THE FIRST FRENCH LARGE SCALE SOLAR PLANT CONNECTED TO EXISTING DH : CHATEAUBRIANT

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Abstract – From case study to realization, Châteaubriant project is one of the success story of the SDHPlus project. In 2013 was studied the opportunity to connect a large scale solar plant to the existing district heating of the city of Châteaubriant. Thanks to the results of the feasibility study, and with the great help of a tour in Denmark, the City was convinced. After 2 years of discussions, a business model emerged and permitted to go further. The design studies and preparation of the call for tenders were done at end of 2015, and now the works are at the planning stage and should begin in December 2016.

An ambitious project is ongoing: about 2200 m2 of solar collectors will be connected to the northern branch of the DH. The system is designed and will be controlled to perfectly fit both load curve and biomass heat production.

Moreover, the designer and planner TECSOL, the installer, the collector provider and the operation manager ENGIE COFELY have accepted to engage them in an Energy Performance Contract: 900 MWh/year has to be provided to the DH or they will pay penalties.

Figure 0 – Aerial photography modelling (source : MCM Architectures)

INTRODUCTION

The project consist in a large scale solar plant of about 2200 m² which will be embedded on the ground and connected to the main Northern branch of the existing DH of the city of Châteaubriant. The project is presented in the SDHplus case study "Chateaubriant" available on the website: http://solar-district-heating.eu and in [Le Denn, 2014]

1. TIMELINE OF THE SDH PROJECT

End of 2012 – mid 2013: a national call for interest is launched by the French partners of IEE SDHplus project. The city of Châteaubriant is selected and a feasibility study is made. It concludes in the interest of integrating a 1900 m² solar collector plant to provide 885 MWh/year for an investment of 1,140 M€ (excl. VAT). The levelized heat cost is evaluated at 98,40 €/MWh (without grants).

June 2014: the project is presented at the SDH Conference in Hamburg [Le Denn, 2014]. The City of Châteaubriant meet the German and Danish experts of SDH: the decision makers are convinced. A first market analysis is done to look after possible provider of collectors for the project.

At the same time, the City of Châteaubriant and ENGIE COFELY are under discussion to find a suitable business model. Châteaubriant requires funds from the ADEME through a new and dedicated call for project for solar thermal large scale operations. The project is selected.

January 2015: the City of Châteaubriant launches a call for tender for the preliminary design studies. Six month later a solution is found for the business model: the City will invest, ENGIE COFELY will operate and the average price of heat will be decrease of about 3%. The final location is selected: a ground which belongs to the City, near the river.

November 2015: the City of Châteaubriant launches the call for tender for the design and planning studies. Architectural aspects are treated, final design and planning aspect also. The call for tender for the works is set-up by the engineers. Control and design issues are discussed with the DH operator because the biomass boiler required continuous operation at a minimum of 1MW.

March 2016: The City of Châteaubriant launches the call for tender for the works: technical premise, solar collectors, hydraulics, storage, etc… The building permit requires long and many administrative operations. The validation is expected for September 2016 and works will begin in October 2016.

2. DESIGN ISSUES

2.1 Solar collector field

The plant design is made in order to reach a solar heat production (injected in the DH) of 900 MWh/year. The plant will be connected to the DH in return-return, to one of the two main DH branch, the Northern.

The DH return temperature is now about 75 to 85°C. It will be limited to 75°C maximum thanks to upgrading action on the substations and negotiations with the main users like with the hospital and a clinic. The negotiations should lead to modification of the DH subscription policy.

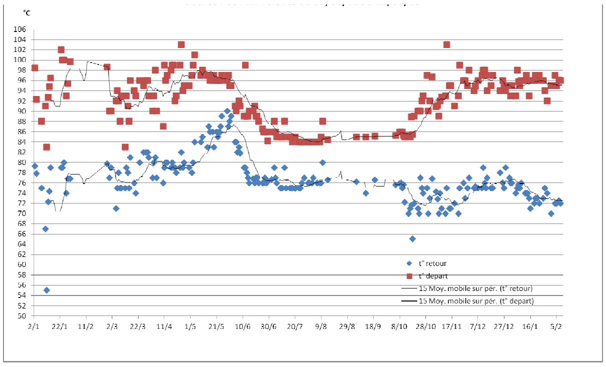

Figure 1 - DH temperature (measure in the boiler room) in 2012 (source: ENGIE COFELY)

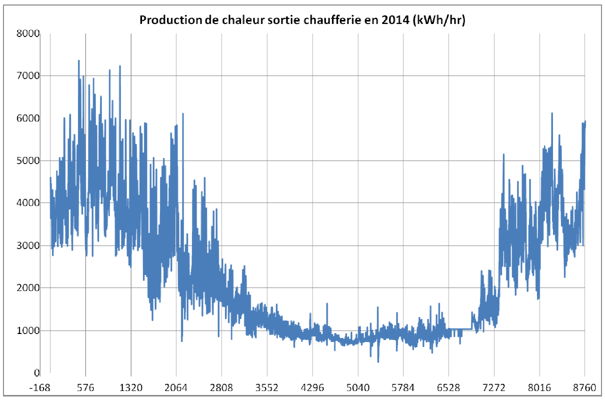

Figure 2 – DH heat production in 2014

To fulfil this objective, about 2200 m² of double glazed large flat plate collector will be set up on the ground, oriented face South and tilted 35° (see Figure 4 at the end of the paper).

2.2 Buffer tank

The other components are sized by is made by taking into account the following constraints: reduced flow rate in the Northern DH branch in summer and no storage on the biomass heater but a 10 km long DH piping.

The objective is to make the solar plant adaptable to the load profile by using a daily storage of 150 m^3 and variable flow rate injection in the DH. The architectural constraints require the use of 3 buffer tanks of 50 m^3

each. To limit the visual impact they will be placed near to the solar substation room, in the middle of the zone.

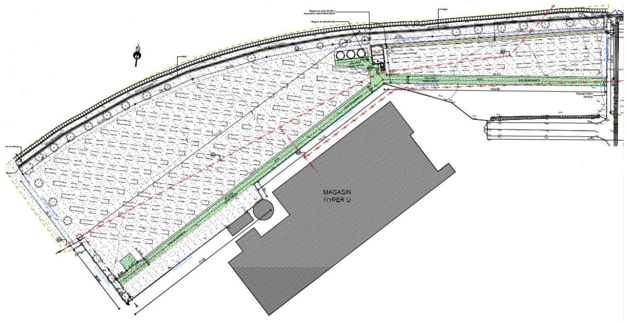

Figure 3 – Ground plan of the solar plant (source: MCM Architecture)

The zone is located near a river. To prevent flooding, the collector and the technical premise will be raised at the adequate level. The general design of the solar plant zone also take into account the architectural and urban planning constraint.

2.3 Hydraulic scheme and operation

The primary solar loop is constituted of several ranks of collectors, connected by underground pre-insulated piping, filled in with anti-freezing liquid (propylene glycol).

The expansion is ensured by expansion vessel with air compressors. A leakage can be detected and an alarm will be sent if the pressure in the circuit falls down.

The overheating is managed by the storage in the DH volume and the operating strategy, by the local solar storage (150 m3) and finally in case of electricity breakdown by the security valves installed in the field and the technical premise.

The primary pump is fixed flow rate, and start-up is controlled according the value of the irradiation and the level of temperature.

The secondary loop is separated thank to an efficient plate heat exchanger.

It is connected in “direct mode” (no buffer storage) in order to limit the heat losses in winter. In this mode, the flow rate will be fixed, because the DH flow rate and demand will always be higher than the solar production. The storage tank will not be used in this mode. The pump will start according the difference of temperature between the collector outlet (measured at the heat exchanger) and the DH return pipe before the solar connexion.

A second mode is possible: when necessary, i.e when the DH heat demand at the heat rejection point is lower than the production (some times in summer), the solar heat production will be stored, and slowly reinjected in the DH. An important element is that the biomass boiler (3 MW) will not be stopped in summer, then the control strategy has to take into account the biomass production regarding the loads (minimum biomass production of about 30% of its nominal capacity).

2.4 Planning

The collector manufacturer and installer are selected thanks to a call for tender with public procedure. As soon as the administrative issues are validated (building permit), the study phase of the project is done. In January the works should begin, for 3 month. Then a period of 6 month, including summer period, is planned to optimize the operation, control and regulation system, maintenance activities and monitoring. EPC will begin at the 1st January 2018.

3. BUSINESS AND FINANCIAL MODEL

The DH is operated by ENGIE COFELY since 2011 under a standard French model called “DSP” (public service delegation): the public local authority (here the City of Châteaubriant) delegate to a private company the design, the realization, the operation and maintenance and the investment of the DH. The “DSP” contract has been signed for 21 years.

The solar plant and the arrangement of the ground (road, fence, electricity networks, etc…) are financed by the City of Châteaubriant. From the start up of the plant, it will be exploited and maintained by the DH operator, ENGIE COFELY.

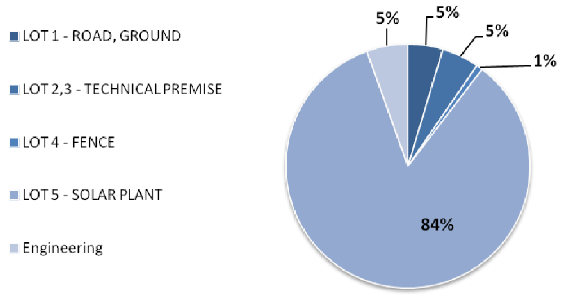

Figure 4 – Investment cost distribution

To financed the investment (about 1,3 M€ excl. VAT), the city, as a public entity, use different tools : loan with low rate and grants from ADEME. The loan reimbursement will be ensured by a “user tax” paid by the O&M company (COFELY ENGIE). The tax covers on 12 years the total amount of the loan.

To finance the “use tax” and the solar O&M costs (about 10 k€.year), ENGIE COFELY will put in place in 2017 a CHP plant (natural gas), with an electricity selling contract of 12 years.

In addition to the decreased of the DH temperature, those actions will permit to lower the yearly heat price of about 3% as soon as the plant is started.

The solar plant will permit to lower the gas consumption and increase the RES share of the DH to reach 75%.

Some work is ongoing to convince and make the users decrease the return temperature. Some “bonus” system (lower heat price) like in Denmark is actually studied to motivate the user to finance works.

4. ENERGY PERFORMANCE CONTRACT

4.1 General principles of the EPC

The aim of the energy performance contract (EPC) is that the builders and the operator take the responsibility of the operation of the plant regarding the investor. In this project, the EPC is concluded for 5 years and signed between the City of Châteaubriant and a group of companies, constituted by :

- the engineering office, designer and planner (TECSOL),
- the installer of the solar plant (call for tender ongoing),
- the collector manufacturer or provider (call for tender ongoing)
- the operator of the solar plant (ENGIE COFELY).

The contract is based on the annual solar energy provided to the DH. The solar energy injected to the DH is measured (ESU_M) and compared to the solar energy produced theoretically (ESU_G) modulo the real/theoric irradiation (G). A return temperature of the DH lower than 75°C (value used for the design of the whole installation) is a necessary condition to reach the objective of the EPC.

The measurement of the solar heat production is part of the installation and should also be seriously done.

4.2 Heat production

The solar heat production is influenced by several external conditions such as irradiation, ambient temperature and temperature and flow rate at the injection point. The irradiation is one of the most influent, with the return temperature. To take into account those variable factors, le guarantee solar heat production (ESU_G) will be calculated from a reference and theoretical values (ESU_{REF}) with the following method inspired by the IEA, SHC program, Task 45 [Nielsen, 2014] method:

$$\mathbf{ESU_G = F_0 \ x \ F_G \ x \ ESU_{REF}}$$

with :

- F_0, equal to 0.9 and set up at fix rate to take into account ambient temperature influence, wind speed, etc… and measurement errors
- $F_G = G_M / G_{REF}$, with G_M the <u>measured</u> annual tilted irradiation and G_{REF} the reference annual tilted irradiation used to calculated ESU_{REF},
- ESU_{REF}, the reference solar heat production calculated by simulation for theoric external conditions.

In the EPC, the average daily heat production (ESU_{REF} in kWh/jour) is provided for each month. This theoretical value has to take into account :

- The characteristics of the solar plant set up in the specifications,
- A given reference hourly meteorological file,
- The provided hourly DH operating conditions set up as “reference”,
- The performance coefficient of the selected solar collectors.

The ESU_{REF} value is calculated by the different CEP partners with several calculations methods (excel hourly method, TRNSYS, etc…). The most realistic will be chosen finally and the values kept for the EPC.

<u>Example</u> (will be recalculated for the selected collectors):

$$\mathbf{G_{REF} = 1463 \ kWh/m^2.y}$$

$$\mathbf{ESU_{REF} = 900 \ MWh/y}$$

	jan.	feb.	march	april	may	june
ESUref (MWh)	25.07	38.60	80.60	107.68	111.82	113.19
ESUref (MWh/j)	0.8	1.4	2.6	3.6	3.6	3.8

	july	aug.	sept.	oct.	nov.	dec.
ESUref (MWh)	107.24	99.12	100.75	55.20	33.95	27.03
ESUref (MWh/j)	3.5	3.2	3.4	1.8	1.1	0.9

Table 1 – Reference solar energy injected in the DH

If the measured irradiation is $\mathbf{G_M = 1350 \ kWh/m^2.y}$ then $\mathbf{G_M/G_{REF} = 0.92}$

Then the guaranted energy will be $\mathbf{ESU_G}$ = 0.9 x 0.92 x 900 = **745.2 MWh/year**

4.3 Penalty

In the case of the solar plant do not produce the expected solar heat, the group will pay in to the Châteaubriant City a penalty, as described bellow.

For each complete year (12 month from January to December), the penalty is calculated with :

- the garanteed yearly solar heat production (ESU_G) in MWh
- the real and measured yearly solar heat production (ESU_M) in MWh
- the average heat price of the previous year (PVC) in € incl. VAT/MWh

For the first year of the EPC, the calculation formulas is the following :

$$\mathbf{I_{year\ 1} = \ 2 \ x \ PVC_{31/12/year\ 0} \ x \ (ESU_{G\ year\ 1} - ESU_{M\ year\ 1})}$$

If I is positive, it represents the total amount of the penalty to be applied to the group for the 1st year.

If I is negative, the amount will be deduced from the amount of the penalty I of the next year :

$$I_{year\ 2} = 2 \times PVC_{31/12/year\ 1} \times (ESU_{G\ year\ 2} - ESU_{M\ year\ 2}) + I_{ear\ 1}$$

The calculation is the same for the following years until the end of the period of the EPC (5 years in this case).

Because the investment is partly granted, the overall penalties (over the 5 years) cannot excess 30% of the investment.

4.4 Invalidity of the guarantee

In some extreme cases described here, the penalty calculation will be « invalidated ». That is to say, yearly ESU_G (theoric guarantee) will be re-calculated by deducing the expected daily ESU_G. These days, the ESU_M (measured) will not be taken into account neither.

The extreme cases are defined because none of the member of the group can be claimed as a responsible of it. These extreme cases are:

- Electricity breakdown due to a failure of the public electricity network
- Extreme climatic condition not taken into account into the European and French standards,
- Water rise higher than the centenary rise
- Earthquake or mudslide higher than the one taken into account in the European and French standards,
- Degradation of materials caused by people, animals, vandalism,
- 24 consecutive hours of stop of the DH,
- Average temperature measured on the return of the Northern branch up to 75°C between 6 a.m and 8 p.m during 6 time steps of ten minutes.

5. NEXT STEP AND PERSPECTIVE IN FRANCE

Nowadays the final collector manufacturer and installer company is being to be selected. Various administrative issues such as building permit are also currently being validated. The timetable is the following:

<u>Last trimester 2016</u> : sizing studies and beginning of the works on the ground (roads, hences, technical premise), construction of the about 200 collectors (3 months)

<u>January 2017</u> : solar plant works

<u>April 2017</u> : start-up phase, monitoring, training of the O&M, optimisation of the control parameters

<u>Until end of 2017</u> : dynamic commissioning, validation of the plant operation

<u>January 2018</u> : beginning of the EPC penalty calculations

The installation is expected to be a best practice and a demonstration plant regarding the business model, the technical aspects (largest installation in France) and the performances. The next grant program and policies should be built according the success of the project [Le Denn, 2015].

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Figure 5 – Future landscape overview (source : MCM architecture)