Case study: Solar Ecodistrict Triangle Sud in Montmelian

Name of the project:	Solar Ecodistrict Triangle Sud
Adress of the project:	Triangle Sud F-Montmélian
Name and type of the owner:	Montmelian city Place Albert Serraz 73800 Montmélian
Owner Contact person:	Jean Rauber, General Director of services directionservices@montmelian.com

A/ Context of the study

A.1/ Motivations

Montmélian is a city of 4,000 inhabitants located in Savoie (France). It is also known in France and Europe as a pilot city in the field of solar energy due to its implication since 1983. The town has 1,564 m² of solar panels that means 390 m² per 1000 inhabitants (10 times more than the national average which is 32 m²).
Winner of the French solar championship in its category for many years, it is one of the four local authorities in France having been awarded in December 2007 with the European label Cit'ergie for his exemplary policy "Energy-climate".

The project of Triangle Sud continues the dynamics of innovation. In his new local urban plan, the town's objective is to host new people and meet the housing needs of tomorrow. Triangle Sud was confirmed as a future urban area with a strong environmental ambition: to make a neighborhood incorporating a solar heating system with a solar thermal fraction of 80 % of the heat demand. The pre-operational planning study for the overall design of a new neighborhood of 800-1000 housings was launched in 2012 on this basis.

A.2/ An original design approach

The aim to build a solar district heating in that future district has defined a new way of working for the team and the city. The technical aspects were first studied to properly identify the requirements of solar area (m² panels), inter-seasonal storage (high volume) and associated network in order to achieve 80% solar fraction of energy demand. While generally the technical approaches come to superimpose the urban approach, the urban planning work has integrated at an early stage and with an iterative approach the technical data to mature and develop a comprehensive environmental coherence.
The pre-operational study of Triangle Sud was given to a group of architects, urban planner, landscape designer, energy consultant with the support of the National Institute of Solar Energy. The project concerns the development of a solar ecodistrict of about 800 housings.

A.3/ Environment data

The future Solar Ecodistrict Triangle Sud is located in the town of Montmelian.

Figure 1 : Implantation of the Solar Ecodistrict Triangle Sud

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

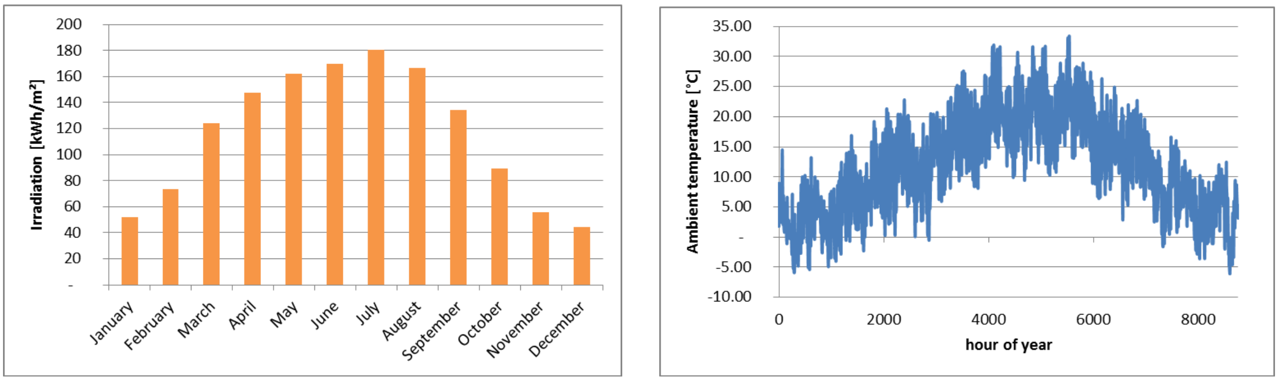

Figure 2 : Monthly irradiation on 30° tilted surface and ambient temperature for the climate of Montmélian

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 positive feedback of the city on existing solar systems
- the willingness of the city to promote solar energy and to ensure a solar fraction of 80%
- integration of the target of 80% of solar energy at an early stage, and a common thinking with the urban planner and architect teams

However, many obstacles have also been apprehended, including:

- the neighborhood development schedule : building of the 800-1000 housings with an annual construction of 40 to 60 dwellings
- the urban integration of solar storage tank due to the objective of 80% solar fraction (thousands of m³)

- 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 business model (legal and financial) of this original project

B/ Methodology and tools used in the study

B.1/ DH load profile

> Space Heating and DHW demand for a standardized housing

The hypothesis for the definition of a standardized housing based on energetic performance of the French thermal regulation RT2012 -20% are:

- average area per housing : 70 m²
- Number of inhabitants per housing : 2.3
- Space heating demand : 2.8 MWh/year
- Domestic hot water demand : 2.1 MWh/year (approx. 40l/(day.person) of DHW at 60°C and 20% of losses for the DHW loop

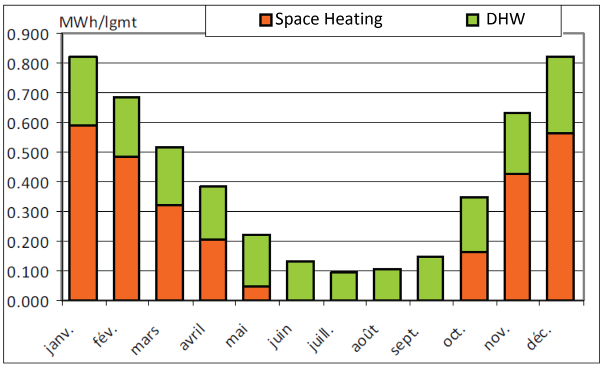

Figure 3 : Space heating and DHW demand for a standardized housing

> Phasing of construction and heat demand

The project plans to build 1,000 apartments. Phasing originally planned for construction is given in the following table and graph as well as the number of units; the number buildings and space heating demand by block including the network losses:

Block	Phasing	Nb of unit	Nb of buildings	Total demand (Heat+DHW+losses)
A	2 years	170	8	884 MWh/an
B	5 years	290	14	1508 MWh/an
C	6 years	290	14	1508 MWh/an
D	3 years	125	6	650 MWh/an
E	2 years	110	5	572 MWh/an

The construction phases proposed the construction of 40 to 60 units per year, this rate being greater the first 2 years of construction.

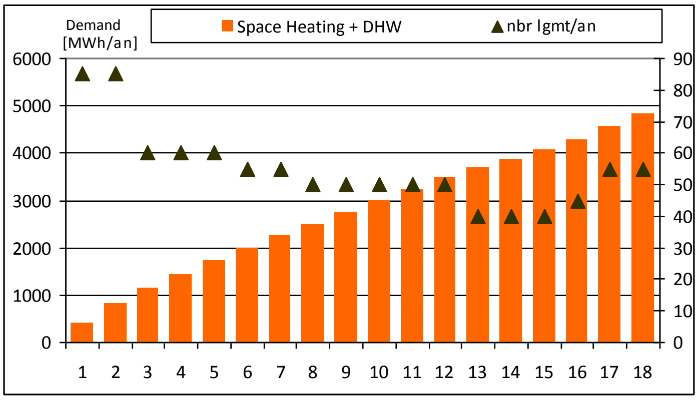

Figure 4 : Phasing of construction (black plot) and cumulated heat demand (orange)

An example of monthly demand profile is shown in Figure 5.

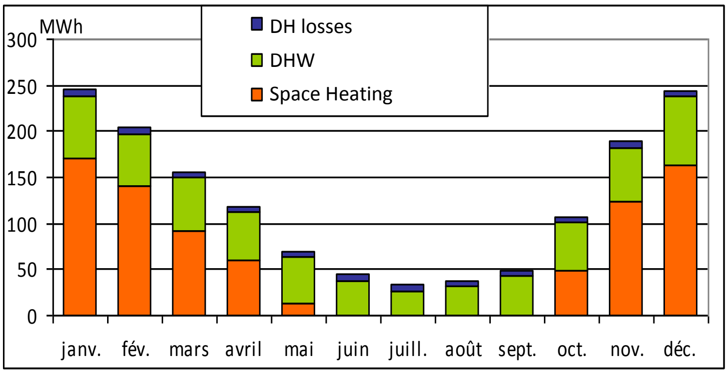

Figure 5 : Monthly distribution of energy demand of district heating for block C (290 units)

B.2/ SDH design and sizing, energy balance

The solar system for the district heating of ecodistrict Triangle Sud is distributed on the building with a centralized solar feed in at the central production plant. The solar system was simulated with the dynamic simulation software TRNSYS.

The solar and production plant have been modeled and simulated. The DH demand is provided by an external file.

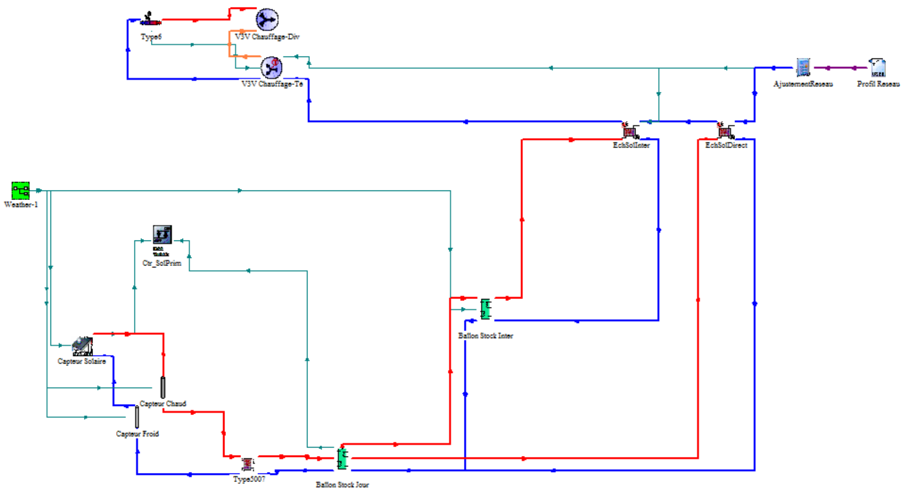

Figure 6 : Modeling of the solar plant with TRNSYS

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.

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

$$Q_{sol,m^2} = \frac{Q_{sol,year}}{A_{solar}*1000} \text{ [kWh/m²]}$$

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

The fractional energy saving f_{SAV}:
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.

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

C/ Results of the study

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

Principle of district heating per block :

The phasing of building leads to an architecture of "decentralized" system to make autonomous each phase (equivalent to a block of 150 units).
The energy is produced by solar collector field located in each building. Solar energy is feed into the network to supply all the buildings. A central boiler, by block, ensures the production of additional energy. Excess energy not used by buildings especially in summer, is stored in a seasonal storage.

The components of this system are (per block):
- A low temperature district heating per block (70/40°C)
- Solar collector fields on building’s roof and connected to the DH
- A centralized auxiliary (gas) production plant
- A seasonal storage : « Tank Thermal Energy Storage » (TTES)
- One substation (SST) per building

The principle is described on the next figure.

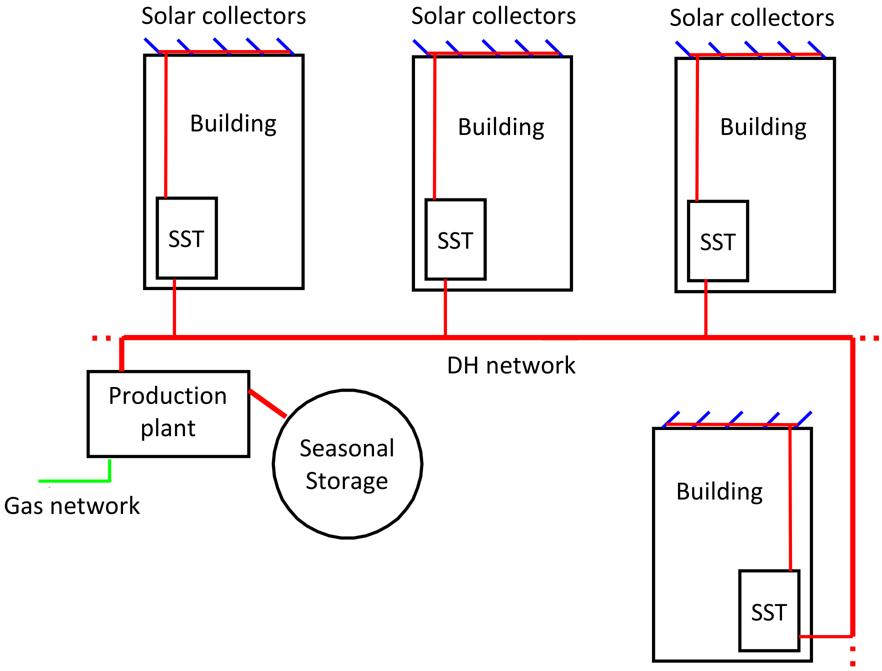

Figure 7 : Diagram of a distributed solar district heating

Performance of solar district heating :

The solar collectors used for this study are high performance flat plate solar collectors (η0=0.817, a1=2.205 $W.m^{-2}.K^{-1}$, a2=0.0135 $W.m^{-2}.K^{-2}$).

In order to achieve a solar fraction of 80%, the energy production should be allocated as described in the next table. The CO2 content of the DH is detailed in the last column with considering a gas boiler as auxiliary energy.

Block	**Nb unit**	**Total demand (Heating+DHW+ DH losses)** MWh/year	**Solar production** MWh/year	**Auxiliary production** MWh/an	**DH CO2 content(*)** g/kWh
A	170	884	709 (80%)	175 (20%)	57.3
B	290	1 508	1 212 (80%)	296 (20%)	56.7
C	290	1 508	1 212 (80%)	296 (20%)	56.7
D	125	650	521 (80%)	129 (20%)	57.3
E	110	572	459 (80%)	113 (20%)	57.3

(*)Hypothesis: boiler efficiency = 90%, PCI/PCS = 0,9 et CO2 emission of natural gas = 234 g/kWh PCI

The characteristics and performance each solar system are:

Block	**Solar collectors area** m^2	**Seasonal storage volume** m^3	**Solar production** MWh/an	**Solar productivity** kWh/(m².an)
A	1 670	6 500	709	424
B	2800	11 000	1 212	433
C	2 800	11 000	1 212	433
D	1 228	4 800	521	424
E	1 081	4 200	459	424

A focus on the performance of the solar system for block A (170 units) is done below.

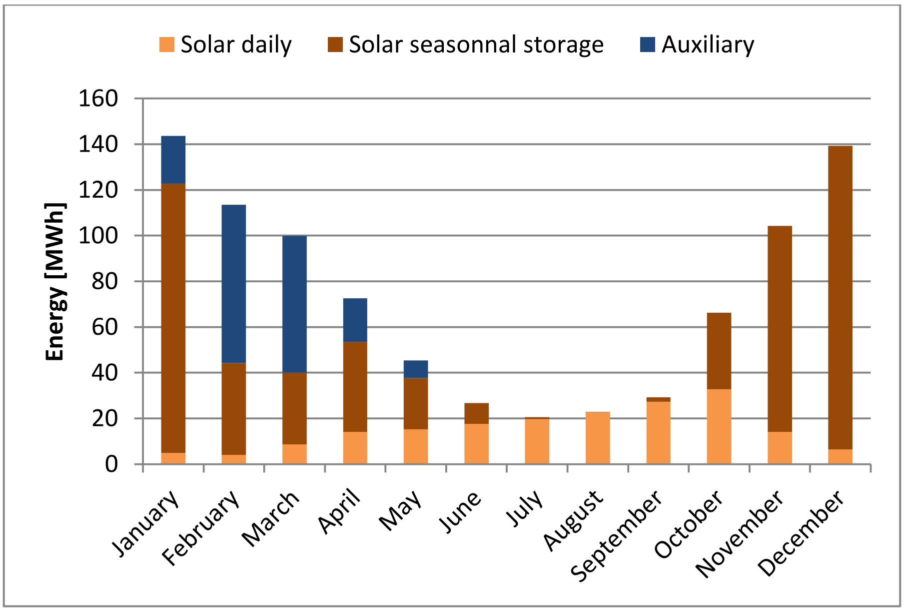

Figure 8 : Monthly distribution of energy supplying the district heating for block A

The following diagram shows the total annual energy involved for block A (170 housings).

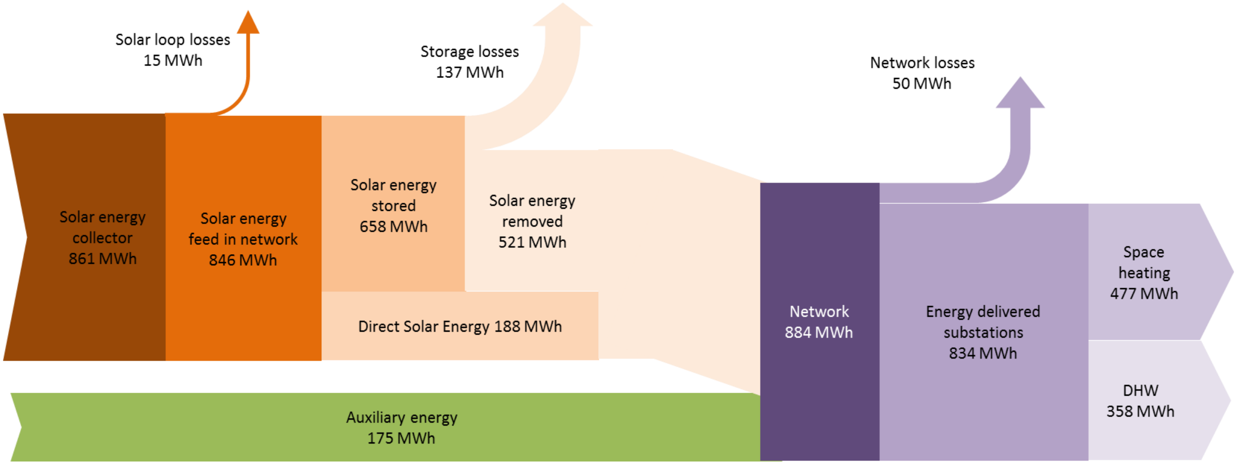

Figure 9 : Diagram of annual energy flow of the solar district heating network of block A

C.2/ Focus on energy storage

TTES storage

The objective of high solar fraction (80%) set by the municipality involves the implementation of high-volume storage for shifting the production and demand of energy. The seasonal storages to implement for different blocks are detailed in the following table :

Block	**Seasonal storage volume** m^3	**Dimensions** Height (m) x diameter without insulation (m)
A	6 500	H15 x D24
B	11 000	H23 x D25 or 2 tanks of H15 x D21
C	11 000	H23 x D25 or 2 tanks of H15 x D21
D	4 800	H12 x D22
E	4 200	H12 x D21

The presence of low depth groundwater limits the possibility of burying the storage to minimize their visual impact in the area. It is therefore important to integrate them as much as possible into their environment.

The next pictures illustrate some possibilities of architectural integration of the storage tanks:


Office round the storage (Germany)


Silo refurbished and dressed with housings (Copenhagen)


Vegetalized silo for parking Lyon(France)


Dressed with a climbing wall

<u>Variant : Borehole storage (BTES)</u>

Borehole thermal energy storage should be used as a variant for tank storage. The principle is to feed heat at high temperature (95°C) into the ground (between 30 to 100 m depth) during summer over production and to remove it during summer when there is not enough solar energy.
The heat is the distributed at a lower temperature (between 65 to 25°C). A heat pump could be used at some moment in order to valorize all the energy.

A first study of hydrogeological and hydrological data has determined that no drilling have been done to a depth greater than 24m. The absence of drilling deeper than 25 m suggests that the presence of water at this depth is limited or nonexistent. It could be a possibility for the implementation of the geothermal storage solution.
The geothermal field would be composed of 100 m depth boreholes with the first 30 meters isolated (to avoid losses to the alluvial aquifer). So the energy could be store between a depth of 30 and 100 m.

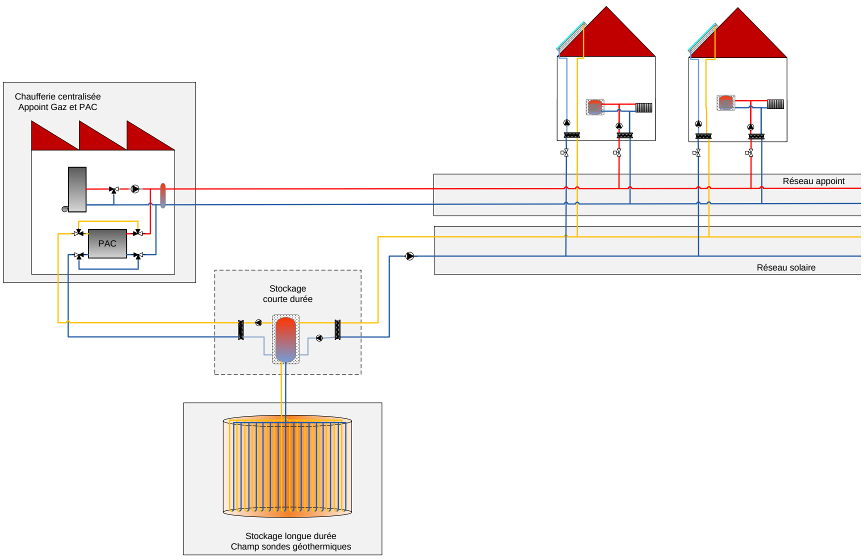

Figure 10 : Diagram of a solar district heating with borehole storage

A first estimation of the size of the system for the case of block A would result in a field of 18 boreholes with 70 meters that are useful coupled to a heat pump of 150 kW and storage tank of 200m3.

The energy distribution per production plant is:
- Solar : 80%
- Heat Pump (electricity) : 9%
- Auxiliary boiler : 11%

C.3/ Economics at SDH level

The distribution of investments in € without VAT is as follows :

Block	Nb unit	Solar field k€HT		Storage TTES k€HT		Auxiliary k€HT		Network k€HT		Total k€HT
A	170	835	40%	931	45%	59	3%	255	12%	2 080
B	290	1 400	44%	1297	41%	101	3%	366	12%	3 164
C	290	1 400	43%	1297	40%	101	3%	464	14%	3 262
D	125	614	38%	760	48%	44	3%	178	11%	1 596
R	110	540	37%	700	48%	39	3%	179	12%	1 458

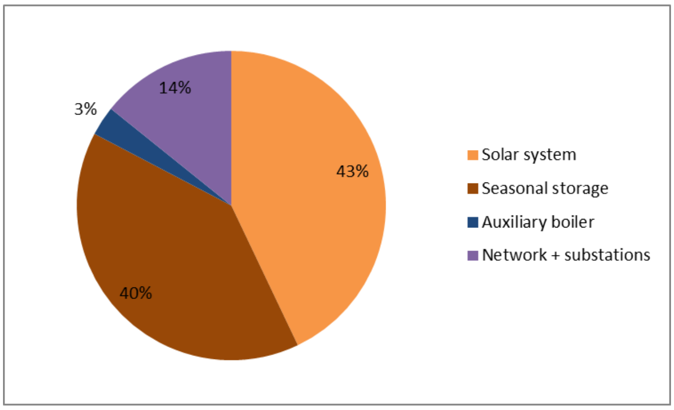

Figure 11 : Allocation of investments by post for block A

The following table shows the amounts of investment and operations costs over 20 years undiscounted, the discounted cash flow, the heat production and the resulting LCOE.

Block	Nb unit	Capital expenditures (CAPEX) k€ HT	Operation expenditures 20 years (OPEX) k€ HT	Total discounted cash flow[1] 20 years k€ HT	Heat production 20 years MWh	LCOE project € VAT included[2]/MWh
A	170	2 080	783	2 661	17 232	233
B	290	3 164	1 268	4 087	27 144	234
C	290	3 262	1 272	4 188	26 390	249
D	125	1 596	580	2 021	12 350	250
E	110	1 458	516	1 838	11 154	249

[1] : discount rate 4% ; [2] : VAT 5.5%

Financing district heating systems is achieved through the sale of the heat produced. Renewable energy solutions, including investment costs are high and are not competitive with existing solutions using fossil fuels: subsidies are available. The calculations were made for the following two scenarios:
- a LCOE of 150 € VAT incl./MWh, that would correspond to an "energy bill" by housing around 780 €VAT incl/year ;
- a LCOE of 100 € VAT incl./MWh, that would correspond to an "energy bill" by housing around 520 €VAT incl/year ;

The residual costs "remaining fund" to achieve these LCOE objectives are:

Block	Nb unit	LCOE project € VAT incl./ MWh	Remaining fund for LCOE of 150 €/MWh		Remaining fund for LCOE of 100 €/MWh	
			k€ VAT excl.	€ VAT excl. /unit	**k€ HT**	**€ HT /lgt**
A	170	233	927	5 455	1 489	8 756
B	290	234	1 445	4 982	2 296	7 919
C	290	249	1 639	5 652	2 460	8 484
D	125	250	793	6 340	1 189	9 510
E	110	249	717	6 516	1 079	9 809

The possibilities for the "remaining fund" are as follows:
- Investment grants for the development of renewable energy
- Support in urban development costs, in exchange for lands sold "heated" as part of a development project which also requires relatively little equipment for public infrastructure

C.4/ Overview of possible business models

The legal structure of such a solution must take into account the particular characteristics of the project. Technical and financial risks are two very important elements that will guide the business model solution.

Financing solutions detailed in the previous paragraph show the necessary implication of the collectivity. Two different business models for the exploitation are possible:
- A public DH
- A public delegation DH

Public delegation district heating are generally used for project with an energy production greater than 5 GWh per year. As it is not the case here, the business model should be more close to a public district heating.

Authors

This study was done by CEA INES, the engineering office TECSOL and INDDIGO ; in collaboration with the consortium of consultants LIEUX-DITS (architecture et urban planning) / PROGRAMMES-URBAINS (urban planning) / MDP (cable transport) / Hélène SAUDECERRE (landscape designer) / HIS&O (hydraulic) / Altitudes VRD.

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