ENTRANCE

Evaluation methods and Performance Indicators for Energy Renovation

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2 Preface

The Horizon Europe project ENTRANCE (*Enabling smart-grid ready buildings through integrated solutions and digital technologies*) aims to develop and showcase innovative solutions that integrate buildings into the energy system while actively engaging end-users in the energy market. As part of the ENTRANCE project, an advanced method for performance-based economic evaluation of existing buildings will be developed based on the principles of the so-called Total Concept method and key performance indicators (KPIs) defined within the project. As a starting point, this report presents the results of a literature and interview survey mainly focused on the Total Concept method and performance indicators for smart readiness, decarbonisation, flexibility, indoor environment and occupancy rate.

The literature survey was mainly conducted and described by the main authors of this report, complemented by inputs from: Tomasz Cholewa, Politechnika Lubelska; Pablo Carnero, REHVA; and Edoardo Scalera and Martin Thalfeldt, TalTech. Interviews were conducted by six of the ENTRANCE project partners—CIT Renergy, TalTech, Politecnico di Torino, Politechnika Lubelska, NTNU and Aalborg University—and the results were analysed and compiled by the main authors.

We gratefully acknowledge the contributions of all interview participants, whose perspectives and experiences provided essential insights for this report and will support ongoing work.

This report is intended to be used together with other materials from work within the project. Accordingly, no definitive conclusions are drawn at this stage concerning content or design of the new evaluation method.

Göteborg, December 2025

Maria Haegermark, CIT Renergy

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3 Executive Summary

As part of the Horizon Europe project ENTRANCE, the aim is to develop an advanced method for economical evaluation of planned energy renovation that, besides energy efficiency, considers aspects such as smart-grid readiness, decarbonisation, flexibility, indoor environment quality, and potential for higher occupancy rate. The method will build on the principles of the existing Total Concept method and performance indicators developed within ENTRANCE.

This report serves as a starting point and intents to provide a basis for the development of the new evaluation method, together with other work within the project. Based on a literature and interview survey it describes and explores: the Total Concept method and other economic evaluation methods for energy renovation of existing buildings; practices and methods for the decision-making process of energy renovation; KPIs for smart readiness, decarbonisation, flexibility, improvement of indoor environment and possibilities of higher occupancy rate; and finally possibilities and challenges in integrating such KPIs into an advanced evaluation method.

Interviews were conducted with 15 stakeholders with experience of, or insight to, the decision-making process of energy renovation, together representing 13 organisations in six countries. Swedish participants were selected for their experience of using the Total Concept method, while only one participant outside Sweden has used this particular method. Apart from this method, and an extended variant, economic evaluations typically rely on standard financial metrics such as internal rate of return (IRR), net present value (NPV), and payback time, primarily based on investment cost versus savings as a result of reduced energy use.

Among the building owners represented in this study, renovation decisions are often based on profitability and the associated requirements to a large extent, but it is seldom the only determining factor. Other influencing factors are: maintenance plans and renovation needs; practical and logistical possibilities and barriers; requests from the tenants; and finally, energy efficiency targets. Potential added values mentioned to be taken into consideration when deciding on energy renovation projects and individual measures were: property value, indoor environmental quality (IEQ) and peak power.

In the interviews, participants were also asked if they would benefit from a more comprehensive evaluation method that, in addition to energy savings and profitability, also takes other parameters into account. All interviewees expressed an interest in such method but also raised some potential obstacles. It was pointed out that this method would need to be practical, time efficient and easy to implement.

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4 Introduction

The energy and building sectors play a crucial role in Europe's environmental and energy policies. As the energy transition accelerates, buildings are increasingly recognised as key players due to their potential to adopt smart management systems and advanced control strategies. The Horizon Europe project ENTRANCE (E*nabling smart-grid ready buildings through integrated solutions and digital technologies*) aims to develop and showcase innovative solutions that integrate buildings into the energy system while actively engaging end-users in the energy market.

As part of the ENTRANCE project, an advanced method for performance-based economic evaluation of planned energy renovation in existing buildings will be developed based on the principles of the Total Concept method and key performance indicators (KPIs) defined within the project. The aim is to reach a new method for economical evaluation that besides energy efficiency facilitates consideration of for example decarbonisation, smart readiness, flexibility, improvement of indoor environment, and possibilities of higher occupancy rate. Overall, the advanced method to be developed aims to increase the ambitions and making it possible to come much further in energy efficiency and decarbonisation during upgrading, operation and maintenance of buildings. For example, this will give the basis needed for decisions of investments to upgrade existing buildings to include grid-integrated solutions, as for example renewable energy production and storage at building level.

The Total Concept is a method for improving energy performance in buildings and applies a systematic approach with the aim at achieving maximum energy savings in a cost-efficient way [1]. In short, the method is based on an action plan comprising a package of energy efficiency measures that fulfils the property owner's profitability requirements.

This report aims to provide a basis for the development of a comprehensive performance-based economic evaluation method for energy renovation decisions based on the Total Concept method and KPIs later developed in ENTRANCE by:

- Exploring current practices for the decision-making process of energy renovation.
- Describing the Total Concept method, an existing method for improving energy performance of existing buildings with the aim of assuring maximum energy savings in a profitable way, and experiences of its advantages and disadvantages.
- Exploring other methods and tools for decision making and economic evaluation of energy renovation of existing buildings.
- Describing KPIs, or KPI categories, that may be used to evaluate smart readiness, decarbonisation, flexibility, improvement of indoor environment and possibilities of higher occupancy rate.
- Examine the building owner's perspective of possibilities and obstacles of incorporating such KPIs in a new method for economical evaluation of planned energy renovation in existing buildings.

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5 Method

This report is based on a critical literature survey and interviews with building owners and other relevant stakeholders.

Interviews were conducted to investigate:

1. Previous experiences of the Total Concept method as well as other economic evaluation methods and tools that are used by property owners when to decide on energy renovation measures.
2. The needs and possibilities to include more KPIs, besides energy savings, in the evaluation of energy renovation, particularly, but not exclusively, related to:
    - climate impact (decarbonisation),
    - smart-grid readiness,
    - flexibility,
    - peak power,
    - indoor climate,
    - occupancy rate.

The interviews were semi-structured and carried out based on an interview material with predefined exploratory questions. This material is shown in Appendix 1.

Suitable interviewees were identified and invited by the project partner in each respective country, with the criteria to have experience of, or insight to, the decision-making process when it comes to energy renovation. The interviewed persons are presented in Table 1. The report gives descriptive results from the interviews, including both individual comments and summarising conclusions.

Table 1. Interviewed persons

Interviewed person	Organisation	Type of stakeholder	Type of property portfolio	Country
Jakob Schytte Nymann Jørgensen	ReMoni	Solution provider		Denmark
	On behalf of customer of ReMoni	Building owner	Office building	Denmark
Mikk Maivel, Energy-efficiency project manager/expert	Riigi Kinnisvara (RKAS AS)	Building owner/ Real estate development and management company	State owned non-residential buildings (offices, educational buildings, museums, etc.)	Estonia
	R8	Solution provider (Digital solution developer)	Customers´ property portfolios: commercial non-residential buildings	Estonia

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Interviewed person	Organisation	Type of stakeholder	Type of property portfolio	Country
Eng. Renato Parizia, Responsible for management of HVAC systems and electrical systems	Politecnico di Torino	Building owner	Educational buildings	Italy
Fund manager	Real estate company	Real estate company	Primarily tertiary buildings	Italy
Trond Thorgeir Harsem, Responsible R&D – HVAC and Automation	Norconsult	Consultant	Customers with residential and non-residential buildings	Norway
Kai-Arne Riersen, Senior Advisor at NTNU Real Estate Department	Norwegian University of Science and Technology	Building owner	Educational buildings	Norway
Technical staff responsible for management of buildings	Lublin University of Technology	Building owner	Educational buildings and residential (dormitories)	Poland
Anders Axelsson, Project manager	Kfast (Eskilstuna kommunfastigheter AB)	Real estate development and management company	Residential buildings and non-residential buildings (schools, residential care, sports facilities and commercial)	Sweden
Anders Levay, Project manager Energy efficiency	Eskilstuna kommun (Municipality)	Building owner	Municipal non-residential and residential buildings.	Sweden
Christian Falkelius, Energy strategist Lisa Engqvist, Energy strategist	Akademiska Hus	Building owner	Educational buildings (for universities)	Sweden
Gunnar Ericsson, Energy controller	Locum	Real estate management company	Healthcare properties	Sweden
Johan Ekman, Energy strategist	AMF Fastigheter	Building owner	Commercial non-residential buildings (mainly offices)	Sweden
Linn Liu*, Energy & Climate strategist, PhD in Energy	Linköping University	Academia	-	Sweden
	SISAB (Skolfastigheter i Stockholm AB)	Building owner	Preschools and schools	Sweden

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Interviewed person	Organisation	Type of stakeholder	Type of property portfolio	Country
systems in buildings, Linköping University				
Pär Bohjort, Energy coordinator	Jernhusen	Building owner	Real estate related to the Swedish railroad system and railway infrastructure	Sweden

*Linn Liu was primarily interviewed in connection to her previous role as a doctoral student at Linköping University, where she worked with both the Total Concept tool and an in-house economic evaluation tool described in the report.

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6 The decision-making process in practice

In order to develop a tool to support the evaluation of energy renovation, it is important to be familiar with current practices, as well as common barriers and drivers, in the decision-making process. This section gives examples of previous studies that have explored and described the building owners' own experiences and routines for decision-making of energy efficiency renovations (EER). Experiences described by the interviewees within the ENTRANCE project are summarised in section 10.1, as part of the presentation of interview results.

Mogensen & Thøgersen [2] examined the final stage of the decision-making process, focusing on reasons why planned EER projects were not implemented and the role of the energy consultation in the process. Based on a survey of 609 Danish homeowners in the final stages of EER decision-making processes, it was concluded that "implementing an EER decision is the outcome of a complex web of contextual factors, perceptions, and actions, including consultations with advisors and contractors." It was also shown that: "The most common self-reported reasons for not (yet) having implemented the planned EER project point to procrastination." Six predictors with a direct and significant effect on EER adoption were identified. Three of these relate to the homeowner's considerations about costs and financing, and two relate to economic and non-economic "expected private benefits", including expectations on CO_2 reduction. However, the strongest predictor was found to be the "perceived easiness of accepting an offer", which in itself is a complex structure, but described as likely influenced by the clarity of the offer and trust, among other things [2].

Other studies examining the barriers and drivers influencing energy renovation decisions among single-family home owners include: Klöckner & Nayum [3], de Wilde [4], Zaunbrecher et al. [5] and Lades et al. [6]. De Wilde examines the role of interpersonal, impersonal and professional trust, and Zaunbrecher et al. focus on the role of intermediaries. Lades et al. examine the effect of present bias over effort, i.e. the tendency to overvalue immediate effort, and procrastination. Based on a theoretical model and simulation, this study shows that "administrative burden can strongly reduce investments in energy-efficient technologies".

With regards to studies that explore the decision-making process for non-residential buildings such as offices and commercial buildings, fewer studies were found. As an example from Europe, Globisch & Dütschke [7] have looked into the decision process for energy efficiency measures in German companies where energy is not related to their core business (as in the case of energy intensive industries). It also explores the roles of different departments within the company and intermediaries. A questionnaire survey focusing on investments in measures that reduce energy use for heating, cooling and ventilation in offices and commercial buildings was sent out, aimed towards decision makers with both experience and influence of refurbishment decisions. Some of the main findings from this survey, based on the answers from a total of 332 respondents, are the following:

- Energy saving in itself was most frequently mentioned as the main trigger.
- Apart from energy saving, a wide range of other reasons for carrying out refurbishment activities exist, that might represent potentially missed occasions for performing energy

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efficiency measures as well. These include aesthetic reasons (both exterior and interior), changes to the business, damage to the building envelope, defective building installations and unsatisfactory indoor climate.

- The willingness of the respondents to advocate for ambitious energy renovation increases if they expect it to contribute to climate change mitigation efforts or making a good impression on customers and visitors, followed by avoiding future renovations (by ensuring a future-proof solution). Other expectations include underscoring the values of the company, economic savings, improving the indoor climate and eliciting positive reactions from employees.

A briefing from the European Environment Agency (EEA) identifies behavioural factors that influence decisions on renovation investment, focusing on residential buildings [8]. The decision-making process is described to often be complex, involving several stages and decisions. Examples of behavioural factors include: social norms, hyperbolic discounting (tendency to prefer smaller, sooner rewards over larger, later rewards), inattention, framing (how the choices are presented) and Status quo bias (tendency to prefer to maintain the current situation). The EEA also summarises the most prominent practical factors affecting stakeholders' decision-making. It suggests that the most important drivers for the owners are:

- Improved living conditions
- Reduced energy costs and increased energy efficiency
- Social and environmental engagement
- Who delivers information on energy efficiency renovation measures to the homeowners.

The following factors were listed as main barriers:

- Hassle factor
- Split incentives
- Access to finance
- Financial benefits are unclear
- Perceived financial risk
- The owners are unsure of the outcome.

A significant non-technical barrier of EER is so called split incentives, where the developer or building owner would not directly benefit from an energy efficiency investment, but instead it is the occupants (tenants) that have the advantage of lower energy costs. A recent report from the International Union of Property Owners (UIPI) explores the relationship between national rental law and energy renovation in different EU countries in the context of the split incentive dilemma [9]. Moreover, acknowledging the split incentive gap as an impediment to building decarbonization, the Sustainable Markets Initiative's (SMI's) Sustainable Buildings Task Force has published a paper that describes the challenges and provides a review of initiatives being taken to overcome split incentives [10]. It is summarised that strategies focus on three key areas: Legislation, Target Setting and Green Leases.

Early involvement of the building occupants is essential to motivate EER decisions from the same occupants and effective in influencing their energy-related behaviours. This is concluded by

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Maghsoudi Nia et al. in a review focused on occupant behaviours in energy efficiency retrofitting projects [11]. However, regarding current approaches in the early stage of the process, it was found that these "seek to minimize occupant involvement by shortening the process and the period of actual renovation." Moreover, it was described that: "in their urgency, they might underestimate the occupant's consent and need for trust-building which will promote the desired energy performance."

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7 Total Concept method

The first parts of this section give information about the aim of the Total Concept method and a description of the method. Thereafter, experiences from previous projects are summarised in subsection 7.3. Lastly, experiences raised in interviews conducted within this study are presented in subsection 10.2.

7.1 Background and aim

The development of the Total Concept method started with a question regarding modest energy improvements in Swedish non-residential buildings, raised by property owners within the so-called BELOK group over 15 years ago. BELOK is a network connected to the Swedish Energy Agency with 30 large Swedish non-residential real estate owners, managing in total about 30 % of the Swedish non-residential building stock [12]. Even though the potential for energy improvements of this building stock seemed to be considerable, national statistics in Sweden had only shown a small energy improvement in the non-residential sector from 1995 to 2002, and thereafter a more or less stable energy use. Interviews with non-residential real estate owners within the BELOK group suggested that two of the reasons for the relatively small improvements were that: i) easy measures, which were profitable in the short term, had already been carried out, and ii) a lack of coordination of energy efficiency measures in connection with ordinary renovation. Moreover, the interviews showed that decisions were often based on profitability of single measures and a simple economic evaluation, which did not consider the whole life costs. With this approach, only the highly profitable measures were usually considered and carried out while a number of possible measures with high energy saving potential were overlooked. Thus, it was felt that another kind of financial method was needed to overcome this problem [13].

The Total Concept method was developed by the BELOK group in Sweden with the aim to motivate property owners to carry out larger energy renovations projects in the non-residential building sector. The Total Concept method aims to present how it can be possible to achieve further energy savings, with more measures carried out, while still meeting the profitability expectations set by the building owner. Or in fewer words: to achieve maximum energy savings in a cost-efficient way. The first Total Concept projects were initiated in 2007.

7.2 Description of the Total Concept method

The method is based on an action plan comprising a package of energy efficiency measures that in total fulfils the property owner's profitability requirements [14]. When forming the action package, both individual cost-efficient measures and costlier measures are considered. From an economic point of view, the most cost-efficient measures will support the costlier measures, that would not have passed the profitability requirements on its own.

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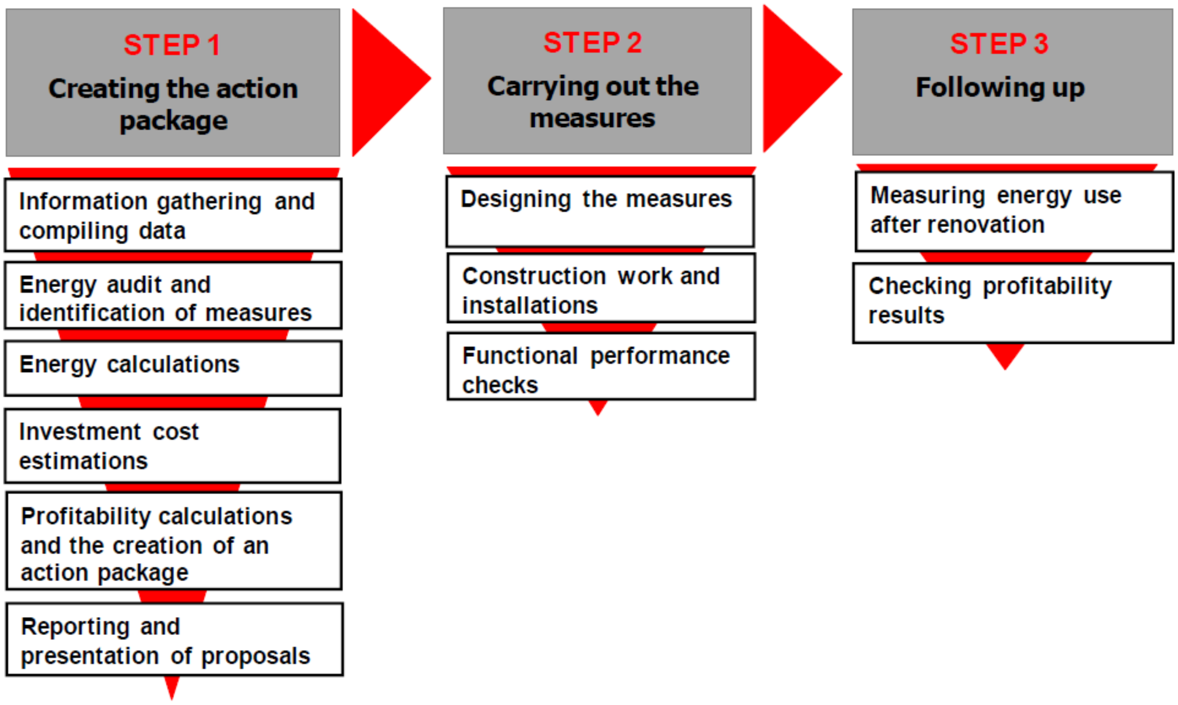

Figure 1 Visualization of the work structure of the Total Concept method. Source: The Total Concept method Guidebook for Implementation and Quality assurance [1]

The work process is structured into three main steps:

Step 1: Forming the action package
A comprehensive inventory in the building is carried out to identify all possible energy saving measures. Calculations and an analysis based on the compiled data lead to a profitable action package and provide an informed basis on which the owner of the building can make decisions. More information about the profitability assessment is given below, see subsection 7.2.2.

Step 2: Carrying out the measures
The energy saving measures in the action package are carried out.

Step 3: Follow-up
The energy use during at least one year after the implementation of the profitable action package is compared to the energy use before renovation to ensure that the expected result has been achieved. Profitability results are checked.

7.2.1 Energy savings

Typically, energy use according to energy statistics is used as the baseline. This type of baseline is usually determined based on measured energy use for the past few years. However, in some cases, establishing a baseline for energy savings requires more than simply using measured energy data. For example, when minimum requirements (functional or legal) are not fulfilled before renovation.

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The Total Concept method Guidebook for implementation and quality assurance [1] describes three different methods for setting the baseline for energy use in order to evaluate an impact of a package of energy saving measures. The three different methods are:

- Method 1: Existing energy statistics is used as a baseline when the minimum requirements set on a building and its function are fulfilled and its function and use will not be considerably changed after renovation. This baseline is usually based on average of measured energy use for the past few years, corrected to a normal year.
- Method 2: This method is applied when a building does not fulfil its function, for example regarding indoor climate, and its function and use will significantly improve after renovation. The baseline energy use is calculated based on expected new conditions and existing or upgraded systems. It is determined by first calibrating the energy simulation model to pre-renovation conditions, then adjusting the model for planned use or system upgrades. Possible energy saving measures can then be analysed.
- Method 3: When implementing an energy-saving measure, national requirements may define a minimum quality level for a system or building after refurbishment. This level becomes the baseline, and any further saving (for example reaching passive house standards) is evaluated based on this level. Investments required to meet the minimum are included in the baseline, not as a part of the energy saving of measurements. Therefore, the baseline must be dynamic, adjusted for each energy saving measure, with the minimum level identified and subtracted for both energy and investment.

Related to this, it is also relevant to mention that the REHVA guidebook No. 32 presents recommendations on how to properly calculate energy savings for different types of HVAC measures [15]. Regarding these recommendations, please see section 8.1.

7.2.2 Profitability assessment

In the following, the basis and steps of the profitability calculations are shortly described. More information can be found in *The Total Concept method Guidebook for implementation and quality assurance* [1], which includes both a thorough description and several examples of profitability calculations and the creation of an action package.

The profitability assessment in the Total Concept method is based on the internal rate of return (IRR) method, taking into account the initial investment, annual savings and expected lifetime of individual measures. The equation used to determine IRR is as follows:

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$$0 = \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t} - C_0$$

where:

$$C_t = \textit{Net cash flow in a given time period}$$
$$C_0 = \textit{Total initial investment costs}$$
$$IRR = \textit{The internal rate of return}$$
$$t = \textit{Time period } (0, 1, 2, \dots, n)$$
$$n = \textit{Total number of time periods}$$

To work with the above equation, it is important to note the following:

- Initial investment costs should include all costs, i.e. material as well as labour costs, incurred by the energy efficiency measure.
- Net cash inflow corresponds to the change in annual operating costs before and after a measure. This should include savings from reduced energy use and changes in maintenance costs. This could also include savings resulted by changes in the load profile and a decreased power demand. Expected future changes in energy prices could also be taken into account.
- Regarding the economic calculation period, this can be the same as the economic lifetime of a measure, but property owners can sometimes also choose shorter periods. Examples of recommended economic lifetimes for different measures are given in an appendix of the Guidebook [1].

The action package is formed by arranging the different energy saving measures according to their profitability (IRR) and calculating a resulting IRR for a number of simultaneous measures. A free software called the Total Tool [16] can be used to show this. Using the Total Tool, the identified energy efficiency measures are ranked and ordered based on profitability, and the IRR is calculated for the entire action package. The criterion determining the number of measures to include in the action package is that the IRR of the action package in total, is larger than the interest rate used by the property owner, i.e. their profitability requirement. In the example shown in Figure 2, the final action package comprises five energy saving measures. The profitability requirement is here set as a minimum 5 % interest rate, represented by the line highlighted in cyan. The final action package is developed step-by-step as follows:

1. One starts with the most profitable measure, which would give the highest rate of return (here above 20%).
2. Then, lesser profitable measures are added to the action package, and for each combination a new rate of return is calculated, which will consequently be lower and lower.
3. Measures are added until the limit for what is considered acceptable is reached, i.e. the profitability requirement (5% in the example in Figure 2).

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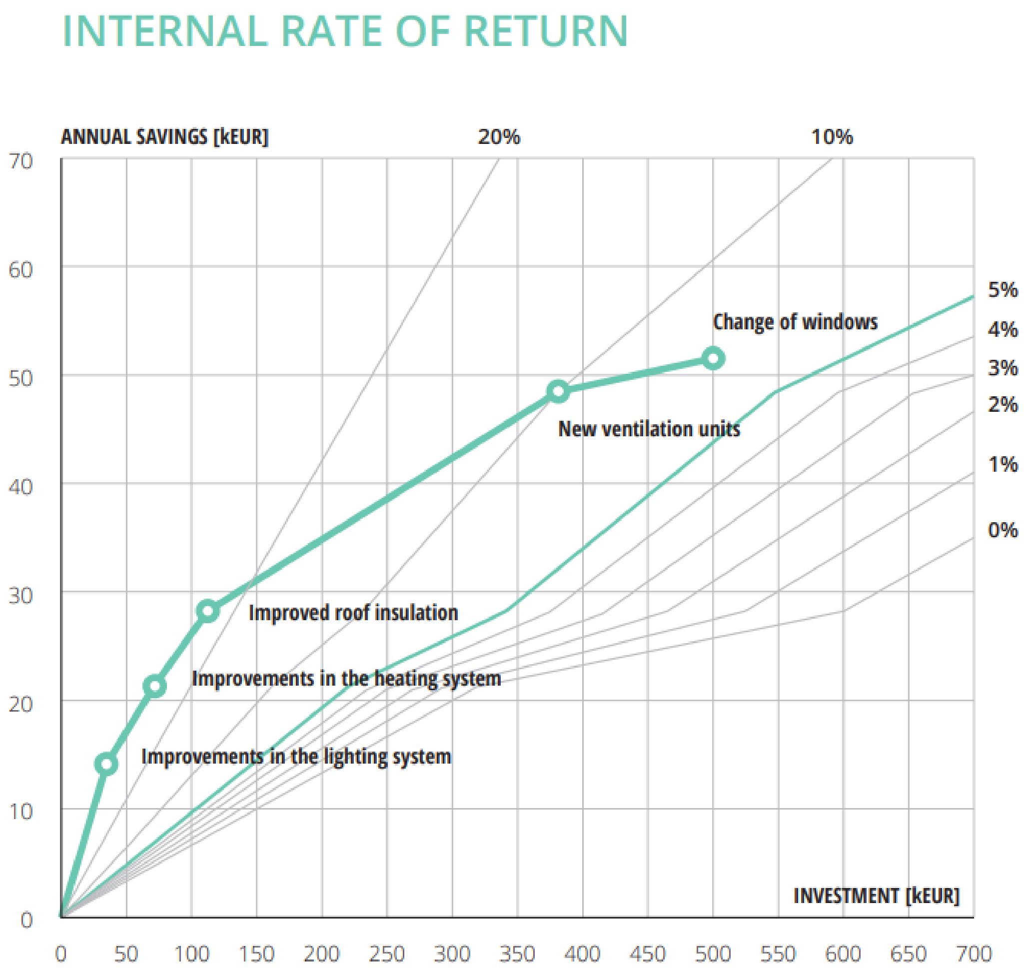

Figure 2. Example of an IRR diagram used in the Total Concept method. Each point in the diagram shows the total investment (x-axis), annual savings (y-axis) and IRR (lines from 0-20%) for an action package including the measure started at the respective point, as well as all previous measures. The last point "Change of windows" represents a package including all five measures in the figure. Source: Project "The Total Concept method for major reduction of energy use in non-residential buildings" [13]

7.3 Experiences from previous projects

In this section, experiences from previous projects regarding the Total Concept method are summarised.

One of these projects was carried out between March 2014 and March 2017 supported by the Intelligent Energy Europe Programme and was called "The Total Concept method for major reduction of energy use in non-residential buildings" [17]. Within the project, the Total Concept method was implemented in 12 pilot studies, in five north European countries. The pilot studies included identification of energy saving measures with cost estimates and energy saving calculations together with a thorough follow-up of energy use in the first year. Experiences from the working process was collected through interviews and questionnaires and was summarised in a report [13].

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Moreover, further documentation regarding the Total Concept method is available from projects where the method has been implemented in different types of Swedish non-residential buildings, among these a fire station [18] and office buildings [19]. A BELOK report from 2022 also described the experiences of a Swedish municipality using Total Concept method to make communal properties more energy-efficient to serve as inspiration for other municipalities [20]. In 2021, an interview study was carried out with the aim to conduct a follow-up on a number of buildings where all three stages of the Total Methodology had been implemented [21].

Experiences regarding the Total Concept method described in the final report from the EU project [13] are quite similar to the experiences mentioned in national reports [18], [19], [21]. The experiences listed below are therefore largely based on the experiences from the EU project but has been supplemented with experiences described in the other reports.

Advantages

Some of the advantages of the Total Concept method highlighted in previous studies are listed below.

- *The visualisation of profitability on an IRR diagram helps to convince the finance departments.* The main strength of the Total Concept method is that it provides a good basis for decision making and communication. The profitability of an action package visualised on an IRR diagram is especially appreciated. Several building owners have mentioned that the method has given them a means to be able to convince the finance departments and the top management in the company to take decisions on larger investments for energy improvements. It has been described as a valuable tool to make the right investments. In addition, the proposed actions are ranked, which also supports decision-making.
- *The method helps to work systematically and strategically.* The Total Concept method helps to work strategically and with a clear plan for energy efficiency renovation.
- *The method offers flexibility.* It can sometimes be challenging to carry out the complete package of measures in one go due to practical reasons, such as the complication involved in relocating the tenants and renovating the entire building at once. Following the Total Concept method, a renovation plan can be developed and implemented progressively over the coming years, following a sequence that aligns with maintenance schedules and other practical considerations, while still ensuring that the full package of measures is eventually carried out.
- *To implement projects in complete packages of measures is time-efficient.* Implementing projects in packages contributes to coordination gains. It also creates an opportunity to carry out several measures simultaneously, thereby avoiding disrupting the tenants multiple times.
- *The method gives a good overview of the status of a building.* One of the important benefits of the Total Concept method is that it gives a good overview of the status of

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a building and provides a good basis for decision making related to aspects other than energy, for example maintenance planning. It facilitates working strategically with a clear plan.

- *The method is easy to adopt to different national conditions.* Within the aforementioned EU project [13], it was put forth that the method is easy to adopt to different national conditions. There were no technical or legal obstacles to implement the Total Concept method.

Challenges

Possible disadvantages, or challenges, to be considered when implementing the Total Concept method (whereof several also concern energy renovation projects in general):

- *Measures aimed solely at improving energy efficiency may be difficult to motivate.* Improving energy use of the building is often not the only driving force for a building owner to undertake renovation works. The main factors that affect the choice of measures are rather changes in the building use, change of tenants, and problems with indoor climate. Therefore, when renovation is planned, for any reason, options that would lead to better energy performance, as well as other energy efficiency measures, should be considered. This offers an opportunity to carry out a number of energy efficiency measures in a cost-efficient way. In the Total Concept method, costs for energy efficiency improvements and upgrading the building are separated. That is, when replacement of products or systems is needed due to for example wear down, only the additional costs for choosing a more energy efficient product, compared to the standard alternative, is included in the profitability calculations.
- *Determining the current energy performance of a building can be challenging.* Most often, measured energy use according to statistics from recent years is used as a base line prior to renovation. However, in many buildings, there may be only one energy meter for heating and another one for electricity, which may be insufficient for an accurate evaluation of the current energy performance. Therefore, installing additional sub-meters for energy use monitoring before starting the pre-study phase, i.e. Step 1 in the Total Concept method, is useful for more accurate energy saving calculations. In some cases, it may also be necessary to determine the current energy performance of a building based on energy simulations.
- *It may be difficult to evaluate the outcome as it depends on several factors.* Experiences from previous studies showed that in some buildings the main reasons for not achieving the expected energy use were higher indoor temperatures than designed and longer operating hours of ventilation systems than what was designed for. This means that monitoring of for example the indoor climate conditions during the energy auditing process may be needed in order to establish the correct baseline conditions. When using the Total Concept method, it is crucial to define a base case (baseline) against which the savings can be compared. The baseline is normally based on existing energy measurements prior to renovation. However, if minimum

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requirements on indoor climate are not fulfilled to begin with or the property owner plans to increase the occupancy in the buildings, the energy use before renovation does not correctly reflect the potential and resulting impact of the energy saving measures. It is therefore important to carefully consider how the baseline should be set.

- *Good quality of input data takes resources.* Previous pilot studies have shown that Step 1 of the Total Concept method (Creating the action package) took a considerable amount of time. One important reason for this was that for most of the participants these pilot cases were also study projects and they had no previous experience of the method. For assuring the quality of outcomes, Step 1 requires somewhat more effort when carrying out an energy audit (interviews with buildings owners, on-site surveys, collection of drawings, indoor climate measurements) and when putting together the action packages (energy simulations, investment cost estimations, economic calculations).
- *A detailed follow up is crucial but can be difficult.* Verification procedures with detailed follow-up are part of the Total Concept method. A follow-up period including adjustments in control and operation of building services systems are needed at least once a year after the renovation work is completed. Previous study has shown that some property owners had difficulties to fulfil a detailed follow up due to a lack of sub-meters.
- *Energy savings are largely dependent on the starting point.* In a previous pilot study, the initial energy saving target in the project was about 50%. This was achieved only in one pilot building and one possible explanation to this is that energy savings are largely dependent on the starting point of energy use before renovation. Most of the pilot buildings already had a reasonably good energy performance. Several building owners already had performed some of the easy measures which led to difficulties to further decrease the energy use in a cost-efficient way.
- *New methods need promotion and training.* One important prerequisite for successful projects is training of the energy consultants and involvement of property owners. Good training courses are important for new actors to start using the method.
- *The quality of the reports in step 1 varies.* Previous study has shown that the quality of the reports in step 1 varies depending on which consultant that carries them out.
- The Total Concept method focuses on changes in bought energy. This might be misleading in a broader energy efficiency perspective.

Suggestions for further development

In the report from a follow-up on Swedish buildings that had previously implemented all three stages of the Total Concept method [21], it was mentioned that it would be interesting to investigate how the method could be applied towards meeting the larger scope of very

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ambitious national energy efficiency targets. Another study chose to also show the difference in primary energy demand, in addition to reduction of bought energy, for the suggested action package, in order to add a broader energy efficiency perspective. [22]

The Total Concept method was originally developed for improving energy performance in existing non-residential buildings. However, the method has also been tested and evaluated for improving energy performance in residential buildings, mainly multi-family buildings. Studies have shown that the method can also be used for single-family houses, although certain adjustments might be needed. One example is that the diagram that shows the internal rate of return should be clarified in a way that makes it easier for a single-family house owner to relate to it [22]. Nevertheless, the idea of combining energy efficiency measures into renovation packages is seen as useful, or even crucial, also for single-family houses. In a report that explores which tools are available to single-family homeowners during renovation, it was suggested that a method based on this principle is necessary in order to make improvements in the national stock of single-family houses sufficient to reach the energy- and climate targets [23].

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8 Other methods, tools and frameworks

As part of the literature study, other methods, tools and frameworks developed to support the decision-making process and evaluation of measures prior to energy renovation of buildings were investigated. Some of the methods takes a more holistic approach, covering several stages of the decision-making process and/or taking various factors into account (see subsection 8.2), while others are more focused on the economic evaluation of energy renovation measures (see subsection 8.3). In addition, methods for calculation of expected energy savings, an important part of the evaluation and decision-making process, is separately acknowledged in subsection 8.1.

8.1 Methods for calculation of energy savings

Energy savings is the basis for all economic evaluations of energy renovation. However, the calculations of energy savings can be carried out using different methods, which give varying levels of accuracy of results.

In the REHVA guidebook [15] it is suggested that evaluation of renovation works from an energy perspective is divided into two main steps, involving:

1. A detailed analysis of the condition of the building and its integrated HVAC systems before and after the renovation. All the necessary background information on the technical systems and scope and exact timing of renovation works is determined from the technical documents of building, site visits and energy audits.
2. A comparison of the energy consumed or supplied by an HVAC system before and after the implementation of a given renovation. For this purpose, it is recommended to use long measurement periods before and after the implementation of a given renovation measure, while considering other factors that may affect the energy use. More specifically:
   - The comparison periods should preferably be one complete year but should at least include one heating season or one cooling season depending on which system is being analysed, or a minimum of six months in the case of domestic hot water or ventilation systems.
   - No other renovation measure should have been performed during the comparison periods .
   - The main internal and external factors that influence the consumption of energy supplied to the building should not deviate much in the period before and after the completion of a given renovation.

Furthermore, the report suggests that the methodology used for calculation of energy savings is chosen based on the type of HVAC system being assessed. The report includes descriptions of suggested methodologies for how to systematically, and properly, evaluating energy savings from:

- Heating/cooling system renovation

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- Domestic Hot Water system renovation
- Ventilation system renovation

Performance gap

Inconsistencies between the projected and actual energy performance of buildings during operation, the so-called performance gap, can be substantial. The reasons behind this, as well as suggestions on how to reduce the gap, have been addressed in various studies, such as within the UPGREAT Project [24]. Research on the performance gap in retrofitting has been summarised in the RE-DWELL vocabulary [25].

8.2 Methods and tools to support energy renovation decisions

Energy building renovation involves various stakeholders, aspects and impacts, which has encouraged the development of different variants of holistic approaches and multi-criteria-based methods. Something to be aware of is that holistic means different things in different studies and that social, economic and environmental sustainability is not always treated equally. This is pointed out by Kamiri et al. [26]: "As such, the models themselves represent a stance on sustainability, which may affect the decision-making process and ultimately the outcome of the renovation project."

A comprehensive review of research on smart urban energy retrofit decision-making was presented by Shu & Zhao in 2023 [27]. Based on 91 journal articles, this paper discusses decision approaches divided into five key categories: simulation (evaluating different energy retrofit scenarios based on energy simulation), optimisation (determining optimal retrofit solutions through optimization models), assessment (assessing urban building energy performance through data analytics), system integration (supporting retrofit decision-making through integrated systems), and empirical study (obtaining retrofit experience from empirical projects).

In the following sections, examples of methods, tools and frameworks to support decision-making of energy renovation are presented. Some of the studies also use real cases to demonstrate the suggested methods. A couple of the presented tools especially aim to help coordinate energy efficiency improvements with maintenance.

8.2.1 AHP-Based Model for Energy-sustainable Renovation of Building Envelopes

A paper by Golić et al. (2023) [28] proposes a model (or framework) for energy-sustainable renovation of residential buildings' envelopes based on a multi-criteria analysis (MCA) method, the Analytical Hierarchy Process (AHP) method developed in the 70s. The proposed model aims to provide systematic guidelines for the different phases of the decision process: from the phase of the designing alternatives to the phase of deciding on the 'best' alternative, considering a defined set of criteria and given building conditions. The model was applied to a real case study of a typical residential building in Serbia [28].

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The model outlines three phases for developing an energy-sustainable renovation:

1. *Phase I:* Analysis and evaluation of the existing state of the building, from the used building materials to the building services systems, and characteristics of the building's surrounding such as climate at the building's location, shadings of the building, etc. The current energy and hot water needs of the tenants, as well as expected future needs based on an assessment of the remaining lifetime of the building, are also determined.
2. *Phase II:* The conceptual solutions are developed for energy sustainable renovation. The objectives for the renewal of the building envelope are defined considering tenants' energy needs, the building's constraints, and investor's financial capabilities/limitations. These objectives become the criteria in selecting the optimal variant solution when applying the proposed AHP technique in phase III. In addition to the economic criteria, environmental and aesthetic criteria are also given priority in defining and selecting the 'best' solution.

   The example case provided in the paper uses the following environment and economic criteria: (1) Annual energy consumption for space and water heating (2) Annual CO_2 emissions, (3) Investment costs of envelope energy renovation and (4) Payback period.

   The model uses a mathematical method (which forms the basis of AHP method) to assign weights to different criteria and determine how important each criterion is overall to develop a prioritised criteria list.
3. *Phase III* consists of the shortlisting of design variants of the best one in the proposed model for energy sustainable renovation of the building envelope.

8.2.2 A holistic renovation approach proposed by REHVA

In the guidebook "Energy Efficient Renovation of Existing Buildings for HVAC professionals" [15], developed by a REHVA[1] Task Force with members from nine European countries, a renovation approach for existing buildings is proposed. The approach is suggested to be used to convert energy inefficient buildings into carbon-neutral buildings. It consists of four key parts aiming to provide a holistic and sustainable approach to energy renovation. These are:

1. Renovation of HVAC systems
2. Energy renovation of the building envelope
3. Use of renewable energy systems
4. Education of users/occupants

The renovation approach aims to cover all the contributing factors that impact energy consumption, indoor environmental quality, carbon footprint, costs and future application of

[1] The Federation of European Heating, Ventilation and Air Conditioning Associations

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renewable energy systems at each stage of the energy renovation process i.e. during the planning, construction and monitoring stages. The early planning stages of the energy renovation process is crucial and determines the success or failure of the latter stages. Ideally, in this phase, an energy audit is carried out focusing on a multi-objective optimisation taking energy-efficiency, indoor environmental quality, carbon footprint and cost into account. Doing so would encourage the selection of energy-efficient as well as carbon-neutral, sustainable and low environmental impact solutions. However, it is common that only the pre and post-renovation energy consumption and simple economic analysis methods such as payback times are considered.

In essence, the energy efficiency of the existing building should be increased as much as possible taking into account the technical and economical constraints. While it does sound obvious, the sequence in which renovation measures are carried out is of significant importance and should always follow an intuitive order. For example, the balancing of ventilation and heating systems should always follow building envelope measures such as additional insulation or replacement of windows. If this order is not followed, the whole renovation process becomes counterproductive and a waste of effort and money.

The report also suggests a methodology for evaluating the impact on energy use from individual renovation measures and divides it into two main phases (see section 8.1).

8.2.3 Holistic Multi-methodology for Sustainable Renovation (HMSR)

A Holistic Multi-methodology for Sustainable Renovation (HMSR) was developed by Kamari, Jensen, Corrao & Kirkegaard [29]. The method aims to make the building renovation design process more robust and efficient by providing a framework that helps encourage and improve stakeholder participation, collective learning and decision-making.

HMSR combines Multiple Criteria Decision Making (MCDM) (such as the aforementioned AHP) and Soft Systems Methodology (SSM) methods. It was developed based on three levels of integrated design process, introduced by the authors in a previous paper [30], paired with the "four main activity approach" from Checkland [31]:

- Decision-making at level 1: Problem structuring and stakeholder engagement.
  - Stage 1: Finding out about a problem situation
  - Stage 2: Formulating relevant purposeful activity models
- Decision-making at level 2: Discussion of the problem
  - Stage 3 Debating the situation, seeking both changes which would improve the situation and achieve the accommodations between conflicting interests which will enable action to be taken
- Decision-making at level 3: Scientific decision-making using quantitative and qualitative evaluation
  - Stage 4: Taking action in the situation to bring about improvement

Based on this, a step-by-step HMSR is suggested. The activities related to Level 1 include, among others, a review of criteria and indicators, with a division on soft and hard criteria, using

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a "Value Map" from a previous article [26], and selection of the main criteria and indicators. Measurement scales and scoring systems for the selected criteria are developed in Level 2, and finally the scores for all criteria are aggregated in Level 3. In the HMSR methodology, various MCDM and SSM methods are proposed in connection to the respective levels and actions of the decision-making process.

The developed methodology was applied and demonstrated in a social housing block in Aarhus, Denmark which was undergoing a planned renovation at the time of the paper's publication. The example was included for comparing how a renovation project was carried out as per standard practices at the time, and applying the HMSR methodology to see how the process could have looked different. In the case study example, the "hard" criteria are related to finances (investment costs, operation and maintenance costs) and thermal capabilities of the building whereas "soft" criteria are related to the general image and safety of the area and socio-economic and cultural-heritage considerations.

8.2.4 ALDREN

ALDREN (ALliance for Deep RENovation in Buildings) is a comprehensive methodological framework developed in a project funded by EU Horizon 2020 to support deep renovations and the European transition towards a nearly zero energy non-residential building stock [32]. The main goal of the project was to support decision making and investments in deep energy renovation of non-residential buildings by implementing the European Common Voluntary Certification Scheme as a support for the deep renovation process, aiming to achieve higher renovation rates and better renovation quality. The main objective of the research was to overcome the regulatory and nonregulatory barriers to facilitate the renovation of existing non-residential building stocks.

The description of the ALDREN framework given is the following sections is based on the research paper "ALDREN: A Methodological Framework to Support Decision-Making and Investments in Deep Energy Renovation of Non-Residential Buildings" from 2021 [33].

ALDREN takes a modular methodological approach and uses step-by-step operational protocols to assess the energy performance, indoor environmental quality (IEQ) and financial value of buildings before and after the renovation. The developed protocols use simulations and measurements based on best practices and those described in CEN and ISO standards to ensure transparency and quality. Its various modules produce a set of indicators that form consistent and holistic sustainability metrics. The indicators are reported in two complimentary reporting tools as follows:

1. *The ALDREN European Voluntary Certification (EVC):* The ALDREN EVC is based on the European Voluntary Certification Scheme (EVCS) described in Article 11 of the 2010 EPBD recast, and is at the core support of the implementation of a common EVCS for non-residential buildings based on CEN-ISO standards. It provides a snapshot of the building performance, quality and renovation potential at any given time. It has been

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created as a template of European certificate, and reports all the indicators together with the recommendation for improvement of energy performance towards the NZEB.

2. *ALDREN Building Renovation Passport (BRP):* The ALDREN BRP is a complementary tool to the ALDREN EVC, which provides a detailed description of renovation activities in time, costs and technical performance. Also, it is meant to be a complementary tool to the Energy Performance Certificate (EPC). ALDREN BRP is a dynamic tool that can be updated over time as the renovation progresses. It consists of two main elements: a building logbook (BuildLog) and a renovation roadmap (RenoMap). The BuildLog consists of six modules, named M1-M6, which informs the building owners and managers about the current condition of the building in terms of its energy performance, indoor environmental quality (IEQ), and financial aspects. The two modules M7 and M8 of RenoMap provide medium- and long-term renovation strategies to reach NZEB target to avoid lock-in effects. The M7 module is called "Elementary renovation actions" or ERAs and aims to identify and define a set of renovation actions tailored to the building characteristics and potential to attain a good level of NZEB-compliance. The M8 module, called "NZEB roadmap", involves the design of a structured roadmap to support the decision-making process, and defines a final timeline visualising the periods of renovation action implementation and its impacts.

The RenoMap provides an assessment of three main KPIs resulting from implementing ALDREN renovation actions:

1. Energy savings (kWh/m^2 year)
2. Renewable energy production (kWh/m^2 year)
3. Investment costs to achieve KPI no. 1 (€ and €/m^2)

In the same research paper [33], the BRP procedure was demonstrated in an Italian office building belonging to the Politecnico di Milano – Lecco campus, and the results of each renovation step were described in detail. For this case study, modules M1, M2, M4, M6, M7 and M8 were selected for consideration by the owner and the ALDREN auditor.

8.2.5 RENO-EVALUE

RENO-EVALUE is a tool developed in Denmark aimed to be used both as decision support and for the evaluation of sustainable renovation projects during and after the renovation. The tool is value-based, focusing on the different interests of the stakeholders involved and intended to facilitate communication between them and aiding in the formulation of renovation objectives. The tool can also be used for comparing alternative project proposals, follow-up and assess the results using four main pillars, called stakeholders, environment, organisation, and economy [34].

8.2.6 Renobuild

Renobuild is a decision-support tool built in Excel developed by the Swedish research institute RISE to help evaluate renovation projects from three key aspects of environmental sustainability,

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economic viability and social impact [35], [36]. It has two separate tools to perform calculations for multi-family buildings and school buildings and allows comparisons of up to ten renovation scenarios in terms of life cycle costs, environmental impacts, and social consequences.

8.2.7 CERPlan 1.0

CERPlan 1.0 (Cost Effective Renovation Plan) is a web-based decision support platform developed by Eurac Research [37]. Castagna, et al. (2024) [38] introduced a methodology to optimise energy renovation strategies by combining building energy performance data, renovation costs, and maintenance needs and implemented it in this tool. The tool aims to help decision-makers prioritise retrofit scenarios based on economic criteria and help coordinate energy improvements with regular maintenance to generate "avoided costs" and make retrofitting more economically advantageous.

8.2.8 SINOM

SINOM is a Swedish data-driven and climate-focused planning tool designed to support property owners in making strategic, sustainable decisions for building maintenance and renovation [39]. The tool aims to help users create long-term, cost-effective plans that align with energy and climate goals. It is described to use advanced analytics to prioritise actions based on technical, economic, and environmental factors, ultimately improving resource efficiency and reducing costs. SINOM is used by the Swedish property owner Uppsalahem, among others [39].

8.3 Methods and tools for economic evaluation

In the following, examples of available methods and tools for economic evaluation are presented. Those thought to be most relevant to the project have been described in the first four sections. Other methods and tools that were briefly looked into have been listed in the last section. In addition to the literature survey, an interview was conducted with Dr. Linn Liu regarding the software OPERA-MILP (subsection 8.2.6).

In the context, it is also relevant to consider the *Commission delegated regulation (EU) of 30.6.2025 supplementing Directive (EU) 2024/1275 of the European Parliament and of the Council as regards the establishment of a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements* [40]. According to Article 2, Member States shall use the comparative methodology framework to compare (a) energy efficiency measures; (b) measures incorporating renewable energy sources; (c) packages and variants of such measures, based on the primary energy, and emission performance and the cost attributed to their implementation. The calculation of total primary energy should be detailed in both its renewable and non-renewable shares. Renewable energy produced and self-consumed on-site (i.e. within building premises) are not to be accounted in the primary energy use. According to Article 4, "Member States shall decide, after calculating the cost-optimal requirement levels from both a macroeconomic and financial

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perspective, which of the two is to be the national benchmark". As for the macroeconomic calculation, this also requires calculation of environmental and health externalities of energy use, meaning at least the monetary value of the health and environmental damage caused by the emissions of fine particulate matter (PM2.5) and nitrogen oxides (NOx), related to the energy use in buildings. The methodology framework differentiates between new and existing buildings and between different categories of buildings.

8.3.1 OPERA-MILP

OPERA-MILP is a techno-economic Life-Cycle Cost (LCC) optimisation software developed at the Division of Energy Systems at Linköping University, Sweden. [41] It is an in-house software that has been used in several scientific studies with the aim of obtaining cost-optimal combinations of energy renovation measures for various building types, including historical buildings with heritage values [42], [43], [44], [45], [46]. OPERA-MILP stands for OPtimal Energy Retrofit Advisory-Mixed Integer Linear Problem and is described to have the advantage of low computational resource usage and a relatively fast optimisation procedure. "In the current version of the software, a Mixed Integer Linear Problem (MILP) problem is designed and solved using the optimizer CPLEX" [44], [47].

The economic assessment in OPERA-MILP is performed through a mathematical formulation consisting of an objective function which considers parameters such as costs and thermal properties connected to energy efficiency measures (EEMs), among other constraints, to calculate the lowest possible LCC for a combination of measures at a preset indoor temperature. [48]

Input data to the software consist of, among others [44], [49]:

1. U-values of building elements
2. Building geometry
3. Air changes per hour (ACH)
4. Climate data
5. Preset indoor temperature
6. Renovation costs for the various building elements

Costs that are included in the LCC are [44]:

1. Investment costs for the heating system
2. Investment costs for energy efficiency measures on the building envelope
3. Energy costs
4. Maintenance costs for building elements
5. End of life cycle residual value which is subtracted from the total LCC.

The Net Present Value (NPV) method is used for the calculations of LCC which requires using a discount rate for determining present equivalents of future expenditure.

Using the cost values, the LCC_{total} can be calculated as:

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$$LCC_{total} = LCC_{investment\ cost} + LCC_{energy\ cost} + LCC_{maintenance\ cost}$$

Using OPERA-MILP, different optimisation procedures related to LCC and energy use could be considered. For example, an optimisation of the LCC was performed in which the lowest LCC was calculated together with the corresponding energy use. This was achieved by the selection of a cost-optimal heating system along with the suggested cost-effective EEMs on the building envelope.

OPERA-MILP has been used in several studies at Linköping University. As an example, it was used in the PhD research by Vlatko Milić [44] where a bottom-up approach for analysis of energy renovation of residential districts built before 1945 was developed from a system perspective, taking into account targets for energy use, life cycle costs (LCC), and preservation of building heritage values. At the building level, a number of EEMs concerning the building envelope were incorporated into the software such as replacement of windows, improvement of airtightness, and additional insulation. Furthermore, incorporated heating supply systems included district heating, electric radiator, groundwater heat pump and wood boiler. Economic and environmental impacts were analysed from a building owner and energy utility point of view, with the latter being evaluated in terms of CO_2 emissions and primary energy use. Weinberger and Moshfegh [50] used OPERA-MILP in a study aiming to "investigate the techno-economic potential for EEMs of 401 multi-story apartment buildings constructed during the 1960s and '70 s located in two Swedish municipalities by using different DH tariffs." Here, OPERA-MILP was used to find cost-optimal EEMs as well as required EEMs to achieve projected energy savings. La Fleur et al. [46] also used the tool to identify combinations of lifecycle cost optimal energy saving measures in a Swedish multi-family building. The heating demand obtained from OPERA-MILP was further validated with building performance software IDA ICE and showed good agreement with one another.

Comments

- The program is unavailable for general use.
- Compared to common building performance simulation software, the program is based on a very simplified, cuboidal building model disconnected from the ground. Additional limitations include the inability to assign unique properties to different façades or storeys, as well as the omission of wind effects in the analysis.

Interview with Linn Liu about OPERA-MILP

Linn Liu, currently working as an energy and climate strategist at SISAB, was interviewed in relation to her previous experience of working directly with OPERA-MILP during her doctoral studies at Linköping University.

The interviewee described OPERA-MILP as an optimisation program that optimises the cost of energy renovation measures based on the given input parameters of the building and the energy costs with the building envelope as the outer boundary. The user is given the opportunity to input various parameters such as the building's geometry, envelope characteristics and economic parameters. It was further described that the program does not provide the

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opportunity to model the building room-by-room and the output generated from the program could be complicated and difficult to understand for those without extensive prior experience of the software. Hence, the user-friendliness and accessibility of the program was something she expressed reservations for.

The measures considered in the program are more related to the building envelope and not to the building systems and/or installations. However, some measures are related to the building energy supply system, and the program gives the user options of choosing between district heating, ground source heat pump, pellets and boilers as the energy supply system.

Compared to the Total Concept tool, which Dr. Liu also had experience with, she opined that a major difference between the tools was how the economic analysis was performed. In Total tool, one has the possibility to investigate more energy measures than in OPERA-MILP. However, in the Total Concept tool, the user should carry out relevant calculations about the energy savings and incurred costs beforehand and enter the values in the tool, meaning that one might have to put in more effort in order to make calculations. However, in OPERA-MILP, one is required to feed the aforementioned input parameters, specify the boundary conditions such as the annual energy use limit or the present indoor temperature, and find the associated costs of measures using which the LCC optimisation is carried out. In that regard, she believes that OPERA-MILP has a simple approach, although obtaining the relevant costs from databases could require more effort and be more time-consuming while using OPERA-MILP.

8.3.2 RentalCal

RentalCal is a web-based tool for economic efficiency calculation in connection with planned energy renovation measures in rented housing construction. The tool is a result of an EU project running from 2015-2018 with a consortium consisting of 11 research organisations from 8 European countries. The following summary is based upon information in the tool's home page and the freely available manual and documentation [51].

The tool works with two approaches for performing calculations:

1. *Assisted mode:* This mode provides more assistance to the user during the selection of a sample building, and the successive calculations. The mode makes use of the European TABULA database [52] consisting of a library of buildings from several European countries classified by their energy performance. Assisted mode is suitable for users that are not looking to work with a specific building in mind but would still like to gain an insight into the profitability of energy efficiency retrofit for different building types, ages and measures. The assisted mode starts from the selection of a reference building based on property type and construction year and default packages of measures taken from the TABULA and RentalCal databases. These measures are pre-defined packages of retrofit measures concerning the building envelope (eg. walls, doors, windows) and a package of the heating supply and ventilation system. The user is also presented with the option of choosing a "standard" or a deeper, more ambitious level of retrofit.

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2. *Freehand mode:* This mode is suitable for users having a developed energy concept, meaning that the tool doesn't provide as many default values or parameters for energy consumption/savings, investment costs or even the option to choose the pre-defined bundles of retrofit measures from the assisted mode. This mode is intended for building professionals or energy consultants who have a better idea of the accompanying technical details and potential costs of the retrofit and would like to perform a quick profitability calculation.

Economic calculations

RentalCal is based on the method Visualisation of Financial Implications (VoFi) which enables a detailed modelling of the economic efficiency [53]. It includes the change in cash flows in the economic efficiency assessment. Hence, the difference between cash flows before and after the energetic renovation is considered in the calculation. The economic analysis also considers indirect payments such as taxes, depreciation, amortisation along with the direct cash flows of the property and resulting energy savings.

The following KPIs are used and calculated in the RentalCal tool, grouped into Economical, and Environmental/Resource KPIs:

Economical KPIs for Investors:

1. Additional net rental income
2. Return on equity
3. Payback period
4. Additional exit value
5. Expected Reduction in Vacancy Rate
6. DSCR (Debt Service Coverage Ratio)
7. Change in non-reimbursable inspection and maintenance costs

Economical KPIs for Tenants:

1. Net Rent
2. Energy expenses
3. Gross rent
4. Apportionable maintenance and inspection costs

Key Performance Indicators (KPIs) – Environmental and Resource Perspective:

1. GHG emissions
2. Consumption of non-renewable primary energy
3. Final energy consumption per energy carrier

The tool also touches upon additional non-monetary impacts of the refurbishment. While acknowledging the difficulties to monetise other impacts and benefits, it presents a list of possible non-monetary impacts after refurbishment, such as positive impacts on indoor air quality, reliability of HVAC systems and inhabitant's health although does not aim to quantify any of these benefits.

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Comments

- The tool helps to differentiate between costs that go directly towards energy savings and those that are made "anyway". For example, the costs for setting up the scaffolding while performing the renovation are regarded as costs that would have been accrued "anyway". Those payments are not regarded as being relevant for making decisions about energy related measures.
- The method takes a lot of different financial parameters into account. This can be seen from the listed Economical KPIs for investors and tenants.
- The tool calculates the cash-flows for every year of the calculation period individually.
- The RentalCal website also provides case stories from different countries of the application of the RentalCal tool.

8.3.3 INSPIRE tool

The information mentioned in this description is summarised from the tool's home page and related documentation [54], [55], [56].

The INSPIRE (Integrated Strategy and Project Development Instrument Reduce Primary Energy Use and Greenhouse Gas Emissions) Tool is an Excel based calculation tool for calculating "energetic, ecological and economic indicators and evaluate various retrofitting and energy production strategies and their mitigation impact in terms of greenhouse gas emissions and primary energy consumption in buildings" [54]. It was developed as part of a project supported by the Swiss Federal Office of Energy (SFOE) and part of the "Sustainable Renovation" call for tenders of the international research network Eracobuild.

The tool works with inbuilt Excel macros and formulas to take user inputs, perform calculations and generate results. The tool asks the user for inputs such as the building's condition, and country-specific information such as energy prices, climate and environmental data. The tool also gives the possibility to add different generic energy renovation measures, ranging from measures targeting the improvement of the building thermal envelope, the building installation systems and the choice of energy carrier. The obtained energy savings, along with the associated greenhouse gas emissions are then calculated as the output.

Furthermore, the program gives the opportunity to define two "reference" cases against which comparisons can be made for energy savings and GHG emissions. The two reference cases represent the current condition of the building based on the input given, and the condition of the building with some "anyway" measures applied (measures intended to upkeep the functionality of the building and not necessarily affect the energy performance) respectively. These cases can then be compared with defined "Variations" which represent possible variants for the modelling of energy efficient retrofitting measures.

Economic calculations

The following costs are taken into account for each energy related package of measures:

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- upfront investment costs
- yearly capital costs (yearly comprising interest and pay-off of upfront investments)
- yearly energy costs
- yearly operational and maintenance costs, and
- indirect taxes (VAT)

The cost-benefit-calculations are carried out with the annuity method. For the economic evaluation, comparisons are carried out for the same building for two different cases: one with energy-efficient retrofit measures applied and the other with the equivalent reference case.

8.3.4 Other economic evaluation tools

Other tools that were briefly looked into are summarised below.

50/50 energy savings calculation tool [57]
An online calculation tool that helps to calculate energy, CO_2 and financial savings achieved in a building as a result of energy saving measures. Thus, it differs from previously described tools and methods, including the Total Concept Tool, which are used prior to renovation. The tool is the result of a European project called IEE EURONET 50/50 MAX which aimed to increase energy savings in public buildings through the implementation of the so-called "50/50 methodology". The methodology aims at achieving energy and financial savings in a public building without large investments and to actively involve the buildings' users in the process of energy management and promote energy-efficient behaviour through practical actions. The financial savings obtained are shared equally between the building users and the local authority (municipality) paying the energy bills. The calculation of energy and financial savings is based on consumption data prior to and after the implementation of energy saving measures, degree days and energy prices.

BEopt (Building Energy Optimization Tool) [58]
The BEopt software is a tool developed by the National Renewable Energy Laboratory of the US Department of Energy (DoE). It uses the building performance software EnergyPlus to evaluate residential building designs and determine cost-efficient packages for various target levels of energy savings. It can be used to analyse new constructions as well as retrofits, and applies to single-family detached or multi-family buildings.

BLCC (Building Life Cycle Cost) Tool [59]
The BLCC tool is an economic analysis tool developed by the National Institute of Standards and Technology in the US. It is described to be useful for evaluating the cost effectiveness of alternative energy measures and building services systems for energy retrofitting projects.

Buildings Energy Efficiency Cost-Effectiveness Tool (v2.0) [60]
This Excel tool is part of the DoE's Better Buildings Residential Program for estimating the cost-effectiveness of a residential energy-efficiency program through a cost-benefit analysis based on the provided inputs. The tool is aimed towards providing a simple way to perform such calculations and helping motivate and support decision-making for funding such programs.

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PARARENOVATE-LCT [61]

A script-based, parametric simulation tool that performs the enviro-economic evaluation of energy renovation strategies in residential buildings using a life cycle perspective. The tool combines the building simulation model from Energy Plus, along with baseline scenarios and to-be-explored renovation strategies in Python to create outputs based on energy, environmental and economic sustainability.

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9 Performance indicators

The following sections give an overview of the categories of performance parameters considered for integration into an advanced evaluation method for energy renovation in existing buildings, to be developed within the ENTRANCE project. Information on each category and corresponding KPIs is given in the subsections 9.1-9.5. In addition, connections to the EU schemes Energy Performance Certificates (EPCs) and Renovation passports are discussed in section 9.6.

Opinions regarding the suitability of including the respective factors in an advanced evaluation method, as a result from interviews conducted within this study, are presented in section 10.3.

9.1 Smart Readiness Indicator

The "*smart readiness indicator*", *SRI*, is the core element and basis of a common EU scheme for rating the smart readiness of buildings initiated under the Energy Performance of Buildings Directive (EPBD). Its legal framework is defined in Article 15 of the 2024 EPBD recast [62], as well as in the Commission Delegated Regulation (EU) 2020/2155 [63] and its annexes and the Commission Implementing Regulation (EU) 2020/2156 [64]. According to EPBD Article 15, "The rating shall be based on an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant, in particular concerning indoor environmental quality and the grid and to improve its energy efficiency and overall performance." Thus, in itself, the SRI covers several of the other aspects and qualities discussed in this report. At this point, the SRI is a voluntary framework, but it should be noted that according to Article 15 of the 2024 EPBD recast, the European Commission shall adopt a delegated act by 30 June 2027 requiring non-residential buildings with HVAC rated capacity above 290 kW to have an SRI certificate.

Information on the smart readiness indicator is provided on the European Commission's homepage under the categories Energy, Climate Change and Environment and EU Energy Policy and Energy Efficient Buildings [65]. Here, it is described that the SRI measures a building's (or a building unit's) ability to use smart technologies that support decarbonisation and promote comfortable and efficient living environment, such as building automation and electronic monitoring of building systems. The initiative aims to raise awareness of the benefits promised by these smart building technologies [66]. The so-called smartness of a building is further described by the Commission to constitute its "ability to efficiently sense, interpret, communicate, and actively respond in an efficient manner to changing conditions in relation to the operation of technical building systems, the external environment (including energy grids) and demands from building occupants" [65].

9.1.1 The SRI calculation and implementation

The SRI calculation is based on evaluating the performance of "smart-ready services" that a building has or could use, categorised within nine technical domains, here presented row wise in Table 2. The performance of each service is assessed against 8 desired impacts of smart

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buildings, presented column wise in the table. Impact criteria and technical domains are defined in the annexes of Commission Delegated Regulation (EU) 2020/2155 [63].

The result of the smart-ready assessment is aggregated into an overall SRI class and score, showing how close the building is to being fully smart-ready, while also providing individual scores for each of the three key smart functionalities defined by the EPBD: 1) energy performance optimisation, 2) occupant-centric adaptability, and 3) grid responsiveness.

Table 2. Technical domains to be assessed against the desired impacts of smart buildings.

		Desired impacts of smart buildings							
		Energy efficiency	Mainte-nance and fault prediction	Comfort	Conve-nience	Health	Wellbeing and accessibility	Information to occupants	Energy flexibility and storage
Technical domain	Heating								
	Cooling								
	Domestic hot water								
	Ventilation								
	Lighting								
	Dynamic building envelope								
	Electricity								
	Electric vehicle charging								
	Monitoring and control								

The SRI scheme is currently being tested and implemented in several EU countries. The SRI Outlook 2024 report provides an update of the status of SRI policy developments within the EU [67]. Also, SRI newsletters are released by the European Union a few times a year, providing smaller updates about ongoing research and developments in the field [68]. The SRI Outlook report contains a short overview of the process for SRI implementation, background, methodology for calculation, and assessment procedure. It also summarises an updated status of the implementation of SRI within the EU. Figure 3 shows a map from the report, giving an overview of the progress of different EU countries in undergoing, and completing, a test phase

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of the SRI at the national level. Additionally, more and updated information is available on the website sriobservatory.eu [69], which is a result of the SMART^2 project [70] described in the subsection below.

Figure 3. SRI Outlook 2024 (Source: https://sriobservatory.eu/wp-content/uploads/2024/09/SRIOutlook2024_v3.pdf)

9.1.2 SRI projects and tools

The European Union's LIFE programme supports EU countries in implementing the SRI through its Clean Energy Transition (CET) sub-programme [71]. As part of the 2022 LIFE program call "Energy performance and Smart Readiness of buildings – making the instruments work", three projects were selected that aim to support the implementation of *Energy Performance Certificates* [72] and enhancing the synchronisation with the *SRI*. These projects started at the end of 2023 and will run for three years. More information about these can be found on the projects' homepages: iEPB [73], SmarterEPC [74] and tunES [75].

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Furthermore, as part of the 2021 call, four projects were selected which aimed to support the successful uptake of the SRI. These projects started at the end of 2022 and last for 3 years and are as follows:

- *easySRI* [76]
  The project aims to improve the potential and contribute to the implementation of the SRI by developing a web platform offering services for automated calculation of SRI. Beyond the calculation of the SRI score, additional parameters regarding the energy efficiency and financial aspects are also introduced to make the acquired information more understandable and quantitative for the building user. These include in-use performance metrics, energy performance forecasts for the former and investment costs and optimal upgrade strategies for the latter. The easySRI solution was demonstrated in a total of six pilot buildings in six European countries. As of now, the final report is not yet available.

- *SRI2MARKET* [77]
  The project has developed an SRI assessment tool as well as an accompanying course called Learning SRI2MARKET that offers e-learning lessons on the SRI and its assessment methodology [78]. To get access to the assessment tool it is required to complete at least the beginner level of the e-learning programme [78]. The SRI assessment tool itself has a reached a Technology Readiness Level (TRL) of 9[2] and is meant to provide a user-friendly interface for users to carry out and store their SRI assessments. It implements the default methodology for calculating the Smart Readiness Indicator, including Methods A and B and allows customisation of all the aspects of the methodology that can be adapted at the Member State level, such as the catalogues of services, the weighting factors, the mandatory services and/or technical domains to be assessed.

- *SRI-ENACT* [79]
  The project "aims to engage stakeholders in national and EU level to co-create tools and services for the Smart Readiness Indicator (SRI) uptake. The project will develop tools and services that calculate the SRI and provide recommendations and guidance for buildings' smartness upgrades." The project website also has an online trainer library that collects past webinars conducted to increase awareness about SRIs. The tools and solutions developed within the project will be evaluated in large-scale pilots in 8 EU countries and implemented in three engagement cycles: 'Testing', 'Scale up' and 'Replication' cycles.

- *SMART^2* [70]
  Within the project Smart Square (Smart Tools for Smart Buildings: Enhancing the intelligence of buildings in Europe), a cloud based open platform for assessing the

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[2] Technology Readiness Levels (TRLs) are indicators of the maturity level of particular technologies, with TRL 1 being the lowest and TRL 9 the highest. TRL 8 – system complete and qualified, TRL 9 – Actual system proven in operational environment.

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SRI of buildings was developed. Also, six pilot buildings were evaluated according to the SRI framework. As of now, the final report, aiming to present key results and lessons learned, is not yet available. In the online platform, called *Smart-Ready-Go!,* anyone can create an account and use a beta version of the tool to assess their building [80]. The assessment is made in accordance with Method A and Method B of the SRI methodology. The tool has reached a TRL of 9[2].

On the EU commission webpage on SRI, information about and links to various SRI digital calculation tools can be found [81]. This includes tools used by official SRI test phases conducted by Member States, which are tools that have been developed by the LIFE CET SMART-READY projects, as well as other tools.

Comment: At the time of writing, no information has been found related to tool comparisons or third-party evaluations of tools related to SRI.

9.1.3 Analyses of the SRI calculation

In this subsection, examples are given of three scientific studies that have examined and tested the SRI calculation methodology.

The first evaluation of the SRI calculation methodology for a comprehensive renovation project was carried out in 2024 for an office building in Greece [82]. The study suggests that applying and determining the SRI is not a straightforward process, as the parameters that need to be considered are not regulated consistently. However, the SRI methodology can stimulate the renovation potential of buildings by integrating various factors and connecting them to the use of innovative technologies.

Secondly, in 2023, an SRI calculation was carried out for a building at the Kaunas Technical University in Lithuania to analyse possibilities to optimise the smartness performance, as addressed by the SRI score, in educational buildings [83]. The study indicates that, despite advancements in the automation and control of building heating systems, the maximum SRI values achieved still fall significantly short of a high-smartness level. The research highlights the crucial role of city-level services in optimising smartness at the building unit level. Additionally, it provides valuable insights into the connection between a building's energy performance and its smartness. The study's policy implications extend to utility management at the district level and emphasise the need for customised SRI service catalogues tailored to different building types.

The third evaluation example of an SRI calculation was carried out in Greece in 2021 [84]. The demonstration object was a single-family residential building. The results show that the SRI methodology is simple and easy for small and simple buildings, and more difficult and time-consuming for larger buildings. The results specifically showed that the triage process is a critical step and remains the most challenging aspect. The researchers suggest that in order to leverage the challenge, each European country must adopt relevant legislation. Such adaptation would enable the SRI to serve as a standardised benchmark for comparison in the building sector,

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ultimately encouraging the adoption of smart technologies in new constructions and the retrofitting of existing buildings.

9.2 Decarbonisation

Decarbonisation of the European building stock is a major strategic pillar of the European Union to achieve climate neutrality by 2050. The 2024 EPBD recast [62] prioritises the calculation of the Global Warming Potential (GWP) throughout the lifecycle of buildings, especially in new construction. It defines the GWP over a building's whole life cycle as the building's overall contribution (both embodied and operational) to greenhouse gas emissions contributing to climate change. The directive specifically lays down the requirement for calculating and communicating the lifecycle GWP of new buildings in the energy performance certificate of the building. Furthermore, the recast also prescribes a method for calculating the GWP, making a reference to the Level(s) indicator 1.2: Life cycle Global Warming Potential for the scope of building parts and technical equipment [85]. By January 1, 2027, the EU Member States must publish a roadmap to introduce limits on total cumulative life-cycle GWP for new buildings by 2030.

Greenhouse Gas Protocol (GHG Protocol) is an international standard for quantifying and managing greenhouse gas emissions [86]. It is often used as a basis for calculating carbon dioxide equivalents in various certification systems. The GHG Protocol uses a variety of indicators to measure greenhouse gas emissions, and it ranges from company to city levels. These indicators are grouped into different categories, and some are related to buildings, infrastructure and business activity.

- Direct emissions from
  - sources such as boilers and furnaces
  - vehicles owned or controlled by the organisation
  - chemical processes within the organisation
  - leaks or other unintended releases of gases
- Indirect emissions from energy emissions from generation of
  - electricity purchased by the organisation
  - of steam, heating, and cooling that are purchased by the organisation
- Other indirect emissions from
  - the production of goods and services purchased by the organisation
  - the production of capital goods purchased by the organisation
  - the production and transportation of fuels and energy purchased by the organisation
  - the transportation and distribution of goods and services
  - the disposal and treatment of waste generated by the organisation
  - employee business travel
  - employees commuting to and from work
  - assets leased by the organisation
  - franchise operations

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- investments made by the organisation

9.2.1 Sustainability performance

There are also other existing assessment tools that more broadly describes the sustainability performance of buildings, where GHG emissions is an important part, along with other aspects.

The LEVELS framework [87] is a common EU framework for assessing and reporting on the sustainability performance of buildings. The framework includes six objectives that are related to key sustainability aspects during a building's life cycle as follows:

1. Greenhouse gas emissions along a building's life cycle
2. Resource efficient and circular material life cycles
3. Efficient use of water resources
4. Healthy and comfortable spaces
5. Adaption and resilience to climate change
6. Optimised life cycle cost and value

These objectives are further divided and measured based on different indicators, which number sixteen in total. By using these objectives and indicators, the aim of Level(s) is to provide a common language for the decarbonisation of the building stock in line with the European Union's sustainability initiatives.

Other tools for assessing the sustainability of buildings include multi-criteria rating systems such as:

- *BREEAM* (Building Research Establishment Environmental Assessment Method) is an international certification system originally from the UK [88]. BREEAM assesses buildings based on various sustainability criteria, including energy use, CO2 equivalents, indoor environmental quality, renewable energy, biodiversity and habitat and water consumption etc.
- *LEED* (Leadership in Energy and Environmental Design) is an American certification system used globally [89]. To obtain LEED certification, a project must first complete all prerequisites and then earn points meeting selected credit requirements. The prerequisites and credit requirements are organised into different categories, including energy and atmosphere[VE1.1] (which relate to decarbonisation), materials and resources, indoor environmental quality and water efficiency etc.
- *Miljöbyggnad* is a Swedish certification system that assesses buildings within the areas energy, indoor environment, and materials [90]. To achieve this certification, several requirements must be met, e.g. a lower level of energy use and that the energy come from a renewable source, indoor environments such as air quality and thermal climate and selection of building materials.

Also, the assessment methods BREEAM and LEED use an "innovation indicator" to describe and asses innovative sustainable solutions in buildings.

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9.3 Flexibility

Energy flexibility—enabled by demand-side management (DSM), demand response (DR) and energy storage technologies—is crucial for balancing the electric power supply and demand, especially with increasing intermittent energy source and increasing electricity demand in buildings and other sectors. In the IEA EBC Annex 67 the energy flexibility is defined as "the ability to adapt/manage its short-term (a few hours or a couple of days) energy demand and generation according to local climate conditions, user needs, and energy network requirements without jeopardizing the technical capabilities of the operating systems in the building and the comfort of its occupants. Energy Flexibility of buildings will thus allow for DSM/load control and thereby DR based on the requirements of the surrounding energy grids" [91]. Moreover, the main characteristics of energy flexibility are defined as: capacity, temporality, efficiency, cost and direction.

Various KPIs for energy flexibility are used and described in literature. A review article by Li et al. [92] has analysed a large number of energy flexibility KPIs, focusing on data-driven KPIs for buildings in operation. Here, energy flexibility KPIs were classified as either baseline-required or baseline-free, with baseline-required meaning that the KPI depends on input from a reference scenario without flexible operation. In this study, a total of 48 data-driven energy flexibility KPIs were identified based on a review of 87 publications. Some of the most popular energy flexibility KPIs are the following:

- *Energy Efficiency of Demand Response Action:* Assesses the efficiency of a demand response (DR) action with respect to energy use.
- *Flexibility Savings Index:* The ratio between the cost of flexible operation and the cost of baseline operation, i.e. the reduced operation costs during the demand response event.
- *Peak Power Shedding:* The difference between the peak power demand during the peak power of the baseline scenario and the peak power demand during the peak hour of the flexible scenario. I.e. reduced power demand during peak hour due to flexible operation.
- *Flexibility Factor:* The flexibility factor was proposed by Le Dréau and Heiselberg [93] to quantify to what extent energy flexibility can be achieved by using the building thermal mass to shift energy use from high-to-low price periods. Also other types of flexibility factors are described in literature. For example, the flexibility factor proposed by Marszal-Pomianowska et al. [94] shows how power use can be increased or decreased at a given time compared to the daily peak power.
- *Load Factor:* The ratio between the average demand and the maximum demand during a specified period.

In a review by [95], various equations, naming and definitions of flexibility KPIs were found in literature. However, the authors note clear similarities between them and classify the KPIs into four main categories: 1) load shifting ability, 2) power adjustment, 3) energy efficiency and 4) cost efficiency. For example, the Flexibility factor proposed by Le Dréau and Heiselberg [93], mentioned above, was classified in this review as a KPI describing load shifting ability [95].

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9.4 Indoor Environment

The EPBD defines *indoor environmental quality* as "the result of an assessment of the conditions inside a building that influence the health and wellbeing of its occupants, based upon parameters such as those relating to the temperature, humidity, ventilation rate and presence of contaminants." Article 13 of the EPBD recast establishes requirements for implementing adequate indoor environmental quality standards in buildings for maintaining a healthy indoor climate [62]. In accordance with this, REHVA, EUROVENT and the Nordic Ventilation Group (NVG) have proposed a common model regulation to support harmonised national implementation [96]. The proposed model regulation was developed by setting requirements with measurable indicators outlined in Level(s), the European framework for sustainable buildings [97] and prescribes design values and requirements for parameters, such as:

a) room temperatures for acceptable thermal comfort
b) ventilation rates in buildings
c) the optimal CO_2 levels
d) noise from building service equipment

Aljas et al. (2023) [98] presented a practical/programmatic method to assess a building's indoor climate quality based on CO_2 data. The method combines and classifies measured CO_2 data to output a single indoor climate class (IDCC) for the whole building or each individual room. The method is based on European guidelines and standards, specifically EN 16978-1:2019, its interpretation guide CEN/TR 16798-2:2019 (EN standard methodology) and the TAIL rating scheme developed by Wargocki, et al., 2021. The method was tested on CO_2 sensor data from 56 zones, mostly classrooms, of a recently renovated educational building in Estonia. The method has several steps, data collection, pre-processing of the data. IDCC boundaries for different climate classes were calculated as CO_2 equilibrium concentrations using the ventilation flow rate design method 1 in EN 16798-1:2019. The study found that poorly estimated occupancy times could lead to a very optimistic IDCC classification.

9.4.1 Monetisation of indoor environment

Energy renovation and efficiency improvements result in co-benefits among which indoor air quality improvement and increased comfort are frequently mentioned [99], [100], [101], [102]. However, due to the difficulty in measuring these factors and their subjective nature, this co-benefit is often not considered for economic analyses or policy evaluations [99], [100]. According to Flagner et al. (2025) [103], not many studies have effectively quantified the financial benefits associated with improved occupant productivity and health due to an optimised indoor environmental quality, and its incorporation in an economic analysis. That said, recent studies have attempted to develop methods to monetise increased indoor comfort and benefits of improved health on productivity.

Buso et al. [100] proposed a multi-disciplinary approach to monetise comfort in hotels using the Contingent Valuation Method (CVM), which is a survey-based economic technique for the valuation of non-market goods such as indoor comfort and air quality. The survey is structured

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to measure the importance placed by individuals on the aforementioned benefits through their willingness to pay (WTP) for resulting benefits or willingness to accept (WTA) specific changes.

The European Commission published guidelines for cost-benefit analysis for investment projects in 2014, wherein a method was proposed to quantify the added benefit of increased comfort for energy-efficient refurbishment [102]. The method assumes that the inhabitants are willing to increase their indoor temperature for increased comfort, made possible by lower unit energy costs resulting from energy-efficiency improvements. It then compares the resulting energy cost savings to a counterfactual scenario for energy consumed for maintaining the "standard" comfort temperature.

Clinch & Healy [104] used a computer-simulation program to model and value the improvements in thermal comfort as a result of from domestic energy retrofit programmes, using Ireland as a case study. The authors describe why improvements in thermal comfort is an important factor to consider in the assessment of energy-efficiency programmes: "…, if a portion of the housing stock has sub-optimal levels of warmth, a domestic energy-efficiency programme is likely to result in some of the energy savings (predicted on the basis of fixed internal temperatures) being forgone in exchange for increased internal temperatures." The paper uses a "trade-off approach", predicting the extent to which energy/emissions' savings might be forgone in exchange for improvements in comfort/health. It was demonstrated that, for the case study, the proportion of energy savings forgone (i.e. the proportion of maximum, potential energy savings not realised), and instead taken as improvements in comfort, was 21%. This was considered in line with previous projects.

Chatterjee et al. [101] developed and demonstrated a method to quantify the benefits of having a good and hygienic indoor environment in high-efficiency buildings using Germany and Hungary as examples. They introduced two terms: "change in active days" and "workforce performance" and developed a novel formula to calculate and quantify these. The former utilises the number of "sick days" and "healthy life years", whereas the latter uses a so-called "performance improvement factor" to account for the improved productivity engendered by indoor climate improvements. In addition, a scenario analysis was carried out with two different scenarios to measure the impact on productivity, which was then monetised.

Fang et al. [105] developed a method to monetise comfort levels based on pre- and post-retrofit conditions using the Annualised Energy Related Cost (AERC). The AERC was calculated for several retrofit scenarios of a residential building and plotted against the comfort level using Fanger's indicators of Predicted Mean Vote (PMV) and Percentage of People Dissatisfied (PPD). The difference in AERC between pre- and post-retrofit with the same comfort level was taken as the monetary amount for comfort, which amounted to a 10.6% increase in heating and cooling costs.

9.5 Occupancy rate

The most commonly used indicator or metric to express building energy efficiency is the specific energy consumption (SEC) measured in kWh/m^2/year. Although this metric is a good indication

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of the technical properties of the building during the design phase, it is not fully reflective of building occupancy or efficient usage of floor space. Using the same physical building properties, buildings with lower space efficiency (i.e. a higher m^2 per person value) and shorter working hours would appear to be more energy efficient in kWh/m^2 than a building which was utilised more efficiently [106]. The results oppose each other when using a different metric that also takes into account the number of occupants and the working hours. By using this new metric, which is different from the standard kWh/m^2, owners are encouraged to compare their energy consumption to that of their peers, and energy efficiency doesn't appear worse for workplaces with longer working hours or with a more efficient office layout. [106]

Huovila et al. [107] made a comparison of other metrics for energy efficiency and tested them in five case studies, four office buildings and one educational building. In essence, the more efficiently a building was used, i.e., the higher the occupancy and space efficiency, the more energy it consumed and the less energy efficient it appeared using SEC. The size of the effect depends on various factors. For example, if the building automation and control systems are not based on demand control, the effect of higher occupancy levels on energy consumption are only minimal due to high space heating demand which is dependent on the building's operating times and not the number of occupants. The study also suggested a new indicator to take building occupancy and space efficiency into account during the building operation phase ($SEC_{u,s}$).

The following indicators were used and evaluated in the study [107]:

1. SEC: specific energy use (kWh/m^2)
2. EIU: energy intensity of usage (kWh/number of occupants)
3. EIO: energy intensity of occupancy (kWh/hours per person). The sum of the number of hours that each occupants spends in the building.
4. SEC_{IO}: specific energy use per intensity of occupancy (kWh/m^2, hours per person)
5. SEC_o: SEC adjusted for occupancy $kWh/(m^2$, occupancy): o representing the average presence of occupants during normal working hours (typically 8-17) and normal workdays, which lies between 0 and 1
6. $SEC_{u,s}$: SEC adjusted for occupancy and space efficiency, which is a new metric proposed by Huovila et al. The proposed unit is kWh/m^2 u, $u = (n*t_{avg})/(A/a_{ef}*t_{ref})$, where

    n = actual number of people using the space,
    t_{avg} = average number of hours present daily per person
    A = the total area studied
    a_{ref} and t_{ref} are normalising factors:
    a_{ref} = amount of space per person available in a typical office setting
    t_{ref} = normal working hours

The use and selection of the type of indicator depends fully on the characteristics of the building, the specific case and what the results are going to be used for. The indicator proposed by Huovila is the only one that takes both the operating hours and the number of people into account. The lack of availability of real-time data about occupancy could be a potential detriment to the use of this indicator [107].

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The occupancy rates of non-residential buildings are important for the property owner also from an income and profitability point of view. High occupancy rates contribute to a stable rental income, which is ultimately connected to operational costs and economic sustainability. Hence, occupancy rates are also a KPI that gives an indication of the effectiveness of property management policies and enhances property value.

9.6 Connections to EPCs and renovation passports

This subsection highlights links between the categories of performance parameters discussed above and the EU schemes energy performance certificates (EPCs) and renovation passports.

Energy performance certificates

Energy performance certificates for buildings have been in use since 2002; however, substantial differences among national schemes persists hindering comparability between EPCs across the EU. This is addressed in the EU Directive 2024/1275 (2024 EPBD recast) by introducing a common scale of energy performance classes as well as a common EPC template [62]. According to Article 19 in the EPBD, by 29 May 2026, EPCs shall comply with the template in Annex V of the same directive. The template present a number of mandatory and suggested elements, whereof several more or less relates to the categories of performance parameters discussed in this report. In the Annex V template, it is instructed that, the EPC shall display the following elements, among others:

- operational greenhouse gas emissions (kgCO_2/(m^2.y)), and the value of the life-cycle GWP, if available;
- a yes/no indication whether the building has a capacity to react to external signals and adjust the energy consumption.

Also, the template suggests that the energy performance certificate may include the following indicators, among others:

- peak load;
- results of the analysis on overheating risk (if available);
- the presence of fixed sensors that monitor the indoor environmental quality;
- the presence of fixed controls that respond to the levels of indoor environmental quality;
- presence, type and size of energy storage systems;
- local primary energy factors and related carbon emission factors of the connected local district heating and cooling network;
- metered energy consumption
- operational fine particulate matter (PM2,5) emissions.

The template for EPCs in Annex V also directly mentions the SRI scheme, suggesting to include a yes/no indication whether a smart readiness assessment has been carried out for the building and where available, the value of the smart readiness assessment.

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Additionally, concerning GHG emissions, according to the EPBD recast Article 19, the recommendations included in the EPC shall provide an estimate for the reduction of operational greenhouse gas emissions, in addition to energy savings. Also, for existing buildings renovated to A + class, Member States shall ensure that the life-cycle GWP is estimated and disclosed in the EPC of the building.

A comprehensive evaluation of the implementation of EPC indicators as outlined in the recast EPBD across the 27 EU Member States is provided by Sesana et al. [108]. The report shows considerable variability in the adoption and integration of the EPC indicators. The only indicators already implemented in the EPC templates in all countries being the energy performance class and the calculated annual primary energy use in kWh/(m^2.y). The indicator operational GHG emissions was found to have been already implemented in all countries except Sweden. The suggested indoor air quality indicators on the other hand, were found to not have been implemented anywhere, with the only exception of the Swedish EPC template monitoring the radon level. Very few countries had implemented indicators considered linked to smart readiness in the EPC template. For example, in only five countries, metered energy consumption was included. Anon-homogeneous and low level of compliance was also seen for thermal comfort.

Renovation passports

Renovation passports were formally introduced in the EU Directive 2024/1275 [62]. A renovation passport is here defined as "a tailored roadmap for the deep renovation of a specific building in a maximum number of steps that will significantly improve its energy performance". By this, it aims to help owners and investors plan the best timing and scope for interventions. In Article 12 of the EPBD, it is stated that Member States shall introduce a scheme for renovation passports by 29 May 2026, and that it should be of voluntary use, unless the Member State decides to make it mandatory.

The renovation passport scheme should be based on a common framework set out in Annex VIII of the EPBD 2024 recast. Here, it is specified which information a renovation passport shall and may include. For example, information about each renovation step is required, including estimations of: energy savings in primary and final energy consumption, reduction of operational greenhouse gas emissions and savings on the energy bill. The renovation passport shall also include, among other things: the share of generation and self-consumption of renewable energy estimated to be achieved after the renovation and "general information on available options for improving construction products' circularity and for reducing their whole-life-cycle greenhouse gas emissions, as well as wider benefits related to health and comfort, indoor environmental quality and the improved adaptive capacity of the building to climate change". Thus, there are strong links to both decarbonisation and the indoor environment. Concerning smart readiness, it is suggested that an independent module on "how the renovation steps and additional measures could improve the smart readiness of a building" may be included.

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In the EPBD 2024 recast, it is acknowledged that there are synergies between renovation passports and energy performance certificates; therefore, "Member States may allow for the renovation passport to be drawn up and issued jointly with the energy performance certificate." (EPBD, Article 12) In this case, the renovation passport should substitute the recommendations in the EPC (EPBD, Article 19).

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10 Interview results

The following sections summarise the results from interviews carried out according to Section 5.

10.1 The decision-making process

In summary, among the property owners interviewed within this study, renovation decisions are often based on profitability and the associated requirements to a large extent, but it is seldom the only determining factor. While the fulfilment of profitability requirements is important, there are other aspects that may be as important, if not more, to the final decision. The most frequently mentioned influencing factors were maintenance plans and renovation needs, followed by practical and logistical possibilities and barriers. Also, requests from the users (tenants) were described by some interviewees to be a key driver, as were energy efficiency targets. Potential added values mentioned to be taken into consideration when deciding on energy renovation projects and individual measures were: property value, indoor environmental quality (IEQ) and peak power.

Some comments on profitability:

- In general, measures demonstrating higher profitability are more likely to be approved for implementation.
- Decisions are heavily influenced by IRR (Internal Rate of Return) goals. Ultimately, it comes down to optimising the return on investment for the landlord or investor.
- Profitability is not the main driver.
- Usually, a budget is allocated and it would be necessary to make a return on investment plan.
- One interviewee described that reduction of maintenance costs is also included in the economic analysis.

Some comments on maintenance plans and renovation needs:

- Investment-intensive measures are more likely to be implemented when there are existing problems that need to be addressed.
- Energy efficiency measures are often coordinated with maintenance and renovation needs. Thus, these might end up with other measures than what was initially suggested in the profitability analysis. Also, this means that the building one chooses to start with is not necessarily the one offering the highest potential savings.
- Maintenance work has its own process which is different and separate from energy efficiency renovation projects. However, energy efficiency measures may be included to some extent in these as well.
- Energy efficiency measures could for example be implemented if there is need for renovation because of maintenance reasons and the energy savings measures may be easily integrated (by low investment), or it may be connected with planned renovation of buildings.

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- If there is deferred maintenance or a decision to renovate the building, this gives a chance to initiate an energy-saving project, and for the inclusion of additional measures.

Some comments on logistics:

- Some of interviewees noted that the decision also depends on what is practically feasible considering the building users and their activities. For example, for a pre-school or school, renovation opportunities may depend on the possibilities to temporarily relocate children, either within the same school or to other schools.
- For investment-heavy measures, it may be necessary to vacate the premises and temporarily relocate the users.

Some comments on user needs and requests:

- Regarding the influence of explicit requests from the tenant, an example was given that the tenant could introduce requests related to building renovation into the negotiation of the lease agreement, in particular during the renewal of the lease agreement.
- Minor renovation can be based on input from tenants and decisions could be made internally.

Some comments on indoor environment quality (IEQ):

- There is more attention on IEQ if the building is certified and it is necessary because of a protocol (LEED, WELL, etc.).
- Energy renovation may be triggered by problems e.g. poor IEQ.

Some comments on energy efficiency targets and strategies:

- The main focus is on deep renovation, based on available funding and political decisions.
- If the measure does not save energy, it is not implemented.

In the following, more detailed examples from the interviews, not covered by the compilation above, are presented. The labelling A-H has no connection to the order of interviewees listed in Table 1 in section 5.

Interview A

The interviewee explained that, given the condition of their building portfolio and the energy efficiency targets, it has been concluded that all future renovation projects will need to include energy efficiency measures. Furthermore, the decision-making process is perceived as efficient, and to run smoothly, largely due to the trust that has been established across all levels of the organisation.

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Interview B

The standard decision process for energy renovation was described by one of the interviewees in steps as follows:

- Step 1: Analysis including energy audit and cost analysis
- Step 2: Choosing the most cost effective option, which includes comparison of different offers on the market
- Step 3: Realisation in building/-s
- Step 4: Post evaluation
- Step 5 (when relevant): Application in other buildings

Some modernisation, especially innovation without many references, are firstly applied as examples in one or two buildings (pilots). Only if the outcome of the subsequent evaluation (step 4) is positive, the measure will be applied in other buildings (step 5). When the planned energy renovation measure already has been proved in practice, step 5 may be omitted.

Interview C

The interviewee describes that the driver for renovation is commonly still asset management, and that elements of energy conservation are inserted onto this, meaning that the organization does not have a standardised procedure for energy efficiency renovation today. However, it was added that the latest works is an exception to this, which are moving more towards a total energy requalification of parts of the building portfolio. It is acknowledged that "these recent projects were born precisely with decarbonisation in mind".

Further, it was explained that the starting point for the decision process is usually the age of the building and systems: "We try to make a modernisation plan for the older buildings and we make the buildings more efficient taking into account the budget."

Interview D

The energy-savings potential and condition of the buildings are assessed, and based on this, decisions on energy audits are taken. The interviewee describes that the organisation have decided on energy audits covering 10-20% of the building portfolio for a number of years ahead. While the decisions on energy audits are taken at a central level, they are made in dialogue with a dedicated support function that includes personnel in the role of energy controllers.

Interview E

The interviewee described a simultaneous top-down and bottom-up approach: "Our decision-making process for energy renovations is primarily driven by two main forces: 'from above' by our shareholders/unitholders, and 'from below' by our tenants. From the top, unitholders, especially institutional investors, often impose specific sustainability targets that we, as managers, are mandated to achieve for their funds. These mandates might dictate that all properties meet a certain energy certification level. From the bottom, the other driver comes from the tenants...today's companies, especially those seeking office spaces, will only rent

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properties that meet certain energy performance criteria. So, they look for specific buildings and exclude others outright if they don't meet certain targets."

The interviewee further explained that, regardless of the main driver, the planning process usually starts with the annual budget update. This is formed not only by the goals of external stakeholder, but also by maintenance plans and technical or regulatory needs. Excluding situations unrelated to energy performance, such as unpredictable breakages or faults, budget allocation is also guided by expected performance and remaining lifespan of components. In any case, when action is taken, the aim is to implement the most modern technologies, which naturally leads to gradual modernization and improved energy performance. It was pointed out that this approach supports multiple objectives and that is effective because it operates within a structured methodology. From a profitability point-of-view, the interviewee considered it reasonable to assume that a building does not necessarily need to achieve top-tier performance; it can still function well as a modernised facility with updated systems, perhaps reaching energy classification Class C, for example.

The multi-year planning, for example over a three-year horizon, was described to involve renovation interventions guided by sustainability criteria and performance improvement, which also effect the annual planning: "This means that in the annual planning, when I prepare the budget that's then incorporated into the business plan, those cost items are already in place." Also, professional assignments are initiated to conduct studies and understand options, sometimes involving multiple scenarios.

Interview F

In general, the interviewee described that they usually take the opportunity to implement energy efficiency measures when an action needs to be carried out for other reasons. Also, they always look at the possibility of combining several measures at the same time.

Before deciding on an energy efficiency project, a decision memo is usually prepared and presented for the regional market manager. "Overall, the decision memo should outline what we intend to do and why, and clearly specify the assumptions underlying the calculations." In the memo, all potential positive effects are listed, such as those related to energy and sustainability, and it is explained how the proposed project contributes to achieving energy efficiency targets as well as any impact on primary energy and energy classification. The interviewee stated that they also try to include other aspects, such as better control and monitoring, indoor environment and technical debt. Finally, the decision memo includes IRR-diagrams to demonstrate the profitability of suggested investments.

It was added that this memo is not always prepared, which may be due to time constraints or because it is simply not needed.

Interview G

The interviewee explained that the property management team and energy engineers work broadly across the organisation to identify measures that are both profitable and energy-saving. A holistic approach is not always taken for the entire building, but if, for example, ventilation

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improvements are identified, they aim to take a comprehensive approach at least regarding the ventilation system. The interviewee pointed out that including additional measures can improve the overall profitability of a project. An example was also given for situations where the application of the Total Concept method can be helpful: assume that replacing ventilation units is considered profitable, while implementing individual room control is not. However, the project as a whole, including both measures, may still give an acceptable economic outcome, and will save more energy than the first measure on its own. The decision on whether a project is considered profitable lies with those who are commercially responsible for the property.

Other values are not (yet) included in the profitability calculation. However, the investment template contains sections where other values or potential risks should be described. Here, increased sustainability could be described as an additional motivation for the project.

Already today, there is a possibility to include the value of reduced peak power in the profitability calculations, but this has not yet been used, or reviewed by the interviewee. A reflection related to this is that identifying load peaks and potential savings might be something they will become better at over time.

The interviewee clarified that maintenance work, also when including some energy-related measures, follows its own process.

Interview H

The interviewee described that the organisation has recently established a new so-called Green Investment Forum. The new forum is intended to create greater interest in energy efficiency initiatives, especially among the property management department, and they aim to use it to form innovative energy advisory groups that can propose measures and present a profitable financial calculation. Also, the idea is to initiate energy projects without burdening the maintenance budget. As an example, solar panels have previously been funded through maintenance budgets. The aim now is to finance them in a more appropriate way.

The interviewee further mentioned that they have begun initiating collaborations with their larger tenants. Within the organisation, they are considering how the tenants' interests can be factored into their energy projects, while also ensuring a economically sound outcome. The possibilities to include other values in the economic calculations, such as reduced climate impact, societal benefits and increased energy resilience, are discussed.

10.1.1 Development plans

During the stakeholder interviews, it was asked if the interviewees had any plans on developing the method that they currently use for evaluation of energy renovation projects. A few of the interviewees stated that they were working towards it. One interviewee stated that they plan to develop simpler, data-driven tools such as lookup tables of pre-defined and proven renovation packages, aiming for streamlined decision-making. Another interviewee expressed a need to disaggregate the impact of different measures, especially in dynamic occupancy scenarios and AI-driven control systems.

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10.2 The Total Concept and other economic evaluation methods

This section summarises the results of the interviews conducted regarding the experiences of stakeholders that are currently using, or have used, the Total Concept method. It also presents responses regarding experience with other methods for economic calculations.

10.2.1 Experiences of the Total Concept method

All the Swedish interviewees have experiences from using the Total Concept method to formulate action packages, and were selected on that basis. However, the extent of their experience differs. One of the interviewees described that the organisation uses the Total Concept method when producing energy audit reports. Another interviewee had experience of working with the Total Concept method at a previous employment, and continued doing so in his new role at a real estate company. After that, more people at the company have started to use the Total Concept method and think that it works well for their work tasks in property management. A common task is to carry out or investigate simpler measures and the Total Concept method provides them with the opportunity to investigate and perform several measures at the same time, which is useful and appreciated. Yet another Swedish interviewee described that they are in the process of developing an energy strategy for the organisation. As part of this strategy, they are considering developing individual energy plans for each building, including information about the building, identified measures and expected outcomes of implementing those measures. The idea is that the individual energy plan should be based on an energy audit following the Total Concept method. During the interview, it was mentioned that they recently tried to implement Step 1 (Creating the action package) of the Total Concept method for one of their buildings. It was also pointed out that the upcoming revision of EU:s legislation as regards energy management systems and energy audits [109] might entail that they must impose an energy management system, and that such documentation would be valuable support towards it.

Some mentioned that they use their own variant of the Total Concept method. For example, one mentioned that they call it the Total Measure Concept (TMC), where they include less profitable measures in a package and measures that are more profitable carries measures that are not as profitable. Another has developed a method called UPMEF ("Upprustningsprojekt med energifokus" - "Refurbishment with energy focus"), originally based on the Total Concept method. More information about UPMEF is presented in section 8.4.1.

Only one of the interviewees in the other countries has experiences from using the Total Concept method. This person mentioned that the method was used for three buildings during the Total Concept project [17] but not since, as it did not fit in their standard procedure.

Typical measures

Among those who have worked with the Total Concept method in various projects, it was described that common measures typically concern building services systems, as these tend to get worn-out relatively quickly. Examples of common measures are therefore updating or

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replacement of control systems, and measures concerning ventilation and lighting. One interviewee mentioned that if the ventilation system is outdated, a common measure is to upgrade the system, which then contributes to a large part of the obtained energy savings. Also, it was pointed out that keeping the systems updated is necessary in order to be able to work with performance optimisation.

Moreover, the importance of control, automation and supervisory functions which help improve the operational efficiency of the building, was raised. One of the interviewees mentioned that by simply installing a new metering arrangement and getting a better overview of the control system, a significant part of the building heating energy was saved. In addition, it was pointed out that since measures that involve performance optimisation often do not require high investment costs, they could help financing more costly measures. However, this requires a reasonable estimation of expected savings. While one of the interviewees claimed that they are able to make fairly good estimates of expected energy savings from such measures based on experience, another interviewee described the opposite and therefore thought that it may be difficult to use the Total Concept method (and tool) for this purpose.

Additionally, it was emphasised that the measures considered, and their level of innovation, can vary a lot depending on the type of building and their size. An example was given that there are often better possibilities to integrate and optimise the operation of different building services systems in larger buildings compared to smaller ones.

Advantages

The following advantages of the Total Concept method were mentioned by the interviewees:

- Less profitable measures can be included in a package. This was also described as making the work more efficient, by carrying out several measures at once.
- It is a flexible tool where one can easily add and remove measures.
- The visual nature of the tool, where one can clearly see different measures and their profitability, facilitates communication with economists.
- It is positive that the tool is based on clear financial frameworks and required rate of return.
- It could be a good basis for supporting the implementation of Energy Management Systems.

Challenges

A disadvantage of the Total Concept method according to some of those interviewed is that it is quite complex. Thus, it can be difficult and time-consuming to utilise for smaller investments. It was also mentioned that it can be difficult to understand the metric internal rate of return. One interviewee suggested to develop a simplified version of the method so that more people could benefit from it. Moreover, interviewee had the experience of calculation and energy audit being quite costly.

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Furthermore, a challenge described by one of the interviewees is determining the energy related investment costs. There is a risk that maintenance costs are also included and hidden in these costs, which might lead to incorrect conclusions regarding the profitability of measures.

A general problem with energy calculations and profitability calculations that was highlighted is that the result is not always as expected. This is affected by, for example, energy markets and demand tariffs. One interviewee also pointed out that initial project conditions and circumstances can change during the project which must also be taken into account. This means that the original calculation can be difficult to compare with or not hold true anymore when the project is completed.

10.2.2 UPMEF

One of the property owners that was interviewed has developed a method called UPMEF ("Upprustningsprojekt med energifokus" - "Refurbishment with energy focus"), originally based originally based on the Total Concept method. The aim of UPMEF is to avoid isolated measures, promoting a comprehensive review of all aspects related to energy use, maintenance requirements, and renovation needs within a building. Based on this assessment, a coordinated package of actions is developed. The objective is to reduce energy use and climate impact, while also improving the working environment for individuals occupying the premises. UPMEF is based on 3 phases, where in phase 1 the renovation and energy saving potential are analysed, in phase 2 the measures are carried out and in phase 3 the results are followed up, both energy and financial savings [110].

At the time of the interview, they have utilised the UPMEF method on 25 properties, approximately 107 000 m^2 floor area in total, which accounts for a large proportion (about 20 %) of their building stock. It was the described that the method has been successfully developed over the years, with a gradual integration of additional elements, such as inspection of fire and safety, accessibility of the premises and operational adaptations. It is today a comprehensive tool and checklist with a broader perspective rather than simply focusing on energy saving. This has provided the property owner with new opportunities to impose smart climate solutions or perform operational adaptations as part of the implementation of measures.

Often, the same types of measures are included, for example:

- Change to LED light with presence and daylight control
- Balancing of heating system
- Replacing of ventilation system
- Water efficiency measures
- New suspended ceiling
- Update of fire protection specification
- Inspection of accessibility
- Installation of photovoltaic panels

In the buildings where UPMEF was utilised, on average, energy use was reduced by 17 percent for electricity and 28 percent for heating.

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10.2.3 Economic calculations

Apart from the Total Concept method and UPMEF, no specific method is used for economic evaluation, apart from standard financial metrics. For the economic calculations, either internal rate of return (IRR), net present value (NPV) or discounted or simple payback time (PBT) is calculated. The basis for this calculation is primarily investment cost versus savings as a result of reduced energy use. Some comments:

- *LCC:* One interviewee described it as quite simple to use, and that it at the same time gives a good picture of whether the investment is paid back within the lifecycle of the investment. One of the interviewees that use this method, but not as part of the Total Concept method, consider it to be a disadvantage is that it is not presented visually (as in the Total concept method).
- *Simple payback time:* An advantage of this method is that it is very simple to use, and it was considered to offer sufficient accuracy for decision-making in many cases. On the other hand, it was also mentioned that it can sometimes be too simplistic.
- *IRR:* It was stated that IRR is used both as a basis for prioritizing between buildings and for selecting measures within each building, as well as at higher levels within the organization. However, it is noted that it is not always calculated; some measures need to be implemented regardless of the IRR.

Some of the interviewees addressed an issue regarding determining the investment cost for an energy efficiency measure. For example, if a part of it should be regarded as maintenance cost, since purely energy-focused projects are few.

10.3 Development of a comprehensive evaluation method

In the interviews, participants were asked if they would benefit from a more comprehensive evaluation method that, in addition to energy savings and profitability, also takes other parameters into account. All interviewees expressed an interest in such method but also raised some potential obstacles. It was pointed out that this method would need to be practical and time efficient. Several interviewees stressed the importance of having an easy implementation. One of the interviewees suggested that the values or parameters that are added should complement rather than be in conflict with each other. Otherwise, it would be counterproductive to the decision-making process and slow down the pace of implementing measures.

10.3.1 Climate impact

The interviewees generally agree on the importance of including greenhouse gas emissions from operational energy use in the evaluation. One interviewee stated that this is already incorporated in their building regulations. Several interviewees highlighted a growing importance of incorporating such parameters especially in markets with environmental certifications (e.g., LEED, BREEAM), and also the parameter's role in corporate responsibility and investor relations.

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It was discussed that, when the climate aspect is also included, the efficacy of solutions to reduce the climate impact would also depend on local conditions, such as the energy supplier. This may therefore mean that the most optimal solution would also depend on the prevailing conditions. Another interviewee highlighted that it may be detrimental for the climate to install photovoltaic panels and that they would therefore like to have a calculation that combined economics and climate impact in order to be able to make a decision. The person further mentioned that while they do not have a reasonable solution for this yet, they are considering it as there is the conflicting nature of the aims.

One person pointed out that they would like the decisions to be based on actual climate impact values, as energy sources need to be valued differently based on the time of the year. In some cases, the climate impact is especially higher during the winter. It was mentioned that it would be interesting to evaluate measures to reduce power consumption and see how much they contribute to reducing the climate impact.

In some of the interviews, it was discussed about considering the climate impact from embodied energy in addition to the operational energy in the tool. Opinions varied among the interviewees regarding the inclusion of both these kinds of emissions. Some interviewees recognised the value of including it, particularly when working with sustainability protocols or regulatory frameworks. One interviewee lifted that it would be beneficial to have standard figures for climate impact for different types of measures in the renovation phase. While the national requirements for climate calculations for new construction[3] [111] drive the availability of such data, it should also be developed for smaller measures.

Opinions among interviewees vary with regards to combining the economic calculation for renovation with a climate calculation. One interviewee described that they currently carry out an in-house climate calculation with the idea to implement this in all projects from 2025, including maintenance projects. The interviewee sees an advantage in combining the climate calculation with the profitability calculation. Another property owner pointed out that several tools for calculating climate impact already exist and believed that it would be too complex and ambitious to link both climate and economic calculation in one tool. The interviewee deemed that it would be preferable to have a separate evaluation method with a focus on economics and energy. However, a suggestion was made to simplify the linking of input and output data, so that data can be easily transferred across the program interfaces.

Finally, one interviewee noted that energy renovation decisions are becoming increasingly complex and that investment decisions, such as replacing a pump or installing solar cells, may need to be considered in a larger context. The interview recommended to be aware of potential conflicts in the development of the new method. As an example, it was described that energy

[3] Swedish legislation on mandatory climate declarations for new buildings entered into force on January 1, 2022. A climate declaration is a report that shows the climate impact of a building during its construction phase.

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measures can be questioned whether they are right from a climate/sustainability perspective, which could either further justify or dismiss their implementation.

10.3.2 Indoor climate

A parameter related to indoor climate is acknowledged by many interviewees as valuable but challenging to monetise. Interviewees note the parameter's relevance to occupant satisfaction, while one interviewee stated that while compliance with thermal comfort standards is their main focus, other indoor comfort parameters such as visual and acoustic comfort are also gaining attention.

Several interviewees emphasised that the starting point for all renovations is that they must not impair the indoor climate but rather improve it. One interviewee pointed out that high energy use is usually associated with a poor indoor climate. For example, excessive air flows can lead to draught, hence offering good opportunities to reduce energy use and improve the indoor climate at the same time. This was mentioned by one of the interviewees. However, it should be noted that this is not always the case. For example, ensuring proper indoor air quality may require higher ventilation airflow, which leads to increased energy consumption. It was also pointed out that by working with optimisation, monitoring, control and regulations and updating installation systems, more information is provided about the indoor climate and the possibility of controlling it. Another property owner acknowledged that it is difficult to evaluate the indoor climate and also difficult to determine the resulting positive impact on the indoor climate by performing a specific measure. It was suggested that, instead of including this parameter in the economic analysis, perhaps simply adding a comment that the measure can improve the indoor climate in the decision-making documentation would be sufficient. One property owner described that they take into account added value for the occupants, but do not evaluate it in monetary terms.

10.3.3 Peak power

The interviews reveal differing opinions among interviewees regarding the inclusion of this parameter and that it is more market dependent. Some interviewees support the monetisation of this parameter when feasible. Another interviewee saw the parameter as being less significant but still useful for operational efficiency and infrastructure planning. One interviewee expressed uncertainty about the value of including this parameter.

Regarding the question on whether to include power in an evaluation method, the answers varied among the interviewees. One of the interviewees thought that this would be valuable. Another reasoned that in the majority of cases, saving energy also means reduced power. This was mentioned by one of the interviewees. However, it should be noted that this is not always the case. For example, installing mechanical ventilation with heat recovery reduces heat consumption but it also results in a marginal increase in electrical energy use and thereby it might mean a slightly higher electrical power demand. One interviewee opined that it would be difficult to make a calculation that includes the cost for peak power since there are many different price models depending on the location, for example for district heating. Another

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interviewee said that they always look at the possibility of reducing peak demand power in both district heating and electricity. However, they do not take this into account through any form of economic calculation but rather consider its overall benefit to the society.

10.3.4 Occupancy rate

Several interviewees considered the occupancy rate/period of use to be interesting, and some suggested the inclusion of this aspect in the evaluation due to its impact on operational strategies and space utilisation. One interviewee is sceptical about the usefulness of including this parameter.

One interviewee mentioned that they believe that a building that is used more throughout the day is more sustainable than a similar building that is used less. It was discussed that energy targets are usually set in terms of kWh/m^2, but that this is not always fair, since energy use depends also on the type of building and activity. For example, there are buildings where activities take place 24/7 and where it is therefore in operation 24/7. Some of the property owners described that they are therefore also starting to consider using other key figures, for example, presence-specific energy use, i.e. specific energy use divided by the number of person-hours. However, there is a difficulty in determining the number of person-hours. One possible way was described as being to count the number of people entering and exiting entrances, but there is a risk that this could easily be wrong. Another way could be to look at leases and thereby determine how many contracted tenants they have and review the number of operating hours per unit. Another interviewee said that they use sensors to measure how many people are in the premises and that they have had contemplated about connecting it to energy use.

10.3.5 Smart readiness

While not all interviewees were familiar with the SRI framework, some were positive to including smart readiness in an extended evaluation method. One of the interviewees that expressed an interest also described that they have had far-reaching projects regarding improving control and regulation functions. Additionally, there is an idea to prepare for the integration of AI in connection with future upgrades to the building control systems. Another interviewee lifted its potential benefit and strategic importance for future-proofing a building and improving operational efficiency, although this would require system upgrades.

One interviewee is hesitant to include this indicator, since, at the time of the interview, the SRI is a voluntary framework. However, it was added that, considering a possible link to EU taxonomy and provided that the banks would offer lower interest rates, then it could be considered in economic calculations well.

10.3.6 Flexibility

Flexibility is seen as an important parameter by most of those interviewed. Most interviewees support its monetisation, and one interviewee even included it when it was financially justified

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to do so. With regards to appraising the flexibility of a building for the development of future smart grid buildings, one interviewee acknowledged that this question has grown in significance in recent times, but was unaware of any existing program that worked with this or took it into account. This person has mainly used Excel for carrying out analyses related to flexibility.

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Appendix 1. Template - Interview questions

Date:	
Interviewer:	
Interviewed organisation:	
Interviewed persons and their professional role:	

Before we start (oral or written consent)**:**

1. **Do you understand that your participation is voluntary and that you are free to withdraw at any time?**

2. **Do you agree to participate in the study?**

3. **Do you agree to the interview being recorded?** (if the interviewer prefer to record)

4. **Is it okay that we mention that we have interviewed you, and the organisation that you represent, in publications?** (If not, this information will be left out)

5. **Do you agree to the use of anonymised quotes in publications?**

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Part 1: About the interviewed person and organisation

6. **Please, briefly describe your role (and responsibilities) with regards to energy renovations and economic evaluation of such.**

7. **Please, briefly describe your building portfolio**
   a) What types of buildings do you own/manage today?
   b) What is the size of the building portfolio (total area)**?**
   c) What is the age of the building portfolio (e.g. construction year for the majority of the buildings, or range of construction year)**?**

Part 2: General information about the decision-making process for energy renovation

8. **Within your organisation, what is the (standard) decision-making process for energy renovation?** What are the main steps?

9. **What are these decisions normally based on?**
   e.g. energy efficiency targets, economic evaluation, maintenance plans etc.

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Part 3: The Total Concept Method - Experiences and comments

Information about the Total Concept Method

Aim

The Total Concept method was developed to motivate property owners to carry out larger energy renovations projects in the non-residential building sector. It was originally developed in Sweden but has also been adapted to and tested in other Northern European countries. Besides non-residential buildings, it has also been tested on residential buildings.

The Total Concept method aims to present how it can be possible to go further with more measures carried out and still meet the profitability expectations set by the building owner. In short, the aim of the method is to achieve maximum savings in a cost-efficient way.

Combining measures in a profitable "action package"

The method is based on an action plan comprising a package of energy efficiency measures that *as a whole* fulfils the property owner's profitability requirements.

When forming the action package both individual cost-efficient measures ("low hanging fruits") and costlier measures are considered. From an economic point of view, the most cost-efficient measures will support the costlier measures, that would not have passed the profitability requirements on its own.

Internal rate of return (IRR)

The profitability assessment in the Total Concept method is based on the internal rate of return method. It takes into account:

- investment costs
- annual savings (from reduced energy consumption)
- (possible future changes in energy prices)
- expected lifetime of each measure

The criterion for how many measures to include in the action package is that the internal rate of return of the package as a whole, is larger than the interest rate used by the property owner, i.e. their profitability requirement.

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Example

The action package is formed by arranging the different measures according to their profitability and calculating a resulting internal rate of return for a number of simultaneous measures. In the example shown in the figure below the final action package comprises five energy saving measures. The profitability requirement is here set as minimum 5% interest rate. Step-by-step:

1. You start with the individually most profitable measure, which would give the highest rate of return (here above 20%).
2. Then you add less and less profitable measures to the action package, and for each combination you calculate a new rate of return, which will consequently be lower and lower.
3. Measures are added until you reach the limit for what is considered acceptable, i.e. the profitability requirement (5% in the example in Figure 1).

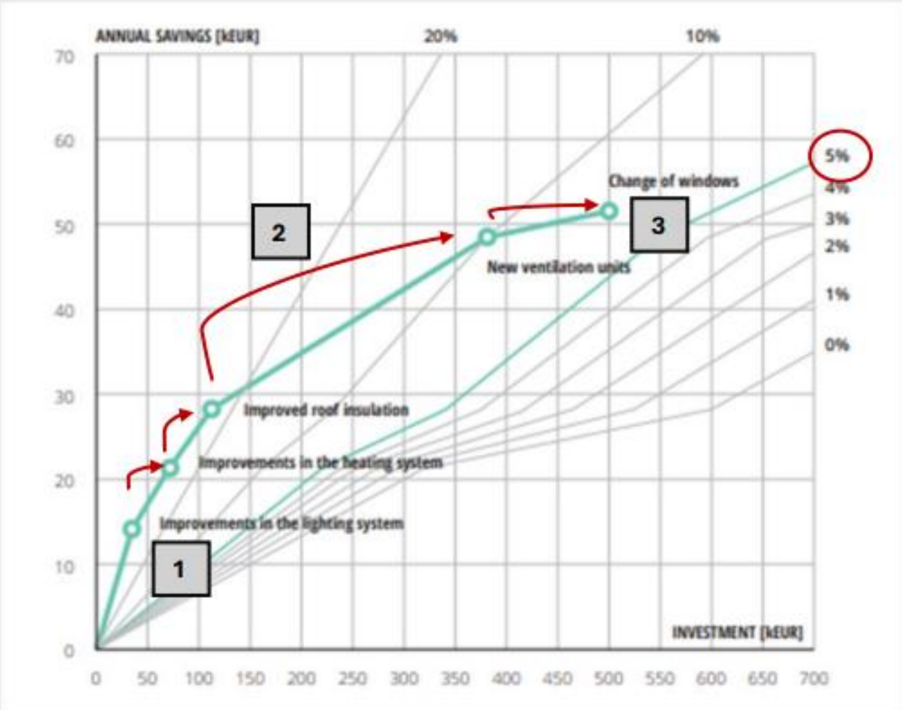

Figure 1 Example of an internal rate of return diagram used in the Total Concept method. Each point in the diagram shows the total investment (x-axis), annual savings (y-axis) and intenal rate of return (lines från 0-20%) for an action package including the measure stated at the respective point, as well as all previous measures. The last point "Change of windows" represents a package including all five measures in the figure.

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10. Do you have any experience of using the Total Concept Method?

If No: Move on to question 15

If *Yes*:

a) When is it used?

b) On how many buildings have you used the Total Concept Method? What types of buildings (e.g. schools, multi-family buildings, etc.)?

c) When was it last used?

d) Do you plan to implement the Total Concept Method for more buildings? If *No*, why not?

11. Tell us more about the projects where you have used the Total Concept Method, please.

a) Can you provide examples of measures proposed in the action packages?

b) Can you provide examples of estimated total energy savings?

c) How many of the proposed measures are normally implemented (e.g. all, most, etc.)?

d) What can be a reason for finally choosing not to implement a proposed measure? (Economic or other reasons?)

e) Did you do a follow-up? If so, what has been the result in terms of energy savings and/or profitability?

12. What advantages and opportunities do you see with the Total Concept Method?

13. What challenges and disadvantages do you see with the Total Concept Method?

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Part 4: Other economic evaluation methods

14. What method/-s do you use for economic evaluation of energy renovation? Describe the method, please.

15. Tell us more about the projects where you have used this method, please.

a) Can you provide examples of measures that were implemented?

b) Can you provide examples of total energy savings (calculated or measured)?

16. What advantages and opportunities do you see with this method?

17. What challenges and disadvantages do you see with this method?

18. Are other benefits, besides energy savings, considered when deciding on energy renovation projects and individual measures?

(e.g. improved indoor climate, reduced peak power, increased property value)

a) How are they assessed?

b) Which KPIs are used?

c) Are these benefits assigned an economic value and included in the economic calculation?

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Part 5: Development needs

19. **Do you have any plans on developing the method you currently use for evaluation of energy renovation projects?**

20. **Do you think that you would benefit from a more comprehensive evaluation method that also considers other parameters?** Which ones?

21. **What is your thoughts on including the following parameters in such a method?**

    a) **Would it be valuable to include this parameter in the evaluation?**

    b) **Should it be monetized and included in the economic calculation?**

    Indoor climate:

    GHG emissions related to energy use in the building:

    Total GHG emissions (related to energy use in the building and materials):

    Smart readiness:

    Flexibility:

    Peak power:

    Occupancy rate:

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