Case study : Düsseldorf-Oberkassel

Name of the project: Solar District Heating for Düsseldorf-Oberkassel

Address of the project: Düsseldorf-Oberkassel

Name and type of the owner: State capital Düsseldorf
Environment office

A/ Context of the study

A.1/ Motivations

The City of Düsseldorf, capital city of North Rhine-Westphalia in Germany, together with its partners, the municipal utilities Stadtwerke Düsseldorf AG and Stadtwerke Düsseldorf Netz AG, participated in the regional competition "CHP - model communities 2012-2017". The concept developed focuses on the connection of the inner city district 'Oberkassel' to the existing district heating net in Düsseldorf and proposes innovative technical and non-technical measures. Within the 'Oberkassel' district, approximately 50% of the 2100 buildings are landmarked. Therefore, the retrofitting possibilities are limited. The connection of this area to the combined heat and power (CHP) district heating system represents a high potential for the reduction of CO_2 emissions caused by its heat supply. In addition innovative measures are to be implemented in order to improve the overall efficiency of the district heating system and achieve a high acceptance among potential clients.

One of the concept's innovation measures is the feed-in of solar heat into the district heating net. The solar thermal collectors are to be partially integrated on public buildings or infrastructures within the district 'Oberkassel' itself.
The following aspects have been analyzed:
1) Development of a concept for the integration of solar thermal energy in the district heating of Düsseldorf
2) Identifying suitable areas for solar thermal collector plants in 'Oberkassel' and the surrounding areas
3) Technical and economical feasibility

Link to the overall concept (in German)

The regional competition "CHP - model communities 2012-2017" was carried out in the framework of the Ziel2-Programme of North Rhine-Westfalia with financial support from the European Regional Development Fund and the Ministry for Economic Affairs of North Rhine-Westfalia.

A.2/ Description of the existing DH

The district heating net of the city of Düsseldorf has a yearly heat demand of 862 GWh. Most of this demand is met by a waste incineration CHP plant, a smaller part by a natural gas CHP plant and the residual part by gas boilers. In summer (July and August), the waste incineration plant is to cover the whole heat demand. However, in 2012 and 2013 the measurements showed that the gas boilers had to deliver a considerable amount of heat during these two months. The feed-in temperature of the net presently varies between 128 °C in winter and 93°C in summer, depending on the outside temperature.

The new extension of the district heating net to the 'Oberkassel' district represents 30 MW and 48 GWh additional yearly heat demand.

A.3/ Environment data

Düsseldorf is the capital city of North Rhine-Westphalia in Germany. For this case study, weather data measurements for 2012 in Bochum (40 km north east from Düsseldorf) have been used. The global solar irradiation in 2012 was 1004 kWh/m²a.

A.4/ Opportunities and barriers

Düsseldorf is a large city with approximately 600 000 inhabitants and the district 'Oberkassel' mainly consists of landmarked buildings. The concept developed in this study takes into account both a central integration of the solar plant at one of the main heating plants and decentral integration along the district heating net (along the connection pipe to 'Oberkassel'), which would make solar collectors in the landmarked district unnecessary. Outside this district, numerous areas for placing the collectors have been identified.

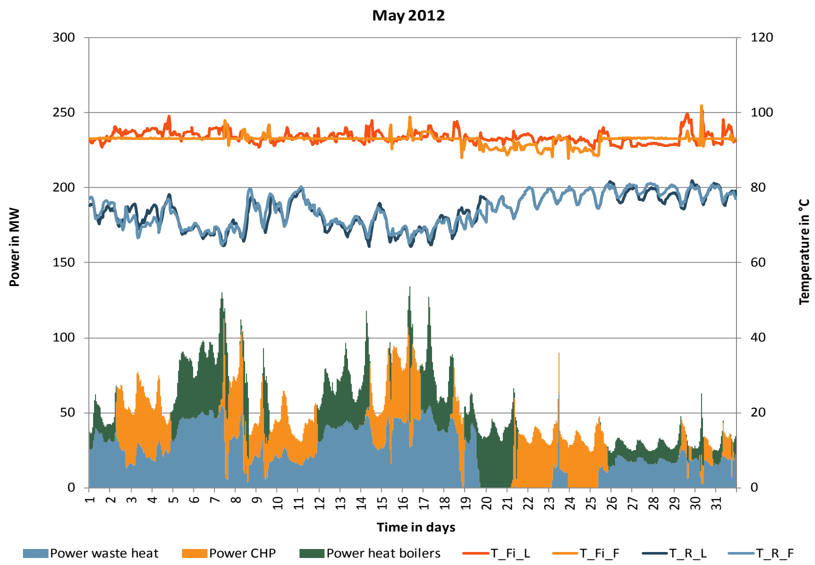
The existing district heating net is supplied to a large extent by high efficiency CHP plants. The feed-in concept for solar heat should, however, additionally improve the overall efficiency of the net. Solar heat should therefore preferably substitute the heat produced by less efficient gas boilers and not the heat produced by the CHP plants.

The operation temperatures of the existing net are rather high, leading to an adaptation of the feed-in concept: in summer, solar heat is to be fed into the supply pipe of the net at a set temperature. From October to May, it is to be fed into the return pipe of the net.

B/ Methodology and tools used in the study

B.1/ DH load profile

Hourly measurements of the total district heating load for 2012 have been provided by Stadtwerke Düsseldorf. However, only the share delivered by the gas boilers was taken into account in the load profile of the simulations in order to avoid replacing of CHP heat with solar heat. During the two summer months, the load from the CHP plants is also taken into account, in order to avoid stagnation in the solar collector plant.

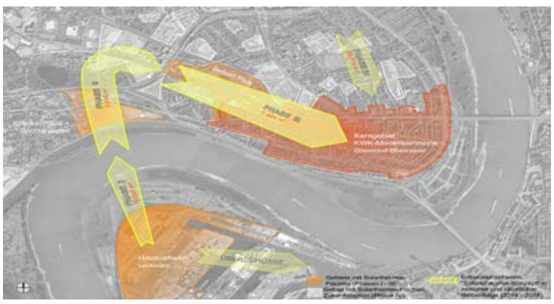


B.2/ SDH design and sizing, energy balance

A concept for the future integration of solar heat in the district heating net has been developed:

- Phase I: realization of a large solar thermal plant of over 10 MW power at the location of the heating plant 'Lausward'. Such a plant is technically and organisationally realisable on short-term. It is suggested that the municipal utility should be owner.

- Phase II and III: decentral integration of smaller plants up to 1 MW located along the district heating pipe to 'Oberkassel' (Phase 2) and in the district itself (phase 3). These plants can be connected to the net when the district heating net extension is sufficiently advanced and delivers enough heat.



- Phase IV: more peripheral areas can be connected.

The economically feasible potential for solar thermal for the district heating net Düsseldorf can be evaluated summarizing all technical and economical feasibilities for solar thermal plants for single buildings and available infrastructure areas in the analyzed district and its surroundings. The suitability of large enough roof areas as analyzed in the 'Düsseldorf Solar Cadastre' is one important but not sufficient source of information. More technical and organizational aspects need to be taken into account to evaluate the potential of single buildings:

1. Necessary minimal collector areas (>500 m²) for feeding into the district heating network and solutions for building integration (architectural)
2. Properties of roofs (flat or pitched) and superstructures (chimney, dormer windows..) which can impede the installallation of solar collectors
3. Orientation of the roof areas
4. Possibility for placing pipes in the building and integrating new elements in the building's technical rooms, feasibility of a connection to the district heating net
5. Organizational aspects (ownership etc..)

The analysis of suitable areas is performed using the following steps:
- Measurement of the usable roof or infrastructure areas in m² (after positive analysis regarding superstructures and orientation)
- Inclusion of a usability factor of 80%
- Calculation of the resulting collector area taking in account the properties of roofs (flat or pitched). This is not important for pitched roofs, but for flat roofs due to the necessary elevation of the collectors and shading effects (app. 67% reduction of the area).
- Collection of data regarding the type of buildings and, where possible, the ownership situation

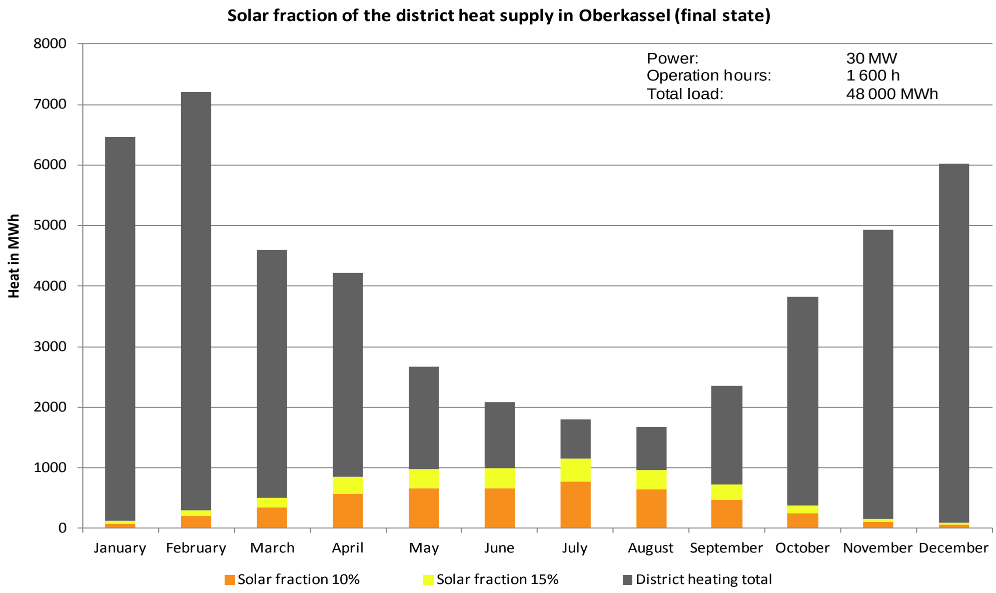
The following roof and infrastructure areas have been listed for the zones of phases 1 to 4:

	Dach- bzw. Infrastrukturfläche	Resultierende Kollektorfläche
Phase 1	65 450 m²	19 608 m²
Phase 2	11 410 m²	3 496 m²
Phase 3	25 665 m²	7 484 m²
Phase 4	67 155 m²	24 116 m²
Gesamt	**169 680 m²**	**54 704 m²**

The first rough dimensioning of the necessary solar collector areas was performed based on the following hypothesis:

- The extension of the district heating net to 'Oberkassel' represents 30 MW and 48 GWh yearly heat demand.

- Solar heat should cover 10 -15% of the yearly heat demand of the new extension, which represents a thermal power between 11.2 and 16.8 MW_{th}, corresponding to a collector area between 16 000 and 24 000 m².



The heat supply of the existing net is planned in order to operate the boilers only from September to June, but not in July and August where the CHP plant should be sufficient. However, the measured data shows that in both 2012 and 2013, because of operational reasons, the boilers were in operation and delivered a relevant amount of heat. The solar thermal plant is dimensioned in combination with a buffer storage, to replace operation of the boilers as far as possible and maintain the hours of operation of the CHP plant also in the summer period.

The yearly dynamic simulations of the solar thermal plant have been performed with TRNSYS 17. The following table presents the values the simulation's parameters:

	Reference	Possible variation
Collector area	16 000 m²	-
Collector type	High-temperature flat-plate	CPC vacuum-tube
Storage volume	1 300 m²	-
Load data	Bochum 2012	
Net feed-in temperature	Data 2012 from gas boilers	128°C in winter 83°C in summer
Operation strategy	From October to April: feed-in in the return pipe From May to September: feed-in in the supply pipe	
CHP substitution	Allowed in July and August	Allowed from mid-June to end of September

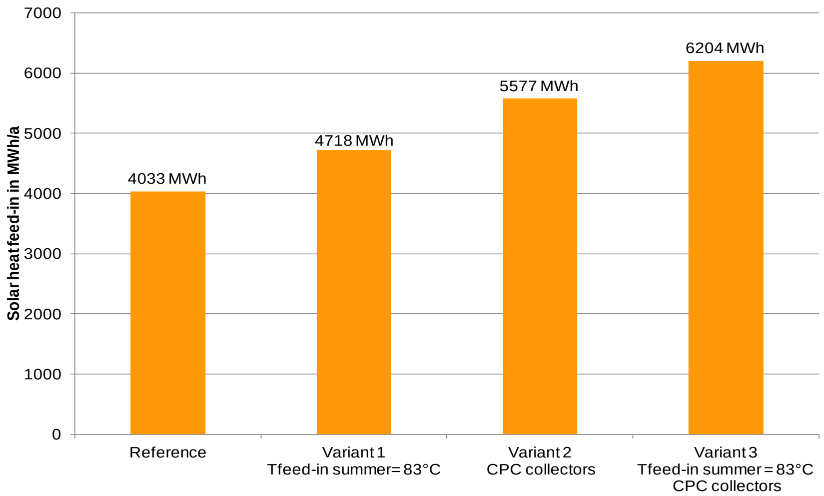
B.3/ Economics

The economical calculations are performed according to VDI 2067 taking into account the main components of the plant. The solar heat costs are calculated and compared to the current district heat cost in Düsseldorf. The German standard subsidies from the 'Marktanreizprogramm' are taken into account.

C/ Results of the study

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

Reference case
Variant 1: Feed-in temperature in summer 83°C instead of 93°C
Variant 2: CPC vacuum-tube collectors instead of high temperature flat-plate collectors
Variant 3: Combination of option 1 and 2



The solar gains obtained vary between 4033 MWh/a and 6204 MWh/a corresponding to specific gains per m² collector area of 252 kWh/m²a and 388 kWh/m²a respectively. For a system feeding into a primary district heating net these values are acceptable to good.
Around 71 % of the solar heat produced replaces heat from the fossil fuel boilers.
The simulation with reduced feed-in temperature in summer leads to a 17% increase of the gain.
The CPC vacuum tube collectors leads to a 38% increase of the gain in comparison to high-temperature flat-plate collectors.

C.2/ Heat production management at network level

The simulations were realized to allow substitution of the CHP heat with solar heat only in July and August. All in all, approximately 30 % of the solar heat fed into the net substitutes CHP heat.
The solar heat produced amounts to a solar fraction of 8.4 % for the reference case up to 13 % from the heat demand of 'Oberkassel'.

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

The economical calculations have been performed for variant 1 and 3 with high temperature flat-plate collectors and CPC vacuum-tube collectors respectively. Collector costs are considered for ground mounted collectors.

Economics of the HT FP collector variant	
Solar thermal plant (16 000 m²)	3 418 000 €
Other infrastructures and services	900 000 €
Total investment without subsidies	4 318 000 €
Subsidies (national funding)	1 687 000 €
Yearly capital costs (interest rate 4%)	207 000 €/a
Maintenance and operation costs	35 000 €/a
Yearly costs	242 200 €/a
Annual heat production	4718 MWh
Solar heat production costs per kWh	0,051€/kWh

Economics of the evacuated tube with CPC collector variant	
Solar thermal plant (16 000 m²)	4 608 000 €
Other infrastructures and services	900 000 €
Total investment without subsidies	5 504 000 €
Subsidies (national funding)	2 200 000 €
Yearly capital costs (interest rate 4%)	265 000 €/a
Maintenance and operation costs	35 000 €/a
Yearly costs	300 000 €/a
Annual heat production	6204 MWh
Solar heat production costs per kWh	0,048 €/kWh

C.4/ Overview of possible business models

Several different business models are possible for the integration of solar thermal energy in large district heating systems for cities. Solar thermal energy improves the CO_2 and primary energy factors of the district heating system. If this improvement is allocated to one district, it can be really significant, even in large cities. This type of business model has already been developed in other urban district heating systems.

Link to the business model description (download)

Decentral integration of heat also opens new opportunities of business models, for example by involving the owner of the building where the solar collector plant is installed, like in Gardsten in Sweden.

Link to the business model description (download)

For marketing purposes, the positive image of solar thermal energy can be used, as shown in this fictive billboard 'Let's get connected to solar district heating!'.

Authors

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