T_B)$ with heat exchanger

$$Q_{Transfer} = m_{district} \cdot c_{pe} \cdot \left(T_{in\_D} - T_{out\_D}\right) = m_{builiding} \cdot c_{pe} \cdot \left(T_{in\_b} - T_{out\_b}\right)$$

Without heat exchanger the solar policies are different in each country, according to the IEA Members [9], most of them they give tax deduction or helps and others they have in their technical building code.

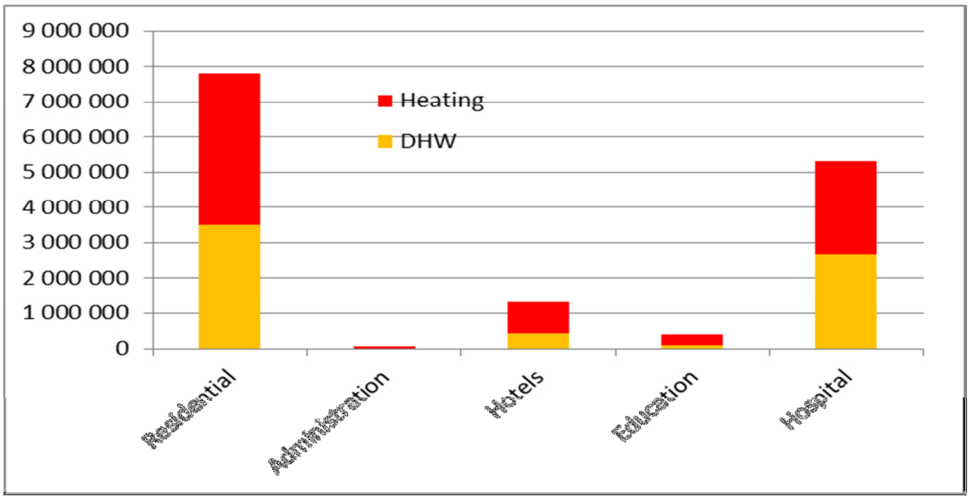
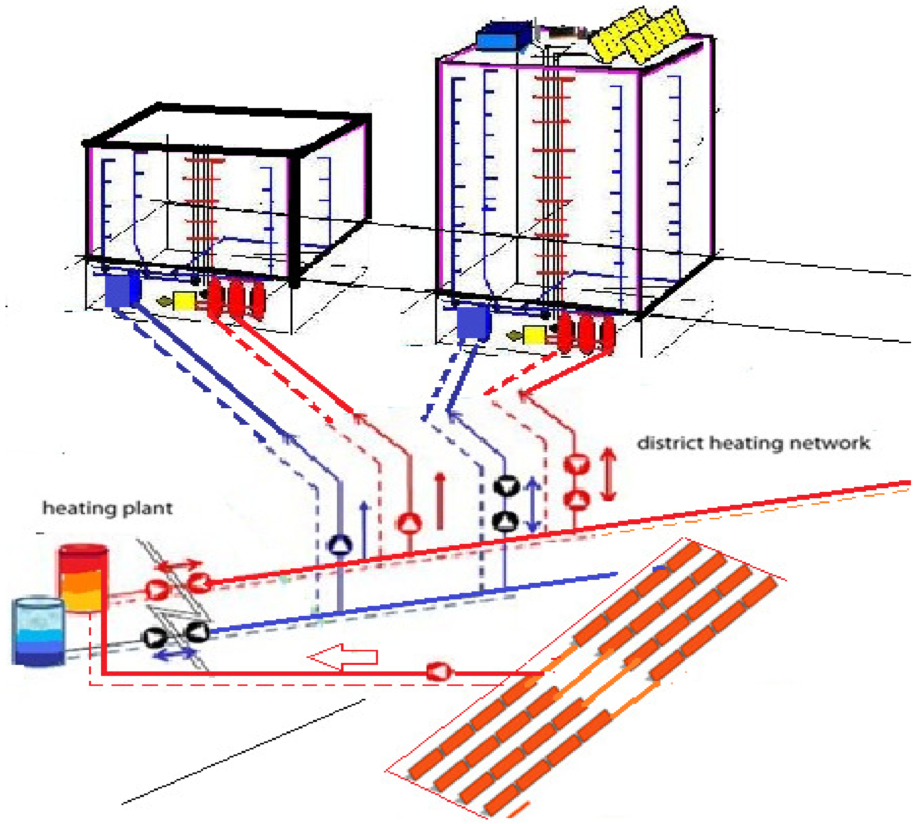


Figure 1. Annual Thermal consumption for uses and buildings in Balearic Islands district

Tab. 1: Demand according to the Spanish Code and solar fraction per year.

	Liters/day person at 60ºC	Solar Fraction
Residential	28	50-70%
Administration	2	70%
HOTEL	55	70%
Education	21	70%
Hospital	55	70%



. **Figure 2. District heating and cooling decentralized network. Unidirectional buildings and bidirectional buildings.**

3. Results

We can see five different scenarios, comparing a completely centralized system (Figure 3) without solar energy in the buildings, to a system with a 100% of the buildings with a solar system providing the 70% of the DHW provided by their FPC (figure 6), and sharing the excess of energy to the District Heating. Other scenarios have been simulated, from 25% to 75% of the building with solar energy. We set a number of buildings for each scenario according the actual situation, and after that we obtain a random normalized number with the average of people on these buildings. Besides we obtain a random number with the % of solar thermal installation deployed with the reference target. So once established, these random values are going to be constant during the whole simulation for each building changing the % of occupation, obtained by another variable in each loop of 8760 cycles averaged by days. In order to run the whole simulation by Visual Basic (VBA), it has been necessary to run that by parts or by buildings.

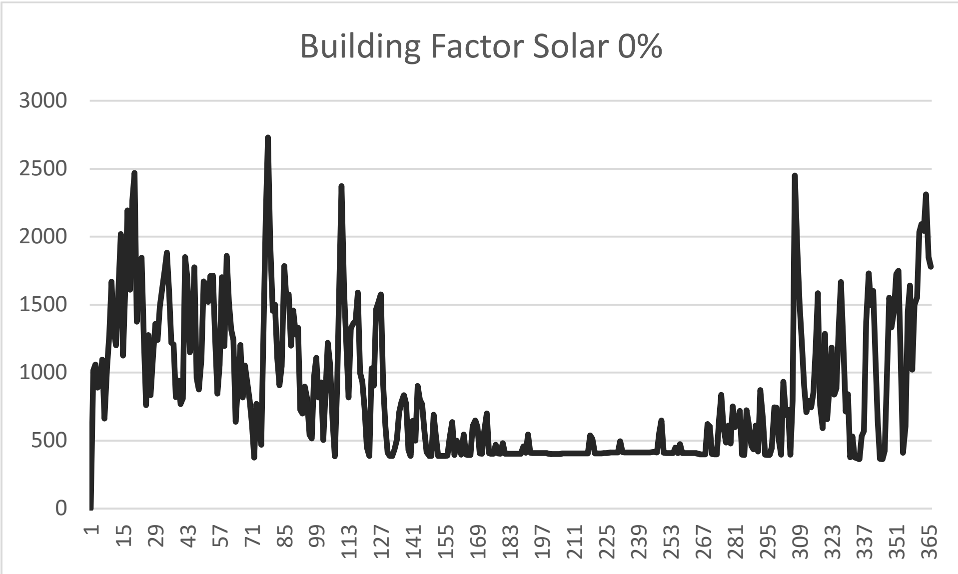


Figure 3. Annual Thermal consumption in a completely centralized District heating network.

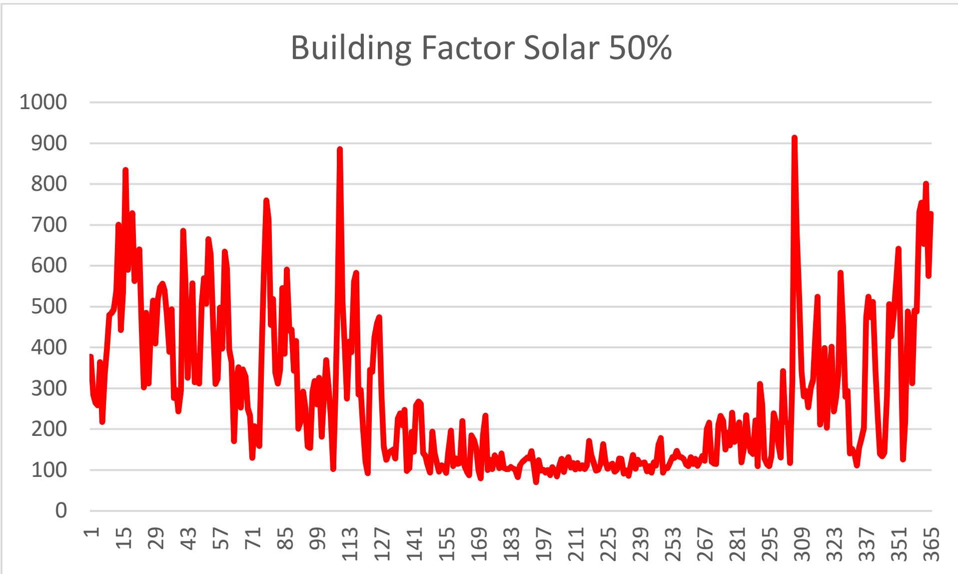


Figure 4. Annual Thermal consumption in a 50% distributed Solar District heating network

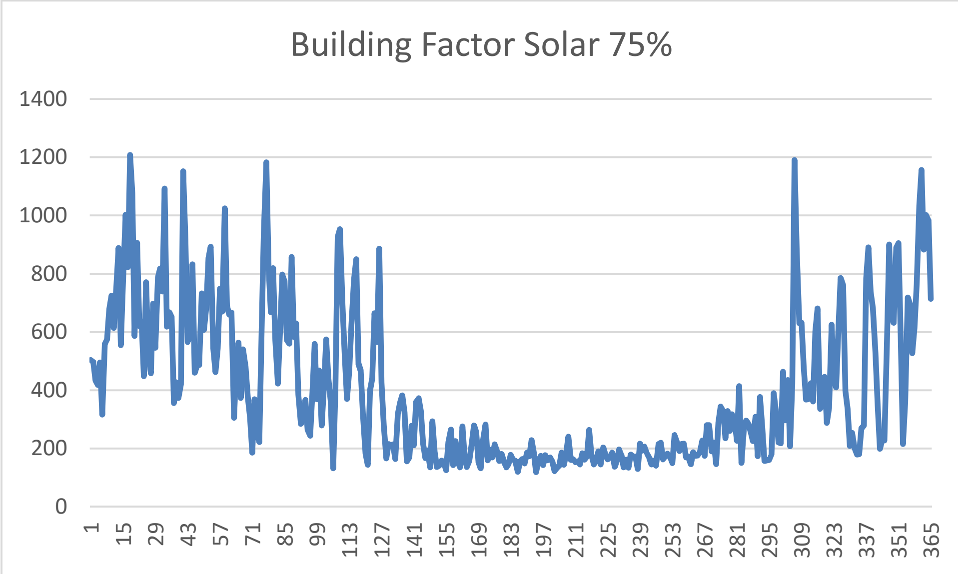


Figure 5. Annual Thermal consumption in a 75% distributed Solar District heating network

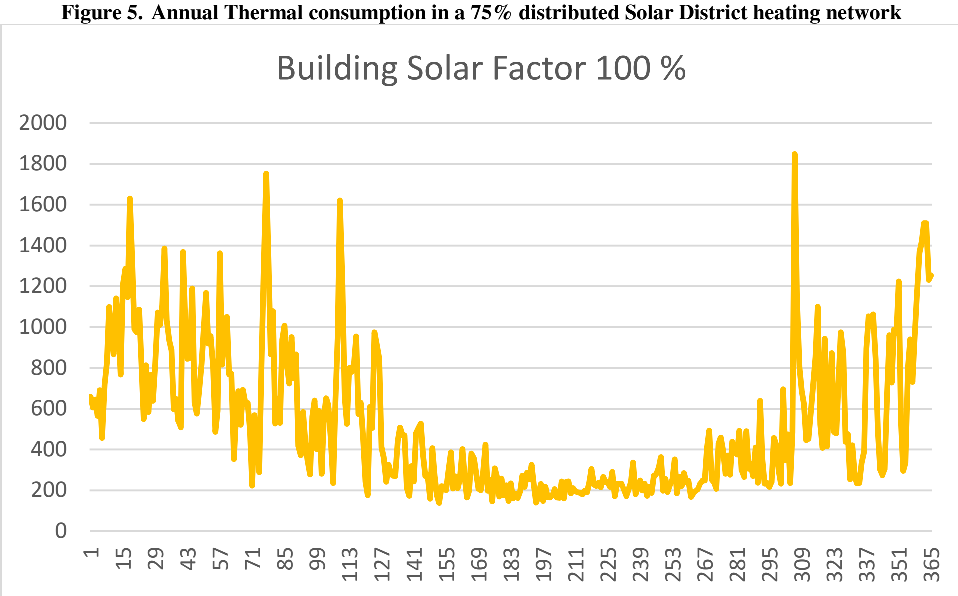


Figure 6. Annual Thermal consumption in a 100% distributed Solar District heating network

The decentralized systems with the actual laws will be better than the conventional solar district. Solar – Photovoltaic - Thermal Technology is an interesting solution for micro thermal generation as well micro electric generation to compensate electric demand of pumps by net zero balance. Heating and cooling solar district is the way in southern locations to thermally efficient buildings with high thermal demand as residential and hospital locations should have an absorption chiller for their micro thermal installation.

As the majority of solar irradiation is in most regions (especially in southern countries) not produced during heating season, summer time operation is crucial for financial effects of a solar thermal plant (Streicher & Fink 2006). The centralized systems have the advantage of not having thermal excess, according to the production system and the storage systems, but they need larger dimension of pipes and pumping consumption.

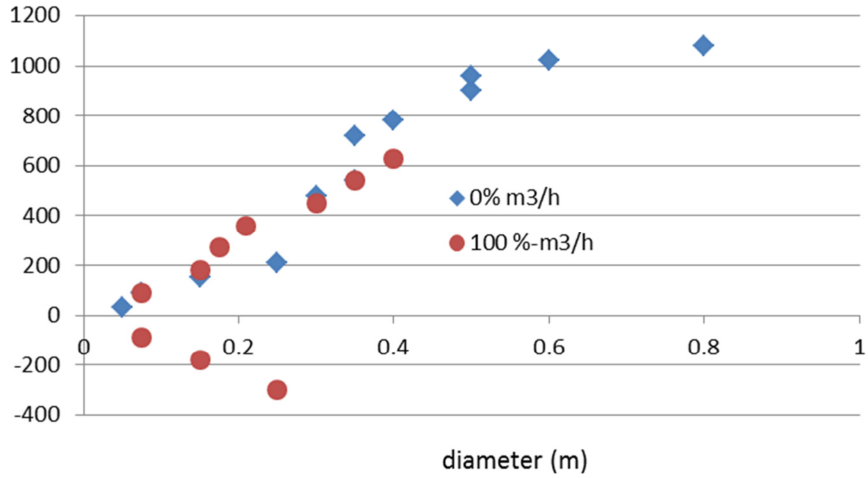


Fig. 7 : Peak Flow vs. diameter in a centralized (0%) vs. distributed(100%) Solar District heating network

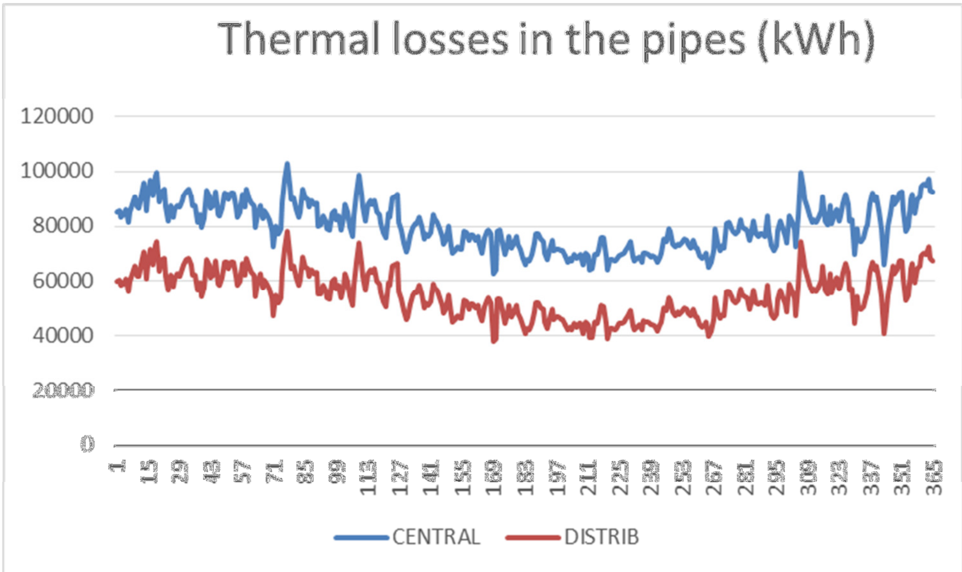


Fig. 8 : Thermal losses of the Pipes of a Centralized vs. distributed Solar District heating network

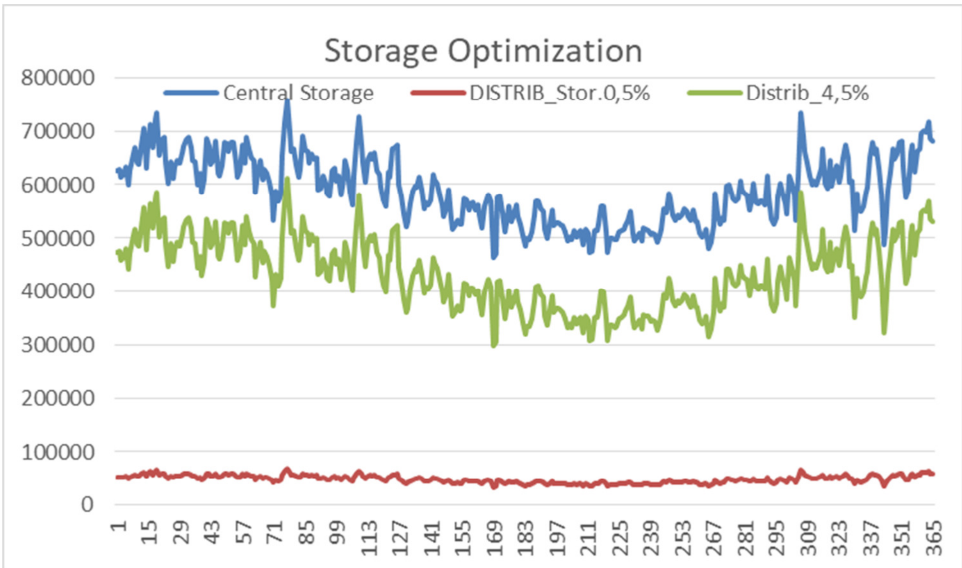


Fig. 9 : Thermal losses of a Storage Centralized vs. distributed Solar District heating network

Some scenarios of storage have been studied, the thermal losses of a distributed system are higher due to the surface of the tank, but in the distributed system the storage is necessary to reduce the thermal losses of the pipes. The optimal storage of the central tank vs. the distributed tank have to be studied from another point of view, like safety reasons, and have thermal safety in each building. The engineers usually put the volume of one day of DHW consumption. Figure 9, which shows the storage thermal losses, makes it clear that it´s better to have a large centralized tank with small tanks distributed, the 4,5% (220 m^3) of the storage has almost the same losses than a central tank with the 95,5% of the volume (4900 m^3). Some storage is needed in each building for have more reliability and safety for the distributed FPC.

If we center on distributed systems with a high fraction of solar thermal energy, with the radiation of a southern country, like Balearic Islands, we achieve districts where we need storage systems, seasonal storage or design to be improved, but the best in these cases will be found in other uses, like cooling systems (absorption or adsorption technologies) in the biggest buildings, where the cost of the devices is similar to the compression machines.

These systems are necessary in southern countries where tertiary buildings usually have more cooling necessities than heating (Moià-Pol et alt 2014). The distributed systems have another advantage: smaller dimension of pipes and less pumping consumption, because only peak demands are needed to pump to the grid. The diameter of the distributed system is almost a 50% smaller than the centralized systems. Strategies of flow and Delta T can be designed in order to control the pumps from the maximum flow to the minimum flow (figure 7). The usage of bidirectional substations reduces the centralized heat production for the DHW of all the consumers of the District Heating Network, even during summer (Lamaison et alt 2017).

It is planned to install this system in a District of the Balearic Islands, however it will be necessary in order to have real testing results, to improve the simulation program and algorithms and find new technologies, materials and systems. According to the actual Spanish law the maxim solar fraction for all the thermal uses will be less than the 21%. In the future with the NZEB directive these fraction could be 2 or 3 times bigger, depending of the District and the local laws. With bigger fraction, the dimension of the pipes could be even smaller, and have lower pay-backs for the biggest facilities, where each building could sell the over production, with the same rules that the PV systems.

The cooling demand has to be included in future studies, with higher solar fraction, and has to be included in the algorithm so as to improve the mix of the central plant, in order to arrive to zero emissions districts. For areas with more tourism, where in summer there is an increase of the DHW the system could arrive to a perfect balance.

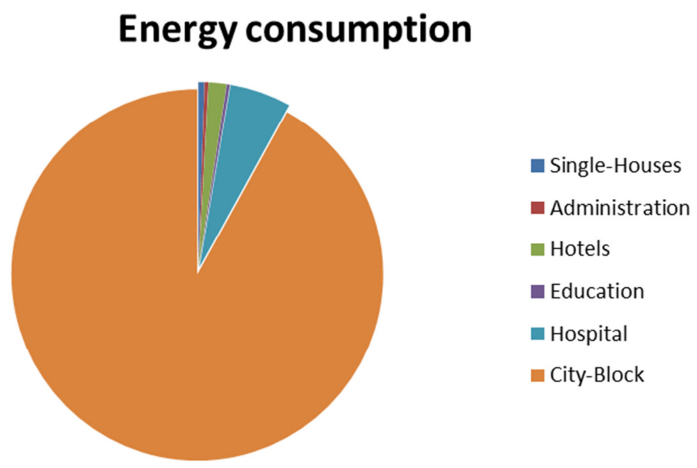


Figure 10. Annual Thermal consumption for buildings

4. Conclusions

The decentralized systems with the actual laws will be better than the conventional solar district, with fewer dimensions of pipes and pumping consumption. Thermal solar energy systems must be increased at the legislative level to reach zero-emission buildings (Heating fraction). District networks are essential if we want solar thermal energy to compete with photovoltaics.

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