SUSTAINABLE NEIGHBOURHOODS RETROFITTING: APPLYING FASUDIR INDICATORS TO ASSESS THE SUSTAINABILITY PERFORMANCE OF A RESIDENTIAL NEIGHBOURHOOD IN WOLFRATHAUSEN, BAVARIA

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Abstract

In comparison to the traditional single building retrofitting, the neighbourhood retrofitting approach is frequently cited as the most sustainable and cost-effective retrofitting option. However, applying the neighbourhood approach usually leads to an exponential growth of the complexity of the decision making process as the interventions affect a wider number of stakeholders.

In the elective course “Sustainable Neighbourhoods” undergraduate students of the faculty of Architecture at Munich University of Applied Sciences in cooperation with the city of Wolfratshausen, have tested the validity of the neighbourhood approach on a real case study site using on-site collected data and GIS files and FASUDIR (Friendly and Affordable Sustainable Urban District Retrofitting) key performance indicators (KPI’s) to assess the sustainability performance of the neighbourhood and developed a number of viable retrofitting scenarios.

1 Introduction

The European building sector is responsible for 40% of overall energy consumption sector half of it is used for Heating, cooling and ventilation [1]. With more than 70% of the building stock built before the first energy crisis (1970’s), energy retrofitting of buildings represents the largest and the most effective untapped source to reach the EU’s “40-27-27” targets [2]. However, the results of current practice of retrofitting projects have shown that in order to fully exploit the potentials of retrofitting the existing building stock each building need to be investigated within its context in the neighbourhood and as a part of a global system in a district. This approach requires treating each individual building not as a standalone building but in relation to its context, where all the buildings within the neighbourhood are treated as a single entity. In this case, applying a chosen retrofitting measure is not limited to single building scale but can be applied on whole neighbourhood aiming at elevating the ecological, economic and social aspects of the development, through exploiting synergies and interactions between buildings and their surroundings.

However, applying the neighbourhood approach usually leads to an exponential growth of the complexity of the decision making process as the interventions affect a wider number of stakeholders who usually lack a common view on the current state of the neighbourhood and/or a common goal. Therefore, having a quick and accurate assessment of the current and the post-retrofiring performance of a neighbourhood is crucial for the success of the neighbourhood approach, as it provides the stakeholders with a better insight into a state of the neighbourhood and helps them to define a common retrofitting goal.

Although the neighbourhood approach appears to be very promising, there is really a limited number projects that can show the advantages of the neighbourhood retrofitting and even more limited number of holistic planning tools and assessment systems such as FASUDIR and District ECA that are specially designed for such project.

In the winter semester of 2014/15 in the course “Sustainable Neighbourhoods” the students of the faculty of Architecture at Munich University of Applied Sciences in cooperation with the city of Wolfratshausen, have been introduced to the neighbourhood approach of retrofitting and were given the chance to test the validity of the neighbourhood approach on a real case study site using on-site collected data, GIS files, the methodology and a set of Key performance indicators developed by FASUDIR and District ECA software. The results of the current state assessment and the retrofitting scenarios are then compared to each other and documented in the final report, which was later presented to the mayor of Wolfratshausen.

1.1 Case Study Site

The case study site was identified by the city of Wolfratshausen as a suitable site to conduct the sustainability assessment with the aim for the site to be a pilot case for testing the neighbourhood retrofitting approach in the future. The chosen residential neighbourhood is located in the district of Farchet, which is one of the five districts of the city of Wolfratshausen. The city of Wolfratshausen is located at the border of the German Alps, some 35 Km to the south of Munich, the capital city of the federal state of Bavaria.

The area of the site is about 1.5 Hectares and is dominated by multi story buildings that mostly date back to the 1960's. Most of the buildings in the site are for residential purpose only, however some commercial spaces occupy the ground floor of the row housing development on the south east side of the block . A restaurant dating back to the early 1900s is located within a public green space at the south east side of the block. The site is home to some 210 inhabitants. The vast majority of the buildings are connected to the local Gas supply network, one building uses wood pallets with the rest relaying on oil fuel for their heating demand.

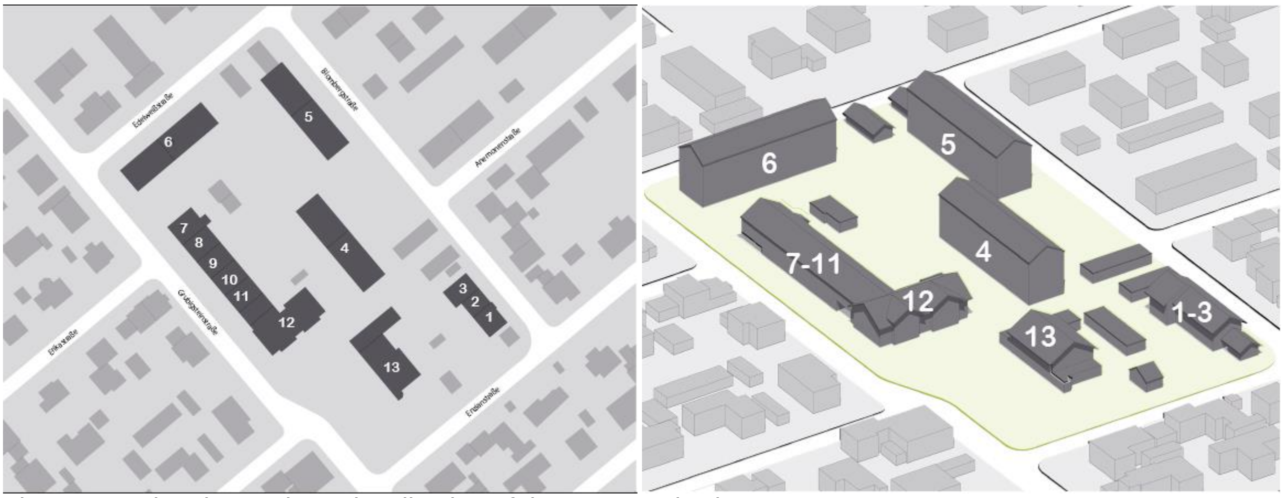

Figure 1   Site plan and 3D visualisation of the case study site.

Table 1 Summery of the buildings in the case study site

Building Number	Use	Construction Year Class	Energy Source	Net Floor Area	Roof Orientation and Area
1	Single Family house	1969-1983	Gas	239,2 m²	SW 52,7 m² NE 50,2 m²
2	Single Family house	1995-2006	Gas	173,3 m²	SW 38,6 m² NE 36,3 m²
3	Single Family house	1984-1994	Gas	252,3 m²	SW 53,2 m² NE 53,4 m²
4	Apartment block	1949-1968	Gas	1756,3 m²	SW 252,8 m² NE 252,8 m²
5	Apartment block	1949-1968	Gas	1757,1 m²	SW 253 m² NE 252,8 m²
6	Apartment block	1949-1968	Oil	1744,3 m²	SE 251,7 m² NW 251,7 m²
7	Mixed: Bank and Row housing	1977-1983	Gas	123,8 m² 216,7 m²	SW 66,5 m² NE 79,6 m²
8	Mixed: shop and Row housing	1949-1968	Gas	101,3 m² 177,3 m²	SW 59,1 m² NE 59,2 m²
9	Mixed: Office and Row housing	1949-1968	Gas	99,7 m² 174,5 m²	SW 58,2 m² NE 58,2 m²
10	Row housing	1949-1968	Oil	274,3 m²	SW 58,2 m² NE 58,2 m²
11	Office	1977-1983	Gas	278,7 m²	SW 59,3 m² NE 59,3 m²
12	Multi Family house	2007-2012	Wood pallet	1218,6 m²	SW 81,5 m² NE 80,2 m²
13	Restaurant	1900-1948	Gas	675,4 m²	SW 122,2 m² NE 133 m²

1.2 Methodology

The students' task was to assess the sustainability performance of the neighbourhood in its current state and to develop viable retrofitting scenarios aiming at improving the neighbourhood overall sustainability performance using a selection of FASUDIR KPI's for benchmarking.

To carry out this task the students were provided with a CityGML file of the case study site made available courtesy of the Bavarian State Office for Survey and Geoinformation and were briefed about the case study site condition, location from a representative of the municipality Wolfratshausen. Due to the time and resources limitation and the fact that at the time of doing this research the FASUDIR IDST tool was still in development as well as benchmarking some of the KPI's. The following table presents summary of the used FASUDIR KPI's in the performance assessment of the neighbourhood in its current state and after retrofitting, along with the method used to calculate achieved points of each KPI [3].

Table 2 Summary of the used FASUDIR KPI's

Level	Category	Indicator	Sub-Indicator	Calculation method
District	Environmental	Energy demand	Operational Energy Use	Aggregation of the building level results
District	Environmental	Energy demand	Share of Renewable Energy on Site	District ECA Software, aggregation of the building level results
District	Environmental	Impact on the Environment	Global warming potential (GWP)	District ECA Software, aggregation of the building level results
District	Social	Motor transport infrastructure	Parking facilities	On site collected data
District	Social	Motor transport infrastructure	Infrastructure for innovative concepts	On site collected data
District	Social	Public transport infrastructure	Internal Accessibility	Google maps and on site collected data
District	Social	Bicycle and pedestrian	Bicycle facilities	On site collected data
District	Social	Accessibility	Barrier - Free Accessibility	On site collected data
District	Social	Accessibility	Access to services and facilities	Google maps and on site collected data
District	Social	Accessibility	Access to parks and open spaces	Google maps and on site collected data
District	Social	Thermal comfort	Heat Island	Google maps and on site collected data and GIS data
District	Economic	Life cycle cost	Running Costs Energy	Aggregation of the building level results

2 Current state analysis

The results of tge current state analysis have showed that the neighbourhood with its 9.747,90 m² of net floor area has a total primary energy demand of 2943 MWh/a and emits 745 T/a of CO² equivalent of emissions. The net floor area of the buildings is calculated using:

$$NFA = \text{Building footprint} \times floors \times 0.8(\text{gross to net factor}) \text{ [8]} \qquad (1)$$

The total primary energy demand along with the amount emitted emissions are calculated using the default values in the District ECA that are derived from the construction year class of the buildings and the Primary energy factor and CO² equivalent emission of the energy sources. The share of renewable energy in the neighbourhood is about 9%. For assessing the indicator operational energy use in the district the results of the operational energy use indicator of each building are aggregated to cover the neighbourhood , the assessment is then done using the following FASUDIR formula [3] :

$$PE_{op} \div PE_{op/\lim} = 0\% \quad = 100 \text{ Point} \tag{2}$$

With the PE limit = 200 kWh/m².a. the running energy costs of the neighbourhood account for 154.388€/a based on the price of wood at 5,5ct/kWh, natural gas at 7,7ct/kWh and fossil oil at 8,36 ct/kWh [4].

Figure 2 Calculated current operational energy Use for each building in the case study site

Table 3 Summery of current state analysis results

Category	Sub-Indicator	Points achieved from 100
Environmental	Operational Energy Use	0 Points
Environmental	Share of Renewable Energy on Site	45 Points
Environmental	Global warming potential (GWP)	No benchmark available
Social	Parking facilities	38 Points
Social	Infrastructure for innovative concepts	0 Points
Social	Internal Accessibility	100 Points
Social	Bicycle facilities	25 Points
Social	Barrier - Free Accessibility	100Points
Social	Access to services and facilities	75 Points
Social	Access to parks and open spaces	100 Points
Social	Heat Island	50 Points
Economic	Running Costs Energy	No benchmark available
Total		53.4 / 100 point

Figure 3 Impressions for the case study site

3 Analysis of the retrofitting variants

Out the nine analysed retrofitting variants, three are presented in this paper and are given the codes Variant 1, 2 and 3. The retrofitting scenarios were investigated in terms of their impact on the environmental as well as the economical KPI's of the neighbourhood. All the three variants address retrofitting the building system as well as the building envelope. Variant 1 and 2 present the scenarios where the building envelope is retrofitted to meet the minimum requirements of the German Energy Saving Ordinance (EnEV) of 2014 [5]. Variant 3 presents a scenario where the building envelope is retrofitted to meet the requirements of the passive house standard [5]. Variant 2 uses a gas driven district heating system in order to meet the demand of space heating, thus representing a district solution, while Variant 1 and 3 use a gas driven condensing boiler and geothermal heat pump respectively, thus representing a single building solution. The Table 3 provides a summary of the investigated retrofitting parameters.

The social KPI's Infrastructure for innovative concepts and Bicycle facilities are considered in the three variants to be retrofitted to achieve the maximum points. The KPI result of the other social aspects: parking facilities, heat island and access to services and facilities are not changed from the current state analysis as they are beyond the scope of this limited study. The KPIRunning costs and the KPI Global warming potential (GWP) were not considered in the assessment, as at the time of conducting this study no benchmarking for these KPI's is published [3].

Table 4 Summary of retrofitting measures parameters

		Variant 1	Variant 2	Variant 3
Building systems	Space heating	Condensing boiler	District heating	Geothermal heat pump
	hot water	Solar thermal	District heating	Solar thermal
	Ventilation	Window	Window	Heat recovery DC 75%
	PV	10% of available& suitable space	10% of available& suitable space	40% of available& suitable space

Building envelope	Windows	U = 1,3 W/(m².K)	U = 1,3 W/(m².K)	U = 0,8 W/(m².K)
	Exterior wall	U = 0,24 W/(m².K)	U = 0,24 W/(m².K)	U = 0,11 W/(m².K)
	Top floor ceiling/Ceiling to attic	U = 0,3 W/(m².K)	U = 0,3 W/(m².K)	U = 0,07W/(m².K)
	Floor slab	U = 0,4 W/(m².K)	U = 0,4 W/(m².K)	U = 0,12 W/(m².K)
	basement ceiling	U = 0,35 W/(m².K)	U = 0,35 W/(m².K)	U = 0,25 W/(m².K)

3.1 Results of analysis

The results of the variants analysis show that as anticipated that Variant 3 with its passive house standard insulation is the most energy saving option but also the most expensive one in terms of initial investments as well as running costs, with the electricity costs being calculated at the level of 28,8ct/kWh [6] .Variant 1 consumes about double as much energy as variant 3 and it also costs half as much to run. In comparison with the variant 2 it appears to be the balanced option between both variants as it achieves a very good saving level in terms of energy demand, it fulfils the /renewable energy goal of 20 % and its running costs are marginally higher than of Variant 1 with its costs of district heating reaching about 9,2ct/kWh [7].

Table 5 Summary of variants performance

Sub-Indicator	Variant 1	Variant 2	Variant 3
Operational Energy Use	1418 MWh/a = 28 Pt	1238 MWh/a = 37 Pt	781 MWh/a = 60 Pt
Share of Renewable Energy on Site	24%= 100Pt	20% = 100 Pt	50% = 100 Pt
Global warming potential (GWP)	352t/a	345 t/a	219 t/a
Parking facilities	38 Points	38 Points	38 Points
Infrastructure for innovative concepts	100 Points	100 Points	100 Points
Internal Accessibility	100 Points	100 Points	100 Points
Bicycle facilities	100 Points	100 Points	100 Points
Barrier - Free Accessibility	100 Points	100 Points	100 Points
Access to services and facilities	75 Points	75 Points	75 Points
Access to parks and open spaces	100 Points	100 Points	100 Points
Heat Island	50 Points	50 Points	50 Points
Running Costs Energy	109 186 €/a	113 896 €/a	224 928 €/a
Total	69.1	70	73.1

3.2 Comparison of the results of current state to the retrofitting variants

Table 6 Performance of current state vs. variants

Sub-Indicator	Current state	Variant 1	Variant 2	Variant 3
Operational Energy Use	2943 MWh/a	- 52%	- 58%	-73.4%
Share of Renewable Energy on Site	131.7 MWh/a	+ 132%	+ 31.2%	+ 241%
Global warming potential	745	- 52.7 %	- 53.7%	+ 70.6%
Parking facilities	97 off street	0 %	0 %	0 %
Infrastructure for innovative concepts	148 on street	0 %	0 %	0 %
Internal Accessibility	100 Points	0 %	0 %	0 %
Bicycle facilities	25 Points	+ 300 %	+ 300 %	+ 300 %
Barrier - Free Accessibility	100 Points	0 %	0 %	0 %
Access to services and facilities	75 Points	0 %	0 %	0 %
Access to parks and open spaces	100 Points	0 %	0 %	0 %
Heat Island	50 Points	0 %	0 %	0 %
Running Costs Energy	154.388€/a	-29.2%	-26.2%	+54.7%
Total	53.4 Pt	+ 29.4%	+31%	+37%

4 Review on FASUIR Key performance indicators

FASUDIR Key performance indicators are unique in their nature as they are one of very few Key performance indicators especially designed for District retrofitting projects. The FASUDIR KPI's are developed with the intention to be applicable in three very different European countries namely, Germany, Hungry and Spain. Applying the FASUDIR KPI's to this case study have provided us with a valuable insight into the way the KPI indicators preform, their advantages, their short comings as well as facilitated some suggestions to improve them as summarized in the Table below :

Table 7: Review on applied FASUDIR KPI's

Sub-Indicator	Shortcoming/suggestions
Operational Energy Use	The current calculation doesn't allow to use different benchmarks for different building types and use
Share of Renewable Energy on Site	The share of renewable energy on site can be very challenging to estimate especially with tall buildings and/or outdated satellite images
Parking facilities	Access to underground / off street parking is not always granted to the planner
Infrastructure for innovative concepts	The indicator doesn't take into account the free floating car sharing concepts which do not require a dedicated parking space
Bicycle facilities	The four facilities are giving the same weighting which might need to be reconsidered, as having a bike path can be more important than to have built protection against theft. The method of calculation the four facilities on a district scale is not clearly explained.
Barrier - Free Accessibility	The indicator doesn't specify for each type of disability the required type of Barrier-free, such as the enabling a deaf person using a traffic light

Access to parks and open spaces	The indicator doesn't specify a minimum area for a green space so the green space is considered sufficient for the district. Setting green area per inhabitant threshold might help overcome this short coming
Heat Island	The indicator deliver a qualitative result, that doesn't not give a clear indication between the anticipated comfort level and the resulted heat island

5 Conclusion

In this paper, the results of applying neighbourhood approach for retrofitting the existing building stock as well using the FASUDIR district KPIs on pilot real case study are presented. A critical review on the performance of FASUIR KPI's for district level along with suggestion for improvement the KPI's for further use are discussed.

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