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A CASE STUDY OF IMPLEMENTING A RENOVATION CONCEPT

Matthias Haase

Zurich University of Applied Sciences, Institute of Facility Management, Grüental / RA, P.O. Box, CH-8820 Wädenswil, Switzerland

correspondence: matthias.haase@zhaw.ch

Abstract. There is an untapped potential for reducing GHG emissions by district renovation. It needs a detailed Energy Master Planning (EMP) of the district and support for the decision-making processes. If applied in a comprehensive manner it can contribute significantly to reducing energy consumption and thus to a long-term sustainable development of districts and climate neutrality in our cities.

The EMP typically includes combinations of energy supply and consumption, but it is equally important to understand the different solutions for district renovation. The multi-owner structure in many districts requires another set of solution finding that is embedded in potential analysis, stakeholder analysis, participative planning, and multi-actor-Management. A district near Winterthur, Switzerland was used as a case study. Site visits and structured interviews with key stakeholders were used to collect data which was then used to model the technical-economic situation and to determine the possibilities for the future.

Keywords: District renovation, renovation packages, building renovation, energy supply.

1. Introduction

Previous research shows, that renovation strategies on building level need to be derived from the energy-efficient renovation of buildings and the use of renewable energy sources to reduce the energy supply of regions or cities. The combination of energy efficiency and renewable energy sources covers both energy supply and demand in the built environment. In this sense, the renovation of buildings is a suitable strategy to reduce demand, while the use of renewable energy aims to reduce carbon dioxide emissions from the energy supply system.

However, identifying technical solutions is not enough to implement large-scale renovation strategies and to achieve the predicted decarbonization of the building stock. The renovation rate in Europe is clearly below the 3 percent annual target [1, 2]. Some of the main barriers to remediation relate to remediation costs and access to finance, as well as complexity, awareness, stakeholder management and supply chain fragmentation [1, 3].

As a result, business models are relevant to implementation and acceleration of renovations. Seddon et al. [4] define “business model” as the outline of essential details of a firm’s value proposition for its various stakeholders, and the activity system the firm uses to create and deliver this value proposition [5]. In other words, a business model is the abstraction of a strategy, focused on the system of activities through which a firm creates economic value.

Opportunities to reduce greenhouse gas emissions through neighborhood renovations are largely untapped. It requires not only in-depth energy planning (EMP), but also the support of decision-making processes [4]. This can not only significantly contribute to reducing energy consumption and ensuring the location of energy infrastructure (production, distribution, storage), but also to long-term sustainable development of districts and climate neutrality of our cities.

1.1. Energy and emissions

To be able to reduce GHG emissions in the built environment it is important to focus on the reduction of CO2 emissions from the operation of the buildings [6]. The reduction of energy use should come from the implementation of efficiency measures through energy renovation of the building stock. Another possibility is the decarbonisation of the energy supply with on-site renewable energy measures.

However, in renovation planning it is often unclear which energy supply options are available and what influence the energy renovation has on CO_2 emission reductions.

1.2. Reduction paths and its elements

A two-phase approach is proposed to reduce carbon dioxide emissions: First, reducing energy consumption with efficiency measures in connection with the renovation of the building stock. Secondly, CO_2 emission reductions from on-site renewable energy supply.

When it comes to costs and financing, it is crucial to relate different measures with different stakeholders. Energy supply is a political (municipal) matter, but the renovation of residential buildings mostly depends on the owners [6]. In order to achieve carbon reduction goals, it is important to find ways to involve

FIGURE 1. The settlement seen from above with eight building blocks containing 51 row houses.

homeowners in long-term carbon reduction investment strategies [7].

This case study was modelled with different power supply options and the performance was simulated [1]. The performance gives energy consumption over a year and with energy prices the costs were calculated. The cost savings could then be used in part to finance an energy-efficient renovation. In the base case, fossil fuels (oil) are delivered to the district and different power supply options offer energy and cost savings compared to the base case. After that, the energy saving measures are calculated, which lead to energy cost savings for the building owner. Finally, local renewable energy sources are integrated into the roofs of the buildings which provide electricity production and income when sold to the utility company. The final investment costs are calculated and presented to the building owners.

2. Case study

2.1. Situation

Settlement 51 in Dinhard was built in a first stage in 1974 and in a second stage in 1977 as a cooperative settlement. Eight blocks contain 51 row houses as shown in Figure 1. The row houses have different sizes and different number of rooms (3.5 rooms, 5.5 rooms and 6.5 rooms) resulting in different row house types. Some of the houses are already being retrofitted with new windows and additional roof insulation, but so far no district renovation (of all houses) took place. The heating center in front of Block F next to the swimming pool (in white in the middle lower part) supplies all row houses with heating and hot water. The oil boiler with 465 kW heat output was replaced in 2019.

2.2. Energy consumption

An average of 99 370 liters of oil (average for the years 2000 to 2014) was consumed in the district. With an average energy reference area of a row house of 140 m^2, an energy figure for heat $E_W = 140\,\mathrm{kWh/(m^2a)}$ can be found. This value is somewhat below the Swiss average for older, non-refurbished residential buildings ($E_{W avg} = 160\,\mathrm{kWh/(m^2a)}$) [3].

2.2.1. Energy supply option

Three different building standards (Standard 1, 2 and 3) with different peak power was modelled. For each building standard, the following energy supply options were considered [1].

- 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.

2.2.2. Energy, costs and emissions

The simulations provided energy consumption results for each option. These were taken as input for cost and emission calculations. The following assumptions were considered as shown in Table 1 (energy costs and emissions), Table 2 (investment costs), Table 3 (maintenance costs) and Table 4 (energy costs).

3. Results

The results of the case study are presented in energy use, investment and maintenance costs as well as energy costs, and GHG emissions. The link between costs and emission reduction will then be presented to the investors/housing owners.

Energy carrier	Costs	Emissions
Electricity	0.15 CHF/kWh	0.25 kg CO_2eq/kWh
Pellets	375 CHF/t	0.01 kg CO_2eq/kWh
Oil	1.05 CHF/l	0.28 kg CO_2eq/kWh

Table 1. Energy costs and emission factors of different energy carriers.

Unit CHF	Oil boiler	Central oil boiler + dec. HP boiler	GSHP	Pellet boiler
Electricity	0	7500	34290	0
Pellets	0	0	0	60000
Oil	84000	68250	0	0
El. for pumps and motors	2000	1800	2000	2000
Total energy	86000	77550	36290	62000

Table 2. Investment costs of different supply options (in CHF).

Unit CHF	Oil boiler	Central oil boiler + dec. HP boiler	GSHP	Pellet boiler
Cleaning, control, fees, services	2500	2000	1000	2500
Repair fond	3400	6570	5000	6480
Total	5900	8570	6000	8980

Table 3. Maintenance costs (in CHF).

Unit CHF	Oil boiler	Central oil boiler + dec. HP boiler	GSHP	Pellet boiler
Electricity	0	7500	34290	0
Pellets	0	0	0	60000
Oil	84000	68250	0	0
El. for pumps and motors	2000	1800	2000	2000
Total energy	86000	77550	36290	62000

Table 4. energy costs (in CHF).

	Annual energy use [kWh]	Type 1	Type 2	Type 3	Type 4
Block A	135564			5	1
Block B	135564			6	
Block C	170680		1	5	1
Block D	194972	1		7	
Block E	146388	1		5	1
Block F	189878	1		6	1
Block G	124643	0		5	
Block H	97168	0		4	
Sum	1194858	3	1	43	4

Table 5. Energy use.

Unit kWh/(m^2a)	Type 1	Type 2	Type 3	Type 4
Heating	118	118	118	118
DHW	22	22	23	24
Electricity	24.4	31.6	36.3	39.12
Sum	164.4	171.6	177.3	181.12

Table 6. Energy use in different housing units.

Renovation measure	Description	Investment costs [CHF]
Roof	tiles + wind barrier + 30 cm insulation + vapour barrier	653 158
Facade	+ new windows + insulation panels + doors	705 944
Ventilation	Ventilation unit + heat exchanger + ductwork	324 602
PV	1339 PV modules + fastening structure + inverter + cabling	709 322
PVT	1339 PV modules + inverter + cabling, partly integrated with 354 m2 solar thermal collector modules solar thermal collector (5, 6, 7, 8 m^2 for building types 1, 2, 3, 4 respectively) + piping + storage tank	852 422

TABLE 7. Renovation measures with investment costs.

		Operational energy [kWh]	Energy savings [kWh]	CO_2 emissions [kg CO_2]	CO_2 emissions savings [t CO_2]
Ref	1212971	-	322688,35	-	
Reno 1	roof	938563	274409	242573,05	80,1
Reno 2	roof+fassade	801354	411617	202069,10	120,6
Reno 3	roof + facade + balanced ventilation	664146	548826	161565,16	161,1
Reno 4	reno1+PV	821331	391641	224425,58	127,8
Reno 5	reno1+PVT	740929	472042	201384,15	150,8
Reno 6	reno2+PV	679185	533786	183157,37	169,1
Reno 7	reno2+PVT	603721	609251	160880,20	191,3
Reno 8	reno3+PV	541977	670995	142653,43	209,6
Reno 9	reno3+PVT	466512	746459	120376,25	231,8

TABLE 8. Renovation options.

3.1. ENERGY

There are a total 8 different blocks with four different types of row houses (type 1, 2, 3, 4). Energy use in the eight different building blocks is illustrated in Table 5. A total of 1195 MWh is used.

Table 6 summarizes the energy use per m^2 heated floor area for heating, domestic hot water (DHW) and electricity. The different types have different annual energy use between 172 kWh/(m^2a) (type 1) and 181 kWh/(m^2a).

Table 7 shows the different renovation measures for the eight buildings. The first measure focuses on the roof and adds a vapour barrier, 30 cm insulation, a wind barrier and new tiles. The investment costs for this measure were calculated to 653 158 CHF. The second measure focuses on the facade and includes changing doors and windows as well as insulation panels underneath the windows. The investment costs for this measure were calculated to 705 944 CHF. The third measure includes a balanced ventilation system consisting of a ventilation unit per house, heat exchanger and ductwork. The investment costs for this measure were calculated to 324 602 CHF. The fourth measure includes a PV system on all roof surfaces, including fastening structure and cabling as well as inverters. The investment costs for this measure were calculated to 709 322 CHF. The fifth measure includes a PVT system, adding to the PV system solar thermal collectors (5, 6, 7, 8 m^2 for building types 1, 2, 3, 4 respectively), piping and a storage tank. The investment costs for this measure were calculated to 852 422 CHF.

The five measures were combined to nine different renovation options (Reno 1 to Reno 9). It follows step by step renovating the roof, the façade, and then integrating the different technologies PV and PVT in different options as listed in Table 8. The energy use and savings were calculated for heating, DHW and electricity separately. In the case of PV, a separate calculation included a share of self-consumption (30 %), and the economic implications which arise from different tariffs for purchasing and selling electricity [8].

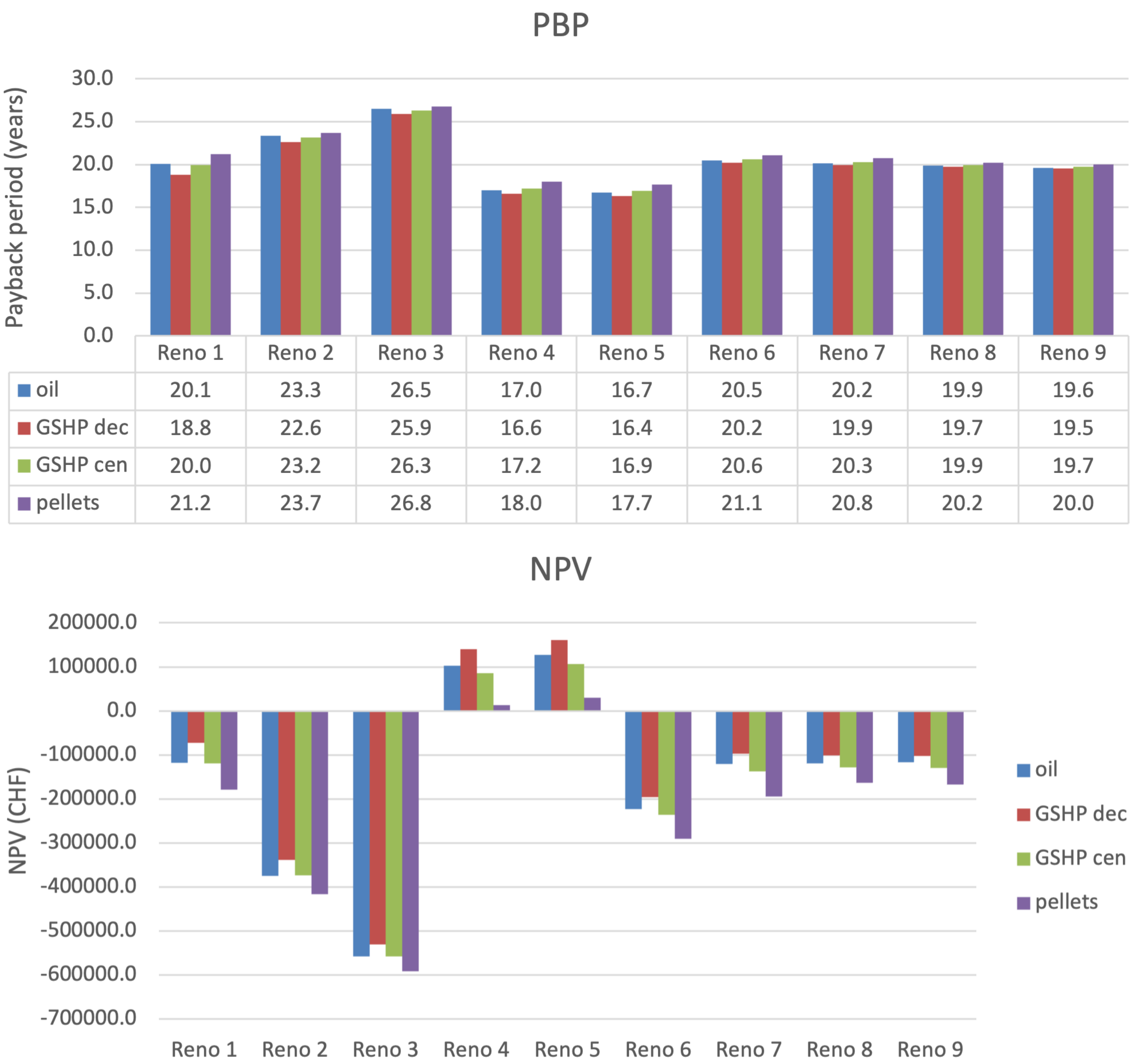

FIGURE 2. Economic evaluation of the renovation options (PBP and NPV).

In the two columns on the right the CO_2 emissions of each renovation option is shown together with the potential savings compared to the reference case.

3.2. ECONOMIC EVALUATION

Figure 2 shows the net present value (NPV) and payback period (PBP) of the different renovation options (Reno 1 to Reno 9) without the different options for energy supply. It can be seen that the PBP varies between 16 (Reno 4) and 25 (Reno 3) years. With the chosen discount rate of 3.5 % and a lifetime of 25 years two renovation options have positive NPV (option 4 and 5) and are economically feasible.

However, renovation option (Reno 1, Reno 7, Reno 8 and Reno 9) are very close to a positive NPV and in combination with a wood pellets boiler they become also economically feasible.

The payback periods are lowest for renovation options (Reno 4) (15.5 years) and (Reno 5) (15.4 years). The highest PBP shows renovation option Reno 3 (24,5 years). Eight renovation options show a PBP below 20 years (Reno 1, Reno 4, Reno 5, Reno 6, Reno 7, Reno 8 and Reno 9).

3.3. GHG EMISSIONS

Table 8 gives the GHG emissions and the savings of the different renovation options. We included investment as well as maintenance and energy costs of the supply options. Figure 3 shows investment costs over the saved CO_2 emissions of the different renovation options for different supply options (see Table 3) over the period of 25 years.

The lowest costs per t CO_2 provides the renovation of the roof (Reno 1) in combination with a wood pellets boiler (100 CHF/t CO_2). The other renovation options are more expensive with (Reno 6) providing the highest costs (489.4 CHF/t CO_2).

Further, costs are always highest for the oil boiler

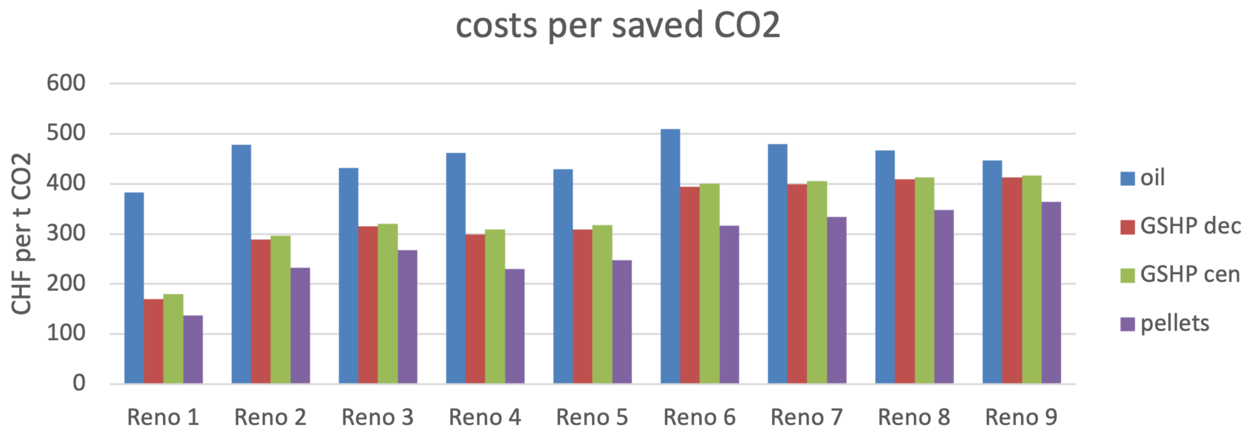

FIGURE 3. Economic evaluation of the renovation options with different supply options.

option, while the two GSHP solutions rank second and the wood pellets solution is always the cheapest.

The renovation options (Reno 2), (Reno 4) and (Reno 5) (options 4 and 5 have a positive NPV) with wood pellets boiler provide the second lowest costs (205, 196 and 214 CHF/t CO_2 respectively).

4. Conclusions

The results of the case study clearly show the potential to save energy and greenhouse gas emissions. Correlation with the necessary investment and maintenance costs and energy costs shows that at least two basic improvement options are advantageous. Here, the economic advantage of the energy savings of roof renovation is combined with regenerative energy production on the roof. When presenting the emission reductions and avoided costs, it becomes clear that this effect can be strengthened by additional fees for greenhouse gas emissions. In this case, as the fees increase, depending on the CO_2 level, more renovation options become financially viable.

Several renovation options are close to economic profitability, and especially the renovation options (Reno 1, Reno 7, Reno 8 and Reno 9) become feasible with a combination of wood pellet boilers. This is due to several reasons. First, the CO_2 payment savings are greater. This is due to the higher CO_2 savings of the delivered energy. With the CO_2 coefficient of wood pellets, 0.036 kg/kWh has been calculated, compared with the CO2 coefficient of oil of 0.295 kg/kWh. The economic benefit of each saved kWh consists of energy costs and a higher CO_2 payment saved. Finally, the renovation versions Reno 4, Reno 6 and Reno 8 produce electricity. While the self-consumption rate (30 %) lowers energy costs, the excess of electricity is sold to the grid. This lowers energy costs and increases CO_2 payments.

In the renovation options Reno 5, Reno 7 and Reno 9, additional hot water is produced in PVT collectors. The share of own consumption (43 %) is used directly for hot water in buildings. The remaining part (57 %) is not used. However, it can be used for other purposes (such as heating the swimming pool or heating other neighbours). We want to explore the possibilities of using this extra heat for other purposes in the next phase of research. In this work, each building has a small part of the roof with a solar heat collector (5, 6, 7, 8 m^2 for building types 1, 2, 3, 4). If all roof areas were supplied with PVT, the excess heat could be stored in seasonal storage increasing the use of locally produced renewable energy and the district's self-sufficiency.

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References

[1] M. Haase. Implementation strategies for renovation concepts based on participative planning. *IOP Conference Series: Earth and Environmental Science* **1078**(1):012081, 2022. https://doi.org/10.1088/1755-1315/1078/1/012081

[2] I. Artola, K. Rademaekers, R. Williams, J. Yearwood. Boosting building renovation: What potential and value for Europe?, European Union, Brussels, 2016.

[3] K. Laffont-Eloire, N. Peraudeau, S. Petit, et al. Sustainable business models for the deep renovation of buildings, STUNNING – Sustainable business models for the deep renovation of buildings, 2019.

[4] P. B. Seddon, G. P. Lewis, P. Freeman, G. G. Shanks. The case for viewing business models as abstractions of strategy. *CAIS* **13**:25, 2004. https://doi.org/10.17705/1CAIS.01325

[5] BPIE. Europe's buildings under the microscope, Building Performance institute Europe, Brussels, 2011. [2022-06-22]. https://bpie.eu/wp-content/uploads/2015/10/HR_EU_B_under_microscope_study.pdf

[6] M. Haase, D. Baer. Constraints, stakeholders, and framing goals in energy master planning between neighborhood and district. In A. Bisello, D. Vettorato, D. Ludlow, C. Baranzelli (eds.), *Smart and Sustainable Planning for Cities and Regions*, pp. 3–13. Springer

International Publishing, Cham, 2021. https://doi.org/10.1007/978-3-030-57764-3_1

[7] Buildings Performance Institute Europe (BPIE). Scaling up deep energy renovations. Unleashing the potential through innovation & industrialization, 2016. [2022-06-22]. https://www.bpie.eu/wp-content/uploads/2016/11/BPIE_i24c_deepretrofits.pdf

[8] European Commission DG Energy. Financing the energy renovation of buildings with Cohesion Policy funding, 2014. [2020-04-01]. https://ec.europa.eu/energy/sites/ener/files/documents/2014_guidance_energy_renovation_buildings.pdf