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Analyzing the Energy-Saving Potential of Buildings for Sustainable Refurbishment

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Abstract

For the sustainable redevelopment of existing properties, it is important that the measures taken pay off economically as well. With the energy-scoring method presented in this paper, portfolios can be classified according to their energy-saving potential. Besides the various factors affecting the reduction of primary energy demand, the 3-tier model analyzes and correlates the economic efficiency. The result is an objective ranking of each object, from which property owners can deduce where they should ideally invest in order to optimize the energy efficiency of their building stock sustainably.

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Keywords: energy consumption; building stock; energy-scoring; sustainable refurbishment; sustainable buildings; classification of energy-saving potential; portfolio management

1. Motivation

The European Union attaches great importance to buildings as part of its strategy to achieve the climate targets for 2020[1]; after all, 40 percent of the energy consumption and one third of the CO_2 emissions in Europe are caused by the real estate sector.[2] In order to change this, existing buildings need to be energetically refurbished, as about one third of the stock is in fact older than 50 years[3] and therefore does not meet the current standards. However, it is difficult to decide where and how to realize energy savings in the most efficient and economical way – especially for property owners with a large and heterogeneous building stock. An analysis of the various buildings` saving potential helps to prioritize measures increasing energy efficiency.

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2. The epiqr energy-scoring method

The epiqr energy-scoring method pursues a holistic approach to the prioritization of properties to be refurbished and the determination of necessary investments. A uniform and objective procedure was designed to ensure that buildings could easily be compared and aligned. Considering economic aspects as well as the possible future use of renewable energies, the energy-saving potential of existing properties is analyzed. This facilitates for each building the identification and subsequent derivation of needs for action with regard to the improvement of its energy efficiency. One of the objectives of the epiqr energy-scoring is to minimize the effort and cost for the survey of the property, by focusing on the most impacting building components that can be identified with a quick visual inspection.

2.1. The 3-tier model

The scoring is based on a 3-tier model, which analyzes the various factors influencing the primary energy-saving potential and sets them in relation to each other.

- The three pillars on the first level represent the objectives of the energetic refurbishment leading to the diminution of primary energy consumption:
  - "Energy demand reduction"
  - "Renewable energy inclusion"
  - "Economic efficiency"
- The second level consists of the most significant variables for each of these pillars in the form of criteria (see Fig. 1.).
- Each of these criteria is in turn composed of various indicators on the third level. The criterion "potential for use of renewable energies" is, for example, defined by indicators such as "solar thermal energy", "photovoltaics" and "wooden pellets - wood chips".

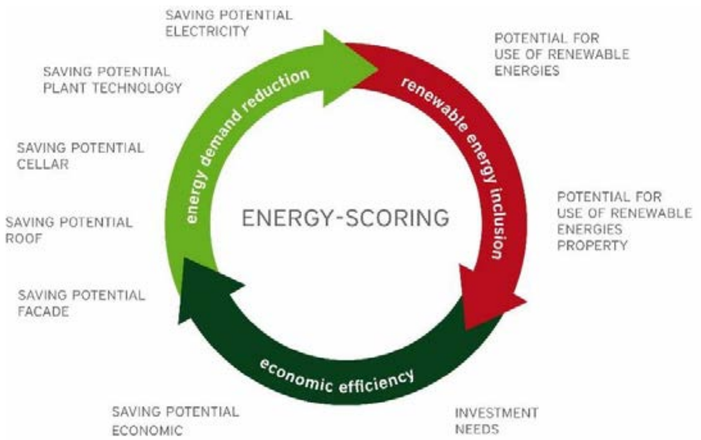

Fig. 1. The model`s three pillars consist of different criteria.

In establishing these criteria and indicators, special attention was paid to their completeness, balance and non-redundancy. In addition, the indicators have been thus defined as to ensure validity, sufficient variability, reasonable expenses in the procurement of data and their sufficient influence on the result.

The various elements of the model are individually weighted according to their importance for the achievement of the objectives. To determine, for example, the potential for the use of renewable energies, solar thermal energy is with 20% weight less important than the use of wooden pellets weighted with 60% (see Table 1). A weighting can be performed on all three levels.

Table 1. Example of the weighting of pillars, criteria and indicators.

Criteria model	Weighting		
2 Renewable energy inclusion	20%		
2.1 Potential for use of renewable energies		40%	
2.1.1 Solar thermal energy			20%
2.1.2 Photovoltaics			20%
2.1.3 Wooden pellets – wood chips			60%
2.2 Potential use of renewable energies property		60%	
2.2.1 Presence of renewable energy sources			100%

2.2. Assessment of criteria

In the development of the potential analysis, importance was attached not only to its objectivity, logic and comprehensibility, but also to its subsequent implementation. To determine the energy-saving potential of a building, an assessment of the windows, the walls, the basement, the roof and the plant technology is initially required. This is performed using the epiqr method, which has been co-developed by the Fraunhofer Institute for Building Physics (IBP) in the course of a European research project[4]. In the assessment process, only few geometrical quantities are captured. The epiqr software then derives the necessary masses through statistical extrapolations. In addition, only the most cost-relevant building components are assessed according to their state:

- state "A" = "good condition"
- state "B" = "light deterioration"
- state "C" = "serious deterioration"
- state "D" = "end of life reached"

Four categories have been chosen to make it impossible to calculate an average in the course of the visual evaluation on-site. State "A" and "D" can be assigned easily and largely objective. Only for state "B" and "C“, a detailed decision has to be taken on the part of the person performing the assessment. To minimize the subjectivity in cases of fluent transition between states, standards and guidelines have been created. These standardize the assessments of different persons and make them comparable. Each of these states is associated with maintenance measures (see Table 2), ranging, for example, from a simple surface treatment of a facade to its total replacement. The system automatically calculates the costs necessary for the implementation of the respective measure.

Table 2. Description of states and resulting measures using the example of the component closed facade surface – plaster“.

State	Definition	Measure
A	No visible damages. Paint clean.	No intervention.
B	Paint weathered, plaster damages (< 20%) on facade surface.	New base coat and final rendering on defective spots (20% surface).
C	Paint weathered, plaster damages (20-50%) on facade surface.	New base coat and final rendering on defective spots (50% surface).
D	Paint weathered, plaster damages (50-100%) on facade surface.	Complete removal of the existing plaster. Cleaning of the masonry, new plastering. Painting of the facade.

For the energy-scoring method, a new grading system is used ranging from 1 (very good) to 4 (very poor). The energetic grade for each component is derived from the assessed degradation state according to the epiqr method. Since the assessment with state "A" solely reflects the defect-free condition of a component, it cannot be equated with its compliance with current energy requirements. For example, a low temperature boiler rated with "A" in accordance with the epiqr method due to its correct functioning will be given an energy grade 2, while a condensing boiler rated with "A" will be given the grade 1, as it is generally more efficient. As the correlation between the degradation state and the energetic performance varies with each element, specific grade translation tables have been developed for each building component.

Table 3. Translation of the assessment of state into an energetic assessment using the example of facade insulation.

epiqr state	Definition			Energy-scoring grade
Good (A)	Wall thickness ≥ 50 cm;	sufficient thermal insulation	→	1
Sufficient (B)	Reinforcement/armoring fiber damaged		→	2
Deficient (C)	Insulation requirements not met		→	4
Inadequate (D)	Wall thickness < 50 cm;	thermal insulation < 8 cm	→	4

2.3. Defining economic efficiency

The evaluation of the economic efficiency is the centerpiece of the energy-scoring. For this reason follows a more detailed description of how the criteria "investment needs" and "saving potential" are analyzed in accordance with the above-described method.

2.3.1. Assessment of investment needs

The energy-related additional costs are the indicator for the investment needs` analysis, representing the costs that additionally arise through energetic refurbishment in contrast to mere repair. For this purpose, the costs of two different planning scenarios (which have been determined using the epiqr method) are compared. In contrast to the scenario "energetic modernization", the scenario "plan repair" only considers measures necessary to maintain the building`s value. On this basis, it is possible to generate a factor indicating the energy-related additional costs` share of the overall measures:

$$\frac{scenario\ energetic\ modernization\ [€] - scenario\ plan\ repair\ [€]}{scenario\ energetic\ modernization\ [€]} = factor\ [/] \quad (1)$$

A high factor (0.51 to 1.00) means that the building is in an energetically poor condition, resulting in a high refurbishment potential. Although this requires high investments, it is likely that the energy benefits are as well higher than for a building with a low factor. For this reason, the indicator with a factor bigger than 0.51 is evaluated with the grade 4.

2.3.2. Assessment of economic saving potential

To determine the saving potential the indicators “amortization period”, “utilization concept”, “vacancy”, “saving of final energy” and “saving of operating costs” are analyzed.

2.3.2.1. Amortization period

To estimate the energy-saving potential it is necessary to determine how much energy in percent can be saved by improving the state of the respective components in the context of a refurbishment project. A facade that is already sufficiently insulated would therefore have an energy-saving potential of 0%. If the insulation of a facade is, however, inadequate, a saving potential of 20% is estimated by the application of sufficient insulation. For non-residential buildings, two different types of buildings are thereby distinguished: halls and hall-like buildings on the one hand and other buildings on the other. The reason being that with these varying types the same refurbishment measure leads to different savings (see Table 4).

Table 4. Estimation of the energy-saving potential using the example of facade insulation.

Parameter	Saving potential	
	Buildings	Halls
Facade insulation	A → 0%	A → 0%
	B → 0%	B → 0%

	C → 8%	C → 3%
	D → 20%	D → 8%

This estimate is based on practical experience. The alternative to this approach would be a theoretical calculation of energy requirements in accordance with DIN V 18599. This, however, would not only cause considerably more effort, but also only provide seemingly more reliable results. In this case, for example, the heat transition coefficient of a facade may be estimated based on the type and year of construction, as a detailed metrological determination (with representative core extraction, moisture determination or long-term measurement) is not feasible at a reasonable cost. Thus, the supposedly accurate but complex calculation involves risks similar to the relatively simple estimation method.

Based on the assessed degradation state, it is possible to add up the saving potentials for each building. With this value and the consumption rate, the static amortization period of energetic maintenance measures can be calculated:

$$\frac{scenario\ energetic\ modernization\ [€] - scenario\ plan\ repair\ [€]}{\Sigma potentials\ [\%] \times consumption\ data\ [€/a]} = amortization\ period\ [a] \quad (2)$$

The results are integrated into the scoring: the shorter the calculated amortization period, the higher the potential.

2.3.2.2. Utilization concept

For energetic refurbishments to amortize, an appropriately long utilization concept must exist for the respective building. Otherwise, the expenditure cannot be generated within the utilization period. Thus, buildings with a long-term utilization concept of course score significantly better in the economic analysis.

2.3.2.3. Vacancy

The consequence of vacancies – that for example appear if its location or state make a building unattractive to users – is that no rental income is being obtained. However, to fund modernizations income generated by the property is essential. Therefore, energetic refurbishment measures are economically more profitable for buildings without vacancies.

2.3.2.4. Saving of final energy

To determine this indicator, the sum of a building`s saving potentials is calculated and graded. Buildings with high saving potential are most attractive for energetic refurbishment measures, as they still do not meet high standards (see Table 5).

Table 5. Assessment of the saving potential.

Saving potential	Definition	Grade
> 30%	Low potential	1
31% – 50%	Regular potential	2
51% – 75%	Increased potential	3
> 75%	High potential	4

2.3.2.5. Saving of operating costs

The operation and maintenance of technical facilities generate running costs. The more sophisticated the facilities, the higher usually the maintenance costs. For buildings with very high saving potential and consequently very high modernization effort, it is therefore reasonable to expect rising operating costs after energetic refurbishment. They are evaluated with low grade in the scoring. On the other hand, in buildings with moderate modernization effort, the replacement of old facilities susceptible to break down with new ones can lead to a reduction of operating costs. This is valued with a high grade in the scoring.

3. The energy-scoring`s results

Based on the scoring model the real estate portfolio can be classified according to its potential for reduction of primary energy demand balanced with the economic efficiency. The result is an objective ranking of each property in graphical or tabular form. The potential analysis sorts the buildings according to their overall grade (see Fig. 2), which is calculated from the results of the different pillars according to the weighting. At the top figure therefore the objects with the worst overall assessment and accordingly the greatest potential. However, these are not simply the buildings for which the highest savings in primary energy consumption could be realized by energetic refurbishment. In addition to a high energy-saving potential, the measures also have to be economical, which is ensured by the pillar "economic efficiency".

Rank	Building type	Year of construction	Overall rating	Energy demand reduction	Renewable energy inclusion	Economic efficiency
1	Administrative building	1980	3,95	3,95	3,95	3,95
2	Gymnasium	1980	3,90	3,90	3,90	3,90
3	School	1962	3,89	3,85	3,90	3,95
4	Multipurpose hall	1950	3,79	3,90	3,90	3,45
5	School	1975	3,77	3,85	3,90	3,45
6	Nursery	1971	3,75	3,85	3,85	3,45
7	Gymnasium	1965	3,75	3,85	3,85	3,45
8	Fire station	1977	3,63	3,85	3,95	2,85
9	Administrative building	1969	3,56	3,40	3,90	3,45
10	Multipurpose hall	1982	3,55	3,40	3,85	3,45
11	School	1977	3,53	3,95	3,85	2,40
12	Gymnasium	1980	3,51	3,45	3,90	3,15
13	School	1989	3,50	3,30	3,85	3,45
14	Hospital	1992	3,49	3,85	3,40	2,95
15	Hospital	1975	3,49	3,85	3,85	2,40
16	Hospital	1971	3,48	3,30	3,85	3,35
17	School	1964	3,47	3,40	3,85	3,15
18	Multipurpose hall	1996	3,44	3,40	3,90	2,95
19	Fire station	1978	3,30	3,85	2,85	2,85
20	School	2006	3,28	3,85	2,85	2,75
21	Retirement home	1960	3,19	3,85	3,05	2,15
22	Nursery	2004	2,98	3,85	2,45	2,05

Fig. 2. Ranking of individual properties according to saving potential.

Rank	Building type	Year of construction	Saving potential plant technology	Heat production plants	Supply and disposal technology	Ventilation systems	Heat recovery in the ventilation system	Mesuring and control technology heating
1	Administrative building	1980	2,40	1,00	4,00	2,00	4,00	2,00
2	Gymnasium	1980	2,25	1,00	3,00	2,00	4,00	2,00
3	School	1962	3,25	3,00	3,00	4,00	4,00	2,00
4	Multipurpose hall	1950	3,05	3,00	3,00	2,00	4,00	2,00
5	School	1975	2,25	1,00	3,00	2,00	4,00	2,00
6	Nursery	1971	2,90	3,00	2,00	2,00	4,00	2,00
7	Gymnasium	1965	2,40	1,00	4,00	2,00	4,00	2,00
8	Fire station	1977	1,95	1,00	1,00	2,00	4,00	2,00
9	Administrative building	1969	2,25	1,00	3,00	2,00	4,00	2,00
10	Multipurpose hall	1982	2,25	1,00	3,00	2,00	4,00	2,00
11	School	1977	2,15	1,00	3,00	1,00	4,00	2,00
12	Gymnasium	1980	1,95	1,00	1,00	2,00	4,00	2,00
13	School	1989	2,15	1,00	3,00	2,00	4,00	1,00
14	Hospital	1992	2,25	1,00	3,00	2,00	4,00	2,00
15	Hospital	1975	1,95	1,00	1,00	2,00	4,00	2,00
16	Hospital	1971	2,10	1,00	2,00	2,00	4,00	2,00
17	School	1964	2,45	1,00	3,00	4,00	4,00	2,00
18	Multipurpose hall	1996	1,95	1,00	1,00	2,00	4,00	2,00
19	Fire station	1978	3,20	3,00	4,00	2,00	4,00	2,00
20	School	2006	2,40	1,00	4,00	2,00	4,00	2,00
21	Retirement home	1960	1,95	1,00	1,00	2,00	4,00	2,00
22	Nursery	2004	2,15	1,00	3,00	1,00	4,00	2,00

Fig. 3. Excerpt from the assessment results for criteria and indicators within the ranking.

A detailed overview of the results is provided by the depicted grades of the individual pillars, criteria and indicators. The color gradient from green to red indicates which criteria have a high (green) or no (red) saving potential. Figure 3 displays a section of the scoring with the grades of the criterion "saving potential plant technology", which belongs to the pillar "energy demand reduction". The administrative building ranking number one shows, for example, with a score of 4.00 a high potential at the criterion "heat recovery in the ventilation system". Consequently, the installation of a modern ventilation system would be a possible measure of improvement.

Therefore, from this list can be quickly and easily derived, where potentials lie and where to invest in order to raise the portfolio`s energy efficiency and thereby act economically. Thus, the epiqr energy-scoring method provides a reliable decision basis for planning energetic investments.

4. The energy-scoring method`s advantages

The epiqr energy-scoring represents a holistic evaluation model that allows an objective comparison of a portfolio`s individual objects in terms of their energy-saving potential. The focus is on the efficiency and quick applicability of this method. Since the necessary data is largely collected as part of the portfolio assessment, the cost of its provision is rather low. Consequently, it is possible even with large property portfolios to relatively quickly rank properties according to their estimated primary energy-saving potential, as well as identify most impacting building components in terms of energetic refurbishment's efficiency. On this basis, the necessary measures can be quickly identified and implemented. The connection to the epiqr software system delivers for this purpose – in addition to the components` states – the planned costs for their improvement. Thus, the energy-scoring supports a strategic and sustainable portfolio management, while providing information for more detailed energetic analysis.

The entire model is flexibly adaptable to the users` specific requirements. From the pillars, criteria and indicators through to weighting, all elements can be specified individually.

5. Conclusion

In real estate lies indeed a significant potential for energetic optimization that needs to be realized – and not just in a few especially energy-efficient lighthouse projects, but extensively. The consideration of the economic efficiency, which distinguishes the energy-scoring method here presented, provides hereto the decisive lever. After all, the owners of existing properties will only energetically refurbish these on a larger scale, if it pays off economically as well. Therefore, the scoring does not just represent the energy-saving potential, but prioritizes the properties according to the optimal ratio between the effort and the result of the measures to be taken. This truly holistic approach can help to accelerate the sustainable development of existing properties – and thus actually achieve the climate targets set for the future.

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