

Implementation strategies for renovation concepts based on participative planning

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Abstract. The potential for reducing Greenhouse gas (GHG) emissions by district renovation is largely untapped. It not only requires a thorough Energy Master Planning (EMP) of the district but also support of the decision-making processes. This can not only contribute significantly to reducing energy consumption and securing the location of energy infrastructure (generation, distribution, storage), but also to long-term sustainable development and climate neutrality. Understanding the different solutions for district renovation which include combinations with energy supply and consumption is important in districts. A technical as well as economical analysis is proposed that combines reduction of GHG emissions potential with an economic appraisal. A district near Winterthur, Switzerland was analyzed in respect to the aforementioned aspects. Site visits and structured interviews with key stakeholders were used to collect data which was then analyzed. Different renovation options were simulated, and investment and energy costs were calculated. The results show that the technical potential for a decarbonization is large. However, financial and social aspects are significant and lead to a delay in implementation.

Keywords: small urban unit, city, case study, energy renovation, energy master plan, participation

1. Introduction

Renovation strategies on building level need to be derived as a combination of energy efficiency upgrades for buildings and the use of renewable energy to decarbonise the energy supply, on district or city scale. By combining energy efficiency and renewable energy sources, both energy supply and demand in the built environment is addressed. In this sense, building retrofitting is an appropriate strategy to reduce demand, while the use of renewable energy aims at decarbonizing the energy supply system.

Nevertheless, to apply the large-scale renovation strategies and achieve the projected building stock decarbonisation, identifying the technical solutions is not enough. The renovation rate in Europe remains well below the targeted annual 3% [1], [2]. Some of the main barriers to renovation have to do with the renovation cost and access to finance, as well as complexity, awareness, stakeholders' management, and fragmentation of the supply chain [3], [1], [4].

The potential for reducing GHG emissions by district renovation is largely untapped. It not only requires a thorough Energy Master Planning (EMP) of the district but also support of the decision-making processes [5]. This can not only contribute significantly to reducing energy consumption and



securing the location of energy infrastructure (generation, distribution, storage), but also to long-term sustainable development and climate neutrality.

To be able to reduce GHG emissions in the built environment (with a focus on CO₂ emissions) it is important to reduce GHG emissions from operation of facilities [6]. It needs a reduction of energy use by implementing efficiency measures in the renovation of the building stock. Another possibility is the decarbonisation of the energy supply. For this, (on-site) renewable energy measures should be applied.

However, in renovation planning it is often unclear what energy supply options are available and what influence has different technology options including demand reduction through energy renovation.

Thus, a two steps approach is proposed: first a reduction of energy use by implementing efficiency measures in the renovation of the building stock. Secondly, a decarbonisation of the energy supply. For this, on-site renewable energy measures should be explored.

When it comes to costs and finance it is often critical to relate the different measures to different stakeholders. While the energy supply is of a political (municipal) matter, the renovation of own buildings mostly depends on the owners [6]. In order to reach the decarbonization goals it is important to find ways to engage homeowners in the long-term investment strategies of decarbonization [7].

2. Energy Master Planning

The concept of Energy Master Planning (EMP) can help to initiate a better planning and implementation process to fulfil these goals through providing a roadmap for energy planning. The application of principles of a holistic approach to neighbourhood and districts, often coined community energy planning in the literature and discussed in Haase and Baer (2020) [5]. The concept of Energy Master Planning (EMP) can help to initiate a better planning and implementation process to fulfil these goals through providing a roadmap for energy efficiency in the district as a basis for energy planning that points into the future. Haase and Lohse (2019) tried to define EMP and explained the different steps involved in the process; energy efficiency (1) and comprehensive energy planning (2) [6].

In addition, to provide the necessary methods and instruments to stakeholders involved, it is essential to identify and frame the constraints that bound the options towards an optimized energy master planning solution [7].

Far less common in EMP guidance and related literature is information on the identification of constraints that limit energy technology options and how stakeholders influence the decision-making process. Although the work of Sharp et al. (2020) contributes by widening the definition of constraints into EMP, it is limited in its scope while focusing on single-ownership neighbourhoods like campuses or military garrisons [7]. Not much work is available on the role constraints, stakeholders, and boundary conditions in EMP for multi-owner, multi-stakeholder neighbourhoods many cities and regions are characterized of more complex ownerships and therefore a more complex stakeholder group with more complex framing goals that can lead to further constraints in EMP.

3. Objectives

As more and more countries push to improve the efficiency, environmental impact, and the resilience of buildings and neighbourhoods, the need for (front-end?) comprehensive EMP on neighbourhood level from the beginning is critically important. A successful EMP is highly dependent on a thorough understanding of framing goals and constraints, both local and regional, and their associated limitations that will dictate the optimum master planning design. For this case study, we calculated the costs of different energy supply options. The savings could then be used to partially finance the energy renovation. In the base case, the district is supplied with fossil fuel (oil). The energy supply options provide savings compared to the base case. Then, energy conservation measures are calculated and provide energy cost savings for the building owners. Finally, local renewable energy sources are integrated into the roofs of the buildings. The final investment costs are calculated and presented to the building owners together with savings in GHG emissions.

4. Method

An Energy Master Plan (EMP) involves the six steps as illustrated in Figure 1.

An important part is the constraints analysis as part of the assessment when energy options are developed which can be divided into the following five categories:

- Natural Locational Constraints – Resources and threats
- Distribution System & Storage Constraints
- Building and Facility Constraints
- Indoor Environment Constraints
- Building Equipment and District System Constraints

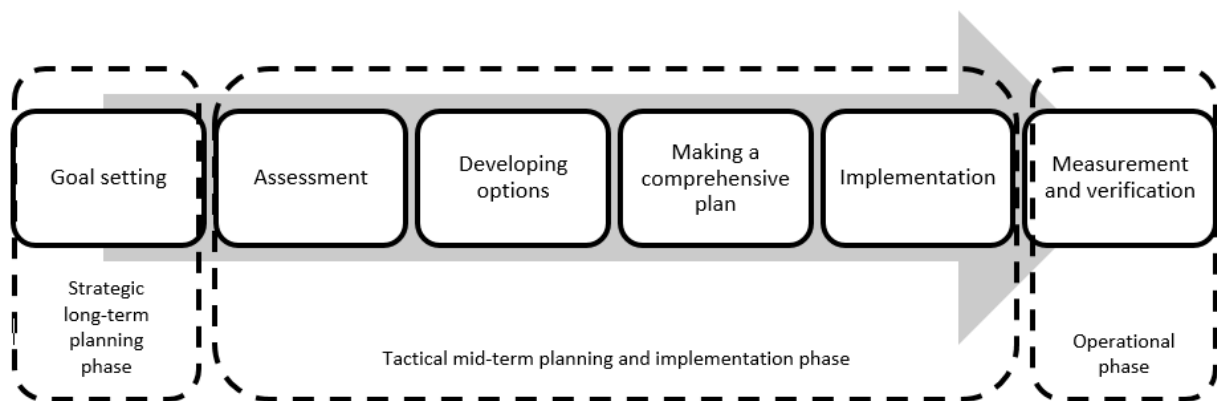


Figure 1. Strategic energy master planning on district level (Haase and Baer, 2020)

These constraints are specified in Haase and Baer (2020) [5]. Local stakeholders are interested in natural locational constraints, but also planners who relate their design on locational constraints as climate data on wind access, solar radiation, air temperature distribution and time series, water temperatures (and wind temperatures). The distribution system & storage constraints are mostly important for local maintenance staff and facility managers, but larger thermal storages could be visible and important for inhabitants as well. Also, the level of noise of the distribution system could impose interest to inhabitants and users of the neighbourhood. When it comes to the building and facility, there are planners and architects involved. The end users or inhabitants play a limited role as they are often unknown and therefore categorized (according to building typology and use of the facility). Here, building codes have the role to define minimum requirements that shall ensure a comfortable use of the building. Even more so in the next set of constraints which is in particular concerned with the indoor environment. Again, minimum requirements are established through building codes and standards. The building owner can decide on the level of indoor comfort, typically choosing between different levels/classifications (low, medium, high).

When it comes to the equipment in buildings and district systems the technical functionality is defined in building codes and related standards. Planners and architects have the expertise to define them. However, some technologies can be chosen by the building owner or investor, e.g. if the building shall have a certain heating technology or specific façade technology.

There are different levels for applying EMP within an urban context: starting from the city level, followed by the neighbourhood and then the district. At the end is the group of buildings with their building regulations.

The potential reduction goals should be discussed ideally on different levels with the relevant stakeholders in different constellations. A stakeholder forum would encourage a top-down approach, however in some cases a bottom-up approach seems more promising. There is an intrinsic problem that different stakeholder perspectives may result in an unclear nature of the problem since stakeholders at different levels view the problem differently. Architects and planners must rethink buildings and spaces; public authorities need to adapt organization and procedures; lawyers need to adapt legal and policy

adaptation, etc. This can cause a lack of a unique problem statement and the choice of inadequate solutions for emission reduction.

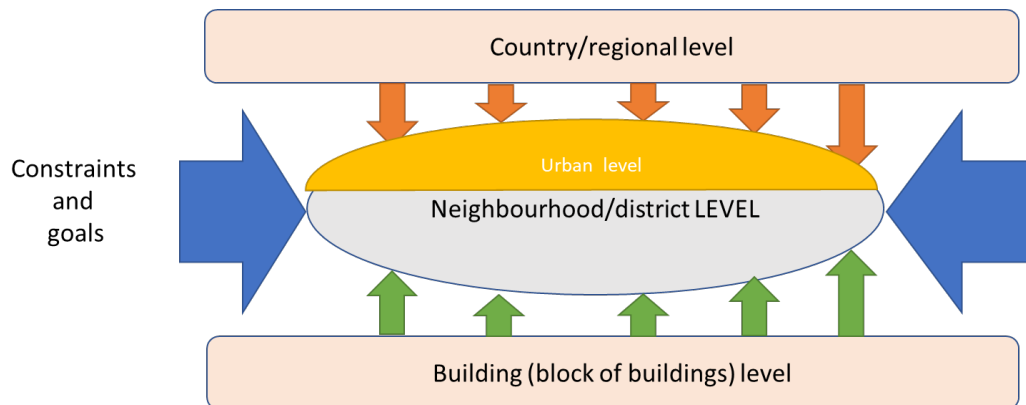


Figure 2. Constraints, stakeholders and boundary definitions (Haase and Baer, 2020)

Figure 2 illustrates the model by visualizing the boundaries in EMP by illustrating the top-down and bottom-up approaches for EMP on neighbourhood level. There are constraints coming from building level as well as from regional level that will limit the technical possible solutions for a site-specific EMP. Various valid objectives possibly conflict on short to medium terms require prioritizing (carbon-free cities; cheap affordable energy for all; regional energy self-sufficiency; job promoting energy system; fully renewable energy sources; etc.). This problem is intensified by the dynamic nature of energy planning parameters (energy price fluctuation; evolving new technologies; population growth; high urbanization rates; changing political actors and agendas; etc.).

The quality of physical data is often not available, hindered by privacy and/or measurability issues. This aspect is enhanced by a vast set of technology options, uncertainties on effectiveness and constantly evolving new solutions at different technological readiness level.

Identified framing constraints should be evaluated as either hard or soft constraint. If not, constraints that can be overcome may be missed and promising technologies stripped out of a final EMP solution. From the political level we find often unclear policy responsibilities and ambiguous values to address climate change as well as disagreement on societal effectiveness of climate change policy. This is enhanced on the administrative level with ill-defined responsibilities budgets and implementation procedures, no established standardized way on the definition, the monitoring and reporting of key performance indicators. On top of it, governments need to reach sustainability targets and safeguard public interest while energy providers need to make benefit and individuals need to reduce expenses.

5. Case study

A district in Switzerland is facing some pressure on decision making with regard to their energy consumption and supply systems. The authors decided to make a case study with respect to EMP. Here, the first steps of situation analysis and goal setting could be applied, integrating the different constraints mentioned before. With the help of this case study it is hoped to get more insights into the implementation of EMP in practice.

5.1. Location

Settlement 51 is located in Dinhard near the city of Winterthur in the North of Switzerland. This cooperative settlement was built in a first stage in 1974 and in a second stage in 1977. The 51 row houses are arranged in eight blocks and were privatized in the 1990ies. Three blocks are north-south oriented, while five blocks have an east-west roof orientation as shown in Figure 3. There are connecting paths

in between the rowhouses, two parking houses and a common swimming pool (white area above one parking house).



Figure 3. The settlement seen from above with eight building blocks comprising 51 row houses

5.1.1. Local renewable energy production

Solar energy potential was calculated for PV and solar thermal (PVT). The solar data from PVGIS was used to calculate electricity production from PV and domestic hot water (DHW) production from the thermal element in the PVT. Solar fraction for DHW was 43%, excess heat was calculated to estimate the potential for selling this excess heat to neighbours (Table 1).

Table 1. Local renewable energy (solar) production

| | type 1 | type 2 | type 3 | type 4 | sum |
|-----------------|--------|--------|--------|--------|--------|
| PV yield | 31500 | 5250 | 392000 | 39900 | 468650 |
| own consumption | 9450 | 1575 | 117600 | 11970 | 140595 |
| feed-in | 22050 | 3675 | 274400 | 27930 | 328055 |
| PVT | 11696 | 1949 | 159201 | 15595 | 188442 |
| own consumption | 5029 | 838 | 68456 | 6706 | 81030 |
| Excess heat | 6667 | 1111 | 90745 | 8889 | 107412 |

5.2. Distribution system

Settlement 51 consumes an average of 99,370 litres of oil (average for the years 2000 to 2014). The heating centre in front of Block F supplies all row houses with heating and hot water from an oil boiler with 465 kW heat output. A total of 1195 MWh is used and distributed over the eight different building blocks. The average energy reference area of a row house is 140 m², which results in an energy figure for heat $EW = 140 \text{ kWh} / (\text{m}^2 \text{ a})$. This value is somewhat below the Swiss average for older, non-refurbished residential buildings (160 kWh / (m² a)) [3].

The size of the energy supply system depends on the peak power of the buildings. We calculated three different building standards (Reno 1, 2 and 3) with different peak power. Then, for each building standard the following energy supply options were considered.

- Oil boiler (status quo), centralized system with distribution system
- Oil boiler for heating, HP system for DHW
 - Oil boiler for heating, centralized system with distribution system.
 - Decentralized heat pump system for DHW
- Ground source heat pump, centralized system with distribution system
- Pellet boiler, centralized system with distribution system

The around 100,000 litres of heating oil currently cost around CHF 100,000 and emit 265 t CO₂ per year. The CO₂ tax introduced in 2010 currently costs CHF 20 / t CO₂ per year. The maximum possible avoidance costs are 210 CHF / t CO₂, which could later cost CHF 55,650 per year. One kWh of heating oil in this delivery amount currently costs around 0.10 CHF.

5.3. Buildings

There are a total 51 row houses in 8 different blocks. three different types of row houses with 3 rooms (type 1), 5 rooms (type 2) and 6 rooms (type 3). The smallest row houses have 3.5 rooms, the largest 6.5 rooms, the majority are 5.5 room row houses. Some of the houses have already new owners or will soon be by inherited to the second generation, which is why the renovation seems attractive to new house owners. The windows of some houses were replaced, and few were also insulated from the outside. The refurbished or partially refurbished houses consume less heating energy, which is why the call for a consumption-based heating cost billing (VHKA) is getting louder.

Table 2 shows the energy use per m² heated floor area for heating, domestic hot water (DHW) and electricity. The different types have different annual energy use between 172 kWh/(m² a) (type 1) and 181 kWh/(m² a).

Table 2. Energy use in different housing units in kWh

| (kWh) | type 1 | type 2 | type 3 | type 4 | sum |
|-------------|--------|--------|---------|--------|---------|
| heating | 43575 | 14957 | 679028 | 72402 | 809962 |
| DHW | 8124 | 2789 | 126598 | 13499 | 151010 |
| electricity | 9000 | 4000 | 215000 | 24000 | 252000 |
| sum | 60699 | 21745 | 1020627 | 109901 | 1212971 |

5.3.1. Renovation measures

Table 3 lists the different renovation measures in the district. It consists of five different measures for roof and façade, including a measure to install a balanced ventilation system in the house. Table 4 summarizes the renovation options (Reno 1 to Reno 9) that are put together in different combinations of the renovation measures. It follows the logic of renovating the roof (the façade) and then integrating different technologies like PV and PVT.

Table 3. Renovation measures with investment costs

| Renovation measure | Description | Investment costs (CHF) |
|--------------------|---|------------------------|
| roof | tiles + wind barrier + 30cm insulation + vapour barrier | 653158 |

| | | |
|-------------|--|--------|
| facade | + new windows + insulation panels + doors | 705944 |
| ventilation | Ventilation unit + heat exchanger + ductwork | 324602 |
| PV | 1339 PV modules + fastening structure + inverter + cabling | 709322 |
| PVT | 1339 PV modules partly integrated with 354 m ² solar thermal collector modules + inverter + cabling + piping + storage tank | 852422 |

This resulted in 9 renovation options in combination with the aforementioned energy supply options.

Table 4 lists the renovation options of the different options. It summarizes total operational energy use and savings of each renovation option. The energy use and savings were calculated for heating, DHW and electricity separately. In the case of PV, a separate calculation was made including a share of self-consumption (34%), which has economic implications due to the different tariffs for purchasing and selling electricity [8].

Table 4. Renovation options

| | | Operational energy (kWh) | Energy savings (kWh) | Investment costs (CHF) |
|--------|--|-----------------------------|-------------------------|---------------------------|
| | ref | 1212971 | - | |
| Reno 1 | roof renovation | 938562 | 274409 | 653158 |
| Reno 2 | roof+fassade renovation | 801353 | 411618 | 1359102 |
| Reno 3 | roof+facade+balanced ventilation installed. | 702354 | 510617 | 1683704 |
| Reno 4 | Reno 1+PV | 861301 | 351670 | 1362480 |
| Reno 5 | Reno 1+PVT | 785837 | 427134 | 1505580 |
| Reno 6 | Reno 2+PV | 724093 | 488878 | 2068424 |
| Reno 7 | Reno 2+PVT | 648628 | 564343 | 2211524 |
| Reno 8 | Reno 3+PV | 628047 | 584924 | 2393026 |
| Reno 9 | Reno 3+PVT | 552582 | 660389 | 2536126 |

5.4. Indoor environment (overheating issues)

The different housing types were modelled in IDA ICE and represented by three zones in each model. Heating and cooling and ventilation was modelled accordingly. The model was used to evaluate the hours per year with an operative temperature above 27°C. In the simulations it could be shown that openable windows with cross-ventilation reduced overheating hours effectively.

5.5. Costs and GHG emissions

Table 5 gives the GHG emission savings of the different renovation options for different energy supply options. Wood pellets were calculated with a GHG factor of 0.036 kg/kWh while oil has a CO₂ factor of 0.295 kg/kWh. The emission factor for electricity in Switzerland is 0.155 kg/kWh [9]. At the moment, the CO₂ fee is at 20CHF/t CO₂, which is the basis for the figures in Table 5. However, the fees are going to increase in the future. Also, emission factor for electricity is much more dynamic and might increase in the future due to larger amounts of electricity imports (from e.g. Germany).

It can be seen that GHG emission savings are increasing more for the oil boiler solution (column C) while the highest CO emission reductions are resulting from the wood pellet solution. Interestingly, the highest GHG emission reduction comes from Reno 7 (reno 2 + PVT), with 279 t CO₂ reduction.

The following economic calculations were performed, and results illustrated in Figure 3:

$$PBP = \frac{\text{investment costs}}{\text{annual savings}} \quad \text{eq. (1)}$$

with

$$\text{annual savings} = \text{energy cost savings} + \text{CO}_2 \text{ fees savings} - \text{maintenance costs} \quad \text{eq. (2)}$$

with

Energy cost savings = energy costs reference case – energy costs renovation case

CO₂ fees savings = CO₂ fees reference case – CO₂ fees renovation case

Table 5. GHG emission reductions of different renovation options

| GHG emissions savings (t CO ₂) | | oil | GSHP | Wood pellets |
|--|--|-------|-------|--------------|
| Reno 1 | roof renovation | 80.1 | 177.4 | 259.7 |
| Reno 2 | roof+fassade renovation | 120.6 | 198.6 | 264.7 |
| Reno 3 | roof+facade+balanced ventilation installed | 155.6 | 214.0 | 263.3 |
| Reno 4 | Reno 1+PV | 126.7 | 189.4 | 271.7 |
| Reno 5 | Reno 1+PVT | 149.0 | 201.0 | 274.4 |
| Reno 6 | Reno 2+PV | 167.2 | 210.6 | 276.6 |
| Reno 7 | Reno 2+PVT | 189.5 | 222.3 | 279.3 |
| Reno 8 | Reno 3+PV | 201.4 | 225.5 | 275.2 |
| Reno 9 | Reno 3+PVT | 223.6 | 237.1 | 277.9 |

Figure 3 shows the simple payback period (PBP) of the investment costs over the saved energy costs and CO₂ fees of the different renovation options for different supply options (see Table 4).

The lowest PBP provides the renovation of the roof in combination with PV (Reno 4) and with PVT (Reno 5) in combination with a GSHP (decentral) of 17.7 and 17.7 years respectively. The other renovation options have a higher PBP, with (Reno 9) providing the highest PBP (23.1 years) for the combination with wood pellets.

Further, PBP are lowest for the GSHP (decentral) option, while the other solutions rank slightly worse.

The renovation option (Reno 3) is the solution with the highest PBP with 31.8 years for the wood pellets solution and 30.8 years for the GSHP (decentral) solution.

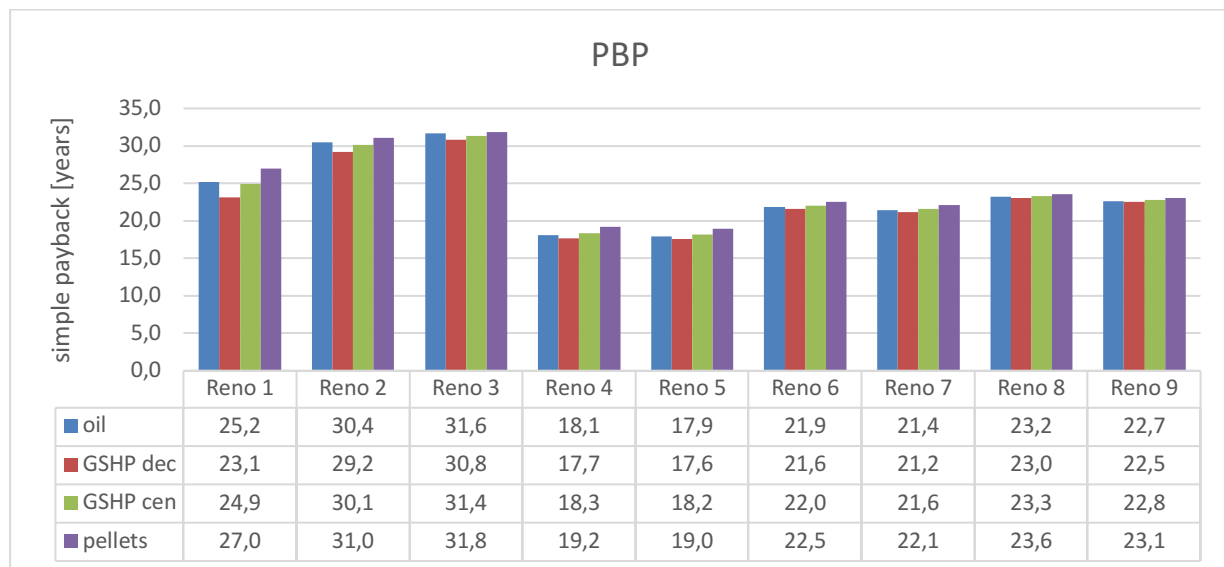


Figure 4. Economic evaluation of the renovation options with different supply options

6. Conclusions

The results of the case study clearly show the options for energy and GHG emission savings. The correlation with the necessary investment energy costs shows that at least two renovation options are cost effective. Here, the economic advantage of energy savings by roof renovation is combined with renewable energy production on the roof (Reno 4, Reno 5). When showing the emission reductions and the avoided costs it becomes obvious that this effect can be enhanced by additional fees for GHG emissions. In that case, more renovation options become economically feasible depending on the CO₂ rate at which the fees are increasing.

Several renovation options are close to economic feasibility and especially renovation option become feasible with a combination of decentral GSHP solution. This is due to several effects. First, the CO₂ fee savings become higher. This is due to the higher GHG savings of the provided energy. With each kWh saved the economic benefit consists of reduced energy costs and a higher CO₂ fee saved. Then, the renovation options Reno 4, Reno 6 and Reno 8 produce also electricity. While the self-consumption part (34%) is reducing the energy costs, the remaining electricity could be sold to the grid. This can further reduce energy costs, however this is not a model at the moment.

6.1. Analysis of design constraints

The first analysis covered design constraints such as emissions, sustainability and resilience goals, and regulations and directives, and regional and local limitations such as available energy types, local conditions and different levels of stakeholders as well as community objectives. It then illustrated how a comprehensive consideration of these can be used to guide the planner toward design options that will lead to an optimum solution for a master plan. The analysis was based on the local constraints and different planning levels. The key stakeholders could then be identified, characterized by different governance structures and thereby stakeholder constellations. Particularly interesting are the results with respect to the shift in delivered energy. While oil is not a favourable solution (as the canton of Zurich plans to ban oil from its local energy services), it makes a difference whether electricity or wood pellets will be delivered in the future (together with the amount of energy).

Here, the PVT makes a distinct difference. With the renovation options (Reno 5), (Reno 7) and (Reno 9) there is in addition to electricity production also hot water generated in PVT collectors. The self-consumption part (50%) is directly used in the buildings for DHW. The remaining part (50%) is not used. However, it could be used for other purposes (e.g., for heating the swimming pool or for delivering heat to neighbours). In a next step of our research, we would like to explore the possibilities of using

this excess heat for other purposes. In this calculation, each building has a small part of the roof with solar thermal collector (5, 6, 7, 8 m² for building types 1, 2, 3, 4 respectively). If all roof area would be supplied with PVT, the excess heat could be stored in a seasonal storage to increase the use of locally produced renewable energy and the self-sufficiency of the district.

6.2. *Economic and social implications*

The owner structure of the 51 row houses is not homogeneous. There are several age groups represented which all have different economic capabilities. The technical solutions and economic appraisal was shown to few building owners and it became obvious that investment costs and payback period are not sufficient indicators to be communicated with the home owners. In addition, it was recently decided to increase maintenance funds in the community. Therefore, it was decided not to communicate these figures directly with the homeowners. Instead, further work is needed that includes optimization, consolidation of costs of different technical solutions and a basis for discussion how the investment could be financed was seen as evidently needed. Due to recent political developments the need for reducing oil has gained more interest and pressure. Therefore, further analysis work should be conducted to specifically identify those technical solutions with minimal need for oil (and those that can substitute oil).

6.3. *Further work*

Further work includes the following tasks:

- Different stakeholders (homeowners and municipalities) perspective will be collected in three dedicated workshops and supported by questionnaires.
- The figures from this paper will be developed further to other sets of economic indicators and presented to the housing owners in a dedicated workshop. The key goal of the workshop will be to link private investments with GHG emission savings.
- GHG emission savings and immediate economic benefits of the building owners will be contrasted with the GHG emission reduction goals of the municipality to identify additional financing mechanisms in decarbonization of the district.
- A holistic, agile approach to energy master planning will be integrated in forming a collaborative platform for EMP.
- This Collaborative Platform will be further developed to form an integrated decision-support tools.

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