Heating Concepts for Quarters

HEEAT an interaktive Heating Solutions Tool

Anna Sophie Rothardt
Matr.Nr.: 11134574
anna_sophie.rothardt@smail.th-koeln.de

Jens Simon Schaaf
Matr.Nr.: 11104029
jens_simon.schaaf@smail.th-koeln.de

Prof. Dr. Eberhard Waffenschmidt
Technische Hochschule Köln, Faculty 09
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Abstract: *In times of rising environmental awareness climate protection targets are set and will further restrict greenhouse gas emissions and energy consumption. Far – sighted developers are now deciding to build houses with higher standards as currently needed, trying to match prospective requirements. However, selecting the best heating solution for a projected estate can be difficult. In order to accomplish this target, the purpose of this project is to develop an interactive heating solutions tool. The EXCEL VBA based HEEAT – Tool offers a highly functional opportunity to simulate and compare different heating concepts, regarding specific heat production costs, carbon dioxide emissions and degree of autarky.*

Keywords – Heating Concepts, Simulation Tool, EXCEL VBA, Heat Production Costs, CO_2 Emissions, Degree of Autarky

I. Introduction

Due to a proceeding climate change and its significant impacts on the environment and mankind, solutions to decrease our ecological footprint are in great demand. Governments and confederations of states such as the European Union (EU) are defining targets to reduce carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions. Based on this, Germany introduced its own reduction targets in the following sectors energy production, building and transportation. The energy transition in buildings is crucial, since "our homes account for approx. 35 % of our final energy consumption, and most of this energy is used to provide heat and hot water"[1]. An 80 % reduction of greenhouse gas emissions is targeted to be accomplished by 2050. The combination of ambitious goals and high energy consumption offers a great conservation potential thus ecofriendly heating solutions are highly demanded. In order to meet this demand, the purpose of this project is to develop an interactive heating solutions tool for new building quarters. To set up the tool an in - depth market analysis, regarding prices and technical specification of different technologies as well as heating fuels, is necessary. Criteria for the analysis are CO_2 emissions of the system alongside autarky and profitability. Applying the researched data and assumptions made, a simulation tool based on EXCEL VBA is created.

HEEAT *(**H**eating System – **E**conomy **E**missions **A**utarky – **T**ool)*

It enables the comparison of different heating technologies and thermal storage systems in centralized or decentralized ways of construction. The results offer recommendations for the most suitable heating system of the projected quarter.

The first criteria of economic efficiency is relevant for building owners on a tight budget. Since every highly ecological and autarkic integrated system is only realizable if it's affordable and the cost aren't skyrocketing. Regarding the aforementioned climate protection targets the reduction of CO_2 emissions for heating purpose is crucial in this analysis. The combination of technology, fuel and storage with the lowest carbon emissions is predicted to be the best option. Besides good ecological performance the level of autarky is in times of grid parity and accelerating fuel prices a highly relevant factor.

In times of rising environmental awareness easily applicable and flexible tools such as HEEAT can support developers and property owners to find the best heating system meeting their specific requirements.

II. Background and Approach

Developing a new settlement or quarter can be challenging. Specific standards must be adhered and many other decisions have to be made. For the heating system plenty of options regarding technology selection or technical configuration are possible.

Due to the climate protection targets mentioned above national construction standards and other legal requirements are likely to be further modified and adjusted in the nearer future. As a result of that several developers are deciding to build houses with higher standards as currently needed, trying to match prospective requirements. By integrating renewable energies and storage options emissions levels will decrease in contrast to increased degrees of autarky for the new housing estate.

Solar Village Moitzfeld-Bensberg

In the peripheral region of cologne, in Moitzfeld - Bensberg, a socalled Solar Village is planned. As depicted on the site plan (Figure 1), the

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project includes 22 private houses on an area of approx. 1,2 ha.

Figure 1: Site Plan Moitzfeld-Bensberg
(Eikamp GbR [2]*)*

To meet the future goal of climate neutrality in the building sector several corner pillars will guarantee the compliance with this objective [3].

- Every house has to be built with a KfW 40 plus construction standard, implementing a high level of insulation.
- To meet the power demand of the future residents a photovoltaic system is mandatory. Additional power demand has to be covered by green power supplier.
- A charging infrastructure will promote a further coupling of the power -, heating - and transport – sector.
- The heating system should be as eco-friendly as possible including low carbon emission levels as well as a high degree of autarky.

To identify the best integrated heating system HEEAT was created.

III. HEEAT THE HEATING SOULTIONS TOOL

Since this tool should not be used exclusively for the Solar Village, the structure is highly flexible. Any settlement can be investigated by entering the specific project data. Nevertheless Moitzfeld-Bensberg will be the base case scenario for this investigation.
In the first step project data will be inserted and adjusted manually. The underlying simulation program will then calculate the specific technical requirements. In the last step several heating concepts can be compared regarding the criteria of heat production costs, CO_2 Emissions and degree of autarky.

Data Foundation

An in – depth market analysis has been providing data for different heat generation technologies [4][5][6][7], heating fuels [8][9][10], thermal storage options (centralized [11], decentralized [12][13][14][15] and local district heating networks [16][17][18][19], regarding costs, emissions and technical specifications.

Calculation Procedure

Initial requirements for the simulation are defining and manually inserting data of the projected settlement.
Up to five building types can be designed and differentiated by following factors:

- construction standard: KfW Standards [20]
- structure: solid or wood construction
- physical dimensions, storey height and quantity

Base case: Solar Village Moitzfeld-Bensberg

The assumptions for the base case simulation are shown in Table 1.

Table 1:Structural Assumption of Reference Estate

House Type	***1***	***2***	***3***	***4***
Construction Standard	KfW 40+	KfW 40+	KfW 40+	KfW 40+
Structure	Wood	Solid	Wood	Solid
Floor Space	136 m^2	232 m^2	136 m^2	232 m^2
Storeys (Heigth)	1,5 x 2,5 m	2,5 x 2,5 m	1,5 x 2,5 m	2,5 x 2,5 m
Wall Thickness	0,625m	0,25m	0,625m	0,25
Window Surface	20,2m^2	20,2m^2	20,2m^2	20,2m^2
Quantity	6	6	5	5

With these information, HEEAT determines the heating demand for the estate, based on the underlying formulas derived by DIN EN 12831[21]. Via the simplified procedure, the standardized heating load and accruing thermal loss are calculated. Due to the requirement of meteorological data an averaged temperature profile [22] of the weather station in Cologne-Stammheim has been applied.
To generate the absolute heating demand, hot water load has to be considered as well. With the computational method by BBSR [23] the required energy for hot water generation is calculated.
In Figure 2 one can see the annual heating demand of the investigated reference estate. Thermal loss and hot water demand are assumed to be constant.

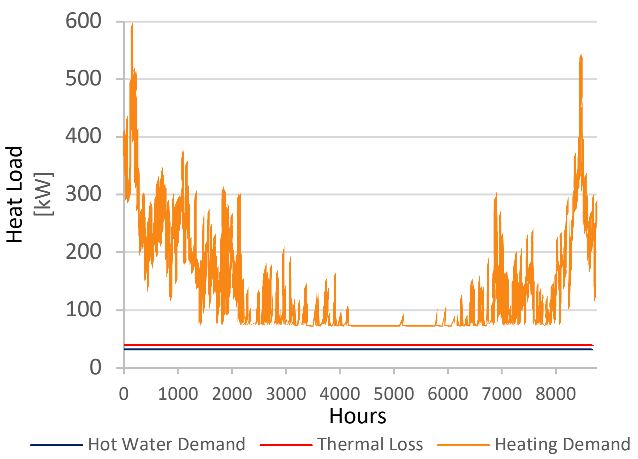

Figure 2: Heating Demand of Reference Estate *(own depiction)*

The peak load for the projected Solar Village is 597 kW and the annual heating demand, combining heat load, hot water demand and thermal losses is 120 MWh.

Comparison of Concepts

Past calculating the required data, HEEAT offers the comparison of different heating concepts. The tool – user can choose between the heat generating technologies and thermal storages shown in Table 2.

Table 2: Technology and Storage Options

Technology	*Storage*
Solar Thermal Installation (south/east-west)	**Decentralized**
Heat Pump (water/geothermal/air)	Hot Water Cylinder (Viessmann/Vaillant)
Pellet Boiler	
Biogas Boiler	**Centralized**
Natural Gas Boiler (reference)	Gravel Water Heat Store Hot Water Heat Store

In the Base Case analysis the following concepts are selected (see Table 3).

Table 3: Concept Descriptions Solar Village

Concept	*C/D**	*Technology*	*C/D*	*Storage*
1	D	Natural Gas Boiler		
2	D	Solar Thermal Installation (east-west)	C	Gravel Water Heat Stores
3	C	Biogas CHP		
4	D	Solar Thermal Installation (east-west)	D	Hot Water Cylinder
5	D	Heat Pump (geothermal)		

*C = Centralized; D = Decentralized

Since the majority of buildings in Germany are heated by natural gas boilers Concept 1 has been designed to display the status quo for heating systems. The remaining concepts shall cover the full variety of different heating solutions, including a great variety of centralized and decentralized heat generators and storages. Centralized storage options used in Concept 2 requires the implementation of a local district heating system. This will be calculated automatically.

Figure 3 depicts the underlying selection process for setting up a new heating concept.

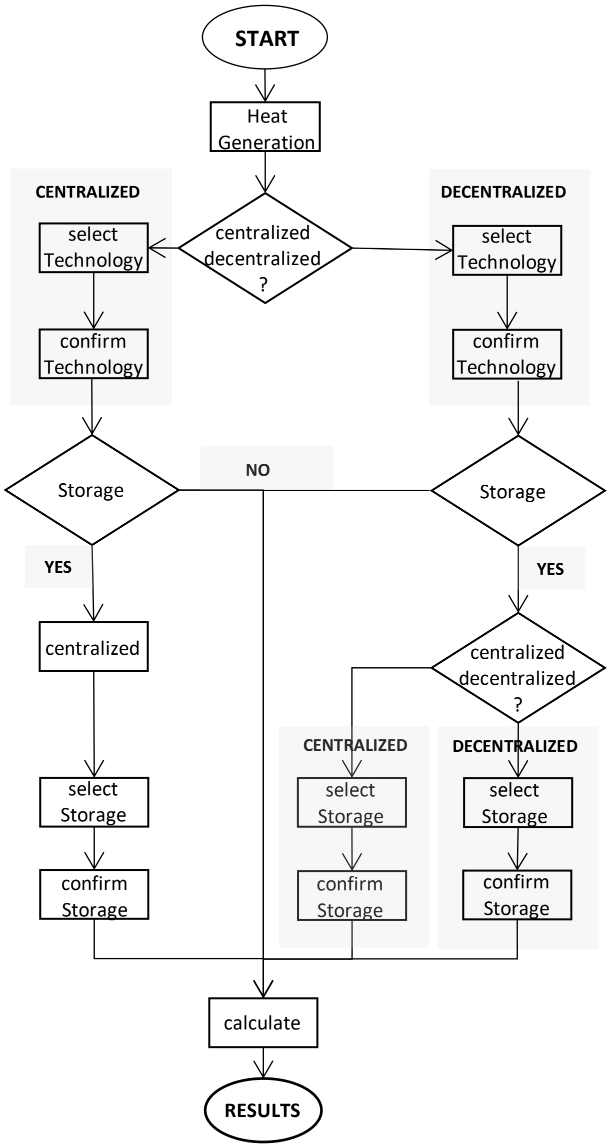

Figure 3: Selection process for heating concepts *(own depiction)*

The starting point decides between centralized or decentralized heat generation. After selecting and confirming the desired technology (Table 2) it has to be determined if a storage shall be implemented or not. If the answer is "NO", the results will be calculated immediately.

In case of "YES" as an answer two different options are possible, depending on prior assumptions regarding the heat generation. With a centralized heat generator the tool – user can only select a centralized thermal storage. Concepts with decentralized heat generation offer the opportunity to decide between centralized or decentralized Storages. After selecting and confirming a thermal storage option, the results will be calculated.

IV. Results and Discussion

The analysed concepts of the reference estate Moitzfeld deliver results for the three aforementioned examination criteria. Three graphics illustrate the resulting values for Concept 1 to Concept 5.

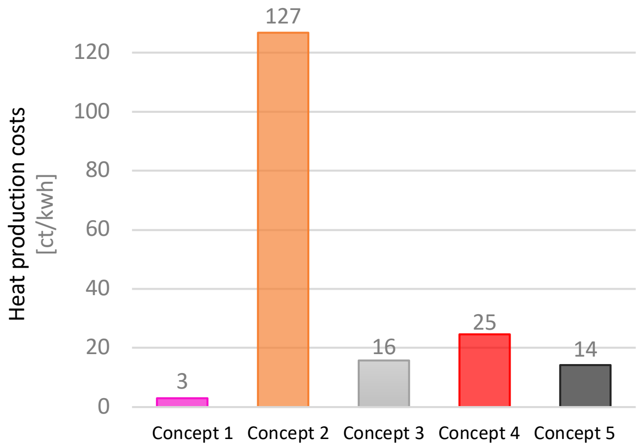

Figure 4: Heat production costs in ct/kWh
(own depiction)

The heat production costs, depicted in Figure 4, varies in a wide range of price levels. The reference Concept 1 with a decentralized natural gas boiler (no storage) shows the lowest cost. This is mainly due to comparably low fuel prices and a well - established heating technology. Which leads to low purchase prices of natural gas boilers.

With 127 ct/kWh Concept 2 (solar thermal installation + decentralized Gravel Water Heat Store) causes the highest heat production costs. This price spike can be attribute to three main factors. Firstly, as a renewable energy technology, solar thermal installations are more expensive then e.g. natural gas boilers by providing equal amounts of heat. Secondly, including a centralized thermal storage (here: Gravel Water Heat Store) induces increasing costs due to their tremendous investment costs. Finally, a centralized thermal storage requires a local district heating network, as mentioned before. This will further raise costs of heat production for Concept 2.

The effect of a decentralized storage (including local district heating network) can be seen by comparing Concept 2 and 4. Despite the integration of a (centralized) storage, heat production costs of Concept 4 are many times over lower.

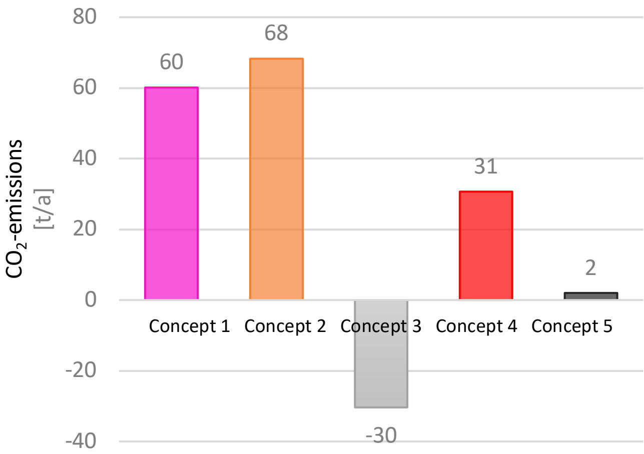

Figure 5: CO_2-Emissions in t/a
(own depiction)

Figure 5 one can see the calculated emissions in tons of CO_2 equivalent per year for each concept. As it might be expected, emission levels of Concept 1 are high due to the fossil heating fuel. The elevated values of Concept 2 can be attributed to the impact of the centralized storage and the local district heating network. For producing the required pipes, excavation and constructing of the network, high amounts of emissions are released. In combination with a comparably high ecological impact of solar thermal installations as a technology, the values can be explained. As mentioned before, the impact of a centralized storage / local district heating network can be read of by comparing Concept 2 and 4. Heat pumps are assumed to use green power thus Concept 5 is close to be climate neutral. Following this approach, the negative values of Concept 3 can be explained. Since Combined Heat and Power (CHP) plants produce both, electricity and heat, the ecological contemplation differ from other technologies. The tool assumes CHPs to run heat based and the electricity output to be fed into the grid. As a consequence of that, the generated CHP power replaces conventional electricity and lower emission levels thereby.

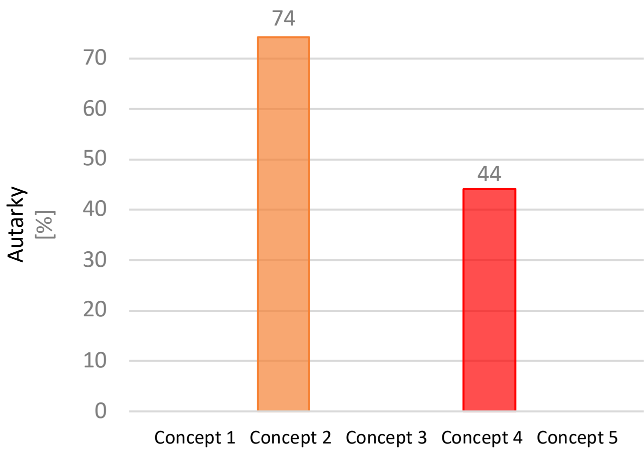

Figure 6: Degree of autarky in %
(own depiction)

The degree of autarky has been examined as last criteria in this analysis. In Figure 6 one can see a lopsided allocation. Exclusively solar thermal based concepts (Concept 2 and 4) achieve a degree of autarky. This is due to the fact that a fuel input (e.g. biogas) or the use of purchased power (e.g. green power) is assumed to be not autarkic. Only heat, produced exclusively on site without external input, can be seen as self - sufficient. In this base case analysis heat pumps are assumed to be powered by non-domestic green power. If generated solar power is not needed for residential or transportational power supply, the usage in heat pumps could induce degrees of autarky.
Concept 2, with 74% is more self – sufficient compared to Concept 4 with 44 %. The centralized storage option of Concept 2 causes this gap. A one – week home storage is not as effective as a long – term option, by storing possible surpluses and decoupling production and consumption effectively.

V. Conclusion and Recommendation

HEEAT offers the possibility to analyze and compare different heating concepts for settlements or quarters. Past analyzing different heating solutions for the Solar Village Moitzfeld, the only proper concept cannot be identified or recommended. Different heating systems can promote different examination criteria. Selecting the perfect concept is highly depending on the tool – users expectations. Comparing, for instance Concept 2 and 4 in Figure 7, Concept 4 show rather better results for emissions and heat production costs. Expect from lower degrees of autarky, Concept 4 is a rather holistic concept.

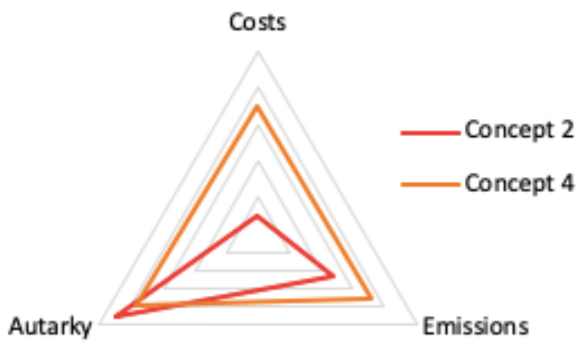

Figure 7: Network Diagram Concept 2 and 4

If autarky is the main criteria, Concept 4 would be recommended. Implementing a centralized storage is expensive but integrated in a pilot project with potential governmental funding, it is reasonable.

Even though the overall simulation results are highly satisfying the tool has minor drawbacks. Preset assumptions regarding the supply with solar power are essential for autarky levels of heat pumps and will modify the calculated outcomes.
Besides, editable assumptions, the underlying data foundation for technologies, storages and local district heating networks are limiting the accuracy of the simulation tool. Since centralized storages aren't an established and widely used technology yet, finding compliant data is a difficult task in particular.
It is advisable to constantly verify the set assumptions and update the underlying data regarding potential market trends, before using the tool.

With proper input, HEEAT will then provide a highly functional opportunity to simulate and compare heating concepts for planned new building projects, such as the Solar Village in Moitzfeld-Benberg.

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