REVALUE

Data-driven case studies into asset energy renovations

D2.6

13.02.2019

Deliverable	*2.6*
Title	*Data-driven case studies in to asset energy renovations*
Editor(s):	*Bax & Company*
Contributor(s):	*Savills, Maastricht University, Luwoge Consult*
Reviewers:	*RICS, Vanhier Accountants*
Type (R/P/DEC):	*R*
Version:	*v.3*
Date:	*13.02.2019*
Status:	*Final*
Dissemination level:	*PU*
Download page:	*http://revalue-project.eu/downloads/*
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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649705. The sole responsibility for the content lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EASME nor the European Commission are responsible for any use that may be made of the information contained therein.

Executive Summary

The REVALUE project collaborated with affordable housing providers in the Netherlands, Sweden, Germany and the United Kingdom to understand internal awareness and decision-making regarding energy efficiency in individual refurbishment investment projects and on a portfolio level. The data-driven cases studies, described in this report, explore the trade-offs between different asset energy renovation strategies and were developed in order to provide alternative views for the asset owners on the impact of energy renovation strategies. The case studies developed a custom investment-planning model, based on backcasting methodology, to project the impact of various investment strategies on key financial and energy indicators over different investment periods. The pathways allowed the exploration of: the impact of continuing current strategies (identified in a report identifying existing bottlenecks and scope for improvements in benchmark investment programmes[1]), and the impacts of alternative pathways such as increasing the annual renovation budget or taking advantage of economies of scale when investing.

The necessary asset, finance and other data from case study participants were collected and characterised and an analytical model was developed describing main EE improvement options for key dwelling archetypes. With key decision-makers from REVALUE study organisations[2], the investment policies and decision-making factors derived from the case studies, were later further explored. The joint outcomes of these tasks are reported in report called "Recommendations for housing providers on valuation techniques and strategies in their investment programmes", as practical insights to housing provider and other stakeholders on EE investment planning[3].

The report in hand, combines an overview of the methodology and outcomes of the 4 individual reports on "Data-driven analysis and strategies for asset energy renovation". Four confidential reports were produced for each individual REVALUE pilot country (the United Kingdom, the Netherlands, Sweden, Germany). The reports were built for comparing different strategies for asset energy renovations. The reports showed a miss-match between the current organisational sustainability goals and the current investment strategies – as BAU[4] approach did not achieve the set targets in the time frame envisioned in any of the cases. Thus, it can be concluded that backcasting is a valuable approach for housing associations, as it helps to set more realistic ambitions for asset energy renovation, by taking into account both operational and financial constraints.

[1] Report identifying existing bottlenecks and scope for improvements in benchmark investment programmes: accesible at http://revalue-project.eu/identifying-the-existing-bottlenecks-and-scope-for-improvements-in-benchmark-investment-programmes/
[2] http://revalue-project.eu/case_studies/
[3] http://revalue-project.eu/downloads/#presentationspublications
[4] Business as Usual approach

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Chapter 1 Introduction

The REVALUE project collaborated with affordable housing providers in the Netherlands, Sweden, Germany and the United Kingdom to understand internal awareness and decision-making regarding energy efficiency in individual refurbishment investment projects and on a portfolio level. The data-driven cases studies, described in this report, explore the trade-offs between different asset energy renovation strategies. The case studies developed a custom investment-planning model to project the impact of various investment strategies on key financial and energy indicators over different investment periods. The pathways allowed the exploration of: the impact of continuing current strategies (identified in a report identifying existing bottlenecks and scope for improvements in benchmark investment programmes), and the impacts of alternative pathways such as increasing the annual renovation budget or taking advantage of economies of scale when investing. Furthermore, the analysis presented the trade-off between the cost/energy savings of the alternative renovation ambitions. The case studies contribute to different tasks:

- The case studies were prepared in parallel with the work done in a report[5] identifying existing bottlenecks and scope for improvements in benchmark investment programmes, which provided insights into investors' decision-making process when preparing renovation programmes that integrate EE components. The results of this report were used in the final control group meeting with the housing providers, valuers and financiers, referred to therein in order to test the barriers to investing in EE.
- Using the case studies and pilot sites, recommendations were developed on investment programmes and value-driven strategies for investment planning for housing owners. The resulting recommendations were tailored to different levels: building portfolio level (for housing owners – test group), and for the housing sector in general. Mainly, this report provides insights for a questionnaire aimed at housing providers on the level of data and on how housing providers should collect their data in order to make long-term investment planning.

The main objective of those individual reports was to trigger investment in the social housing sector towards asset energy renovations, by showing the long-term impact and financial feasibility of different asset energy renovation strategies. The 'backcasting' approach was chosen as the methodology for conducting those analyses. The approach of backcasting takes final policy objectives as a starting point to define local transition pathways that could realistically achieve long-term goals. This approach allows moving from pilots into scaled processes. Furthermore, it helps organisations align expectations and better understand the constraints for reaching previously defined ambitions. The backcasting approach used in REVALUE aimed to highlight energy efficiency as a topic for integrated, board-level discussions on investment strategies. Using the backcasting methodology was made possible by the additional data gathered for analysis - a result of the project's ambition to go beyond EPC label and look also at component-level relations of EE and value. This high-level data-driven approach allowed to compare up to individual asset level.

The goal of this approach is to design investment programmes in the decision-making framework most relevant for the affordable housing providers. The main assumptions for the case studies were the following:

a) The affordable housing sector in the studied countries base their approach to refurbishment mostly on a strategy aimed at compliance;

b) A key factor in choosing to refurbish is the availability of cash-flow and required ROI;

c) Most housing providers see energy quality as contributing to health and well-being of tenants. However, the reduction of energy bills (associated with energy poverty) is an emerging factor.

The deliverable has been divided into two parts: i.) description of the methodology of the case studies; ii.) description of the results of the individual case studies.

[5] http://revalue-project.eu/identifying-the-existing-bottlenecks-and-scope-for-improvements-in-benchmark-investment-programmes/

Chapter 2 Methodology

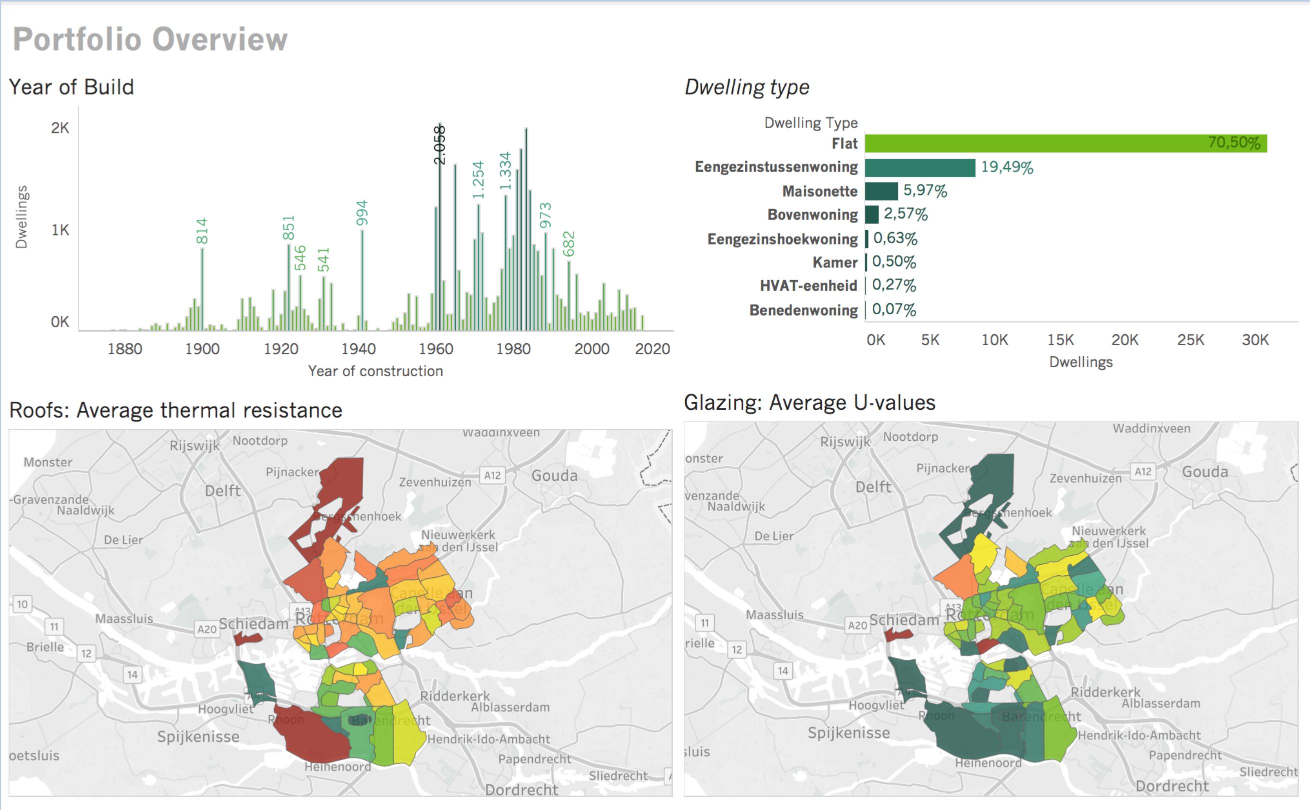
This chapter gives an overview of the methodology used for conducting the data-driven case studies for asset energy renovation.

2.1. General approach

Energy efficient renovations in the built sector are key to reducing energy consumption in the coming years. Around eighty per cent of the global building stock of 2050 has already been constructed and many of these buildings have very poor energy performance. With increasing concerns about the impact of energy consumption on the environment, energy efficient renovations become essential. The current rates of building renovation are insufficient to realise the levels of energy efficiency improvements needed to reach environmental and energy policy targets for the reduction of greenhouse gas emissions in the EU.

Housing associations are increasingly considering sustainability as a strategic objective. However, for many, it is a new topic that needs a level of technical expertise not typically yet present in the organisation, thus insights are not fully available at a strategic level. This data-driven analysis intends to connect the strategic concepts with analytical tools to provide first assessment for the organisation.

The objective of this analysis is to provide affordable housing associations with alternative strategies for long-term energy renovation investments. The proposals will be data-driven, based on an analysis of the portfolio building stock, and taking into account national and local policy requirements as well as organisation's financial constraints. Renovation package alternatives will balance the trade-offs between lifecycle costs and energy performance of available technologies.



Sample portfolio assessment dashboard

Depending on the needs of the housing associations, the individual case studies include:

1. **Assessment of the entire building stock**: a visual representation of the portfolio's main characteristics, including:
   - Categorisation of buildings by archetype and year of construction;
   - Distribution of energy performance or label disaggregated by various relevant factors such as build year; and
   - Mapping of the properties and geographical analysis of building clusters.

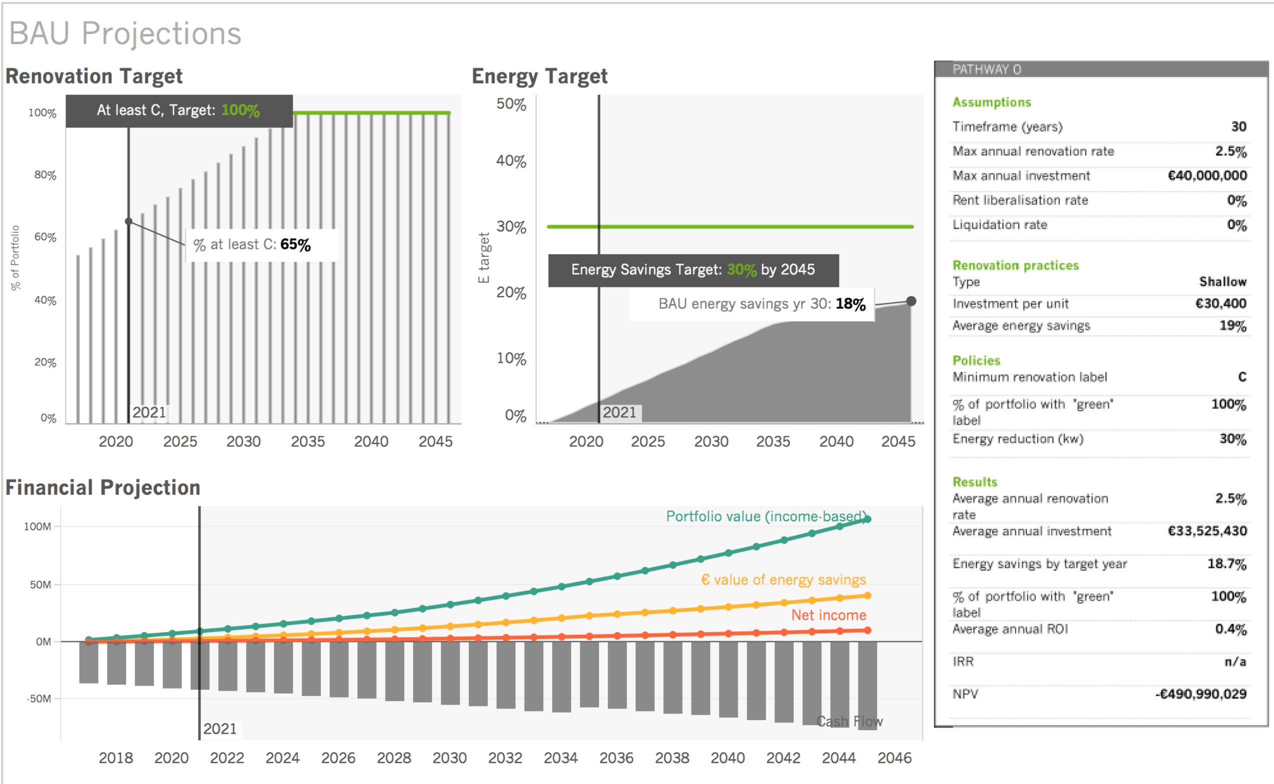
Purpose: To identify and prioritise opportunities for large-scale renovation of multiple buildings with similar needs where economies of scale can be achieved.

Value added: For many building owners, this will be the first time they will see their portfolios through an energy efficiency lens. Furthermore, the graphical representation will make it accessible to technical as well as financial decision-makers.

2. **Calculation of the gap to policy target**: A projection of organisation's ability to achieve long-term energy targets for its portfolio given current renovation practices. Based on:
   - A discussion with the portfolio managers about the typical decision rules for investment planning currently in use.
   - A set of locally relevant policy targets (including EU, national, local).

Purpose: To project the evolution of the portfolio in the long term under a Business-as-Usual (BAU) scenario.

Value added: With investments typically planned in 5-year increments, organisations lack insight into the long-term effect of their current short-term approaches, therefore being unaware of the likelihood of reaching targets.



Sample pathway dashboard

3. **Proposed renovation and investment pathways to achieve targets**: 3-4 alternative pathways to reaching policy targets. The pathways will be evaluated based on the most relevant KPIs on energy and financial performance and presented in a visual, interactive dashboard. Pathways will represent the most appropriate solutions to optimise each of the different factors considered, including:
    - Technological combinations (including passive and active technologies) given building energy renovation rules (minimum label/quality required);
    - Return on investment thresholds and the investment capacity of the building owner;
    - Location and typology priorities within the stock to achieve economies of scale.

Purpose: To provide viable alternatives to long-term investment planning under scenarios of fixed and flexible conditions.

Value added: Through a stylised interactive dashboard that integrates financial and technical indicators, decision-makers – managers, engineers, and CFOs - have a common language to discuss options and understand the relationship between internal priorities. A more detailed report supplements the dashboard.

2.2. Data

The basic condition for conducting the individual analysis was the availability of data, as it determines the depth and accuracy of the analysis. For example, the detailed component level information on individual asset allows to design more accurate renovation packages, from energy savings perspective as well from the perspective of investment costs.

The data categories necessary for conducting a basic long-term investment planning data-based analysis are the following:

i. At least one variable describing dwellings' energy performance quality (e.g. EPC label/SAP score/ kWh/m2 consumption etc.);

ii. Building type;

iii. Construction year of the dwelling;

iv. For this specific analysis the exact dwelling location was a necessary variable. It was used for mapping the dwellings, however, the analysis could also be done without the latter.

v. Usable area in m2 or an approximation.

In all cases, the housing providers had more data available. As seen in table 1, the data received from different housing providers varies in terms of data quality as well as in the amount of different type of data collected. The housing providers involved in the study typically have data on 10-20 building components, with data available on 50-100% of dwellings. The moment and method of data collection are usually not centrally registered. For very basic analysis, however, only 10-15 data points are necessary. Given the large number of units under management by partners, missing key data (property type, year of construction) could be cloned.

Data received from housing providers				
Type of data	Average data availability %			
	UK	Sweden	Netherlands	Germany
Property type	98,68%	100,00%	100,00%	100,00%
Year of construction	99,96%	100,00%	88,00%	100,00%
Window type	85,12%	76,74%	n/a	85,73%
Heat generator	75,50%	100,00%	100,00%	100,00%
Boiler install year/service	72,46%	0,00%	0,00%	0,00%
Boiler type	63,03%	0,00%	100,00%	0,00%
Roof type	47,90%	64,31%	99,00%	99,67%
Energy label	39,74%	97,32%	46,00%	99,67%
Fuel type	20,30%	100,00%	0,00%	100,00%
Wall type	15,39%	0,00%	0,00%	99,29%
Insulation type	20,85%	0,00%	88,00%	0,00%
Date of refurbishment	0,47%	48,68%	9,00%	15,49%
Floor type	0,12%	0,00%	0,00%	0,00%

Table 1 Example of collected data quality

For an appropriate level of analysis, more data points can be used. The additional variables can increase the accuracy of the long and short-term investment plans as the accuracy in matching the dwelling with specific characteristics with the most optimal renovation packages is improved. For achieving these matches the following data categories are desirable:

i. Component level information (window type, roof type, boiler type, etc.);
ii. Levels of insulation on different components;
iii. Date of refurbishment;
iv. Fuel type or heat generator in order to have more accurate CO2 reduction measurements.

2.3. Archetypes

Working with recognised building archetypes and age groups helps simplify analysis and scenario development, while recognizing the vast differences in building quality and renovation options in (large) house provider's building stock. In addition, using few archetypes helps to build visualisations and stock renovation plans for building easily understandable insights. The TABULA[6] methodology was used; the TABULA data structure provides data and a methodology for segmentation, which can serve as a template to determine typologies, with enough flexibility for country and regional adaptions. The level of aggregation depends on the respective country, the particular property market and the data allocated to the building types. Through an enhanced data basis that comprise more data provided to valuers

[6] http://episcope.eu/building-typology/tabula-structure/concept/

consideration of building EE can be supported and the data can be used to derive and adjust relevant input parameters used for valuation. Even the information about potential for EE improvements or existing limitations for specific building types could have an influence on the value. The method, created through a collaboration of national building technology institutes, recognises 4-6 main dwelling types per country, and describes the technical and energetic characteristics for typically 6 construction periods. In REVALUE, TABULA is used for categorising the dwelling stock, as well as forming the basis for describing building-specific shallow and deep energy efficiency retrofit options.

In the REVALUE project, the vast majority of dwellings analysed were flats in multifamily buildings, mid/end/terraced houses & semi-detached houses, with construction periods varying between 1871-2015.

2.4. Renovation Packages

To indicatively assess the relationship between refurbishments and energy savings that can be achieved at portfolio level, standard 'renovation packages' are modelled for most relevant TABULA typologies for study participants. These packages consist of combinations of renovation actions that lead to a certain gain in energy efficiency measured as the improvement of the dwelling's energy label. The packages are priced and linked to other indicators, including CO2 emissions, energy bill saving and energy consumption/production. To develop the renovation packages, participating housing providers were consulted for relevant energetic quality outcomes. From those starting points, national public renovation calculation tools were used[7] to generate indicative solution packages. These were verified and adjusted by housing providers, mostly to correct for price differences. In addition, the online tool developed by Luwoge was used as a reference.

Typically, 2 or 3 renovation packages were described for 3 building types and 3 construction periods; this usually covered 75% or more of a provider's stock. A typical renovation package describes 6 technical components: wall type, window type, roof type, heating system, ventilation and photovoltaic capacity. Pre- and post-renovation energy indicators in terms of labels/index, heating cost and CO2 emissions. Dwelling financial indicators included investment costs, and pre- and post-renovation value and rents.

[7] In the UK, Energy Savings Trust Calculator (accessible at: https://www.energysavingtrust.org.uk/resources/tools-calculators/home-energy-check) was used in combination with the information from local asset manager;
For the Netherlands, Energy Savings Browser created by the Netherlands Enterprise Agency;
For Sweden, case study examples were used from previous renovation projects "Persson, Agneta. Sustainable cities-Energy efficiency renovation and its economy. Stockholms stad, 2015." Accessible at: : http://webcache.googleusercontent.com/search?q=cache:ME_qjH-hdP4J:www.stockholm.se/PageFiles/299326/Sustainable%2520cities%2520-%2520Energy%2520efficiency%2520Renovation%2520and%2520its%2520Economy%25202015.pdf+&cd=1&hl=en&ct=clnk&gl=ae&client=firefox-b-ab
For Germany, the renovation packages information was provided by the housing provider (confidential document).
For the Netherlands the renovation packages were made using the tool available at https://www.verbeterjehuis.nl/

	FLATS			
	1. Shallow renovation		2. Deep renovation	
	Before	After	Before	After
Year built	1980s		1970s	
Investment cost (€/dwelling)	11700		14367	
Energy label	C	B	F	A
Components				
Windows	double glass	HR++ glass	single glass	HR++ glass
Insulation	none	Very good	none	Very good
Roof insulation	none	No change	none	No change
Ventilation	Mechanical	Balanced	natural	natural
Heating system	Gasverw.+geiser	HR Combi	VR-combi	HR Combi+ solar boiler
Solar panels (m2)	0	0	0	0
Energy impacts				
Energy costs (€/dwelling/month)	62	49	100	47
Energy index*	1,574	1,301	2,529	1,078
KWH (year)	4960	3920	8000	3760
CO2 kg *	2403	2036	3848	1555
Financial impacts				
Contract monthly rent*	615,7	709,1	549,2	716,3
Market monthly rent*	756,5	831	774,2	862,6
Unit Market value*	162450	205473	190530	224488

Table 2 Example of renovation packages for one typology

2.5. Modelling pathways for asset renovation

For modelling pathways for asset renovations by the organisation, two approaches were used. Forecasting the impact of currently applied renovation approaches or realistic alternatives, and backcasting from long-term energy quality objectives. The model allows selecting goals such as reaching certain CO2 savings, EPC label change, renovation priorities, etc. Furthermore, the organisation could set the minimum and maximum amounts of yearly investments, portfolio renovation rate and other operational and financial constraints. Energy impact averages are calculated for the entire portfolio, but not taking into account acquisitions or sales – only units already in the portfolio. In addition, the model allows to set maximum annual budget, limit to the portfolio renovation rate, typology priority, saving from economies of scale, inflation and other financial limitations.

Typically, for each case study, at least 3 different investment pathways were built. A first pathway based on the forecasting of the ´Business-As-Usual´ (BAU) approach, where long-term goals are projected against current renovation practices. A second pathway based on backcasting from current (medium-term ambition) long-term policy goals, identifying the lowest amount of financial resources needed. A third pathway would be based on likely future policy goals based on higher ambitions. The scenarios would run for timeframes relevant for the housing providers, typically 15-30 years.

Since most pathways do not require a renovation of the complete housing stock, additional pathways varieties included immediate start or latest possible start with renovation, and priorities for certain building types, building age or geographic sections of the building stock.

Scenario Assumptions	BAU	Pathway 1 (increase budget)	Pathway 2 (deeper renovations)
Max Annual Budget	€13.8m	€20m	€15m
Renovation priority (building)	shallow	shallow	deep
Timeframe	15 years	15 years	15 years

Table 3 Selected renovation pathway assumptions

Chapter 3 Collaboration with affordable housing providers

REVALUE collaborated with housing providers in four different European countries (the United Kingdom, Sweden, Germany, the Netherlands). For each pilot country, REVALUE prepared a case study report "Data-driven analysis and strategies for asset energy renovation" for selected housing providers, while the regression analysis was based on a wider sample of housing associations. The reports described the current state of the housing association portfolio, their institutional background and their sustainability related targets. In addition, for each case, a set of renovation packages was prepared that fitted the specific needs of the housing provider; these renovation packages were used for calculating the different investment pathways that could lead to the fulfilment of organisation's long-term sustainability goals. The report usually described 3 or more alternative pathways.

The following analysis will give an overview of the findings regarding the state of the social housing in the REVALUE pilot countries, secondly it will show which renovation pathways are most beneficial for the housing association and its tenants, and finally, where possible, the results are connected to the potential future value of the renovated stock in each pilot country.

Due to the signed non-disclosure agreements and sensitivity of some data, the full reports are not published on the REVALUE website.

Chapter 4 Overview of Individual Case Studies

4.1. The Netherlands

Policy Background: In the Netherlands, the social housing sector has set ambitious targets to reach an average energy label B (Energy Index 1,25) for the totality of their stocks by 2023 – with an aim to become energy neutral by 2050. As part of that, natural gas will be abandoned as source for heating and cooling. From an earning model perspective, the rents can only be increased when new tenants move in. The maximum allowed rents in the social housing sector is based on points system where energy efficiency counts but only with minor weight.

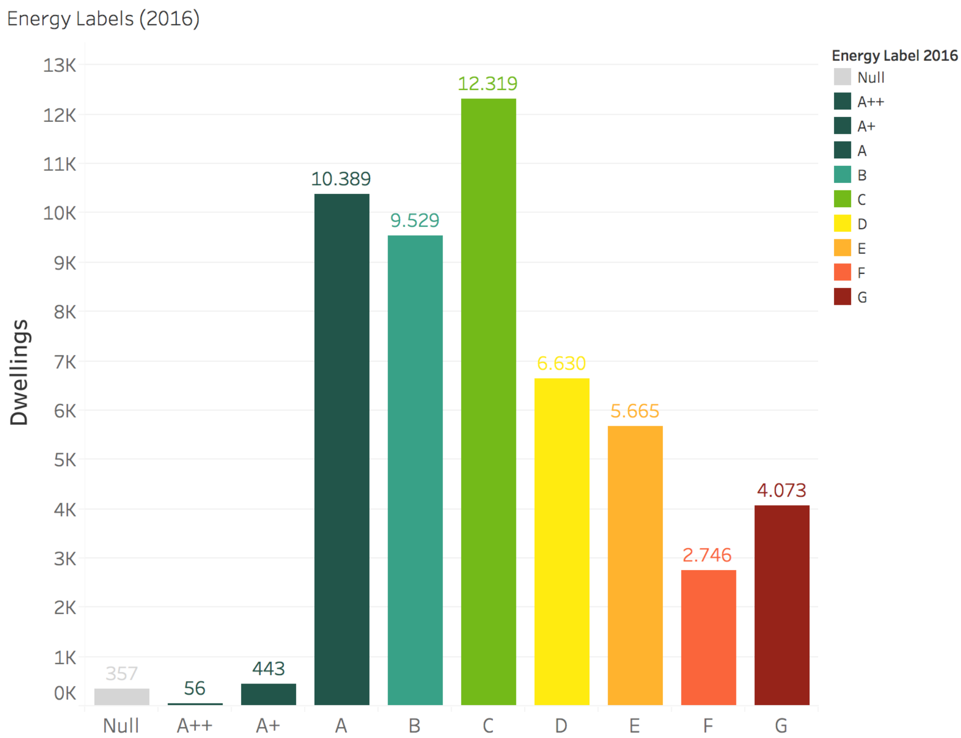


Figure 2 Overview of stock's energy performance

Portfolio Overview: The Dutch housing provider analysed is a social housing provider in the Netherlands with over 60,000 dwellings under management. More than 50% of the studied portfolio are multifamily buildings. The majority of the stock was built between 1950s and 1990s, with a concentration of late-50's and mid-80's buildings. 60% of the stock has an energy label of C or below, and 37% of dwelling have an EPC label D or worse.

Internal Sustainability Ambition: The housing association aims to reach an energy index of 1,25 (EPC equal B) from current 1,75; and 20% of CO2 savings by 2032 (in following 15 years).

	FLATS			
	1. Shallow renovation		2. Deep renovation	
	Before	After	Before	After
Year built	1980s		1970s	
Investment cost (€/dwelling)	11700		14367	
Energy label	C	B	F	A
Components				
Windows	double glass	HR++ glass	single glass	HR++ glass
Insulation	none	Very good	none	Very good
Roof insulation	none	No change	none	No change
Ventilation	Mechanical	Balanced	natural	natural
Heating system	Gasverw.+geiser	HR Combi	VR-combi	HR Combi+ solar boiler
Solar panels (m2)	0	0	0	0
Energy impacts				
Energy costs (€/dwelling/month)	62	49	100	47
Energy index*	1,574	1,301	2,529	1,078
KWH (year)	4960	3920	8000	3760
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Financial impacts				
Contract monthly rent*	615,7	709,1	549,2	716,3
Market monthly rent*	756,5	831	774,2	862,6
Unit Market value*	162450	205473	190530	224488

Figure 3 Example of renovation package for the Netherlands

Renovation Packages: For this particular case two main dwelling archetypes in stock are defined: a) flats, which correspond to multi-family homes with one floor and, b) houses, which comprise of all other archetypes in the portfolio. The entire social housing stock to be renovated (dwellings with EPC label C or below) was divided into four groups: C/D flats, C/D houses, E/F/G flats, and E/F/G houses. We focus on the most common construction year within each group to develop estimates for shallow (1-2 label steps) and deep (3+ label steps) renovations packages. Thus, the renovation packages cover approximately 50% of the entire stock. The renovation packages were designed based on the initial and EPC labels, window quality, dwelling type, heating type and the age of the dwellings. The reported renovation packages were presented to the housing provider to determine rough accuracy.

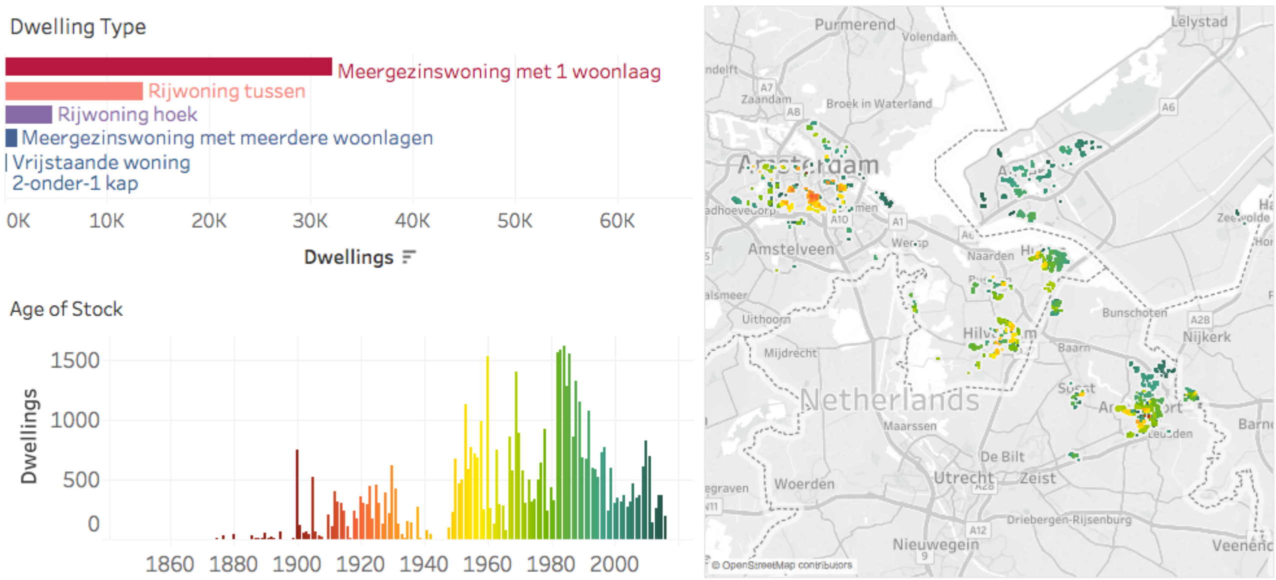

Figure 4 Overview of stock's typologies

Results: The current strategy is based on medium renovations, achieving label B. With a foreseen investment of €136 million over 15 years, the programme will reach CO2 reductions target in 2043, 11 years after target year. Therefore, there is a need to explore alternative approaches. The pathways explored suggest that deeper renovations are the more financially-viable approach for meeting organisation's sustainability goals. When following a strategy of prioritising shallow renovations, the objectives would be reached by increasing annual max investments by €6.2 million. This approach would achieve 20% CO2 use reductions by year 15, and total energy bill savings of €16.9 million. An alternative strategy focusing on deep renovations but investing only €1.2M more yearly would cover 9.882 (17%) dwellings at a cost of €225 million, and achieve €109 million in energy bill savings, with 20% CO2 use reductions. While it is the most cost-effective, fewer tenants would benefit from renovation under this strategy.

Social Benefit: In monetary terms, it could be concluded that the highest benefit in terms of reducing the tenants' total energy bill is associated with the pathway targeting deep renovations, as the total yearly energy bill savings and life time saving are the highest. However, in terms of overall comfort level and well-being, this pathway does not bring the best results. In pathway 1, the housing association would be able to bring up to 76% of its stock to energy label B. It has been argued that additional label steps do not considerably increase tenants' well-being and comfort.

Potential Rent Increase: As a social housing provider, the organisation is required to – and wishes to maintain – a discount over market rents. Units are leased at €600-€750 a month on average, which represents a 10-20% discount. Based on those numbers and average initial prices in portfolio, it was possible to estimate the hypothetical rent increase that in free market conditions the housing provider would be able to collect by the end of year 15. In both cases, BAU and in deep renovation scenario the cumulative rent increase would be almost equal to the total investments. Thus, over the building life time of 25 years, the housing association should theoretically be able to generate positive return on its investments in EE improvements.

Scenario Assumptions	BAU	Pathway 1 (increase budget)	Pathway 2 (deeper renovations)
Max Annual Budget	€13.8m	€20m	€15m
Renovation priority (building)	shallow	shallow	deep
Timeframe	15 years	15 years	15 years

Scenario Indicators	BAU	Pathway 1 (increase budget)	Pathway 2 (deeper renovations)
Total Investment	€135,979,013	€300,133,692	€225,000,000
Portfolio average energy index	1.59	1.26	1.28
CO2 savings	7.47%	20.13%	20.78%
% stock at least B	65%	76%	59%
Dwellings Renovated	12939	22676	9882
Cumulative rent increases	€140,822,064	€231,688,513	€220,859,395
total energy bill savings	€16,692,338	€44,821,389	€109,673,126
Lifetime energy savings	€56,211,633	€228,132,937	€569,114,942

Figure 5 Results of the comparative pathways

4.2. The United Kingdom

Policy Background: In the United Kingdom, the social housing sector is directly influenced by two UK´s policies: 1) Health and Safety; and by 2) the minimum standard for social housing assets established in 2006 by the Department for Communities and Local Government. In addition, in 2015, the UK government approved a new Energy Efficiency Regulation that sets out minimum energy efficient standards for any properties rented out in the private sector. The minimum energy performance rating has to be at least E on an EPC as of 1st of April 2018 for all new lets and renewals of tenancies, and for all existing tenancies from 1st of April 2020 (only applicable for private landlords). In addition, it is important to bring out that currently UK social housing has to decrease its rents by 1% a year until 2020, since 2016 (Welfare Reform and Work Act 2016).

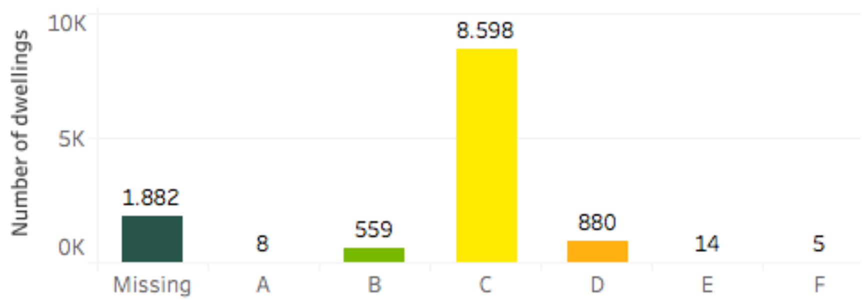

Figure 6 Overview of stock's energy performance

Portfolio Overview: The selected housing provider owns and manages over 12.500 homes in Manchester. The most common archetypes of dwellings in this portfolio are end-terraced houses (18%); cottage flats (17%); terraced houses (17%) and flats corresponding to the remaining 16% of the stock. These four types equal to 68% of the housing providers' stock. Moreover, there is a significant number of dwellings built in 1919 (14%). Nonetheless, the majority of the units were built between 1965 and 1985, equalling to 53% of the total stock. The majority of this housing provider's stock has energy label C (72%), which is above the average UK energy performance.

Internal Sustainability Ambition: The housing association did not have any clear sustainability ambitions. The driver for asset development and management is to achieve modern standards for its stock - meeting legal requirements - and to reduce energy poverty. Sustainability is understood in terms of EPC label and thus CO2 emissions. The Energy Performance ambition is to meet the minimum required EPC of C, SAP band 69-80. No specific targets and or tracking method have been set up to relate energy efficiency with energy poverty and tenants' comfort and health.

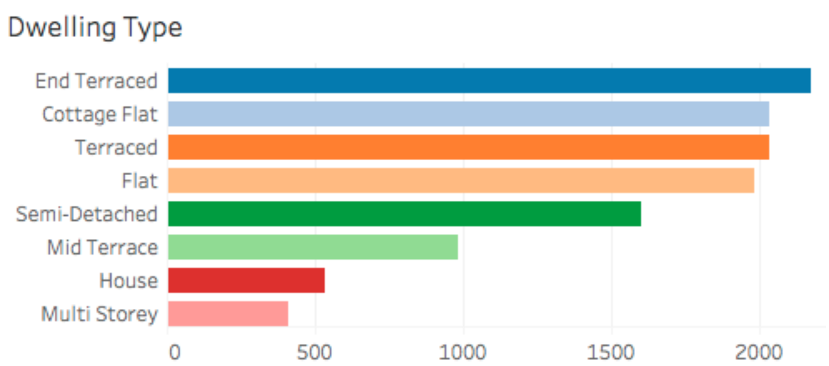

Figure 7 Overview of stock's typologies

	FLATS C		
	Current state	1. Shallow renovation	2. Deep renovation
Number of dwellings		2207	
Investment cost (€/dwelling)*		£690	£2.730
Energy label	C	C	B
Components			
Windows			
Doors		New insulated external doors	New insulated external doors
Roof insulation			
Heating controls		Thermostatic radiator valves or additional thermostatic controls	Thermostatic radiator valves or additional thermostatic controls
Heating system			Mains gas combi-condensing boiler
Lighting		Install remaining low energy lighting	Install remaining low energy lighting
Energy impacts			
Energy costs (£/dwelling/year)*	£1.100	£1.050	£970
Energy savings (£/dwelling/year)*		£50	£130
Energy consumption (kWh/year)*	11.678	11.147	10.298
CO2 kg/year*	3350	3.000	2.610

Figure 8 Example of renovation package for the United Kingdom

Renovation Packages: The dwellings in the portfolio have been grouped according to the two main archetypes and four construction periods. As the grouped dwellings will share similar construction characteristics and energy efficiency standards, they will fit within the same renovation packages: terraced and mid-terraced houses with a C label (1.176 buildings), end-terraced and semi-detached houses with a C label (1.757 buildings), all flat types with energy label C (2.207 buildings) and all housing types with an EPC label below C (778 buildings). The renovation packages were designed

Scenario Assumptions	BAU	Pathway 1 (Shallow renovation)	Pathway 2 (Deep renovation)
Max Annual Budget	£1.000.000,00	£1.000.000,00	£5.000.000,00
Timeframe	10 years	10 years	15 years
Scenario Indicators	BAU	Pathway 1 (Shallow renovation)	Pathway 2 (Deep renovation)
Total Investment		£10.000.000,00	£35.654.046,00
CO2 savings	6%	22%	41%
% targeted stock at least A	6%	30%	41%
% targeted stock at least B	12%	53%	64%
Total dwellings renovated	355	2781	3491
Total energy bill savings	£3.131.159	£4.608.050	£33.249.450
Lifetime energy savings	£7.828.967	£11.520.127	£55.415.750

based on average size of the dwelling, heating type, EPC label, dwelling typology and the year of construction, for all others there were not enough data on portfolio level to build accurate estimations.

Results: The current strategy approach prioritises older dwellings over newer ones, aiming to achieve a deep renovation. With a foreseen investment of £10 million over 10 years, the programme will reach 6% of CO2 reductions by 2027. It will bring 12% of the targeted portfolio to a B label or above and 6% to an A label. By prioritising shallow renovations over the same BAU s maximum annual investment and time frame will bring 53% of the targeted portfolio to a B label or above and 30% to an A label. Finally, prioritising deep renovations with a total investment of £5 million over 15 years will bring 64% of the targeted portfolio to a B label or above and 41% to an A label and achieving 41% of CO2 savings through the entire lifetime of the building considered to be 25 years.

Social Benefit: Similar to the Netherlands case, it can be concluded that deep renovations do not necessarily result in higher social benefits. The change that the distinctive pathways show is derived from different costs of individual renovations packages. Reaching very high-level standards of energy efficiency requires a high level of investments, while the benefits for tenant comfort and energy savings are not directly correlated to those investments, unless PV panels are installed, allowing for a positive energy bill.

4.3. Germany

Policy Background: The housing association is pursuing the objective of providing affordable rental apartments for broad sections of the population and increasing the municipal housing stock as set out by the city of Berlin. Furthermore, the city also set the long-term sustainability targets that the organisation needs to comply with. A main long-term driver for sustainability could become the announcement of the city of Berlin in early 2018 to achieve climate-neutrality by 2050. Local rent regulations (based on the Mietspiegel) provide a limited range of rents mostly based on location and size of dwellings.

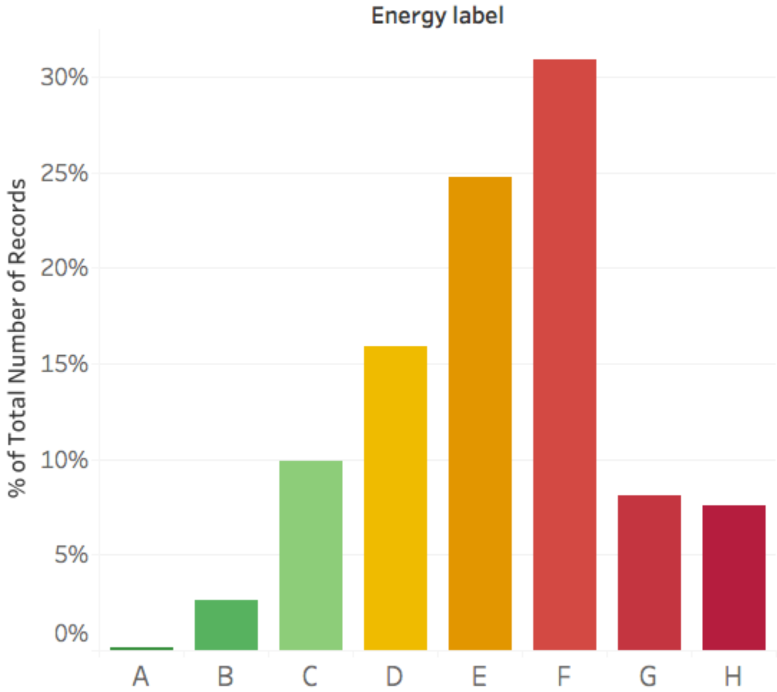

Figure 9 Overview of stock's energy performance

Portfolio Overview: This housing provider is a Berlin-based state-owned provider of affordable housing. It manages nearly 70,000 dwellings. From Figure 7, it can be seen that just 29% of its stock is above the energy label D. The large majority of the stock, a 56% (2.063.943 m2), fits the consumption's range of the energy label E (384 buildings) and F (480 buildings). All dwellings are flats in apartment blocks.

Sustainability Ambition: Organisations' short/long-term sustainability targets pursue the city's goal to become a climate-neutral city by 2050. Initially, the city set that on average in order to reach the set target all existing buildings should reduce their energy consumption by 77kWh/m2 by 2050. Furthermore, the average energy consumption of a dwelling in Berlin should be lower than 123kWh/m2 by 2050[8]. However, the organisation is also exploring ways to renovate its' dwellings to NZEB in the long-run.

	Square meters with an average EPC E (1920 to 1949)		
	Current state	1. Shallow renovation (Energetic refurbishment)	2. Deep renovation (Complete modernization)
Total m2 within this package		1133	
Investment cost (€/m2)*		€500,00	€1.100,00
Energy label	E	D	D
Energy impacts			
Energy costs (€/m2/year)**	€14	€13	€13
Energy savings (€/m2/year)**		€2	€2
Energy consumption (kWh/m2/year)**	140	122	122
CO2 kg/m2/year*	0,04	0,04	0,04

Figure 10 Example of renovation package for Germany

8 Für ein klimaneutrales Berlin: Entwurf für ein Berliner Energie- und Klima- schutzprogramm (BEK) Kurzfassung des Endberichts

Renovation Packages: The target portfolio of the portfolio is defined based on two scores from an organisation's internal assessment: having a building standard below the score of 300 and having a score above 30% for the maintenance condition. Overall, this accounts for 8% from the total stock. The objective of the renovation is to get all the targeted buildings to EPC label D (123kWh/m2). Given the various characteristics of the buildings, prices differ across the different construction periods. For each of those groups, one energy related renovation package was developed (shallow renovation) and one for called deep renovation, which reached the same energy performance but where other maintenance work was done as well. Due to the low level of data the renovation packages were based only on the EPC label.

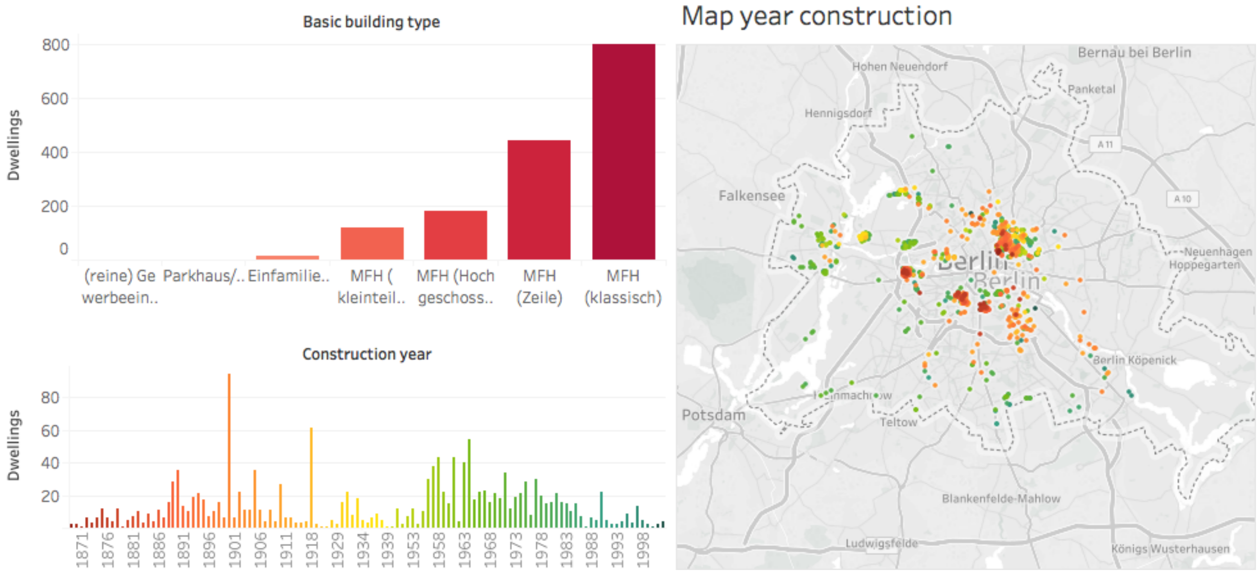

Figure 11 Overview of stock's typologies

Scenario Assumptions	BAU	Pathway 1 (Shallow renovation)	Pathway 2 (Deep renovation)	Pathway 3 (Shallow renovation)
Max Annual Budget	€40.000.000,00	€75.000.000,00	€90.000.000,00	€45.000.000,00
Timeframe	5 years	5 years	10 years	30 years
Scenario Indicators	BAU	Pathway 1 (Shallow renovation)	Pathway 2 (Deep renovation)	Pathway 3 (Shallow renovation)
Total Investment	€200.000.000,00	€135.941.254,00	€265.728.374,00	€1.232.021.709,00
Total renovation rate	0,9%	1,5%	2%	2%
CO2 savings	5%	17%	17%	16%
% targeted stock at least D	60%	100%	100%	100%
Total square meters renovated	166.667	276.229	276.229	2.364.743
Total energy bill savings	€1.666.666,65	€3.546.975,15	€7.093.950,30	€166.781.275,17
Lifetime energy savings	€8.333.333,33	€17.734.875,67	€17.734.875,67	€5.003.438.250,00

Results: Projecting an organisation's current "hypothetical" (D2.3) investment strategy (BAU) over the long term shows a low performance in energy efficiency improvement, leading to a small percentage of CO2 savings. It will bring 60% of the targeted portfolio to a D label, reaching 5% of CO2 savings in 5 years. Increasing the annual investment to €75M over the same timeframe would allow renovating 100% of the target portfolio to an energy label D and bring 17% of CO2 savings. The fourth pathway proposed considers all the square meters with an energy label below D and average consumption higher than 123 kWh/ m2 without any constraint of building standard nor maintenance condition (64% of the stock). Prioritizing shallow renovations with an annual investment of €45M over 30 years would allow to renovate 100% of the target portfolio to an energy label D and achieving the 16% of CO_2 savings.

Social Benefit: In this case, as shallow and deep renovations do not lead to different energy performance indicators, it is not possible to take into account the social benefits of choosing different renovation packages over another.

4.4. Sweden

Policy Background: In the Swedish building sector the energy and/or carbon reduction targets as a policy is set, on voluntary basis, to reach at least energy savings of 12% to 25% for heating and hot water of final energy consumption by 2020. In addition, it should be noted that, in Sweden, the property owner predominantly pays for energy and hot water costs as operational costs[9].

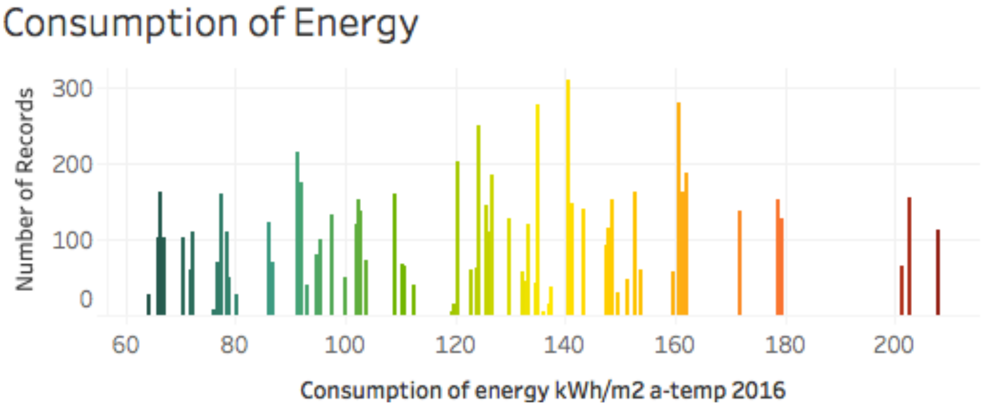

Figure 12 Energy consumption overview

Portfolio Overview: The Swedish housing provider analysed owns 7866 dwellings spread throughout Stockholm's city centre and its close surroundings including Sundbyberg and Kista. It is necessary to underline that this organisation does *not* collect EPC label data. The energy data was stored in kWh/m2. The main archetype in this portfolio are flats in apartment blocks. The year of construction varies between 1883 to 2016. About 68% of the stock has been built after 1950. The stock has a consumption of energy that greatly varies, in many cases exceeding the proposed aim of a portfolio average target of 135 kWh/m2.

Internal Sustainability Ambition: The organisation's 5-year goal is to reach average energy consumption to 135 kWh per square meter a year, this corresponds to overall energy savings of 25%. This is based on an internal five-year environmental plan that defines goals and ambitions. Currently 60,7% (4776 units) of stock comply with this goal. The latest plan (2015-2019) includes key areas such as sustainable energy use, sustainable water use, sound indoor environment, resource and environmentally efficient waste treatment, environmentally sound chemical use and efficient transports.

[9] Revalue D1.1 Overview of National and European Valuation Techniques

	RENO PACKAGE 2: 1965-1980 (150-170 KWh)	
	Current state	Renovation actions
Number of dwellings	49980	
Renovation costs		
Associated costs		
Investment cost (SEK/m2)*		900 SEK
kWh a-temp/m2	152	115
Components		
Heating system		New heating distribution system and heat exchanger
PV panels		(500) m2 PV
Wall		Additional insulation interior walls
Windows		
Radiator		Radiator thermostat valves
Ventilation system		Balanced ventilation system with heat exchange
Energy impacts		
Energy costs (SEK/m2/y)*	162 SEK	122 SEK
Energy savings (SEK/m2/y)*		40 SEK
Energy consumption (kWh/y)*	152	115

Figure 13 Example of renovation package Sweden

Renovation Packages: The portfolio has been divided into four groups based on average energy consumption intervals and construction periods. i. flats in apartment building: 1965-1980 with energy consumption between 109-150 kWh; ii. flats in apartment building: 1965-1980 (e.g. figure 14) with a consumption between 150-170 kWh; iii. flats in apartment building: 1981-1990 with a consumption of 120 kWh; iv. Flats in apartment building: 1991-2000 with a consumption of 165 kWh. Due to the languages barriers, it was only possible to construct one type of renovation packages for each of the focus groups. The renovation packages were based on three main data components that were available for size, dwelling energy consumption and age of dwelling.

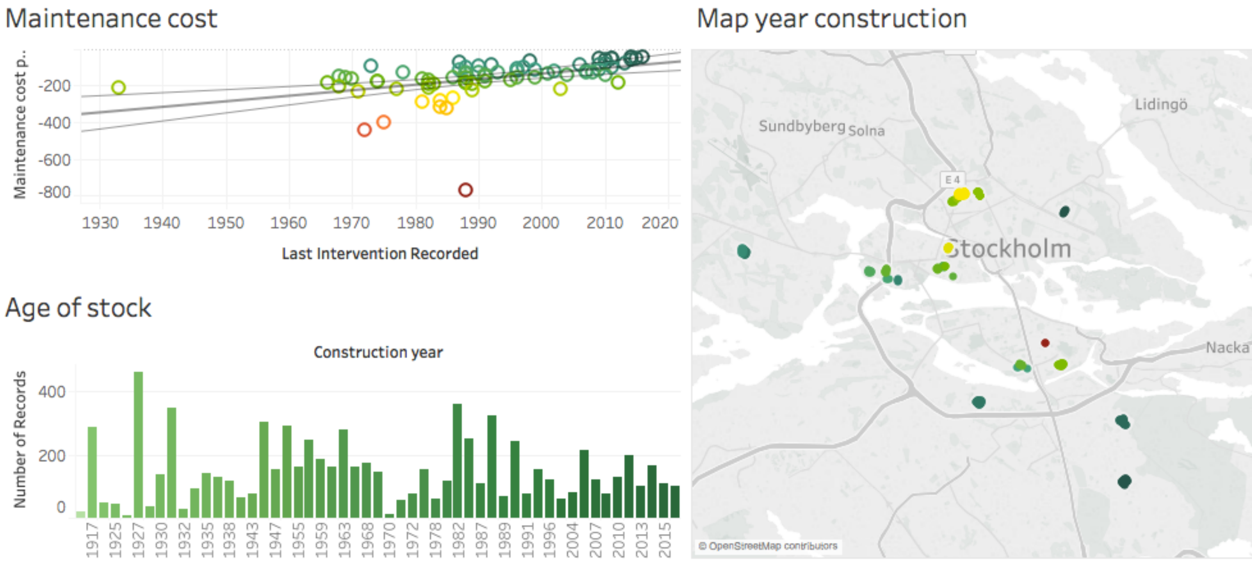

Figure 14 Overview of stock's typologies

Results: The current 5-year investment strategy over a long term shows that the set target to reduce energy consumption by 25% will not be met until 2035, that is 15 years after the initial target year. After 5 years, 70% of stock will be consuming the maximum energy of 135 kWh/m2, having renovated 736 dwellings and accomplishing 4,5% CO_2 savings. Therefore, there is a need to explore alternative approaches. On the one hand, doubling the maximum annual investment while maintaining the same period of 5 years will not mean a significant difference over the BAU. The maximum annual budget will need to increase up to SEK 60 million over the same period of five years, in order to achieve a 97% of stock reaching at least 135 kWh/m2 and accomplish a 17% of CO_2 savings. On the other hand, increasing the annual budget to SEK 30 million and a period of time to 15 years will achieve a 94% of stock being at least 135 kWh facilitating the renovation of 2585 dwellings and accomplishing 19,6% CO_2 savings.

Social Benefit: In Sweden the rents already include heat bills, so the renovation strategies do not lead to a direct benefit for tenants in term of energy bill savings. Nevertheless, the reduced CO_2 and better comfort levels after the renovations are beneficial for the tenants. Therefore, from a social perspective, the most beneficial pathway is the one that reached the highest number of renovations.

Scenario Assumptions	BAU	Pathway 1 (increase budget)	Pathway 2 (increased budget and time)
Max Annual Budget	SEK 10.000.000,00	SEK 20,000,000	SEK 30.000.000,00
Timeframe	5 years	5 years	15 years

Scenario Indicators	BAU	Pathway 1 (increase budget)	Pathway 2 (increased budget and time)
Total Investment	SEK 50.000.000,00	SEK 100.000.000,00	SEK 450.000.000,00
CO2 savings	4,5%	6,2%	19,6%
% targeted stock at least 135 kWh	70%	73%	94%
Dwellings Renovated	736	995	2585
Total energy bill savings	SEK 2.087.395,15	SEK 3.276.403,57	SEK 4.437.117,86
Lifetime energy savings	SEK 52.184.878.79	SEK 81.910.089,29	SEK 110.927.946,43

Chapter 5 Conclusions

Due to increasingly ambitious sustainability policies at European and national levels, housing associations are driven to integrate energy performance objectives in their strategies and asset management programmes. Examples include long-term goals, such as energy neutrality by 2050 in the Netherlands and cities in Germany. Interactions during the REVALUE project showed however that in most cases, planning is currently limited to 1-2 budget cycles of 4 or 5 years each, with aspirational explorations of longer-term vision. While broadly fitting under the label social or impact investment, quantified decision-making frameworks are not yet widely used.

Backcasting methodology applied to larger housing providers in different countries confirmed that this approach is meaningful for housing associations that own more than 5000 dwellings, especially if the portfolio consists of variety of archetypes and constructions periods, and finally if policy allows either more or less ambitious renovation strategy. Therefore, this approach seems to be most applicable for countries with large affordable housing stock with long traditions, such as the UK, the Netherlands, Germany, France and Italy. The approach seems less suitable for countries with low variety in building styles, such as Nordic and Eastern European countries.

5.1. Conclusions on methodology:

- The data-driven analysis provided additional value for the housing providers, whose operational management tools typically do not allow comparison of scenarios nor provide combined analysis of the entire stock.
- Approach has limited value for assessing the future value of the stock, because reference market values are dynamic over time, therefore not applicable for estimations looking more than 10 years ahead. Extrapolation of the point estimates to different property types, and/or properties exposed to different markets and regulations is prone to be inaccurate.
- At best, the housing providers are currently making clear investment plans for the coming 4 years. At worst, the programmes lack clear guidelines and objectives, which reduces the value of backcasting methodology. However, as national governments are setting increasingly higher and more long-term goals, organisations need to change their current practices in order to make sure to meet compliance 20 years from now.
- The BAU[10] approach did not achieve the set targets in the time frame envisioned in any of the cases. This is mainly due to operational constraints limiting the yearly renovation rate, not reaching the total stock in set time frames, and due to an approach starting with 'low-hanging fruit'. Easier, lower-cost renovations are usually done first, postponing more complex, and expensive interventions.
- The analysis helped to connect the entire organisation in decision-making, from the board-level strategy development team to technical staff, thus connecting the organisation both vertically and horizontally, by allowing for clear communication with the entire team (for more details consult D2.3[11]).
- Data is fragmented and of unknown quality; part of the findings is that there is not always enough data available, thus it is necessary to rely on assumptions and key data points. During the process of analysis, the method was simplified, but still allowing for reasonably accurate insights. From the initial approximate 50 necessary data points, this number was reduced to almost 10 by the end of the analysis. This was mainly due to the fact that most housing providers did not hold as much data as was expected. For an overview of the data lists, please see the Annex 1.
- The approach allowed to quantify both sustainability gains as well as the benefits for the tenants.

Overall, it can be concluded that backcasting is a valuable approach for housing associations. It helps to set more realistic ambitions for asset energy renovation, by taking into account both operational and financial constraints. Secondly, by bundling together both technical and strategic aspects of a housing provider's vision, organisational alignment is

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[10] Business as Usual approach
[11] Report identifying existing bottlenecks and scope for improvements in benchmark investment programmes: accesible at http://revalue-project.eu/identifying-the-existing-bottlenecks-and-scope-for-improvements-in-benchmark-investment-programmes/

encouraged in the decision-making process. This, in turn, ensures that the set vision is also translated to all departments, and the set goals will also be implemented over the coming years.

Chapter 6 Annex 1 – Necessary data

Overall, the resultant categories are the accomplishment of a joint effort between 4 different stakeholder groups actively working with housing stock owners: professional valuers, EE consultants, strategic consultants and accountants. The list of data collected was categorized into "necessary", "important" and "wish list" data. This differentiation enables a proper comparison of building archetype components that can be valuable to energy consultants and valuers alike. Furthermore, this categorization and standard way of collecting data diminished data fractioned files and thus time-consuming conversions in order to reach general conclusions. The necessary data list has also been reduced considerably. For example, instead of the initial 40 necessary technical components, only 9 are now part of the "necessary" data collection list, while other 11 were removed completely. These 9 data points allow for a basic assessment of the portfolio renovation options, however, it will not allow for a very deep analysis. Therefore, the "important" data list is highly desirable, as it allows for more accurate investment and renovation planning.

Regarding the breakdown of different component types, the results varied by organisation. For example: for a window type in the UK the most common variables reported were: double glazed or single glazed window. In the Sweden the information was broke down based on the window frame type and not based on glazing. Same applies also to all other data set, there was no common denominator between the countries.

Initial data collection list

Item	Data source	Name/example
General information		
Identifier (dwelling, building)	Asset management data	UPRN
Location	Asset management data	Address, coordinates
Usable area	Asset management data	m2
Number of units in the building	Asset management data	Number of flats in a building.
Basic building type	Asset management data	Archetype / Multi family home, Terraced house, etc.
Level individual apartment	Asset management data	Floor
Number of stories in the dwelling	Asset management data	Number of floors
Rooms of the apartment	Asset management data	3
Construction year	Asset management data	1975
Date of refurbishment	Asset management data	Last renovation / 2001.
EPC rating	Asset management data	EPC, SAP in the UK, Energy Index in the Netherlands
Date of energy survey	Asset management data	2010
Financial information		
Valuation (two moments/years)	Financial data	amount and date of valuation.
Valuation method	Organisation policy/setting	RICS-based valuation method: description of valuation practices e.g. frequency, internal/external appraiser, etc.
Tenant turnover	Organisation policy/setting	
Vacancy (long term)	Organisation policy/setting	
Voids / defaults	Organisation policy/setting	
Long term inflation	Organisation policy/setting	
Nominal Discount Rate	Organisation policy/setting	
Tenant category	Financial data	Tenant category
Rent (actual)	Financial data	Bruto amount rent contract incl. VAT / 500euros
Energy bill payment	Organisation policy/setting	
Maintenance costs	Financial data	
Management costs	Financial data	
Other operational costs	Financial data	
Building standard		Poor, Fair, Good, Excellent
Badrooms - last renovation	Asset management data	
Kitchen - last renovation	Asset management data	
Maintenance condition	Asset management data	
Building envelope		
Roof (install, replacement dates)	Asset management data	Roof type, roof thickness
Wall insulation (install, replacement dates)	Asset management data	Wall thickness
Window-quality (install, replacement dates)	Asset management data	Windows / double glazing, single glazing, etc.
Building services		
Ventilation type	Asset management data	Mechanical, natural, etc.
For one or several heaters installed in a dwelling:		
Heat generator	Asset management data	Central heating, etc.
Energy carrier	Asset management data	Gas, electricity, etc.
Efficiency system	Asset management data	Generator
Age of heating system	Asset management data	Install, replacement date
Solar thermal system	Asset management data	Install, replacement date
Electricity from PV	Asset management data	m2, install date.

Final data collection list

	Data type	Example
Necessary	Identifier (dwelling, building)	UPRN
	Location	Address, coordinates
	Usable area	m2
	Number of units in the building	Number
	Basic building type/ Archetype	Single family house, Terraced house (single family), Multi-family house and Apartment block.
	Number of stories in the dwelling	Number
	Rooms of the apartment	3
	Construction year	1975
	EPC rating	EPC, SAP in the UK, Energy Index in the Netherlands
Important	Roof (install, replacement dates)	Roof type, roof thickness
	Date of refurbishment	Last renovation / 2001.
	Maintenance costs	Building-specific, physical, material costs
	Heat generator	Central heating, etc.
	Wall insulation (install, replacement dates)	Wall thickness
	Window-quality (install, replacement dates)	Windows / double glazing, single glazing, etc.
	Ventilation type	Mechanical, natural, etc.
	Energy carrier	Gas, electricity, etc.
	Efficiency system	Generator
	Solar thermal system	Install, replacement date
	Electricity from PV	m2, install date.
Wishlist	Tenant turnover	
	Vacancy (long term)	
	Voids / defaults	
	Long term inflation	
	Nominal Discount Rate	
	Tenant category	Tenant category
	Energy bill payment	
	Management costs	Overhead, related to interaction with tenants
	Other operational costs	
	Maintenance condition	Poor, Fair, Good, Excellent
	Refurbishment costs	Estimates amount required to meet regulatory minimum standards