Case study : Ecodistrict Villeneuve in Chambéry

Name of the project:	Ecodistrict Villeneuve
Adress of the project:	ZAC du Coteau F-Cognin
Name and type of the owner:	SCDC, utility company 193 Rue du pré Demaison 73093 Chambéry CEDEX 9
Owner Contact person:	Claude Mortier, Managing director claude.mortier@cofely-gdfsuez.com Jean-Louis Lecocq, Chief operating jean-louis.lecocq@cofely-gdfsuez.com

A/ Context of the study

A.1/ Motivations

Chambery is a city of 60,000 inhabitants located in Savoie (France) with an agglomeration of 210,000 inhabitants. Very active city in the promotion of renewable energy, it received in 2008 the 1st prize in the category Solar cities over 50 000 inhabitants.

A new residential area of 1200 housing is created in Cognin suburbs of Chambery city, with a first phase of 500 housing built on the period 2014-2018. Following a study of the energy supply of the district, it was decided to extend the existing district heating to supply this new Ecodistrict called Villeneuve.

Specifications of the BIA plan the implementation of 1.5 m² of solar thermal collectors for housing to ensure an average of 50 % of the DHW needs. To provide a global energy production to the real estate developer and achieve a higher solar fraction through the solar storage tank, the utility company decided to study a decentralized solar solution connected to the low temperature district heating. The solar system connected to the district heating should contribute to the global commitments of the operator who wants to reduce the carbon content of the DH network.

A.2/ Description of the existing DH

The district heating of Chambery was created in 1949. It is currently the 5th French district heating through its length, and the 15th through its energy production. The district heating has a wide energy mix with recovery of waste, Combined Heat and Power, biomass and gas.

The network operates at high pressure, distributing the energy over 55 km from superheated water (140°C/180°C). It provides energy to 25,000 equivalent housing, to feed including health care facilities, educational institutions, social housing, municipal buildings, industries...

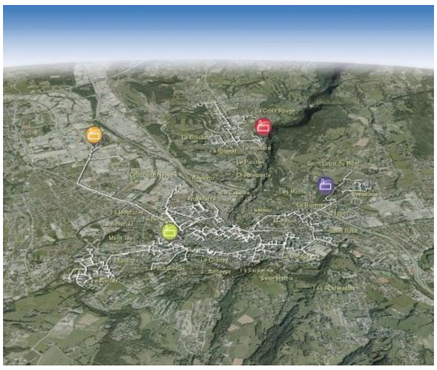


Figure 1 : Production plant of Croix Rouge (left) and Chambery district heating layout (right)

Figures from DH :

- 3 heat production plant
- 1 combined and power plant (CHP)
- 55 km of buried pipes
- 550 delivery points
- More than 25 000 équivalent housing

Production plant :

Bissy plant

- Waste heat recovery 16 MW
- 2 vapor gas boilers 40 MW
- 2 gas turbines 8.5 MWth
- 1 vapor gas boilers 4 MW

Croix-Rouge plant

- 1 biomass boiler 7 MW
- 2 superheated water gas boilers 11 MW et 13 MW
- 1 hot water gas boiler 3 MW

Bassens plant

- 1 superheated water gas boiler 23 MW
- 1 hot water gas boiler 4 MW

In 2013, the energy mix of the network is composed of biomass (12%), waste heat recovery (28%), CHP (23%), gas (37%). The CO_2 content of the network decreases and its value in 2011 is 172 gCO_2/kWh.

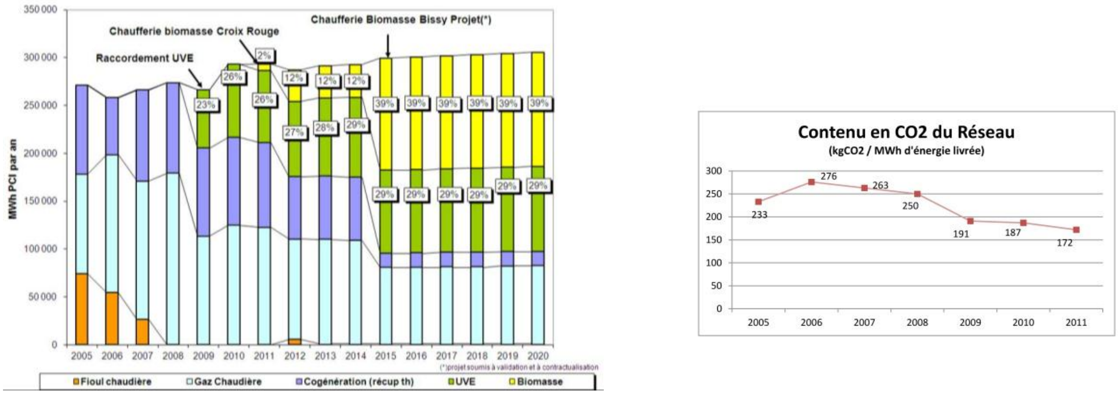


Figure 2 : Current and future energy mix (left) and evolution of CO2 content of the network (right)

District heating operation:

The municipality of Chambery has given the public service of production and distribution of heat through a concession contract since 1987 (public service delegation) to the Société Chambérienne de Distribution de Chaleur (SCDC), a subsidiary of Cofely.

Network extension project:

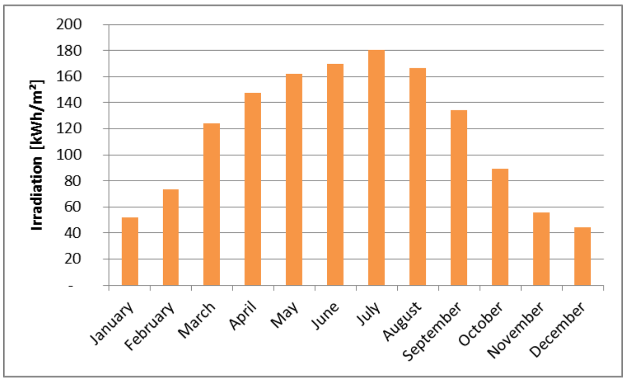
The ecodistrict Villeneuve will be powered by a low temperature sub network (70°C/50°C) connected to the return of the high pressure existing network (180°C/110°C).

A.3/ Environment data

The extension of the district heating is located in the town of Cognin (France) at the end of the existing network.

Figure 3 : Implantation of Ecodistrict Villeneuve

The average annual irradiation on a 30° tiled surface is 1400 kWh/m² and the average ambient temperature is 11.8°C. The number of heating degree days HDD_{18} is 2500.



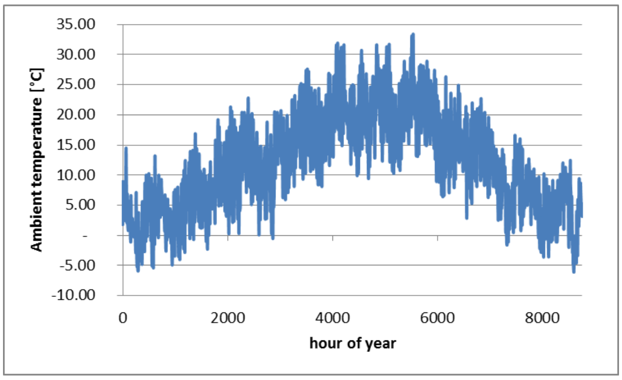


Figure 4 : Monthly irradiation on 30° tiled surface and ambient temperature for the climate of Chambery

A.4/ Opportunities and barriers

The main opportunities having helped initiate and develop the project are:

- the creation of a new district with low consumption buildings
- the will of the city and the DH operator to develop renewable and recovery energy heat, and decrease the CO_2 content of the network
- the choice of a low temperature district heating to provide energy to the ecodistrict
- the requirement for buildings in the ecodistrict to provide 50% of the domestic hot water by solar energy

However, many obstacles have also been apprehended, including:

- the pressure on land and the lack of availability of land to establish a centralized solar collector field. Therefore, a decentralized solar system with collectors integrated on the buildings was chosen.
- the innovative technology aspect of solar integration into the network, and especially the lack of operating experience in France
- large initial investment associated with solar solutions that have in return a very low operating cost
- the lack of a fixed framework for subsidizing solar installations connected to district heating. A specific fund managed by ADEME was implemented in 2013 for the financial support of emerging new technologies demonstrator project: “heat fund NTE”
- the lack of knowledge and motivation of urban planners, architects and real estate developers for the integration of large solar area on buildings and also the integration of a large storage tank within the ecodistrict

B/ Methodology and tools used in the study

B.1/ DH load profile

The current study was focused on the 1st phase of the project which comprises 480 apartments spread over approximately 12 buildings whose annual consumption objectives are:

- space heating : 25 kWh/m^2
- domestic hot water : 20 kWh/m^2

The expected solar system is decentralized with solar collectors integrated on buildings and connected at different points of the heating network. Many architectures for the integration of solar at the level of buildings including local consumption were studied.

Taking into account these constraints, the load curve of the network was defined from the needs of all buildings and losses of network:

- Space heating : building modeling and dynamic simulation performed with TRNSYS software
- Domestic hot water : draw-off profile from the work of the Task 26 of the IEA, and DHW system modeling including DHW loop
- Hydraulic of the network : modeling all the pipes of the network

The total needs of the district heating are 2168 MWh/year.

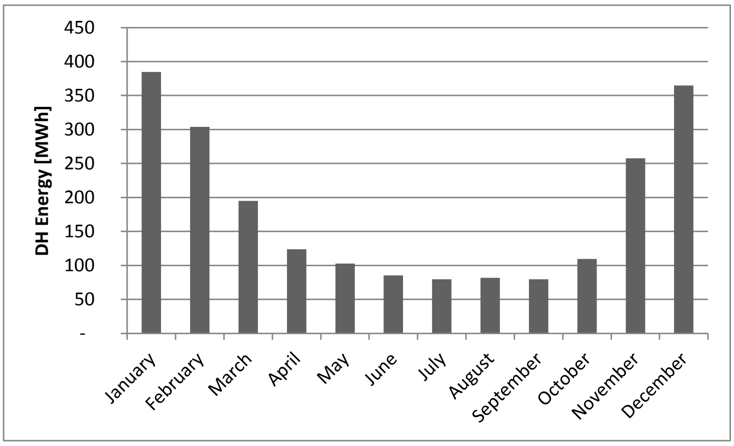


Figure 5 : Monthly distribution of energy needs of district heating

The load duration curve of the district heating is detailed on the next picture.

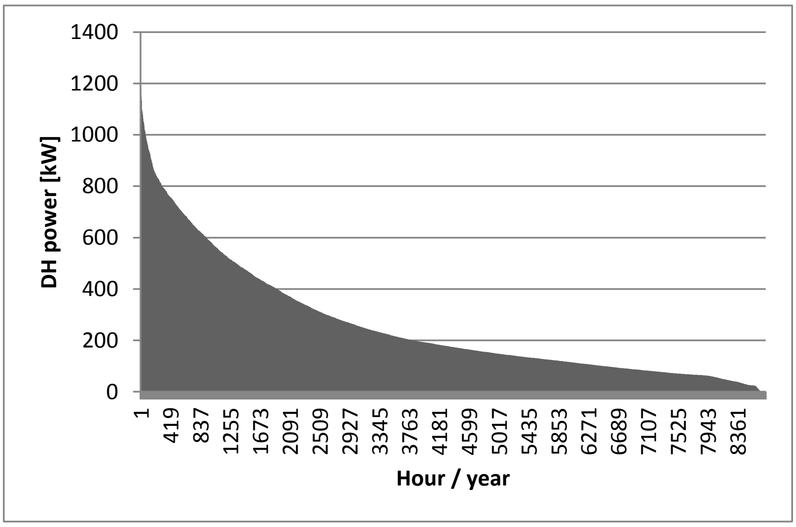


Figure 6 : Load duration curve of the district heating

B.2/ SDH design and sizing, energy balance

The solar system for the district heating of ecodistrict Villeneuve is decentralized with energy feed in many point of the network. The objective is to achieve a high solar fraction of the energy needs of the network. All these specific technical points and also the first of its kind in France oriented the choice of the tool to the dynamic simulation software TRNSYS.
All the network, buildings and solar systems were modeled and simulated.

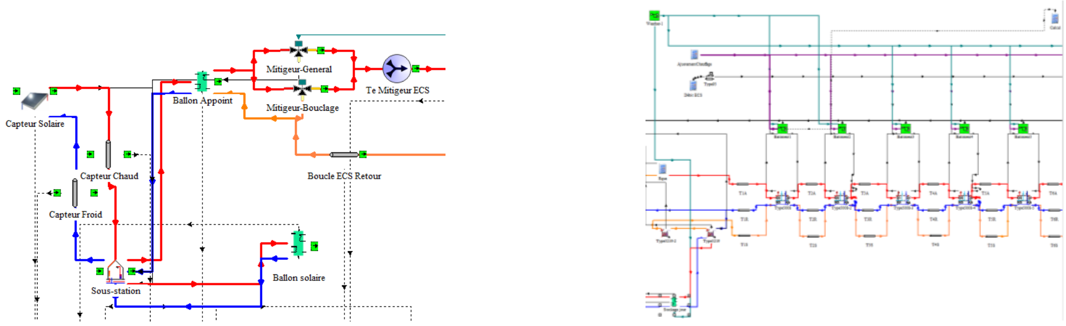


Figure 7 : Modeling of substation (left) and complete district heating (right) with TRNSYS

Climatic data used in the simulation are based on Meteonorm data.

Many energetic indicators are used in order to define the performance of the system.

<u>The network solar productivity Q_{sol,m^2}:</u>
It indicates the solar energy feed in the district heating divided by the total solar collector area.

$$Q_{sol,m^2} = \frac{Q_{sol,year}}{A_{solar}*1000} \text{ [kWh/m}^2\text{]}$$

With : - $Q_{sol,an}$: annual solar production [MWh]
- A_{solar} : solar collector area [m²]

<u>The fractional energy saving f_{SAV}:</u>
It indicates the ratio of the economy of energy compared to a reference case without solar.

$$f_{sav} = \frac{Q_{aux,solar}}{Q_{aux,ref}}$$

With : - $Q_{aux,solar}$: Auxiliary consumption of the system without a solar installation [MWh]
- $Q_{aux,ref}$: Auxiliary consumption of the reference system without any solar installation [MWh]

The reference case is a district heating network without any solar installation. The annual consumption of the 12 substations is 1944 MWh, and the annual consumption of the district heating including heat losses of the network is 2168 MWh.

B.3/ Economics

The energy cost calculations are based on the methodology of the Levelized Cost Of Energy (LCOE).

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{Q_{sol,year,t}}{(1+r)^t}}$$

With : - I_t : Investment expenditures in the year t
- M_t : Operations and maintenance expenditures in the year t
- F_t : Auxiliary energy expenditures in the year t
- n : Lifetime of the system
- r : Discount rate

The hypotheses for the cost calculation are:

- Solar system (solar collector, control, installation) : 365 €/m²
- Solar substation for feed in the network : 12500 €/substation
- Over cost 3rd pipes : 5000 €/substation
- Storage : 250 €/m^3
- Engineering : 7.5% of initial investment
- Operation and maintenance : 1% of initial investment
- Electricity consumption : 1.5% of the solar production
- Discount rate : 4%
- Annual increase in electricity prices : 3%
- Inflation rate for the operation and maintenance costs: 2%

The installation is financed with 10% own founds and a loan of 20 years with an interest rate of 3%.

Other economic indicators specific to the utility company have been calculated by himself to determine the profitability of the solar system.

C/ Results of the study

C.1/ SDH system design, energy balance and performance

Connection to the existing district heating:

The ecodistrict Villeneuve will be fed from a low temperature sub-network (70/50°C) connected via a heat exchanger on the return of the existing high temperature network.

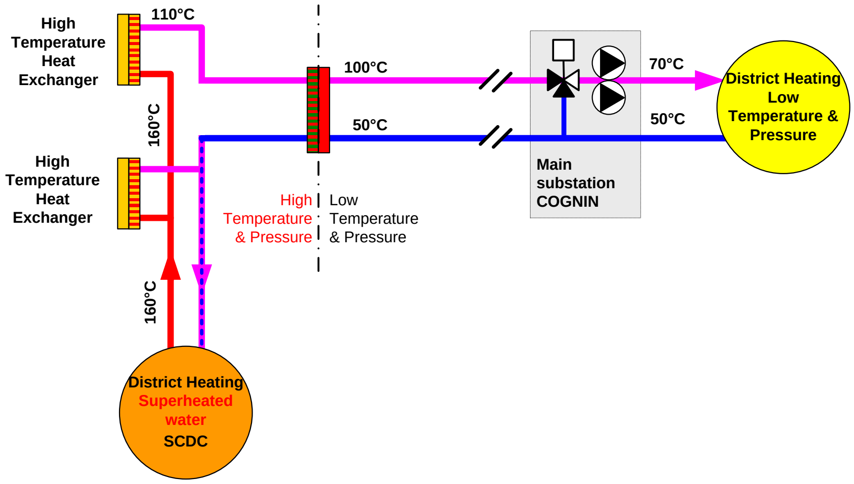


Figure 8 : Principle of connection of the Ecodistrict Villeneuve sub-network to the main district heating

The creation of a low temperature sub-network optimizes the performance of the network supplying the low-energy buildings by reducing heat losses and promoting the integration of solar energy. The connection on the return of the high temperature district heating with a temperature of 110°C allows on one hand the use of the network as it exists without any additional flow rate or work on the pipes due to the over-flow, and on the other hand to reduce the return temperature of the primary network and thus reduce network losses.

Integration of solar in the district heating: decentralized system

The pressure on land and also the lack of availability to establish a centralized field of solar collectors on the one hand, and the will to achieve a high solar fraction (40%) on the other hand, led to the **choice of a decentralized solar system integrated on buildings with a centralized medium-term storage**.

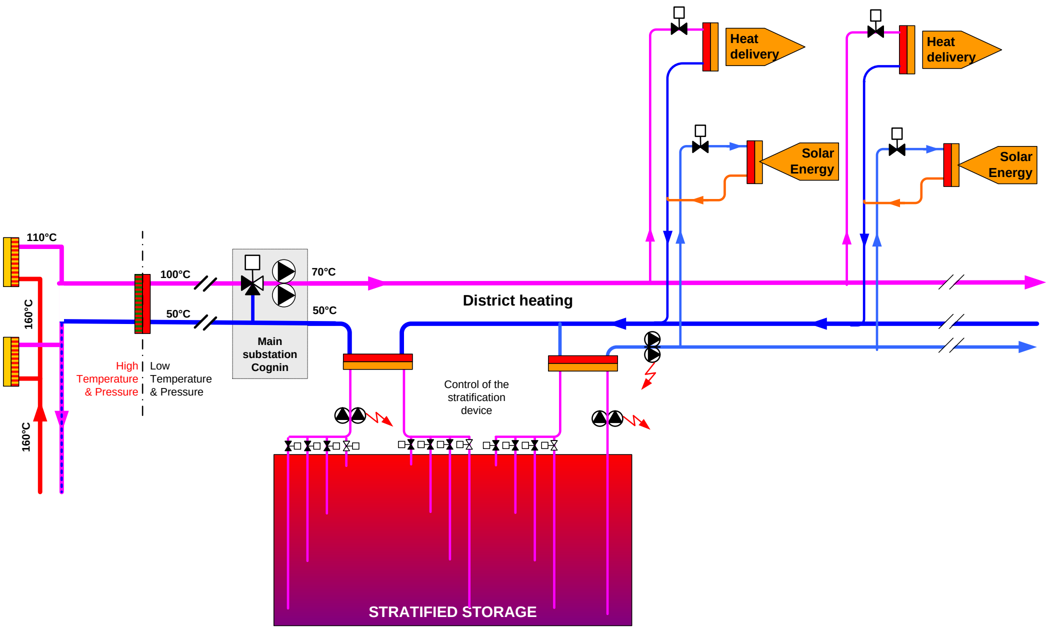


Figure 9 : Example of diagram for the 3 pipes network of Ecodistrict Villeneuve SDH

The high performance flat plate solar collectors are installed on the roof of some buildings depending on the orientation of the building and the availability of roof surface.

The operating principle is:

- *Recovery of solar energy and charge storage*

Solar energy recovered at the building level is fed in the return pipe of the network. The solar loop is supplied from a 3rd tube from the stratified storage.

- *Use of solar energy and discharge of the storage*

Solar energy stored into the storage is used to preheat the return of the district heating. If the set temperature is reached, the HP/LP heat exchanger provides additional energy.

An alternative 3rd pipes district heating is shown in Figure 10.

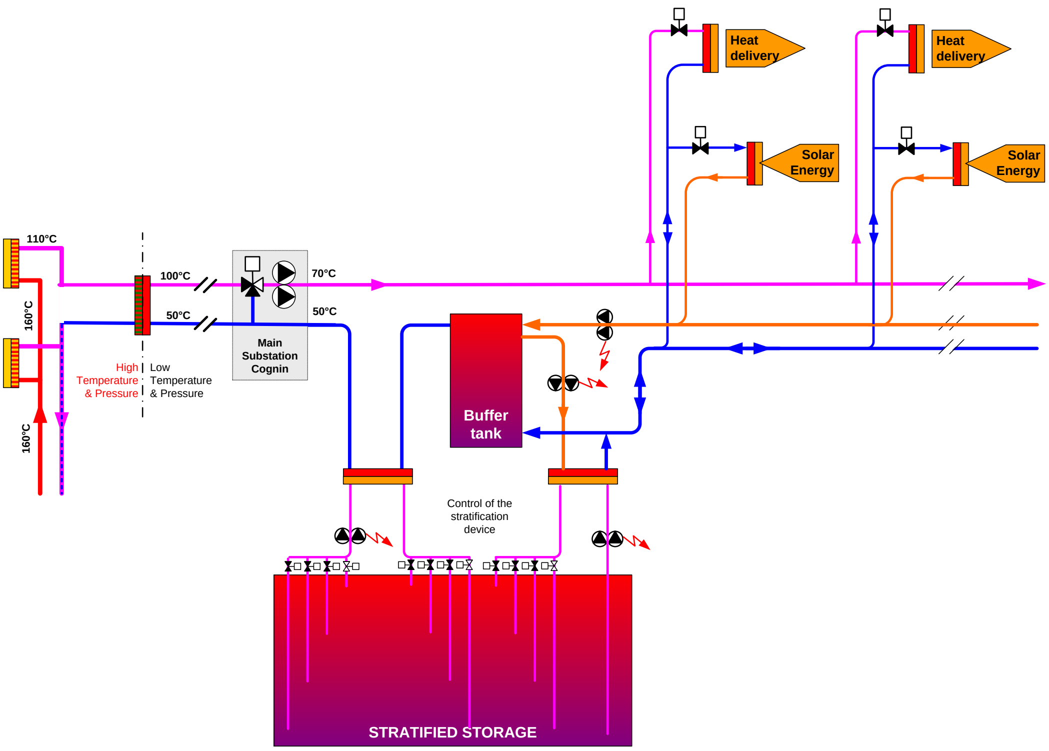


Figure 10 : Alternative diagram for the 3 pipes network of Ecodistrict Villeneuve SDH

In this configuration, solar heat exchangers located in buildings are supplied from the return of the network and recovered energy is fed into a third pipe collecting all the solar energy from different buildings and centralized in a buffer tank. The buffer tank is used to preheat the return of the network and the excess energy of the tank is transferred to the medium-term storage. The principle of valorization of solar energy is identical to the diagram in Figure 9.

<u>Performance of solar district heating:</u>

The system is composed of 2160 m² of double covered flat plate solar collectors ($\eta 0=0.817$, $a1=2.205$ $W.m^{-2}.K^{-1}$, $a2=0.0135$ $W.m^{-2}.K^{-2}$) and a centralized storage tank of $3000m^3$.The annual consumption of the high temperature district heating is 1290 MWh and fractional energy saving of the system is: **f_{SAV} = 40,5%.**

The solar system provides a complete autonomy sub network from June to October.

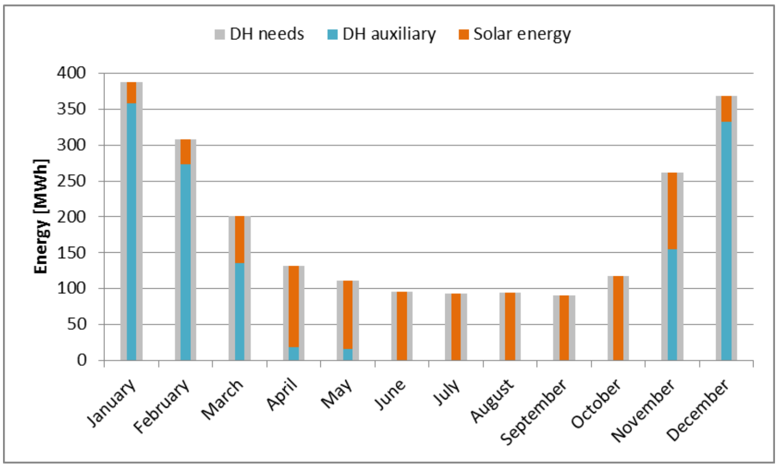


Figure 11 : Monthly distribution of energy supplying the district heating

The following diagram shows the total annual energy involved.

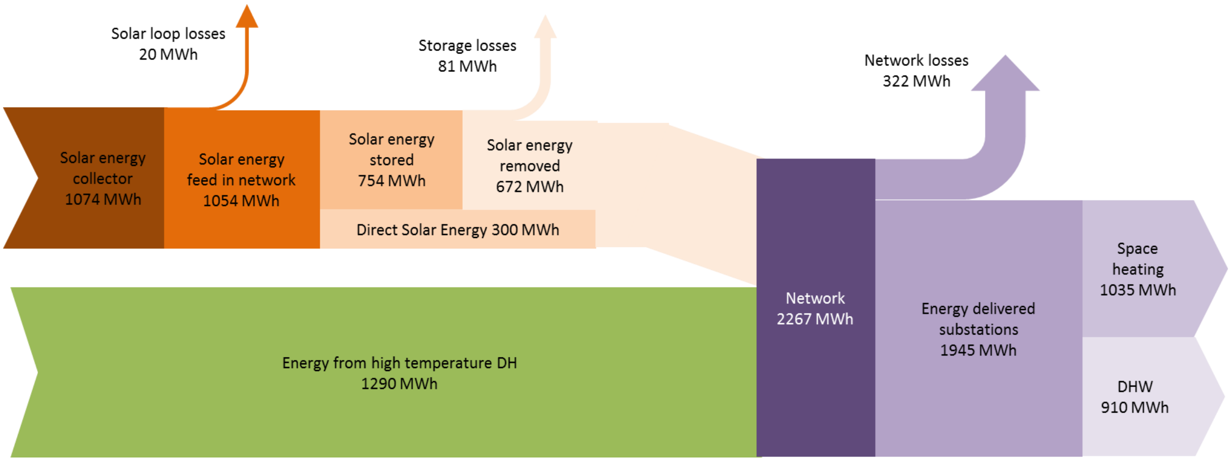


Figure 12 : Diagram of annual energy flow of the solar district heating network

C.2/ Heat production management at network level

The high temperature district heating should provide the auxiliary energy of the sub network supplying ecodistrict Villeneuve. No change in the management strategy of main DH is to be expected thanks to the connection on the return pipe of the existing network. However, improvements in order to maximize the use of the installed storage are considered.

The solar fraction from November to March is low, and it is interesting to observe the charging and discharging of the solar storage tank. In fact, from November the state of charge of the storage is less than 10% and provides no more energy. The storage volume can be valorized:

- by storing carbon-free energy from the high temperature district heating during heat surplus from biomass or incinerators;
- by storing energy to meet the daily consumption peaks and limits the use of peak generators.

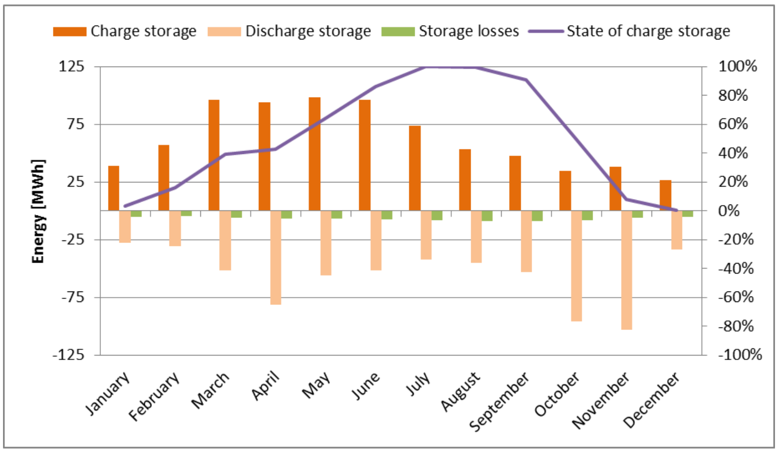


Figure 13 : Charge and discharge of the solar storage tank

C.3/ Economics at SDH level and at network level

The investment required for the implementation of decentralized solar system connected to the district heating network is:

Solar system	788 400 €
Solar substations	150 000 €
Additional cost 3rd pipe and control	102 000 €
Storage	750 000 €
Engineering	134 280 €
Total investment	1 924 680 €
Subsidies (local, regional, national)	1 325 000 €

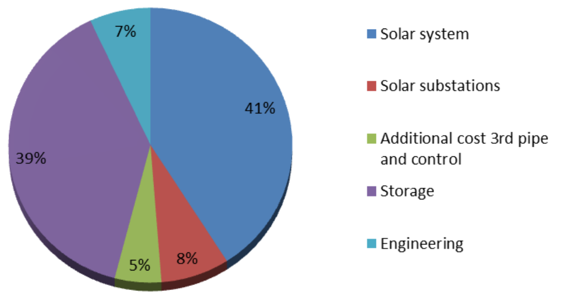


Figure 14 : Allocation of investments by post

Taking into account assumptions detailed in § B.3, the LCOE of solar energy is:

- $LCOE_{without\ subsidies}$ = 142 €/MWh
- $LCOE_{with\ subsidies}$ = 59 €/MWh

It should be noticed that the cost of heat corresponds to a pilot plant to achieve a solar fraction of 40%.

C.4/ Overview of possible business models

The current business model of the district heating is a public service delegation (PSD). The extension of the heating network supplying Ecodistrict Villeneuve is integrated into the existing PSD. The utility company does the investments, operates the solar plant and is remunerated on the sale of heat. The heat price in Ecodistrict Villeneuve will be the same as for other DH customers.

Authors

This study was done by CEA INES, the engineering office ITF and the utility company SCDC.

This factsheet was prepared by CEA INES. Date : 20/12/2013

Cedric Paulus, CEA INES - Institut National de l'Energie Solaire
50, Avenue du Lac Léman, 73377 Le Bourget du lac, France
cedric.paulus@cea.fr, website: http://www.ines-solaire.org - http://www.liten.fr

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