RENOVATING GERMANY'S BUILDING STOCK

AN ECONOMIC APPRAISAL FROM THE INVESTORS' PERSPECTIVE

BPIE

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- Deutscher Mieterbund (DMB) - The German Tenants' Federation
- Bundesverband deutscher Wohnungs- und Immobilienunternehmen (GdW) – Federation of the German Housing and Real Estate Industry
- Global Climate Forum
- Institut für Umwelt- und Energieforschung (Ifeu) – Institute for Energy and Environmental Research
- Naturschutzbund Deutschland (NABU) – Nature and Biodiversity Conservation Union
- Verband Privater Bauherren (VPB) – Federation of Private Building Owners
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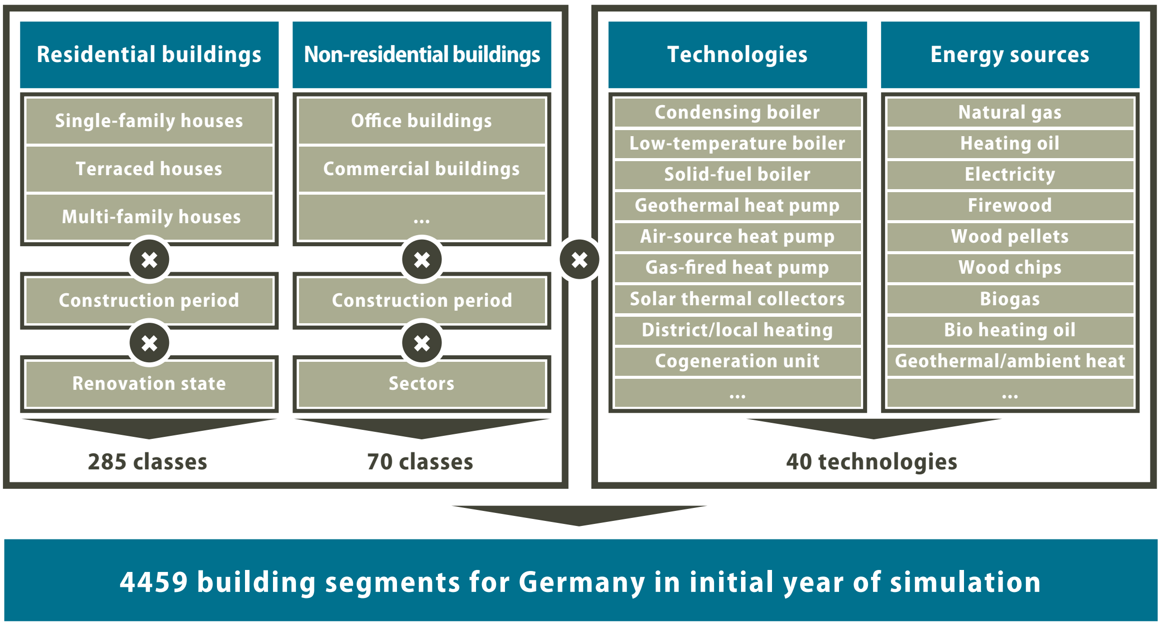
EXECUTIVE SUMMARY

In order to inform the policy debate concerning Germany's renovation strategy for the existing building stock, this report investigates a number of scenarios for improving its energy performance. Our focus is on the economic viability of different levels of renovation from the perspective of the investor or building owner. Results are plotted in Energy-Saving Cost Curves (ESCC) as a quick and simple visualisation tool to assess the potential impact of different combinations of policy levers.

Germany's buildings account for 40% of final energy use and are the source of 30% of the country's greenhouse gas (GHG) emissions. Improving their energy performance can substantially cut energy use, while delivering multiple benefits – cost savings, job creation, improved energy security, increased comfort, better productivity, as well as environmental benefits in the form of improved air quality and lower GHG emissions. However, at the current renovation rate of 1% of floor area each year, it would take 100 years to renovate the existing stock. Furthermore, most renovations do not achieve the full energy-saving potential at present.

The starting point for the analysis in this report is the categorisation of the German building stock according to a number of representative building typologies. The figure below shows the breakdown by building type and heating system. In total, 355 building classes and up to 40 possible combinations of energy sources and heating technologies generate 4459 building segments.



The energy refurbishment potential for each of these building segments is assessed, for three renovation levels: standard, moderate, and ambitious. The methodology adopted in this study has been to focus on comprehensive renovation of the building envelope combined with replacement of the heating system. Partial renovations or single measures are not considered. The associated costs and energy savings for each of the three renovation levels for each reference building are calculated.

An optimisation model is then used to select the least costly renovation option for each building segment for a given set of economic conditions. The factors considered in the analysis are summarised in the table below.

Variable	Description	Range applied in model
Energy-price evolution	Increase in the real retail price of energy from 2015 to 2030	1.1% - 2.6% per annum (equivalent to 19% - 50% total increase to 2030)
Subsidy levels	Grants, implicit value of loan, or other external financial support as a % of total capital investment	0-40%. Varies by technology and renovation package
Transaction costs	Costs associated with preparatory work, planning costs, approvals, etc., including staff time	2.5-5% of total capital investment
Discount rates	Cost of borrowing to finance energy-saving investment	2-4%
Learning and cost reduction	The impact of future price reductions resulting from increased sales volumes, more efficient installation procedures, improved productivity or R&D resulting in new and better ways of saving energy	6-38%, depending on technology
Co-benefit	The value of increased comfort (=forgone energy savings) resulting from installation of renovation measures, valued at the prevailing price of energy	0-30%

Reference buildings are then grouped into 16 building categories:

Building categories
Single-family houses (SFH): split into four age bands (up to 1948; 1949-1978; 1979-1994; 1995-2014)
Multi-family houses (MFH): split into four age bands (up to 1948; 1949-1978; 1979-1994; 1995-2014)
Offices: split into public and private sector
Hospitals: split into public and private sector
Educational buildings: split into public and private sector
Retail buildings
Other non-residential buildings

For the purposes of examining the impact of different economic parameters on the cost effectiveness of building renovation from the investors' perspective, five scenarios were developed, three of which are described in this summary. For a full description of all five scenarios and a comparison across the scenarios, please see the full report.

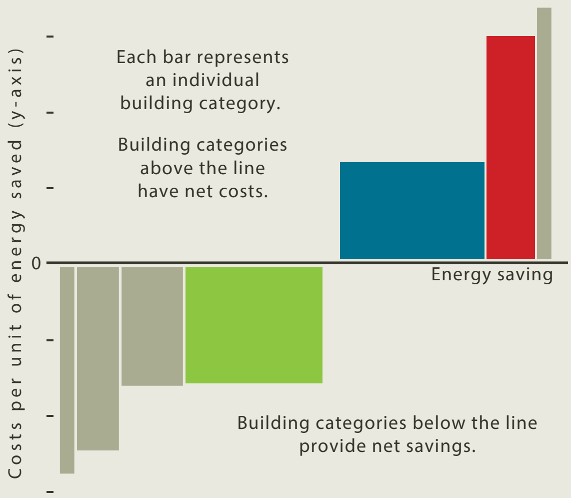
The time horizon of the analysis is to 2030. This is a sufficiently long timescale for the full impact of policies to be witnessed, yet not so long as to necessitate unrealistic assumptions to be made about longer-term technological developments and the evolution of costs of measures and energy prices that may radically change the economic landscape for building renovation. Clearly, within this timeframe, it would only be possible to renovate a proportion of the existing stock, so the results presented in this report should not be considered as being the limits of what can be achieved in terms of energy savings and GHG-emissions reductions from the existing building stock.

A novelty introduced in the present analysis is the comparison of the resulting economic attractiveness of comprehensive renovation both with and without the value of increased comfort gains in the economic appraisal. Extensive evidence shows that occupants enjoy higher internal temperatures following improvements to the building fabric's energy performance – often referred to as the rebound effect. In doing so, they are forgoing the full potential level of cost savings they could have achieved. It is therefore justifiable to argue that occupants place an economic value on the extra comfort that is equivalent to the forgone energy savings. The purpose of doing so within this study is to raise awareness of the desirability of including not only the value of comfort, but also of the many other co-benefits that arise when buildings are renovated. We therefore present results both with and without the comfort benefit, which has been calculated as being worth an additional 30% on top of the energy cost savings. This figure is based on research into the actual temperature increase following building renovation.

The results of the analyses are presented in Energy-Saving Cost Curves which provide a visual representation of the range of cost effectiveness of renovation across a range of building categories.

HOW TO INTERPRET THE ESCC PLOT

The Energy-Saving Cost Curve (ESCC) is a visual representation of the cost effectiveness of building renovation across a spectrum of building categories. The horizontal axis displays annual energy savings for each building category, while the vertical axis shows net costs per unit of energy saved.



If the bar is **above** the horizontal axis, there is a **net cost** for investors in that building category, meaning that the energy-cost savings over the lifetime of the measure are less than the initial investment. Conversely, if the bar is **below** the axis, there are **net savings**. The total cost or total saving for a building category is represented by the area of the bar (i.e. cost per unit of energy saved times the energy saving).

Note that each bar represents a large number of different buildings, each with its own cost-effectiveness result. This means that, for example, a building category that is above the axis (i.e. net cost) could include individual buildings that produce net savings.

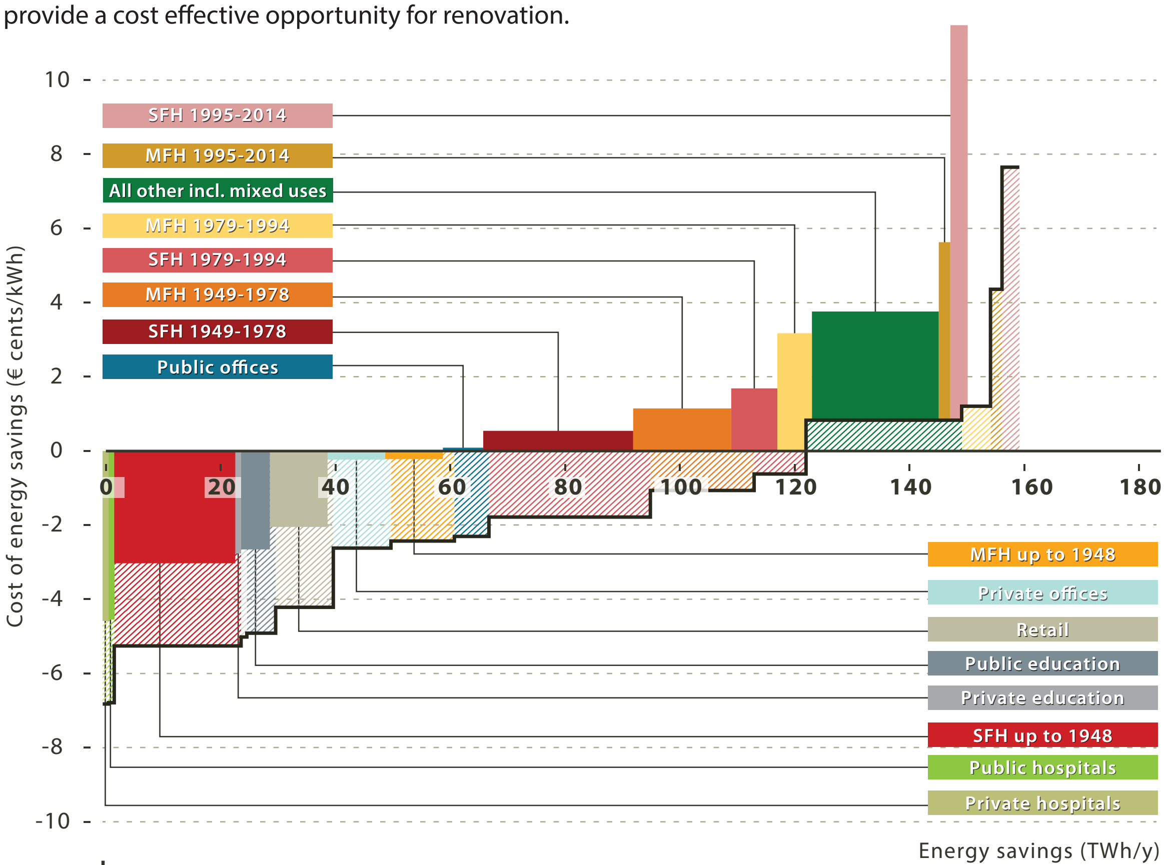
In the scenario results themselves, we plot two curves overlaying each other. The solid blocks present the results when only the energy cost savings are taken into account, while the shaded blocks include the value of the comfort co-benefit in the economic appraisal.

Business as Usual

This scenario assumes the prevailing economic conditions, summarised in the table below, are maintained throughout the period in question.

Subsidies	Transaction costs	Discount rate	Measure cost decrease to 2030	Energy price increase to 2030
10-25%	5%	4%	6-25%	1.1% p.a. (equivalent to a total increase of 19%)

The ESCC plot shows the spread of cost effectiveness of the 16 building categories. Without the co-benefit (solid blocks), only half of the building categories are cost effective, but including the co-benefit the number increases to 12. The two least cost-effective building categories are single-family and multi-family houses constructed since 1995. Given that these buildings already are relatively energy efficient and should not require significant maintenance in the period to 2030, it is not surprising they do not provide a cost effective opportunity for renovation.



Solid colour = no co-benefits | Shaded + black outline = with co-benefits
SFH = single-family houses | MFH = multi-family houses

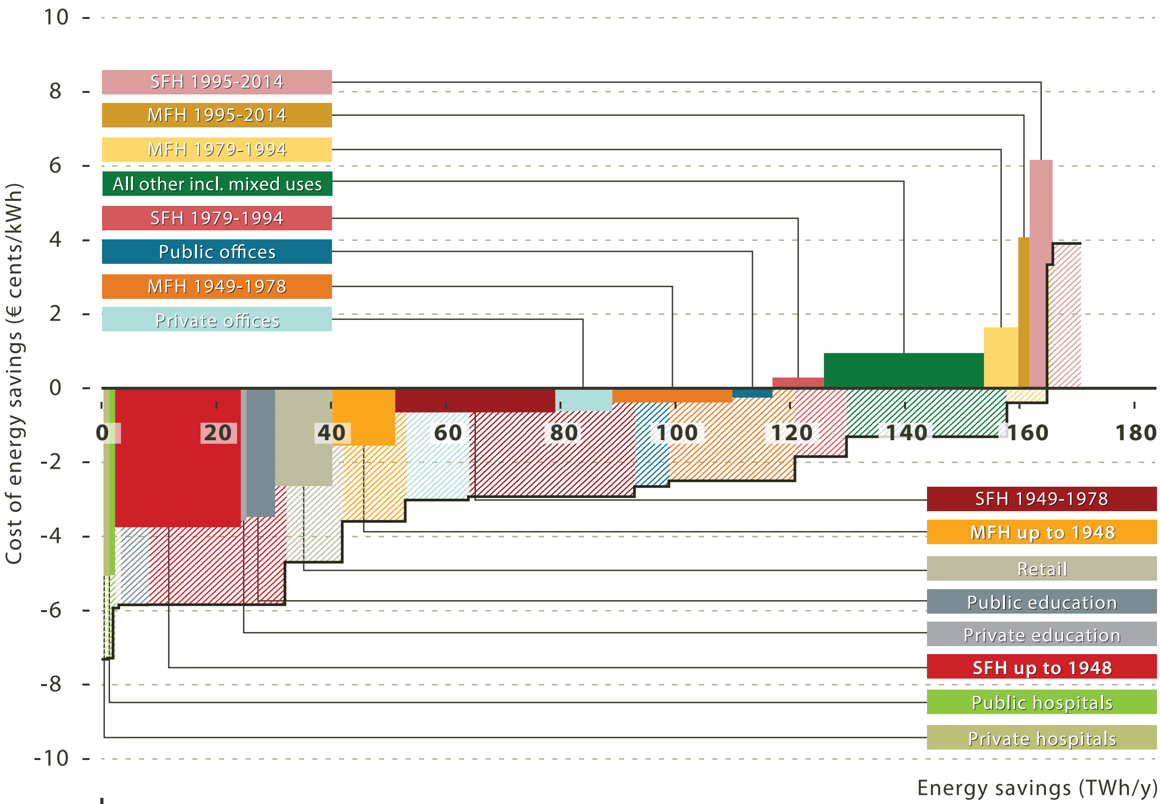
Inclusion of co-benefits (shaded blocks) results in a significant shift towards greater cost effectiveness (downward shift in the bars) and towards greater energy saving (shift towards the right) – up from 150 TWh/year to 160 TWh/year. As shown in the table below, inclusion of the comfort co-benefit also results in the net financial savings turning positive. Total investment amounts to €353 billion of which €65 billion (18%) is subsidised by the state.

	Without co-benefit	With co-benefit
Energy savings (TWh/year)	150	160
Net financial savings (€bn)	-0.8	2.8
Total investment (€bn)	304	353
…of which subsidies (€bn)	50	65

High Subsidy

In this scenario, all economic parameters are the same as in Business As Usual, except subsidies. This results in a considerable improvement in cost effectiveness, with 11 out of 16 building categories now below the line, and an increase in energy savings to 167 TWh/year.

Subsidies	Transaction costs	Discount rate	Measure cost decrease to 2030	Energy price increase to 2030
20-40%	5%	4%	6-25%	1.1% p.a. (equivalent to a total increase of 19%)



Solid colour = no co-benefits | Shaded + black outline = with co-benefits
SFH = single-family houses | MFH = multi-family houses

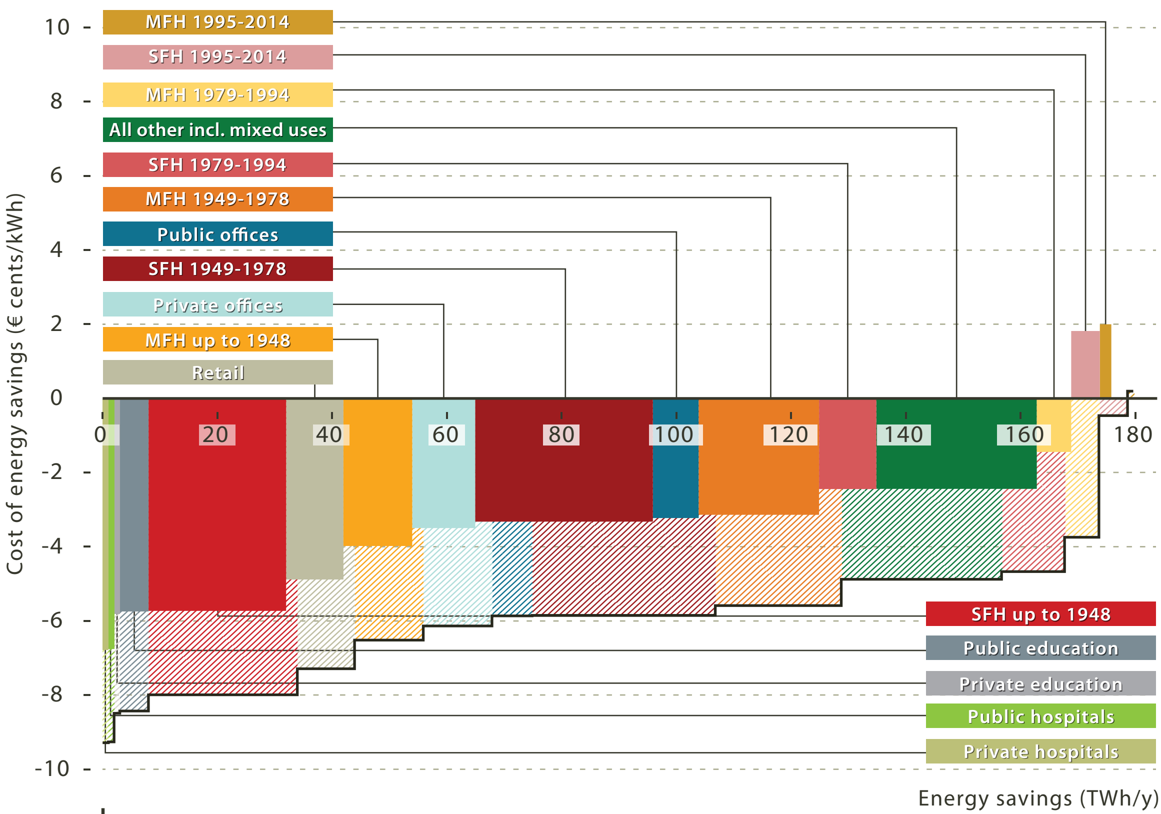
Including the co-benefit has a significant impact, making all but the newest residential building categories cost effective, while also slightly increasing total energy savings from 167 TWh/year to 171 TWh/year. However, the impact on net financial savings is far greater, with a more than four-fold increase from €1.2 billion to €5 billion. As would be expected, subsidies increase considerably compared to Business As Usual, accounting for 26% of the total investment.

	Without co-benefit	With co-benefit
Energy savings (TWh/year)	167	171
Net financial savings (€bn)	1.2	5.0
Total investment (€bn)	405	445
…of which subsidies (€bn)	106	117

Best Case

The Best Case scenario combines high subsidies, high energy prices and the package of soft measures (lower transaction costs, low discount rates and high learning curve) to deliver the best economic conditions for building renovation. The parameters used are summarised below.

Subsidies	Transaction costs	Discount rate	Measure cost decrease to 2030	Energy price increase to 2030
20-40%	2.5%	2%	9-38%	2.6% p.a. (equivalent to a total increase of 50%)



Solid colour = no co-benefits | Shaded + black outline = with co-benefits
SFH = single-family houses | MFH = multi-family houses

All except the two newest residential building categories are cost effective, even without the inclusion of the comfort co-benefit.

As would be expected, this combination of assumptions leads to the highest levels of investment, subsidy, energy savings as well as financial savings for all scenarios.

	Without co-benefit	With co-benefit
Energy savings (TWh/year)	176	181
Net financial savings (€bn)	6.1	10.7
Total investment (€bn)	448	489
…of which subsidies (€bn)	120	132

Discussion

The results show that comprehensive building renovation, comprising the building envelope and heating systems, is cost effective under today's economic conditions (defined in the Business As Usual scenario) in eight out of the 16 building categories, generating energy savings of 60 TWh/year. Savings could, however, be increased three-fold to 180 TWh/year (16% of current energy use in the building stock) by 2030 under the most favourable scenario assumptions and by including the value of increased comfort in the economic appraisal.

Understanding which economic levers have the biggest impact on the cost-effectiveness of building renovation for potential investors is a vital part of the decision-making process for policy makers. By varying one or more of the economic parameters, the impact in terms of cost-effectiveness of building renovation can be readily identified – an essential tool in helping to formulate the optimum policy mix for the existing building stock.

Without the right policy signals, there is a serious risk that sub-optimal, shallow renovations will continue to dominate the market, effectively blocking the achievement of the full energy potential. This will lead to a loss of economic benefit for building owners and the wider German economy.

Recommendations

The analysis in this report demonstrates that additional policy measures are required if the full potential for energy saving in the German building stock is to be achieved. Given the right market conditions, the cost-effective potential for renovation can be more than doubled. For this to be achieved, we put forward for consideration the following recommendations.

Setting an appropriate strategic context

- Society benefits when individual building owners and investors undertake building renovation work. Employment is created, air quality is improved, buildings become healthier and their occupants more productive, while energy security is enhanced and GHG emissions are reduced. For these reasons, the national policy focus needs to shift towards maximising the energy savings achieved in the building stock by stimulating comprehensive, deep renovation. Sub-optimal levels of insulation, or the installation of less efficient building components and equipment, effectively limit the energy-saving potential for the foreseeable future (the so-called "lock-in effect"), and are often more expensive when considered over the lifetime of the measures.
- Designing an appropriate policy landscape to deliver a deep renovation of the German building stock requires due consideration of the full spectrum of factors that currently limit uptake. In the context of developing the national building renovation strategy, a comprehensive, holistic analysis should therefore be undertaken as to how to stimulate the market.
- Investor confidence will be strengthened by providing clear short- and mid-term policy targets within a long-term framework that provides maximum investment security for decisions in the real-estate and energy renovation market in order to lower the investment risk and hence the discount rate.

Providing the right economic signals

- Among the many significant barriers to a thriving renovation market is the absence of sufficiently strong economic signals and appropriately tailored financial instruments. Policies to stimulate deep renovation could, for example, include feed-in tariffs for saved energy, conditional on achieving an ambitious level of energy saving. Further incentives for deep renovation could be provided at property-sale transactions where the associated tax could be reduced if the future owner invests to renovate the property.

- Energy price signals play an important role in motivating investors to cut their energy costs. Eliminating fossil fuel subsidies across the energy supply system and reflecting the true externalities of energy use (for example, through carbon pricing) will provide stronger incentives for building owners to invest in energy saving measures. Fully cost-reflective energy prices, with appropriate safeguards for those in economic difficulty, are also more justifiable and rational from a societal perspective. There is scope to increase the taxation of energy used in buildings. For example, the six cent/litre tax rate on heating oil in Germany is considerably below the EU average of 18 cents/litre.

Focusing financial support where it is most needed

- The well-established financial support system run by KfW could be further developed to stimulate renovation of certain building types which show high energy-saving potentials but are not renovated due to a limited return on investment. Consideration should be given to the stratification of the support programmes in order to encourage greater uptake among particular building types and owner profiles. For example, larger subsidies could be offered to building categories for which deep renovation is marginally not cost-effective. Rented properties, where rent increases are not feasible or not desirable from a societal perspective, might benefit from specific support measures which recognise the limited economic justification for landlords to invest in improving the energy performance of their properties, since they do not receive the resulting cost savings.

- Another way to address the varying cost-effectiveness of different building categories could be in the form of an investment fund, which bundles projects with differing economic performances to lower the average investment risks. Such an approach is common in equity management and could be extended to renovation-project financing. Such an "investment bundling" could provide safe and stable returns to investors while giving owners access to necessary capital.

- Deep renovation of commercial properties is often limited due to tenant laws and split incentives/benefits, rather than by the low economic viability of the investment. This barrier could be overcome through different means, such as mandatory upgrades on a particular timescale or at certain trigger points (e.g. sale, new lease) to achieve certain performance levels.

- Buildings with an important societal function and with resulting societal benefits, such as schools and hospitals, should receive preferential treatment with the help of appropriate support measures to create viable investment cases for deep renovation. First steps in that direction have been made with the new KfW-programmes for non-residential buildings and respective funding strands of the NKI, the national climate initiative. These need to be strengthened to ensure the focus is on achieving deep renovation.

- A programme for the development of accurate modelling and financing tools to increase the effectiveness of subsidy distribution should be encouraged by the government. The return on investment in such a research programme would be an even more intelligent, streamlined, automated process to make use of public finances and increase the effectiveness of funds in reaching renovation targets and in triggering renovations.

Providing the right support infrastructure and systems

- Building owners and investors need the right encouragement, information, support and incentives to choose the deep renovation option, particularly when undertaking other maintenance work on the property, as the additional cost of improving the building's energy performance at this time can be minimised. Such support could come in the form of impartial information centres or one-stop-shops, which guide the owner/investor through the whole process, reducing transaction costs and helping to make the right choice. In certain places in Germany, local or regional energy agencies are already playing a part of that role and should be further supported and strengthened in their endeavour.
- For building owners and investors, encouraging the inclusion of co-benefits such as increased comfort and property values in the economic appraisal can have a big impact on the cost-effectiveness of deep renovation. Advice centres and one-stop-shops could offer free software that includes co-benefits in the economic appraisal. The existing dena guide on cost-effectiveness could be modified to take co-benefits into account.
- Policy measures could increasingly stimulate deep renovation of urban quarters with an identical building typology. Building-type specific renovation packages, which could (partially) be pre-fabricated, would be more cost-effective if deployed in large numbers. Prefabrication could reduce disruption time for building occupiers.
- Efforts to improve skills within the workforce through qualification and vocational training programmes should be continued and enhanced.
- The already significant level of R&D support should be maintained in order to speed up learning curves and the process of cost-reduction.

INTRODUCTION

The aim of this report is to inform the policy debate in Germany concerning the renovation of the existing building stock in order to improve its energy performance, with a focus on the economic viability of different levels of renovation. The report has been prepared by the Buildings Performance Institute Europe, in partnership with Fraunhofer ISI and Technische Universität Wien (TU Wien), using a modelling approach that focuses on the perspective of the investor (or potential investor). The key outputs are Energy-Saving Cost Curves (ESCC) demonstrating the economic attractiveness of renovating different building categories under a range of economic conditions.

Section 1 sets the scene in terms of prevailing climate and energy policies in Germany, with a focus on how they influence the existing building stock. This is followed in section 2 by a description of the methodology adopted in this study, with section 3 presenting the results of the scenario analysis. Section 4 offers a discussion on key findings, followed in section 5 by our recommendations. These are intended to inform the choice of policies that could contribute to making the German building renovation strategy a truly transformational initiative that enables the realisation of the full range of macro-economic, societal and environmental benefits that building renovation can deliver.

1 SETTING THE SCENE

This section sets the scene in terms of European legislation and specific policies and measures that are in force in Germany, relating to climate goals and more specifically, the role and contribution of the building sector to those climate goals.

Climate policies in the German context

In order to curb climate change, the European Union (EU) has set a long-term aim to reduce greenhouse gas (GHG) emissions by 80-95% below 1990 levels by 2050[1]. In support of this target, the EU has adopted a number of policies to limit GHG emissions, to increase the share of renewable energy in its energy mix and to improve energy efficiency in all sectors of economic activity, including households, by the year 2020 – the so-called 20-20-20 targets[2]. In the framework of the on-going international climate negotiations, the EU has decided on a 40% goal for the reduction of GHG emissions by 2030 compared to 1990 levels, together with targets of 27% for both renewable energy and improved energy efficiency.

Buildings play an important role in meeting the EU climate targets, in particular in Germany, the largest economy of the EU, where the building sector accounts for 40% of final energy use and is the source of 30% of GHG emissions[3].

Adopted as part of the "Energiewende"[4] ("energy transition") in 2010/2011, the Federal Government has set national goals to reduce energy consumption for heating by 20% by 2020 and non-renewable primary energy consumption for space heating and hot water by 80% by 2050, compared to 2008 levels[5]. In addition, it aims for a 14% share of heating and cooling generated from renewable sources by 2020[6]. Energy efficiency is deemed the second pillar of the "Energiewende".

Currently, however, Germany is not on track to achieve its 2020 GHG-emissions reduction target of 40%. In the 2013 report to the European Commission[7] on GHG-emissions projections and national programmes, the Federal Government reported a projected 33-35% CO_2 reduction. In order to bridge the gap of 5-7 percentage points, the Federal Government started two new processes in the spring of 2014:

1. The Federal Ministry for the Environment, Nature Conservation, Buildings and Nuclear Safety (BMUB) has elaborated the Action Programme Climate Protection 2020 (AP 2020), adopted by the Cabinet in December 2014[8]. Component two (of nine) of the AP 2020 is the strategy on climate-friendly building and housing. Examples of specific measures include extending support for district-based approaches to urban energy modernisation and for local climate action projects[9]. AP 2020 is supposed to be the first step leading to a Climate Protection Plan 2050, to be adopted in 2016[10]. Also in the latter process, buildings' energy performance is one of five thematic strands[11].

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1 European Council, October 2009.
2 Three key objectives for 2020: A 20% reduction in EU GHG emissions from 1990 levels; raising the share of EU energy consumption produced from renewable resources to 20%; and a 20% improvement in the EU's energy efficiency.
3 BMWi, "Sanierungsbedarf im Gebäudebestand", Dezember 2015, http://www.bmwi.de/DE/Mediathek/publikationen,did=676178.html
4 In September 2010 the German government decided to restructure the country's energy system by 2050 and adopted the "Energiekonzept" (energy concept). It was speeded up and further developed after the Fukushima-disaster in the spring of 2011 and the subsequent decision to phase out nuclear power by 2022, but is in essence still valid today. http://www.bmwi.de/DE/Mediathek/Publikationen/publikationen-archiv,did=573670.html
5 http://www.bmwi.de/EN/Topics/Energy/Energy-Transition/overall-strategy.html
6 § 1 II EEWärmeG – The (federal) renewable heat law of 2008, entered into force on 1st of January 2009.
7 http://cdr.eionet.europa.eu/de/eu/ghgpro/envuucoda/overview
8 DE: http://www.bmub.bund.de/service/publikationen/downloads/details/artikel/aktionsprogramm-klimaschutz-2020/, EN :http://www.bmub.bund.de/fileadmin/Daten_BMU/Download_PDF/Aktionsprogramm_Klimaschutz/aktionsprogramm_klimaschutz_2020_hintergrund_en_bf.pdf
9 BMUB background paper: "Climate Action Programme 2020, 04.12.2014".
10 http://www.klimaschutzplan2050.de/
11 http://www.klimaschutzplan2050.de/handlungsfelder/

2. The responsibility for energy performance of buildings in the Federal Government is shared between the BMUB, in charge of climate protection and construction, and the Federal Ministry for Economic Affairs and Energy (BMWi), in charge of energy. However, the latter is responsible for most matters relating to energy efficiency in buildings, including its financing. BMWi elaborated the National Action Plan on Energy Efficiency (NAPE) [12], also adopted by the Cabinet in December 2014. Fostering energy efficiency in the building sector is one of its three pillars. Under that pillar, four ad-hoc measures were proposed, such as a revision of the KfW [13] CO_2 building modernisation programme, including a new strand for non-residential buildings (see below) and an energy label for old heating systems. However, the one measure called for the most by stakeholders, namely, tax incentives for energy retrofits, stalled (once again, after a first failure in 2011) in the political process in spring 2015. Several processes were started as work-in-progress to implement the NAPE, such as the further elaboration of the Renovation Strategy for Buildings (ESG), as required by Article 4 of the 2012 EU Energy Efficiency Directive. This is the strategy paper for the energy transition in the building sector, targeting an 80% reduction of primary energy in the sector by 2050 through a combination of renewables deployment and energy efficiency. It is expected to be adopted by the Cabinet in November 2015. The NAPE also includes initiatives such as the revision of the Market Incentive Programme for promotion of the use of renewable energy in the heating and cooling market (MAP) or the revision of the legal framework for energy savings in buildings[14].

A long history of policies targeting buildings

Germany has a long-standing history of regulating the energy performance of buildings, dating back to long before the implementation of the respective requirements set by European legislation, notably:

- The 2002 Energy Performance of Buildings Directive (EPBD) [15] (recast in 2010);
- The 2012 Energy Efficiency Directive (EED)[16]; and
- The 2009 Renewable Energy Directive (RED)[17].

The Energy Saving Act (EnEG) was originally introduced in 1976 to reduce German dependency on imported energy carriers. Since then, ordinances that impose energy-related requirements on buildings have been legislated, based on the EnEG, a process that started with the Thermal Insulation Ordinance ("Wärmeschutzverordnung") in 1977. Today, the central piece of German building performance policy is the 2014 version of the Energy Saving Ordinance (EnEV) released for the first time in 2002, merging two earlier ordinances valid up to then. EnEV applies to new and existing buildings, both private and public, as well as to the installations required for space heating & cooling, domestic water heating, and indoor air quality (plus lighting for non-residential buildings). EnEV regulates the following:

- Standards for new buildings;
- Standards for existing buildings in case of major renovations;
- Building installations: standards for new heating, cooling or ventilation systems; and
- Design, content and obligations for the use of Energy Performance Certificates (EPCs).

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12 DE: http://www.bmwi.de/DE/Themen/Energie/Energieeffizienz/nape.html, EN: http://www.bmwi.de/EN/Topics/Energy/Energy-Efficiency/nape,did=680402.htmlEN: http://www.bmwi.de/EN/Topics/Energy/Energy-Efficiency/nape,did=680402.html
13 KfW ("Kreditanstalt für Wiederaufbau") is a German government-owned development bank, based in Frankfurt. https://www.kfw.de/kfw.de-2.html (link in EN)
14 http://www.bmwi.de/EN/Topics/Energy/Energy-Efficiency/nape,did=680402.html
15 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN
16 http://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive
17 https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

Strengthened requirements for new buildings enter into force by the start of 2016. Existing buildings are excluded from these changes.

In addition to the requirements of EnEV, new buildings with a total floor area over 50 m^2 have to comply with the Renewable Energies Heat Act (EEWärmeG) which, since 2009, requires a proportion of energy to be derived from renewable energy sources (RES). Building owners can choose which RES to incorporate, but the percentage required depends on the source. The German Länder (regions) are allowed to oblige private owners of existing buildings to source a percentage from RES too, though Baden-Württemberg is the only region which has been doing so since 2008.

Energy efficiency investments in buildings

Germany has implemented one of the most comprehensive financial support schemes in Europe, which is administered by the KfW development bank and has been lauded in Germany and abroad as a model for financial support for improving the energy performance of buildings. Financial support through low interest loans and subsidies is available for both highly efficient new buildings and the renovation of existing buildings. The requirements of this support go beyond the EnEV standards. Currently, one in three renovations, together with half of all newly constructed buildings, is supported by the KfW programme, which provides progressively higher levels of support according to the resulting energy performance. New funding strands for non-residential buildings came into force in October 2015.

Since 2006, more than 3.8 million dwellings and over 2,100 social or municipal buildings have been built or renovated with these funds, bringing the total investment in building energy performance improvement to €187 billion[18].

Over the years, several studies have shown the positive effects of these investments for the German economy through the creation of economic value, jobs at local, regional and national level, energy cost savings, and the avoidance of CO_2 emissions. In 2011, the research institute Forschungszentrum Jülich published an impact assessment showing the collective value for the German economy of the KfW programme as being €4-5 for every €1 of programme cost[19]. More recently, a study by the research institute Prognos[20] concluded that most support scenarios evaluated for the future are almost budget-neutral or even budget-positive for the German public sector as a whole and for public authorities at all levels. However, the support scheme has already been criticised as not being targeted enough, since the funding is not geared toward addressing gaps in cost-effectiveness of different building categories[21].

18 http://www.bmwi.de/DE/Themen/Energie/Energiewende-im-Gebaeudebereich/kfw-programme.html

19 Impact on public budgets of KfW promotional programmes in the field of energy-efficient buildings and rehabilitation (https://www.kfw.de/migration/Weiterleitung-zur-Startseite/Homepage/KfW-Group/Research/PDF-Files/Energy-efficient-building-and-rehabilitation.pdf) Figures based on three programme years: 2008-2010.

20 EN: https://www.kfw.de/KfW-Group/Newsroom/Aktuelles/Pressemitteilungen/Pressemitteilungen-Details_63488.html, DE: https://www.kfw.de/KfW-Konzern/Newsroom/Aktuelles/News/News-Details_67904.html

21 Diskussionsschrift „Strategie für eine wirkungsvolle Sanierung des deutschen Gebäudebestandes", Dr. Martin Pehnt, Peter Mellwig et al. for Naturschutzbund Deutschland (NABU) e.V., 2012: https://www.nabu.de/imperia/md/content/nabude/energie/strategie_f__r_eine_wirkungsvolle_sanierung_des_deutschen_geb__udebestandes_endg.pdf (see chapter 2.5.3).

Current renovation activity

Despite the above-mentioned regulatory initiatives that have created a leadership reputation for Germany in the field of building energy performance, the overall German renovation rate is just at the level of the European average (around 1% per year)[22]. In addition, out of every three renovations undertaken in Germany, only one results in the implementation of energy saving measures, and most of them are not at optimum renovation depth. While there is general support for the energy transition and action on building performance among the German public[23] and across the political spectrum, there is disagreement about the degree of ambition, the optimal rate of renovation, and the level of financial resources to be allocated to the task.

If the required energy savings and resulting GHG-emissions reductions in the building sector are to be achieved, it is clear that the rate of building renovation needs to be considerably increased, always keeping in mind an improved level of energy performance.

This report aims to provide the underpinning analysis about the effectiveness of a number of economic levers in improving the attractiveness of different levels of renovation, specifically from the perspective of the owner or (potential) investor. As such, it aims to inform the debate on which combinations of policies and measures could most effectively be used to improve the economic attractiveness and hence the rate and degree of renovation across the full range of building categories.

[22] "German building renovation strategy" http://ec.europa.eu/energy/en/topics/energy-efficiency-directive/buildings-under-eed

[23] See representative TNS Emnid survey for AEE (Agentur für Erneuerbare Energien), published 07.09.2015: http://www.unendlich-viel-energie.de/die-deutsche-bevoelkerung-will-mehr-erneuerbare-energien (press release in German).

2 METHODOLOGY

This section describes the methodology adopted by the project partners to evaluate the impact of policies that could enhance the level of building-renovation activity in Germany. The approach has been to develop Energy-Saving Cost Curves for the renovation of Germany's building stock demonstrating the cost-effectiveness of varying depths of renovation, from the perspective of the potential investor, and to explore how that varies under a range of economic assumptions.

A stepwise approach

In order to evaluate the economic attractiveness of renovating different types of buildings under a range of economic conditions, the following steps were undertaken:

1. Assess the current stock of buildings, broken down by sector, taking account of stock changes (e.g. demolitions, conversions);
2. Define three renovation packages resulting in different levels of improvement in the building's energy performance;
3. Calculate delivered energy demand for each renovation package for each building segment[24];
4. Define a set of economic parameters affecting the cost-effectiveness from the perspective of the investor (e.g. energy prices, interest rate, subsidy levels). These can be varied in order to generate different scenarios;
5. Calculate investment costs and resulting energy-cost savings for each combination of buildings and renovation package;
6. From this, identify and select the least costly renovation package;
7. Calculate the cost of energy savings as the ratio between the net cost and total energy savings. The resulting cost of energy savings (expressed as cent/kWh) could be positive, in which case the renovation measures are not cost-effective, or negative, in which case they are cost-effective;
8. Plot the output results as Energy-Saving Cost Curves to allow quick and easy visualisation and comparison of different scenario results.

This process has been achieved through the combination of three elements, each described in the following sections[25]:

- Building-stock data and costs of different renovation measures, provided by Fraunhofer ISI;
- The Invert/EE-Lab Model, developed and operated by TU Wien; and
- The ESCC generator, developed by BPIE.

[24] Energy savings are calculated as the difference in energy demand between the renovation package and the reference system (i.e. no thermal improvement of the building envelope and a natural-gas-condensing boiler)

[25] For information on required investments refer to page 23. A detailed description of the Invert/EE-Lab Model can be found at page 26. A detailed ESCC explanation can be found at page 35.

The modelling period for this study is to 2030. This time scale has been selected as it provides a sufficiently long time frame – 15 years – for strategic and financial planning purposes. However, it would not result in the entire building stock being renovated, since this would require unrealistically high renovation rates, and would also not be consistent with the normal building maintenance cycle of typically 30 years; our modelling assumes energy-related renovation is undertaken at the same time as maintenance work, to reduce costs and disruption. Whilst a longer time frame, say, to 2050, would improve the overall cost-effectiveness[26] and allow the full building stock to come within the scope of the analysis, it would significantly increase uncertainty concerning technologies in use, costs of measures, and also future energy prices. Furthermore, it would be unrealistic to design policies over such a long time frame.

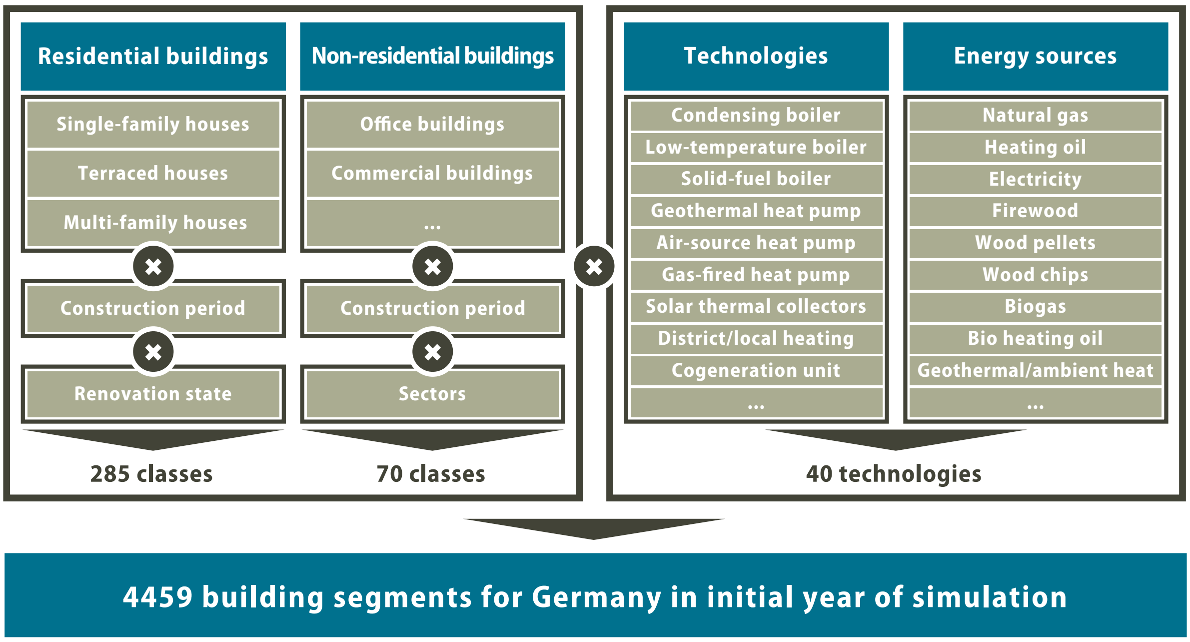
Whilst the renovation scenarios modelled here cease in 2030, the resulting cost savings are evaluated over the full economic life of the measures installed.

Overview of the German building stock and building categorisation

The starting point for the analysis is the categorisation of the German building stock according to a number of representative building typologies.

Figure 1 shows the building stock disaggregation as used in the model. In total, 4459 building segments are differentiated according to the physical characteristics of the building structure and the installed heating systems. This level of building categorisation is relevant for the differentiation of the energy performance of building envelopes. Residential buildings are represented by 285 different classes, non-residential buildings by 70 classes. Building classes are distinguished in terms of building type (e.g. single-family houses, apartment buildings, office buildings, etc.), as well as construction period and presence of existing renovation measures[27].

Figure 1: Definition of German reference buildings (Source: Fraunhofer ISI)



[26] Cost-effectiveness would improve by virtue of large cost reductions due to the learning curve, and also the assumption of increasing energy prices.

[27] The resulting building typology has been applied in previous studies and scientific analysis by Fraunhofer ISI and TU Wien (Dengler et al. 2011; Kockat and Rohde 2012; Steinbach and Schultmann 2015; Steinbach 2015.).

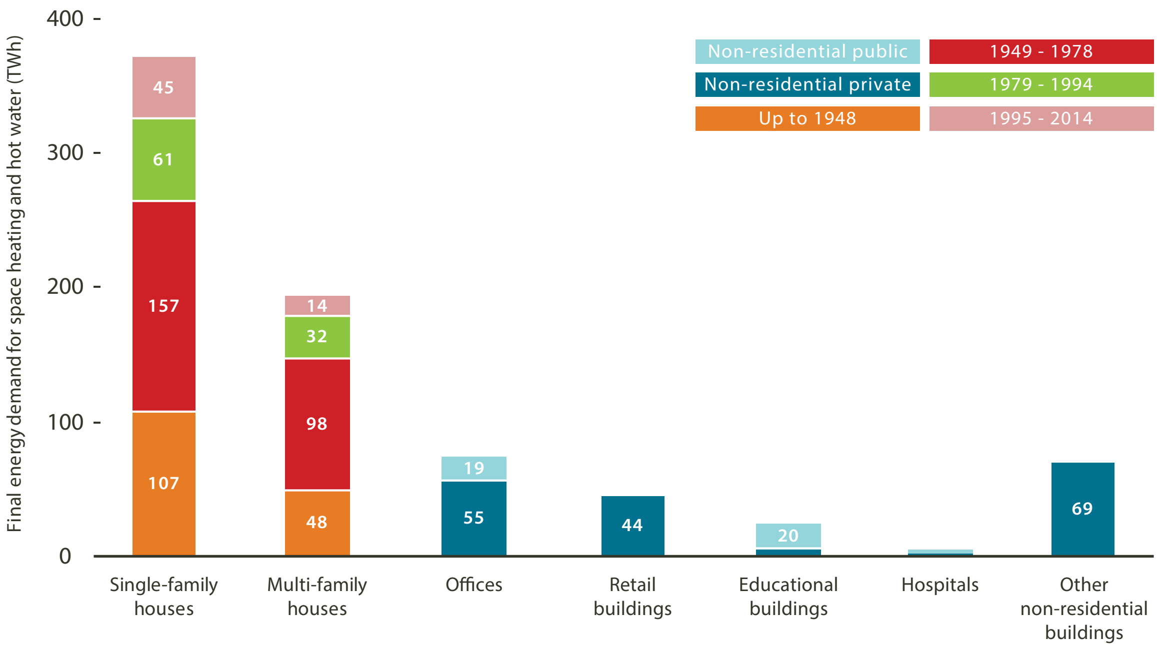
For the presentation of the results, buildings are aggregated in the following categories shown in Table 1.

Table 1: Building categories for the presentation of results

Building categories	Construction period
Single-family houses (SFH)	Up to 1948
	1949 - 1978
	1979- 1994
	1995 - 2014
Multi-family houses (MFH)	Up to 1948
	1949 - 1978
	1979- 1994
	1995 - 2014
Offices - public sector	One age category
Offices - private sector	One age category
Hospitals - public sector	One age category
Hospitals - private sector	One age category
Educational buildings - public sector	One age category
Educational buildings - private sector	One age category
Retail buildings	One age category
Other non-residential buildings	One age category

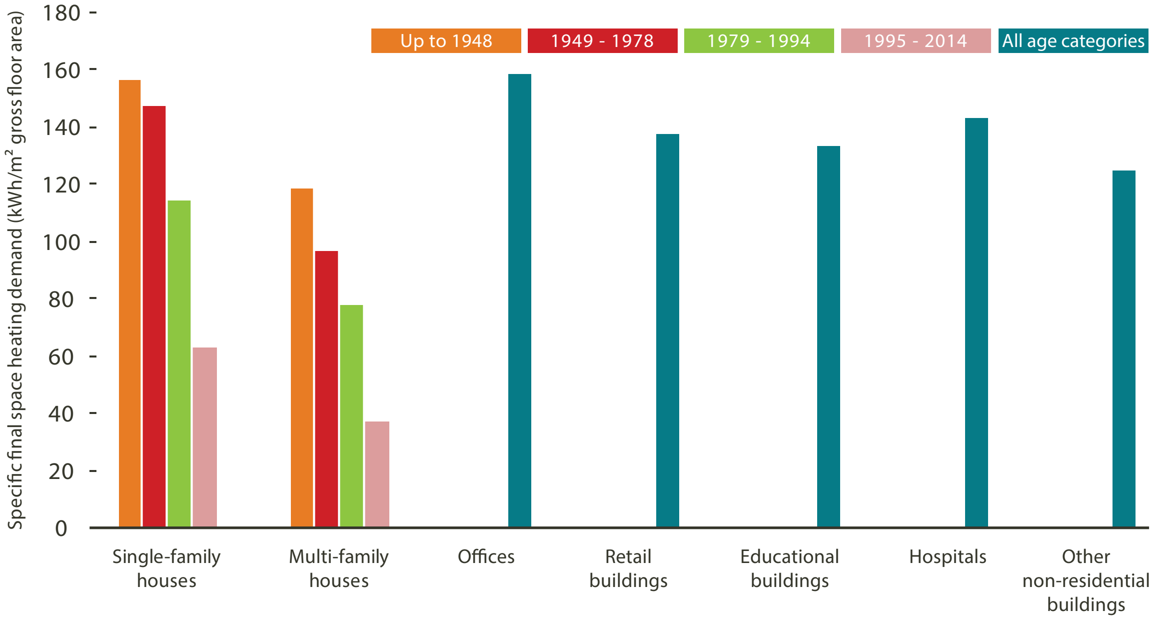
Figure 2 and Figure 3 show the final energy demand for space heating and domestic hot water in the year 2014[28].

Figure 2: Final annual energy demand for space heating and hot water clustered in the building categories used within this project



[28] Since the data on buildings is partly based on the year 2010, results for 2014 have been extrapolated applying the Invert/EE-Lab simulation model and calibrated with the end-use energy balance.

Figure 3: Specific annual energy demand for space heating[29]



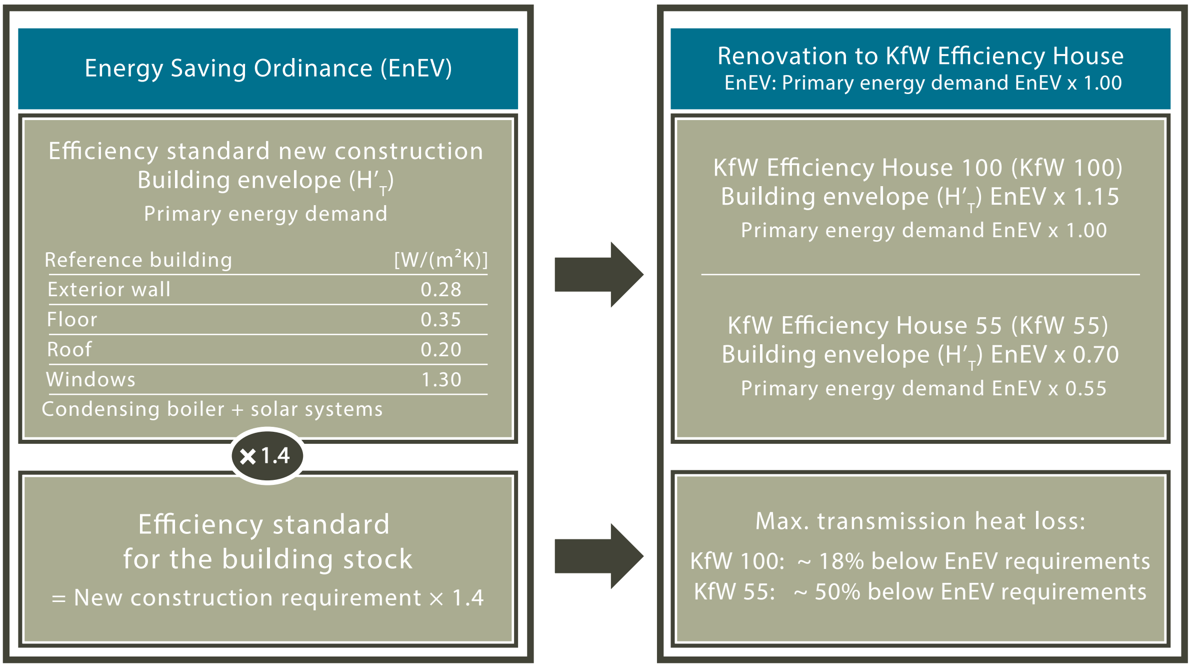
[29] For a comparison of specific space heating demand, it needs to be considered that the share of heated floor area on total gross floor area might differ among the building categories.

Efficiency standards and renovation packages

This study analyses the energy refurbishment of the German building stock according to three different efficiency standards. The standards to be achieved are oriented towards the requirements defined by the German building code (Energy Savings Ordinance, EnEv) as well as the support programmes of the KfW Development Bank[30]. Relevant for measures targeting the energy performance of the building envelope is the maximum value of specific transmission heat losses (H'_T) which reflects a measure of the overall thermal performance of the building envelope.

The target value for the **Standard** refurbishment package assessed in this study is defined by the requirements of the Energy Saving Ordinance on existing buildings in case of major renovation. The **Moderate** refurbishment package meets the target of a *KfW efficiency house 100* with regard to the energy performance of the building envelope, while the **Ambitious** package corresponds to the highest KfW efficiency house 55 level of performance. Figure 4 illustrates the relationship between the efficiency standards relevant to this analysis.

Figure 4: Relevant efficiency standards defined by the German building code and the KfW efficiency houses within the support programme of KfW (Source: Fraunhofer ISI)



For ease of reference, we have adopted the following shorthand description for the three renovation levels:

- Standard Renovation Package = R1
- Moderate Renovation Package = R2
- Ambitious Renovation Package = R3

The composition of refurbishment packages for achieving the respective energy performance standards are determined for each reference building depending on its initial energy performance. In order to achieve the defined energy performance standards, there are degrees of freedom in the choice of building components to be retrofitted as well as in the applied level of insulation thickness and windows quality. Therefore, an

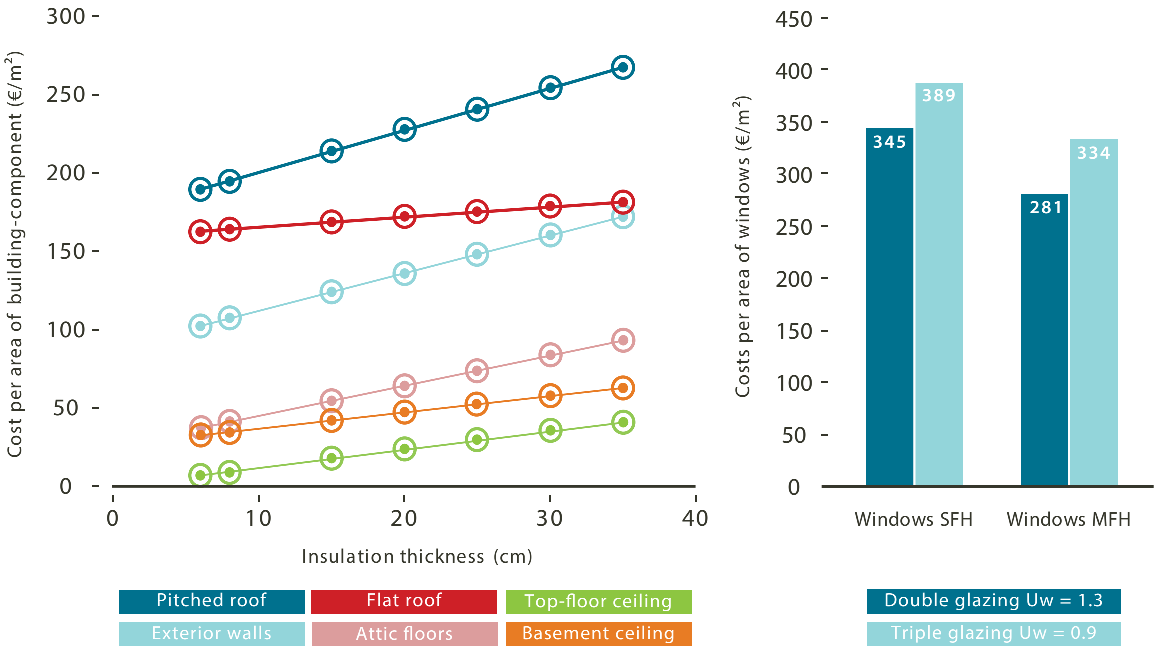
[30] The KfW programme *Energy Efficient refurbishment* provides grants, or soft loans with repayment bonuses, for refurbishment to the so-called KfW efficiency houses. The financial support depends on the achieved energy-performance level.

optimisation model is used to determine the specific refurbishment packages for each reference building while minimising the required investments[31].

Required investments for each renovation package

Figure 5 distinguishes options for energy-efficiency measures applied to the building envelope. The investments are presented by surface area of each building component in relation to the thickness of the insulation material[32] and in relation to the U-Value for window replacement, respectively.

Figure 5: Specific investments in a range of energy efficiency measures on the building envelope, based on an average of different insulation products available for each application (Source: Fraunhofer ISI, based on Hinz (2011))



The illustrated values represent the investments in terms of a full cost calculation for the energy retrofits, including material, transport and labour costs. The data is based on the evaluation of projects that have actually been implemented, while various insulation materials have been converted to an equivalent insulation thickness with a thermal-conductivity value amounting to 0.035 W/(m*K) (Hinz 2011).

The cost-effectiveness of the energy retrofit depends significantly on whether the investment includes concurrent implementation of energy-retrofit measures alongside maintenance measures such as essential replacement of a building component (e.g. roof repair [33]). *Assuming such works are undertaken simultaneously, only the additional efficiency measures are taken into consideration in the evaluation of the cost-effectiveness of building renovation.* Figure 6 shows the share of the investment in maintenance-only measures in relation to the total investment cost for an energy-related renovation[34].

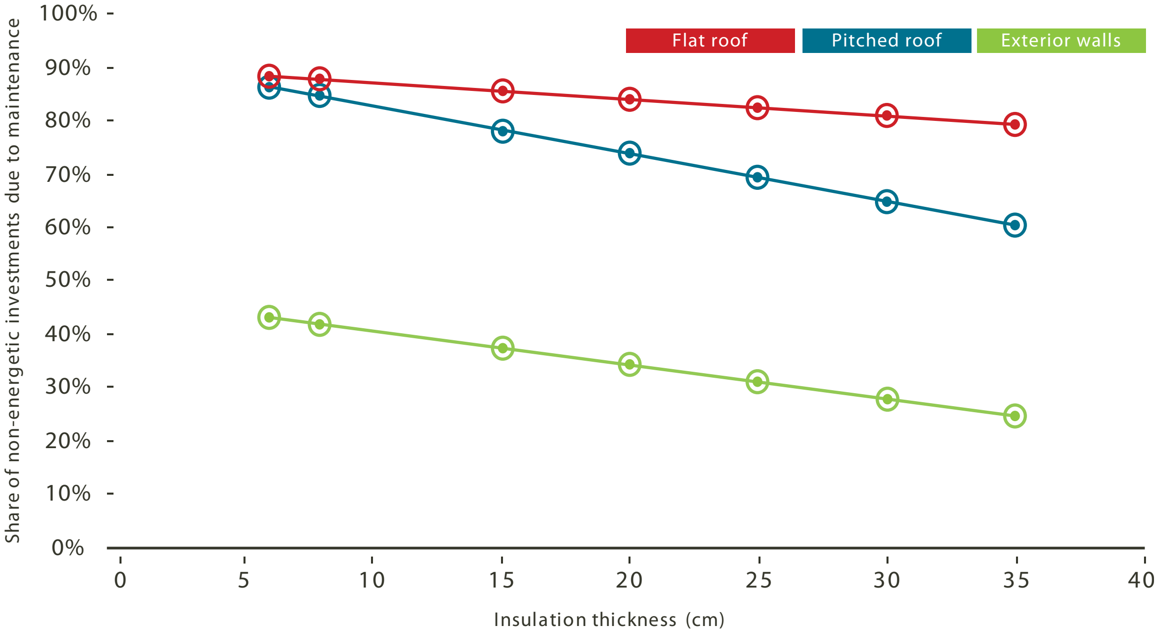
[31] For a description of the calculation model see Steinbach and Schultmann 2015.

[32] The thicknesses discussed here do not refer to a specific type of insulation, but instead are based on an average across a range of products available on the market.

[33] For a detailed description of the conventional retrofit measures that would in any case be implemented (regardless of an energy retrofit or a normal refurbishment), please refer to Hinz (2011).

[34] Insulation of the attic floor (top storey ceiling), the basement ceiling and replacement of windows are considered to be explicitly energy renovation measures (see. Hinz 2011).

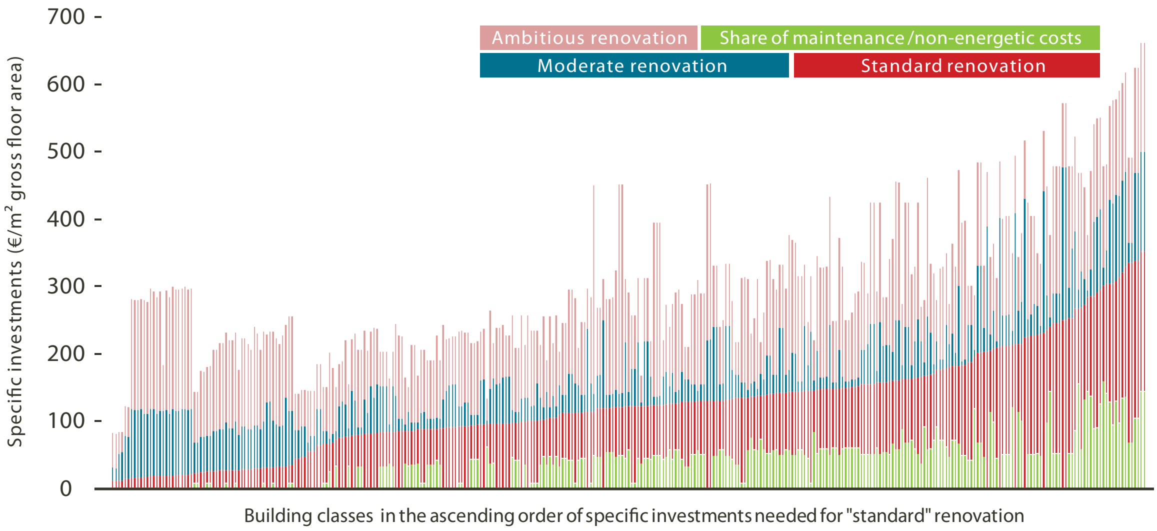
Figure 6: Share of required maintenance investments in the total investments of an energy-related renovation of exterior walls and roof (Source: Fraunhofer ISI, based on Hinz (2011))



The resulting specific investment costs for the renovation packages needed to achieve the three efficiency standards considered in this analysis are pictured in Figure 7 for the reference buildings shown in the model[35]. Non-energy related investments account for 32 % of the total investment for the *Standard Renovation* package on average, weighted by floor area.

Comparison of the renovation packages shows that, for the ambitious renovation option, the additional investments required vary considerably (as illustrated in the graph below).

Figure 7: Specific investments per renovation packages required to achieve the respective efficiency standards (Source: Fraunhofer ISI)



[35] See Steinbach and Schultmann (2015).

The area-weighted average investments of the renovation packages per m^2 of gross floor space are shown in Table 2. The total investment cost, including maintenance measures, for the Moderate package is on average 30% higher than the cost of the Standard package. For the Ambitious renovation package, investments costs more than double on average, compared to the Standard package. However, as Figure 7 shows, costs vary significantly across the building classes. In some cases, the cost to implement the ambitious renovation package is much lower than the average.

It should be noted that the values shown below only include investments for measures on the building envelope, excluding the heat supply system.

Table 2: Average investment required for the different building envelope renovation measures per square metre gross floor area (GFA) (Source: Fraunhofer ISI)

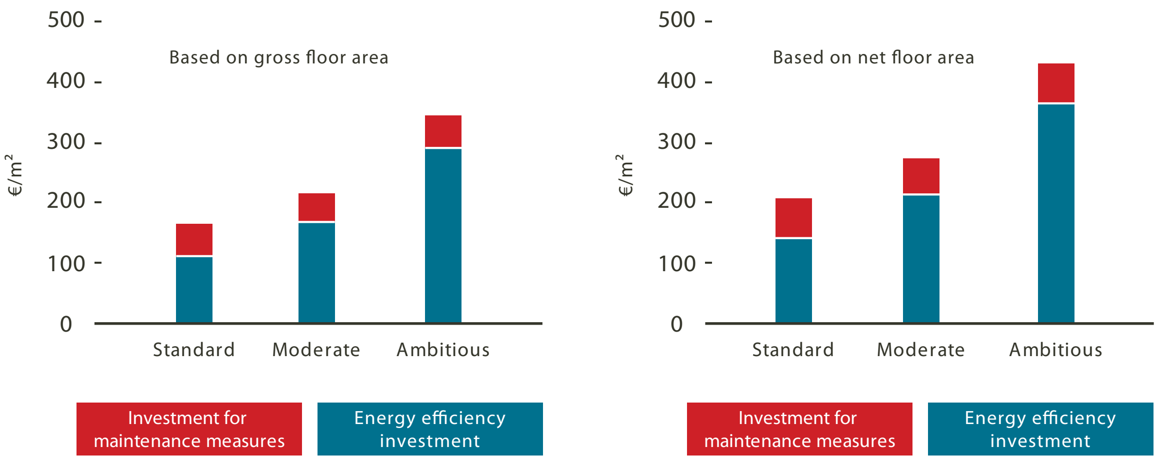
Renovation level	Standard EUR/ m²	Moderate EUR/ m²	Ambitious EUR/ m²
Total investments including required maintenance measures	165	217	343
…of which investments in energy efficiency	113	169	291

For the sake of comparison with other studies and reference values used in practice, specific investments are also shown in relation to a specific net gross floor area in Table 3. Both sets of data are also illustrated graphically in Figure 8.

Table 3: Average investment required for the different building envelope renovation measures per square metre net floor area (Source: Fraunhofer ISI)

Renovation level	Standard EUR/ m²	Moderate EUR/ m²	Ambitious EUR/ m²
Total investments including required maintenance measures	208	273	432
…of which investments in energy efficiency	142	213	366

Figure 8: Investment required for each renovation package (gross and net floor area)



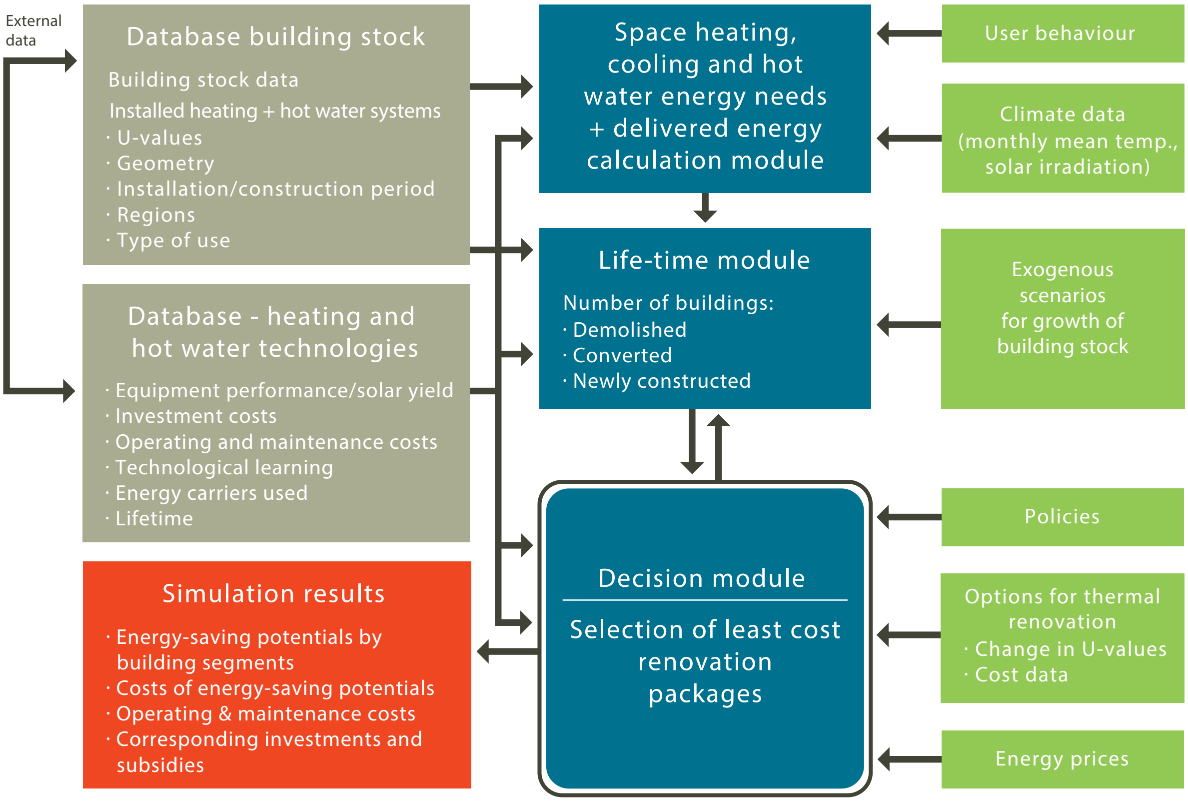
Invert/EE-Lab Model

All data on building stock, energy use, renovation options and costs is fed into the Invert/EE-Lab Model, developed and operated by TU Wien. This is a dynamic bottom-up model using a cost-based approach, the core of which comprises a module calculating energy demand and final energy consumption for space heating and domestic hot water of buildings on the one hand, and a module that anticipates heating-related investment decisions on the other. These modules are connected to a database supplying information on relevant data, such as the building stock and heat supply technologies, as well as external factors such as energy prices, climate data, user behaviour, etc.[36]

The Invert/EE-Lab Model is typically used to derive scenarios for building-energy demand and related policy impacts. In this project we adapted the model in order to provide the outputs necessary to generate Energy-Saving Cost Curves. Figure 9 shows the model structure.

[36] For more details on the model, please see: „Energy Demand Assessment for Space Conditioning and Domestic Hot Water: A Case Study for the Austrian Building Stock", Müller 2015 (PhD-Thesis, Technische Universität Wien).

Figure 9: Structure of the Invert/EE-Lab Model as applied in this study for deriving Energy-Saving Cost Curves (Sources: Müller (2014), Kranzl et al (2014))



Energy-Saving Cost Curves

The final stage of the process makes use of the results from different scenario runs of the model for individual building segments and aggregates them at the level of building categories described in Table 1. The results are displayed in both graphical and tabular form.

Energy-Saving Cost Curves have been developed as the most appropriate tool for the quantification, evaluation and representation of the results of this study. Analogous in many ways to Marginal Abatement Cost Curves (MACC), which compare the abatement costs of different technologies to reduce GHG emissions from a societal perspective, Energy-Saving Cost Curves focus instead on the cost-effectiveness of different packages of measures from the perspective of the investor, given a particular set of economic parameters. As such, they are better geared towards understanding the economic motivation of those actors that policies seek to influence to increase their propensity to renovate buildings.

In addition to the graphical output, which allows a quick visualisation of the scenario results, the ESCC generator provides tabular outputs, in aggregate format and by building category, of the following:

- Weighted average cost of renovations;
- Weighted average shares of renovation depths;
- Energy savings;
- Cost savings;
- Total investment (or capital expenditure - CAPEX) requirements;
- Total value of subsidies.

Economic variables

A number of economic factors relevant to investors have been identified and used as variables in the generation of different scenarios. These are described and summarised in Table 4.

Table 4: Economic variables used in the modelling of scenarios

Variable	Description	Range applied in the modelling
Energy-price evolution	Increase in the real retail price of energy from 2015 to 2030	1.1% - 2.6% per annum (equivalent to 19% - 50% total increase to 2030)
Subsidy levels	Grants, implicit value of loan, or other external financial support as a % of total capital investment	0-40%. Varies according to technology and renovation package
Transaction costs	Costs associated with preparatory work, planning costs, approvals, etc., including staff time	2.5-5% of total capital investment
Discount rates	Cost of borrowing to finance energy saving investment	2-4%
Learning and cost reduction	The impact of future price reductions resulting from factors such as increased sales volumes, more efficient installation procedures, improved productivity or R&D resulting in new and better ways of saving energy	6-38%, depending on technology
Co-benefit – SEE BOX	The value of increased comfort (=forgone energy savings) resulting from installation of renovation measures, valued at the prevailing price of energy	0-30%

Co-benefits

In addition to providing energy savings, improving the energy performance of buildings also generates a number of other benefits that are often acknowledged qualitatively, but rarely factored in during the economic appraisal of such investments. Some of these benefits are experienced by the building occupants, some by the investors and others by the entire society. There is a growing body of studies demonstrating these benefits (see footnote for details of a number of recent studies)[37].

Given that the focus in this report is on the investor (who is also frequently the occupier), we only consider the impact of one of these quantifiable benefits, namely the increase in comfort. Other benefits accruing to the investor may also include health, productivity and increased property value, but in the absence of reliable data to support the analysis, these have not been quantified. Increased comfort is a real benefit that can be quantified in terms of increased temperature from having a better insulated, less draughty building. There is strong monitoring evidence[38] that some of the benefits of improved energy performance are taken by building occupants as increased comfort, also known as the rebound effect, which has been calculated to be worth around 30% of the net energy saving.

The financial value of increased comfort is calculated as being equivalent to the amount of energy that would be required to generate the increase in temperature witnessed by building occupants. Another way of considering this benefit is to say that occupants have forgone some of the potential energy-cost savings by having more comfortable living or working conditions. It is a reasonable economic assumption that, in doing so, they value the increased comfort at least at the same level as the forgone energy-cost saving.

In cases where the owner/investor is not the same as the building occupant, i.e. in rented properties (whether residential or non-residential), the investor would normally seek to recoup the investment through an increase in rent (subject to any legal restrictions). The cost calculation would normally be done solely on the expected energy-cost savings, i.e. without the co-benefit. From this, it is clear that in a landlord-tenant situation, the investor (landlord) is unlikely to take into consideration the increased benefit (i.e. comfort) of the tenants. The landlord may, however, place a value on the increase in property value that a comprehensive renovation would deliver. Due to limited literature availability on the scale of this increase in value, it has not been modelled in this study.

[37] IEA "Capturing the Multiple Benefits of Energy Efficiency" http://www.iea.org/bookshop/475-Capturing_the_Multiple_Benefits_of_Energy_Efficiency
Cambridge Economics & Verco: "Building the Future : The economic and fiscal impacts of making homes energy efficient" http://www.energybillrevolution.org/wp-content/uploads/2014/10/Building-the-Future-The-Economic-and-Fiscal-impacts-of-making-homes-energy-efficient.pdf
Copenhagen Economics "Multiple benefits of investing in energy efficient renovation of buildings" http://www.renovate-europe.eu/uploads/Multiple%20benefits%20of%20EE%20renovations%20in%20buildings%20-%20Full%20report%20and%20appendix.pdf

[38] Loga T, Großklos M, Knissel J. "Der Einfluss des Gebäudestandards und des Nutzerverhaltens auf die Heizkosten" [Influence of building standards and user behauvior on the heating costs]. Institut Wohnen und Umwelt GmbH, Darmstadt: 2003.

Learning and cost reduction

Technological learning reflects the cost reduction due to technology diffusion and as a result of increased sales volumes. Historical evidence of such reductions is plentiful, with perhaps the best known example being the reduction in the cost of photovoltaic panels (PV). In the model, the following learning, in form of cost reduction, is used. As can be seen, a differentiation has been made according to technology, reflecting its maturity.

Table 5: Cost reduction applied for specific technologies (Sources: Manteuffel et al (2014); Henning et al (2013); Fernandez-Boneta (2013))

Technology / Learning curve	Cost reduction in 2030 compared to today's prices	
	Medium	High
Solar thermal	6%	9%
PV	25%	38%
Heat pumps	6%	9%
Ambitious renovation of building envelope	15%	23%
Moderate renovation of building envelope	10%	15%

Scenario variables

The cost-effectiveness from the investors' perspective is estimated in a number of different scenarios based on permutations of economic factors, to illustrate different policy measures that the government might reasonably consider applying to stimulate the renovation market.

Table 6 gives an overview of the exogenous parameters and the chosen variables for the definition of different scenarios. In most cases, a low, central and high value assumption is presented.

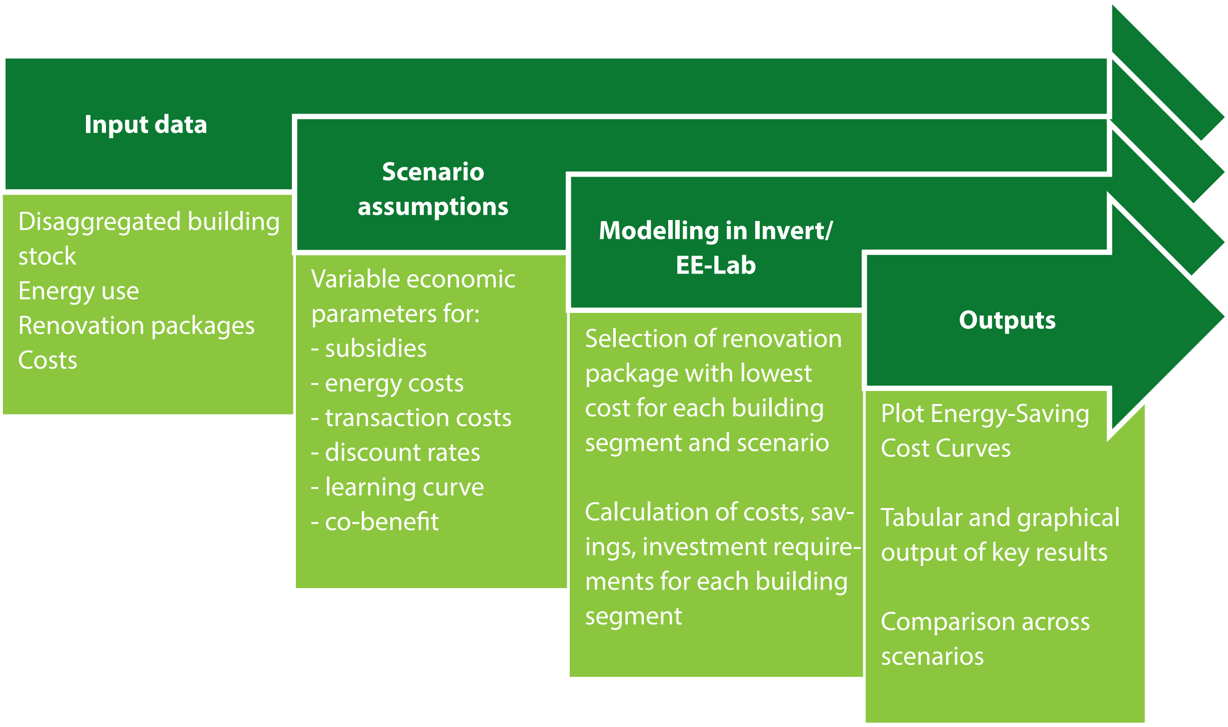
Table 6: Overview of parameters applied in the scenarios

Parameters	Assumptions	Modelling variables
Subsidy level for building envelope measures	low	0%
	medium	10-25% (R1= 0%; R2 =10%; R3 = 25%)
	high	20-35% (R1 = 0%; R2 = 20%; R3 = 35%)
Subsidy level for heating and hot water system measures	low	0%
	medium	10-20%
	high	25-40%
Transaction costs	low	2.5%
	medium	5%
Discount rate	low	2%
	medium	4%
Learning curve cost reduction to 2030	medium	6-25%
	high	9-38%
Energy price increase to 2030	medium	1.1% p.a. (equivalent to a total increase of 19%)
	high	2.6% p.a. (equivalent to a total increase of 50%)
Co-benefit	excluded	0%
	included	30%

Please note that, where a range is indicated, different values are used for specific technologies – see for example Table 1.

The overall process undertaken to generate the results is summarised in Figure 10.

Figure 10: Analytical process flow used to develop scenarios



Boundary conditions

Before the scenario results are presented, it is worth setting out the boundary conditions within which the analysis has been undertaken:

- Firstly, it should be understood that the modelling and analytical approach used does not attempt to predict the future. Rather, it sets out to present the economic attractiveness, from the perspective of the investor, of building renovation under a certain set of economic conditions, and hence the potential savings if all building owners acted in an economically rational manner. In reality, this may not be the case, since there are barriers such as reluctance of owners to undertake renovations (even if cost-effective), the landlord-tenant barrier, competing priorities and a host of other reasons. Nevertheless, the analysis is valid as it provides the economic basis to underpin policy decisions.
- Not every feasible energy-saving measure has been considered in this study. For example, the important role that district heating, co-generation (heating and electricity) and tri-generation (heating, cooling, and electricity) can play in reducing GHG emissions has not been explored.
- In terms of renovation depth, the approach taken in this study has been to select the renovation package with the lowest overall cost, taking into account the investment and resulting energy cost savings.
- Only comprehensive renovations, which result in installation of both fabric and heating measures, are considered. Such renovations can be effected in one stage, or, alternatively, in a number of carefully planned and co-ordinated stages. Partial renovations, or the installation of single measures, are not considered.
- All scenarios run to 2030. This is a sufficiently long timescale for the full impact of policies to be witnessed, yet not so long as to require unrealistic assumptions to be made about longer-term technological developments and evolution of costs/prices that may radically change the economic landscape for building renovation. Clearly, within the period to 2030, it would only be possible to renovate a proportion of the existing stock, so the results presented below should not be considered as being the limits of what can be achieved in terms of energy savings and GHG-emissions reductions from the existing building stock.
- In the Invert/EE-Lab Model the renovation rate is derived based on the lifetime of buildings and building components, and the corresponding age structure of the building stock. Thus, different age bands show different renovation rates. The cumulative share of renovated buildings in the period from 2015 to 2030 varies between about 15% and 37% for different building segments. This is equivalent to an annual renovation rate from below 1% for newer building segments and up to 2.3% for older building segments.
- The results present the full impact of renovations undertaken under a particular scenario through to 2030, rather than an annualised rate. For example, the quoted energy savings will occur from 2030 onwards, once the full complement of buildings has been renovated. The investments and subsidies represent the total requirement for all renovations to 2030, but at today's prices (reduced according to the learning curve applicable under a given scenario). Likewise, net savings (which might be negative or positive) are the energy cost savings over the lifetime of the measures, less the total investor contribution to the investment.
- Within each building category there are a range of buildings, some of which will be more amenable to renovation than others. The results plotted in the results section represent an average across that building category. If a building category is cost-effective overall, it does not necessarily mean that comprehensive renovation of all buildings of that type will be cost-effective. Likewise, a building category that is overall not cost-effective may include buildings which are cost-effective to renovate under the given set of economic conditions.

3 RESULTS

In this section we firstly define the five scenarios used in the modelling and explain how to interpret the Energy-Saving Cost Curve before the results are presented individually. A comparison across the scenarios is then provided.

Summary of scenarios

From a list of over 30 scenarios that were modelled, five have been selected to illustrate a representative spectrum of impacts resulting from different plausible combinations of economic levers that could be brought to bear on the market for building renovation within the context of a national renovation strategy:

1. **Business as Usual**: uses the central economic factors, described in Table 6;
2. **High Subsidy**: as per the Business as Usual scenario, but with a higher level of subsidies;
3. **High Energy Price**: as per the Business as Usual scenario, except with a higher rate of energy price increase;
4. **Soft Measures**: shows the impact of policies that seek to establish a favourable climate for renovation, but without the use of subsidies or relying on high energy prices. Instead, this scenario shows the simultaneous impact of low transaction costs, low discount rates (low borrowing costs; low market barriers) and a high learning curve (lower renovation costs over time); and
5. **Best Case**: uses the most advantageous set of assumptions across all the economic parameters to create a highly conducive environment for deep renovation of buildings.

Interpreting the results

For each of the five scenarios, results are presented both with and without the increased comfort co-benefit. This serves as an illustration of the impact of including a nominal value for the increase in comfort that follows an improvement in building energy performance.

In the Energy-Saving Cost Curve plots, results not including co-benefit are represented by solid blocks, while the equivalent building category with co-benefit is included in the same colour, though shaded. In general, the impact of including the co-benefit can be noticed in the graphs by a shift downwards (more cost-effective) and to the right (higher savings).

HOW TO INTERPRET THE ESCC PLOT

The Energy-Saving Cost Curve (ESCC) is a visual representation of the cost-effectiveness of building renovation across a spectrum of building categories.

The horizontal axis (x-axis) displays projected annual energy savings for each building category (e.g. retail buildings). The vertical axis (y-axis) shows the net costs or savings, discounted over the measures' lifetime, divided by the total lifetime energy savings. The value is presented in cents/kWh saved.

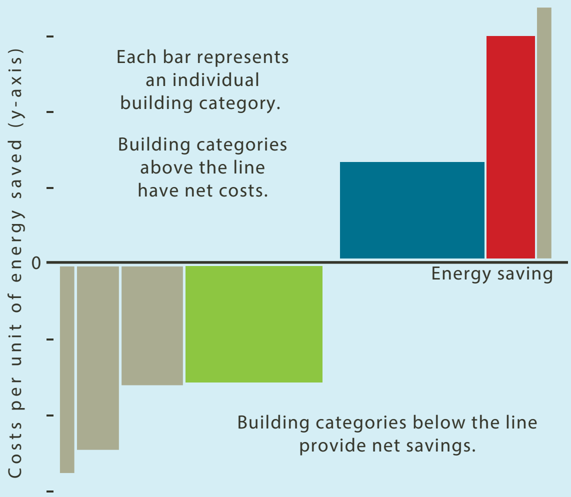
Each bar represents a distinct building category. The width of each bar represents the energy savings, while the height represents the specific costs (or savings) per unit of energy saved.

If the bar is **above** the horizontal axis, there is a **net cost** for investors in that building category, meaning that the energy-cost savings over the lifetime of the measure are less than the initial investment. Conversely, if the bar is **below** the axis, there are **net savings**. The total cost or total saving for a building category is represented by the area of the bar (i.e. cost or saving per unit of energy saved times the energy saving).

Note that each bar represents a large number of different buildings, each with its own cost-effectiveness result. This means that, for example, a building category that is above the axis (i.e. overall not cost-effective) could include individual buildings that produce net savings. Equally, not all individual buildings within a category which is below the line (i.e. overall cost-effective) will themselves be cost-effective.

Different scenario factors can lead to different bar heights, since the costs and/or savings will vary if, for example, the subsidy level or the discount rate changes. This can also impact the bar width, (i.e. energy savings) if a different renovation package becomes the least cost option.

Figure 11: How to interpret the ESCC plot



The key results are also presented in tabular form. They comprise:

- **Energy savings** (TWh/year) – these are the total annual energy savings arising as a result of the installation of the renovation measures. Note that the figures represent total annual savings from 2030 onwards, once all measures have been installed.
- **Net financial savings** (€bn) – comprise energy-cost savings, minus the investment in the renovation measures. The savings under "with co-benefit" also include the value of increased comfort, which has been calculated as equivalent to 30% of the energy cost savings. In other words, the total benefit from a given investment when including comfort is 130% (or 1.3 times) the value of that when only the direct energy-cost savings are considered.
- **Total Investment** (€bn) – these are the total investment requirements, comprising both subsidies and the non-subsidised contributions of investors to the cost of measures.
- **Subsidies** (€bn) – this is the total value of public contribution, in whatever form, to the cost of the renovation measures. As noted in Table 6, deeper renovation and more expensive measures attract higher levels of subsidy.

For each of these key outputs, results are presented according to four different cases for each scenario, as follows:

Table 7: The four cases in which each scenario is presented

ALL BUILDING CATEGORIES WITHOUT CO-BENEFIT	ALL BUILDING CATEGORIES WITH CO-BENEFIT
COST-EFFECTIVE BUILDING CATEGORIES WITHOUT COMFORT CO-BENEFIT	COST-EFFECTIVE BUILDING CATEGORIES WITH COMFORT CO-BENEFIT

The top row illustrates the total impact if all building categories are renovated in accordance with the results generated under the parameters specified in that scenario. The bottom row illustrates the impact if only those building categories for which the renovation provides a net monetary saving (i.e. those below the line in the ESCC plot) are considered.

Scenario 1: Business as Usual

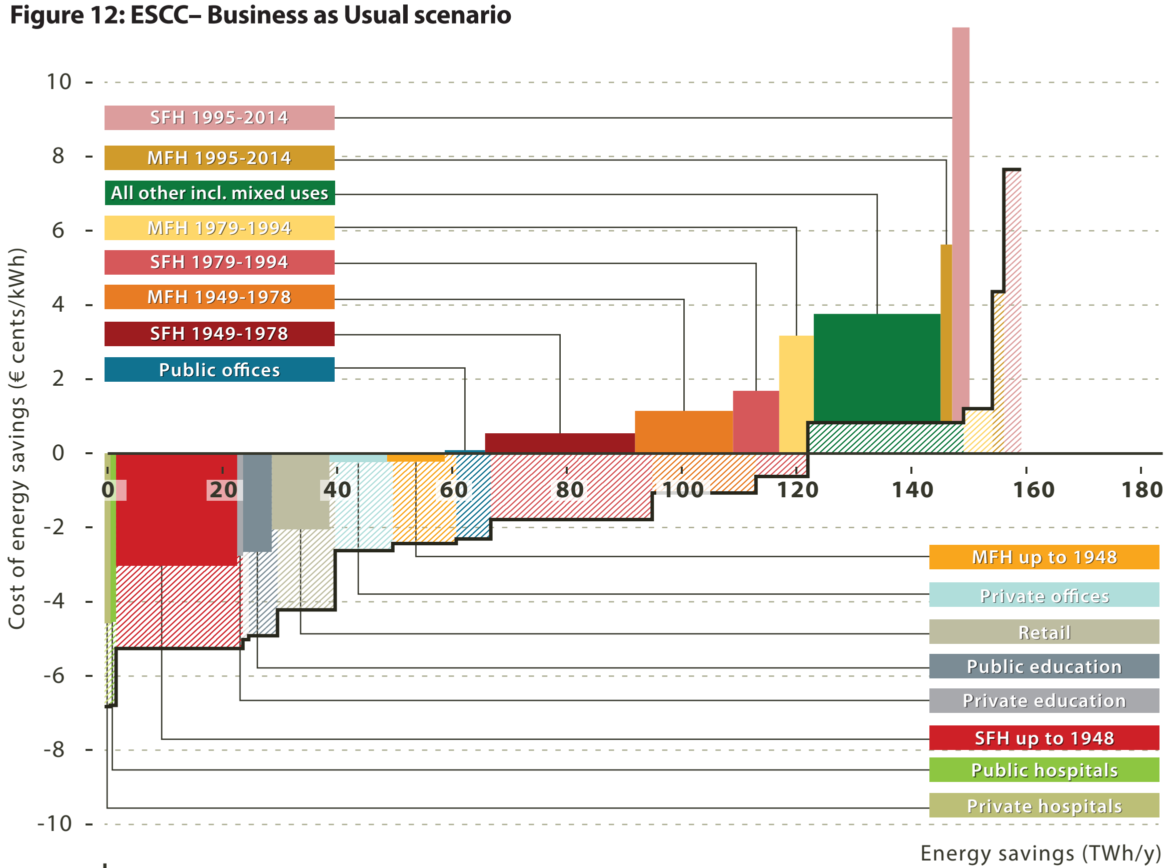
This scenario assumes the prevailing **central** economic conditions in Table 6 are maintained throughout the period in question. The parameters used are summarised in the table below the ESCC plot, followed by the key results.

Under the Business as Usual scenario, half of the building categories are located above the line and thus not cost-effective (without considering the co-benefit). Non-residential building categories hold the most cost-effective potential for retrofits, notably hospitals, educational facilities, retail and private offices. It is noteworthy that, within the residential sector, only older dwellings built up to 1948 exhibit a cost-effective potential for renovation – these are the ones with the highest specific energy demand, as illustrated in Figure 13. However, it should be recalled that we consider full renovation packages only. There would undoubtedly be single measures or partial renovations for newer buildings that deliver cost-effective benefits, even though they would achieve lower savings.

Inclusion of co-benefits results in a doubling of the energy saving of cost-effective building categories, while net financial savings for the total of all building sectors turn positive (€2.8 billion, compared to a net cost of €0.8 billion).

Assuming investors only take up cost-effective renovations, the total investment required amounts to €97 billion, of which €19 billion is public subsidy. When co-benefits are valued in the economic appraisal, total investment increases to €235 billion, of which subsidies account for €41 billion[39].

Figure 12: ESCC– Business as Usual scenario



Solid colour = no co-benefits | Shaded + black outline = with co-benefits
SFH = single-family houses | MFH = multi-family houses

[39] Subsidies are related to the level of investment. They do not rise in exact proportion to the investment, since the mix of measures changes according to the specific input parameters, and different measures attract different levels of subsidy – see Table 6.

Table 8: Savings– Business as Usual scenario

Subsidies	Transaction costs	Discount rate	Cost decrease to 2030	Energy price increase to 2030
Medium	Medium	Medium	Medium	Medium
10-25%	5%	4%	6-25%	1.1% p.a (equivalent to a total increase of 19%)

All building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	150	160
Net financial savings (€bn)	-0.8	2.8
Total investment (€bn)	304	353
…of which subsidies (€bn)	50	65

Cost-effective building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	60	122
Net financial savings (€bn)	1.2	3.4
Total investment (€bn)	97	235
…of which subsidies (€bn)	19	41

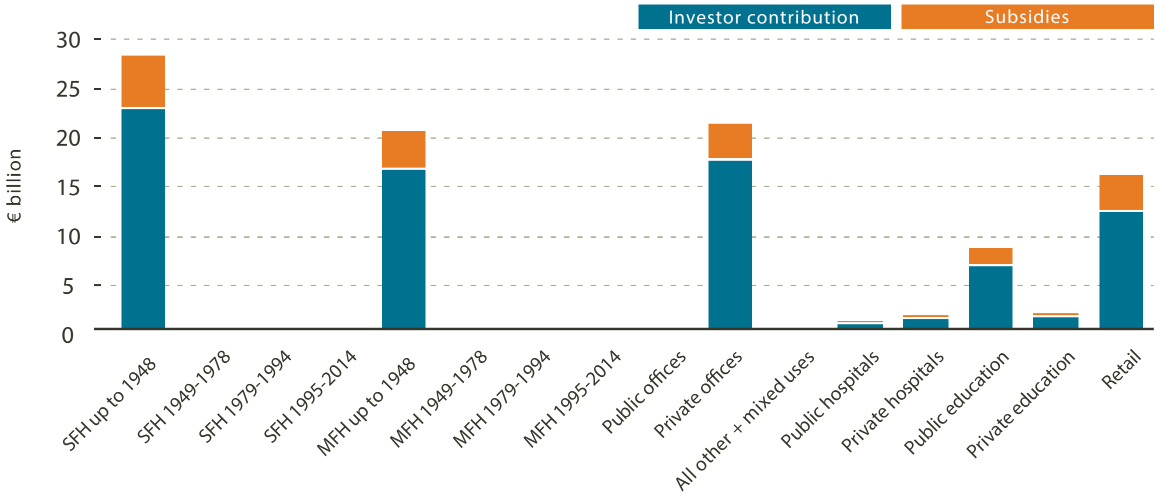
Analysis for the case of cost-effective building categories

For each scenario we present a series of additional graphs illustrating a more detailed breakdown of the results. The case of cost-effective building categories, without co-benefit (bottom left in Table 7), recognises that investors will only invest in renovations where there is a net financial saving, and also that they rarely factor in the comfort benefit. The comparison of the two cases shows the big impact of including the co-benefit in the economic appraisal.

The three graphs below illustrate:

- The **investment requirements** for each building category split according to investor contribution and subsidy. Cost-effective investment is triggered for only eight out of the 16 building categories without co-benefit, but rises to 12 when the co-benefit is included.
- The **average renovation depth**, where it can be seen that over 60% of the non-residential stock could be cost-effectively renovated to the most ambitious level (R3), whereas this is the case for less than 25% of the residential stock. The proportion of R3 rises when co-benefits are included.
- **Renovated floor area**. Over half of the renovation activity would affect just the two residential building categories of single-family houses and multi-family houses, in both cases relating to the oldest stock, constructed up to 1948. Floor area more than doubles when co-benefits are included.

Figure 13: Investment in cost-effective building sectors (top: without co-benefit; bottom: with co-benefit) – Business as Usual scenario



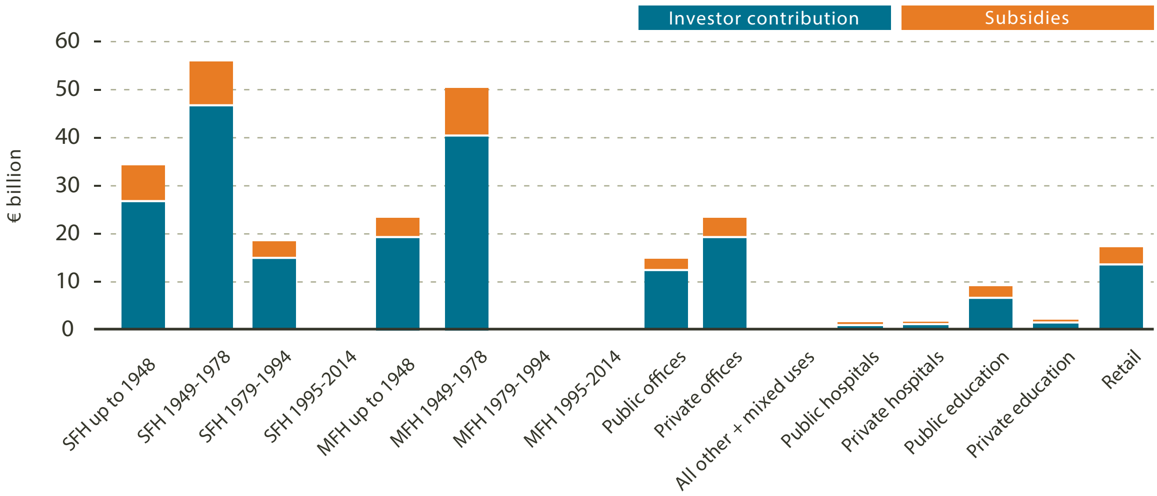


Figure 14: Average renovation depth (left - without co-benefit; right - with co-benefit) – Business as Usual scenario

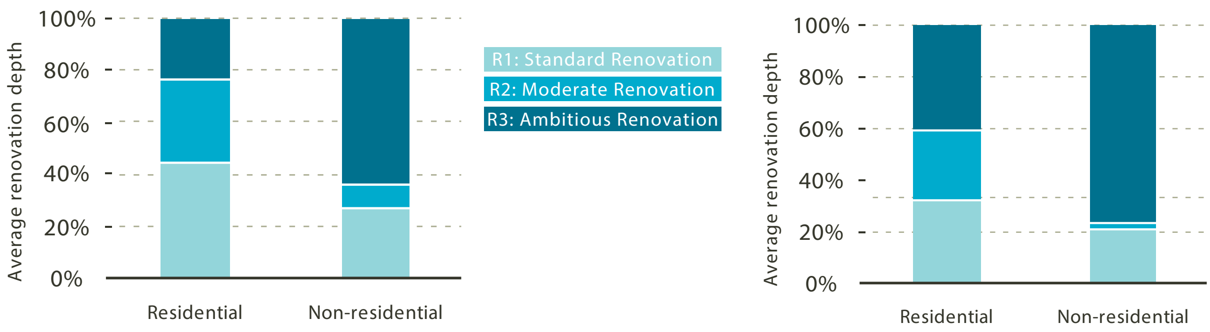
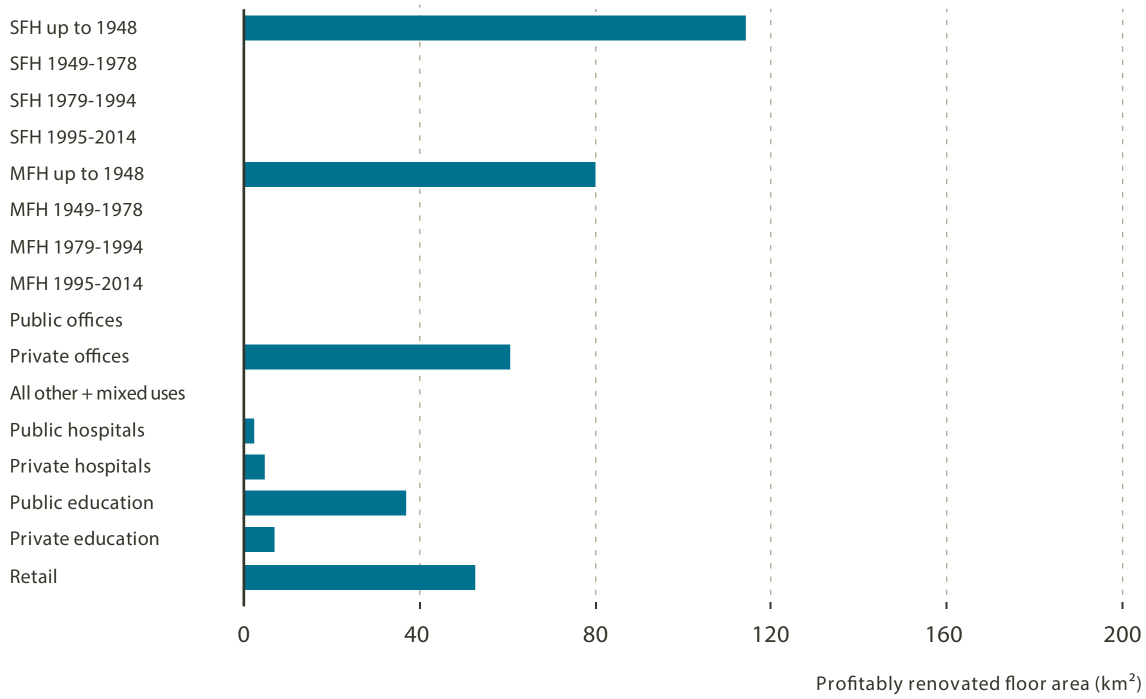
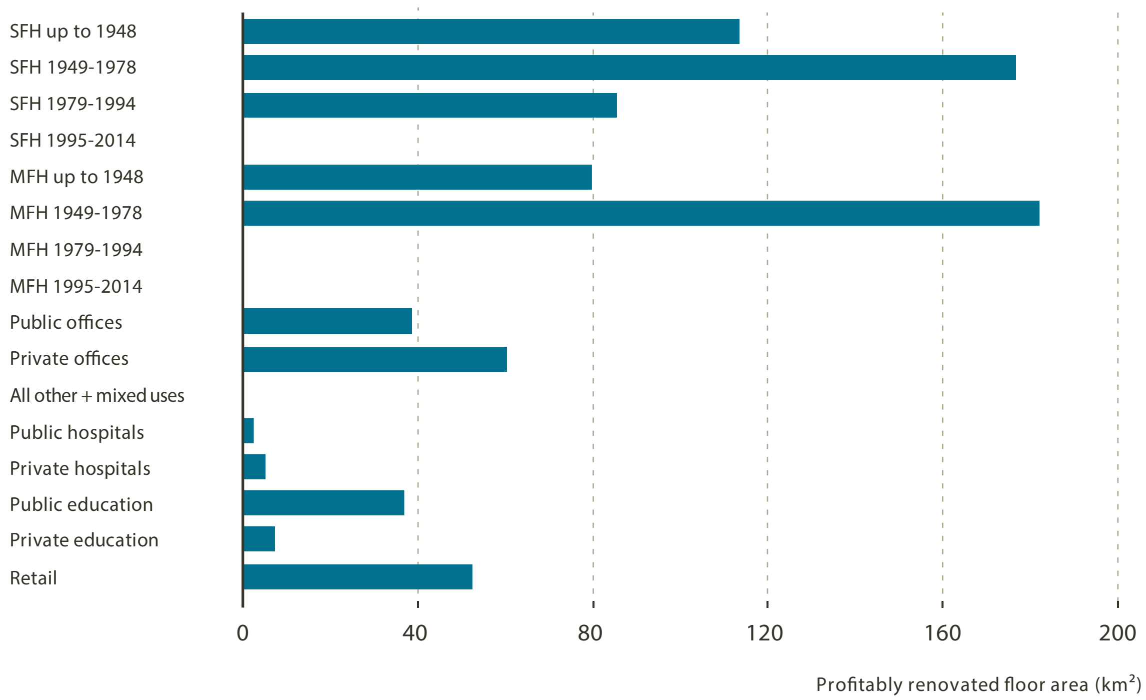


Figure 15: Profitably renovated floor area (top - without co-benefit; bottom - with co-benefit) – Business as Usual scenario





Bundling investment opportunities

Our analysis demonstrates that there is a wide range in the cost-effectiveness of renovating different building categories. Faced with such a range, investors would naturally want to choose those that deliver the highest return on investment. Those building categories that are above the line would therefore not be addressed. However, policymakers should seek to encourage investments across all building categories (except the most recent stock, built since 1995).

One solution could be to set up a bundling fund for renovation projects which proactively manages a combination of projects with different economic performances. Property owners could apply for participation in the fund to get access to investment capital which is paid back over time through energy savings. The government would create bundles of investment opportunities which could be offered on the investment market and provide a guaranteed return. The resulting return would be calculated based on the weighted average return of the components of the investment bundle. In order to increase financial viability, the government could decide to apply subsidies to certain building categories. These would support the investment rather than the renovation project. This could mean that a property owner could pay back less into the fund than the amount which he was provided with when he applied for the fund.

To illustrate with an example: If an investor undertakes renovation measures which only pay back to 80% within a given time frame, the government would add the remaining 20% into the fund, plus the amount which was guaranteed as return to the investor. Fund managers could therefore proactively combine different renovation projects in bundles, with the aim to minimize government support while still guaranteeing the investor's return.

Scenario 2: High Subsidy

Compared to the Business as Usual scenario, the additional incentive in the High Subsidy scenario is to increase the level of subsidies to the high values seen in Table 6, namely:

- For fabric measures: R1 = 0%; R2 = 20%; R3 = 35%;
- For technologies: 25-40%.

The impact of applying the higher subsidy rates can immediately be seen. Compared to the Business as Usual, there is a general shift down (i.e. more cost-effective) and right (i.e. higher energy savings) in the Energy-Saving Cost Curve. The following additional building categories become cost-effective: public offices and residential buildings (both single and multifamily) constructed in the period 1949-1978. Total energy savings increase from 150 TWh/year to 167 TWh/year (not including the co-benefit). The fact that net savings across all building categories are positive, at €1.2 billion, means that a "bundling" approach of transferring the surplus from cost-effective buildings to the non-cost-effective ones could achieve the total energy-saving potential in a way that delivers net cost savings for all building category owners.

Clearly, the higher subsidy rate comes at a higher cost to the public budget – up from €50 billion in the Business as Usual scenario to €106 billion in this High Subsidy scenario.

Including the co-benefit again has a significant impact, increasing the cost-effective savings potential from 118 TWh/year to 165 TWh/year. The net benefit also increases dramatically, from €1.2 billion (all measures) or €1.9 billion (cost-effective measures) to over €5 billion in both cases.

Figure 16: ESCC– High Subsidy scenario

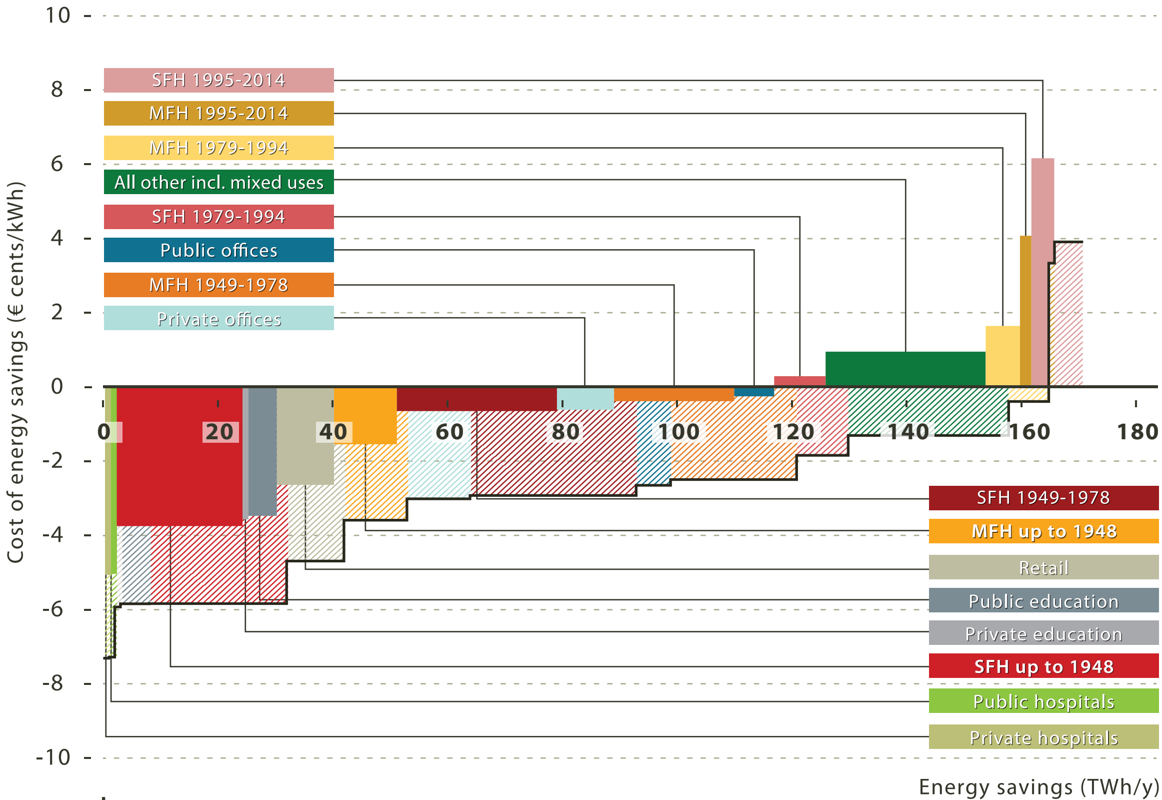


Table 9: Savings – High Subsidy scenario

Subsidies	Transaction costs	Discount rate	Cost decrease to 2030	Energy price increase to 2030
High	Medium	Medium	Medium	Medium
20-40%	5%	4%	6-25%	1.1% p.a. (equivalent to a total increase of 19%)

All building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	167	171
Net financial savings (€bn)	1.2	5.0
Total investment (€bn)	405	445
…of which subsidies (€bn)	106	117

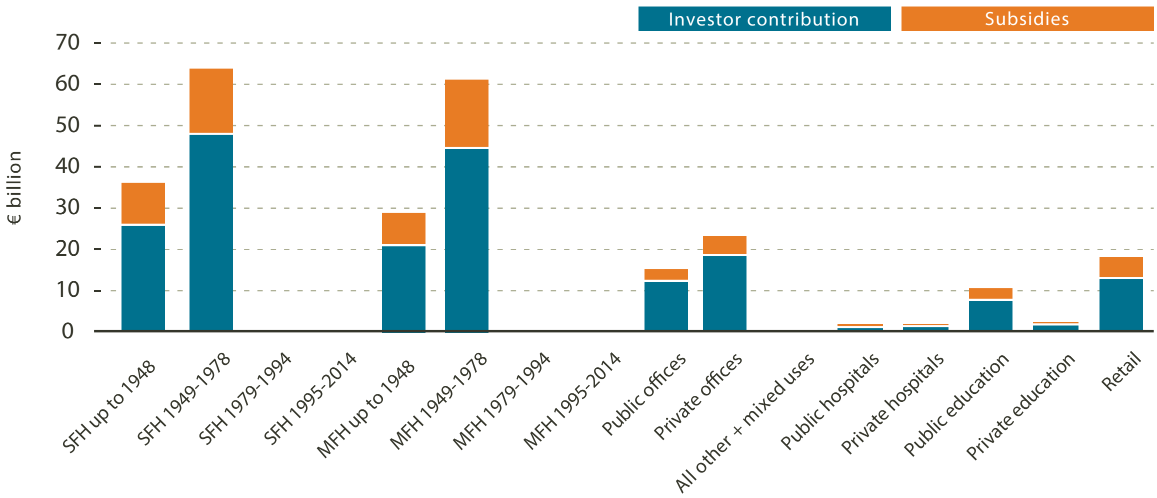
Cost-effective building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	118	165
Net financial savings (€bn)	1.9	5.2
Total investment (€bn)	254	426
…of which subsidies (€bn)	65	113

Analysis for the case of cost-effective building categories

The three graphs below illustrate:

- (Figure 17) Cost-effective investment is triggered for 11 out of the 16 sectors, compared to eight under Business As Usual, rising to 14 with co-benefits included.
- (Figure 18) Higher subsidies have a positive effect on the renovation depth. Both residential and non-residential sectors exhibit a higher proportion of the ambitious renovation depth, amounting to 80% of the total in the case of non-residential buildings. There is a slight increase in R3 renovations when co-benefits are included.
- (Figure 19) Renovated floor area increases dramatically compared to Business As Usual by bringing the two largest building categories – single-family and multi-family houses constructed in the period 1949-1978 – within the cost-effective range.

Figure 17: Investment in cost-effective building sectors (top – without co-benefit; bottom – with co-benefit)



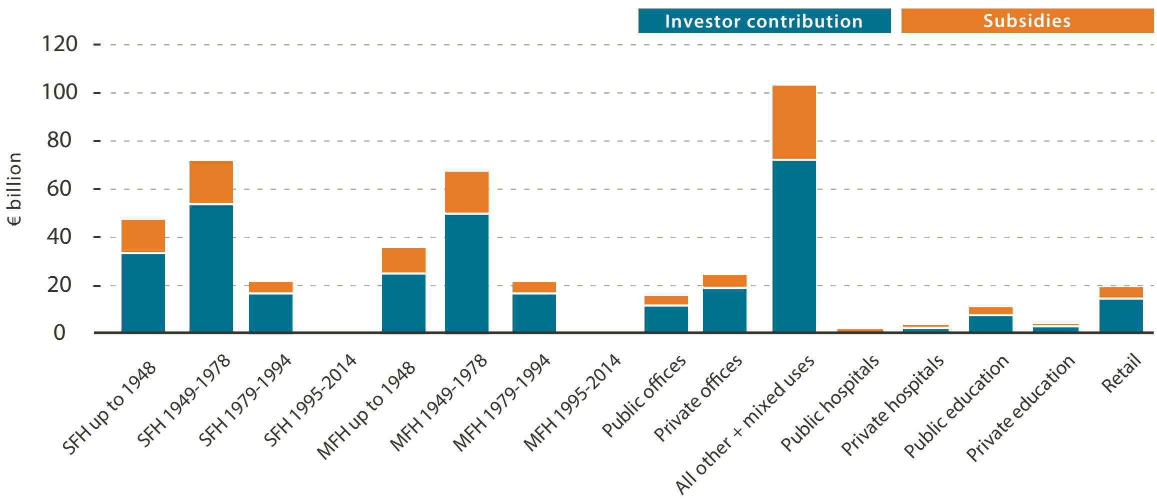


Figure 18: Average renovation depth (left - without co-benefit; right - with co-benefit) – High Subsidy scenario

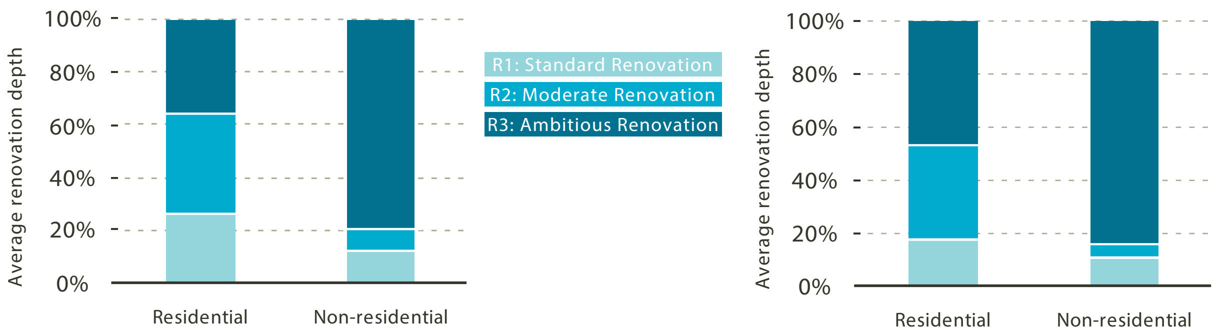
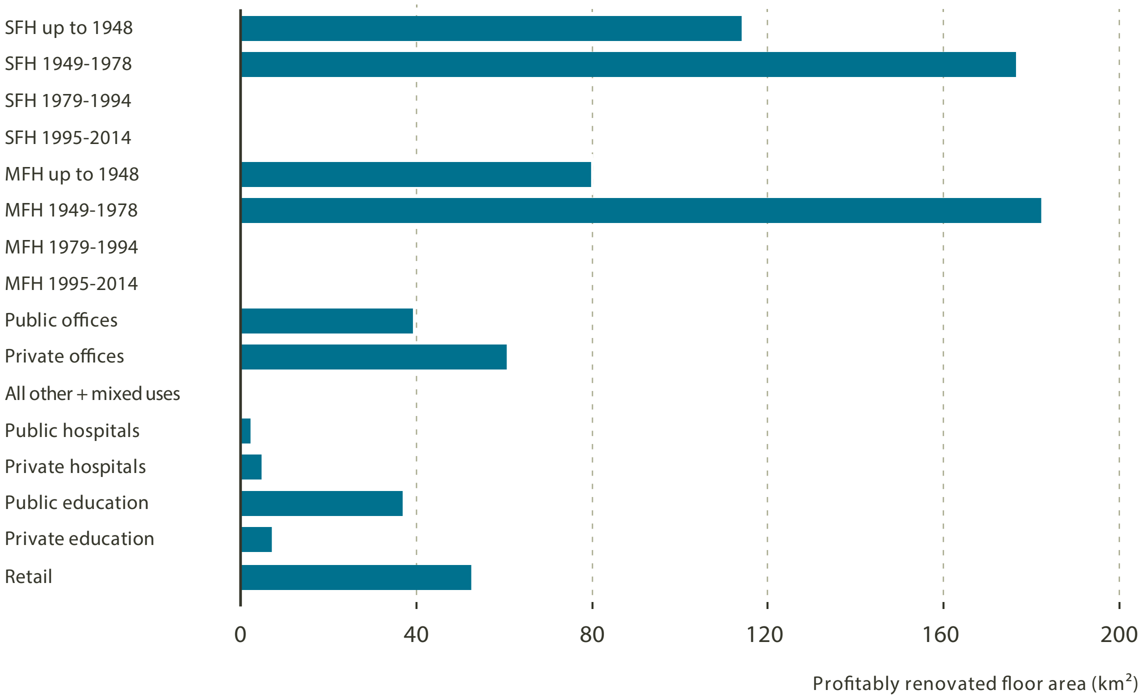
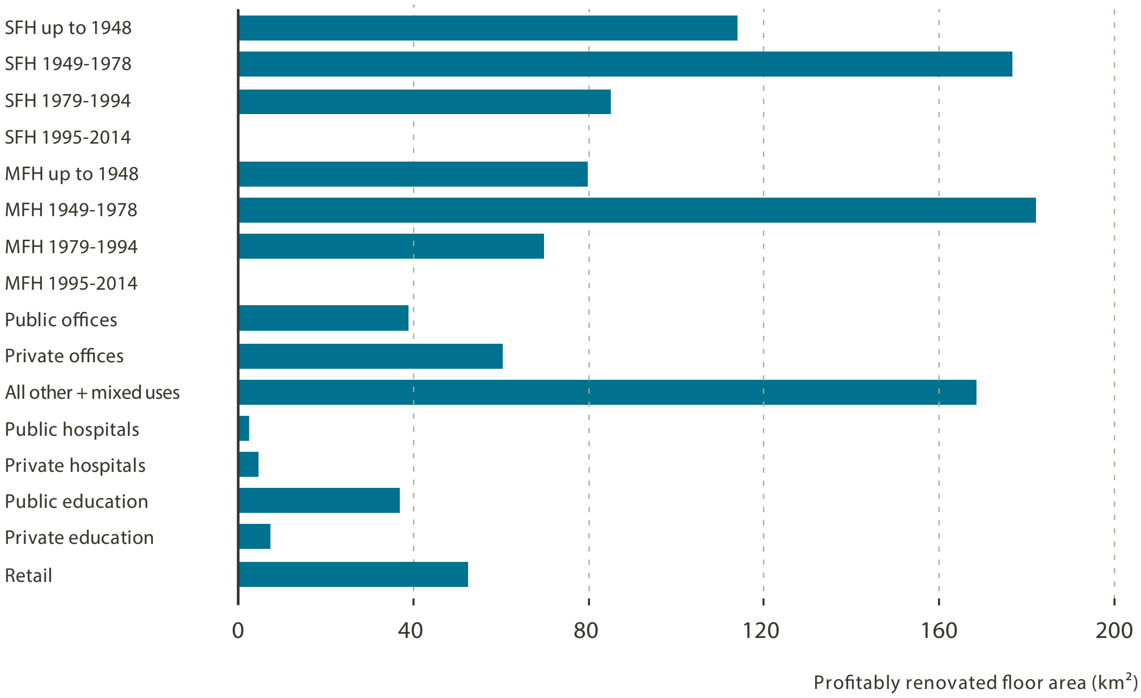


Figure 19: Profitably renovated floor area (top - without co-benefit; bottom - with co-benefit) – High Subsidy scenario





Scenario 3: High Energy Price

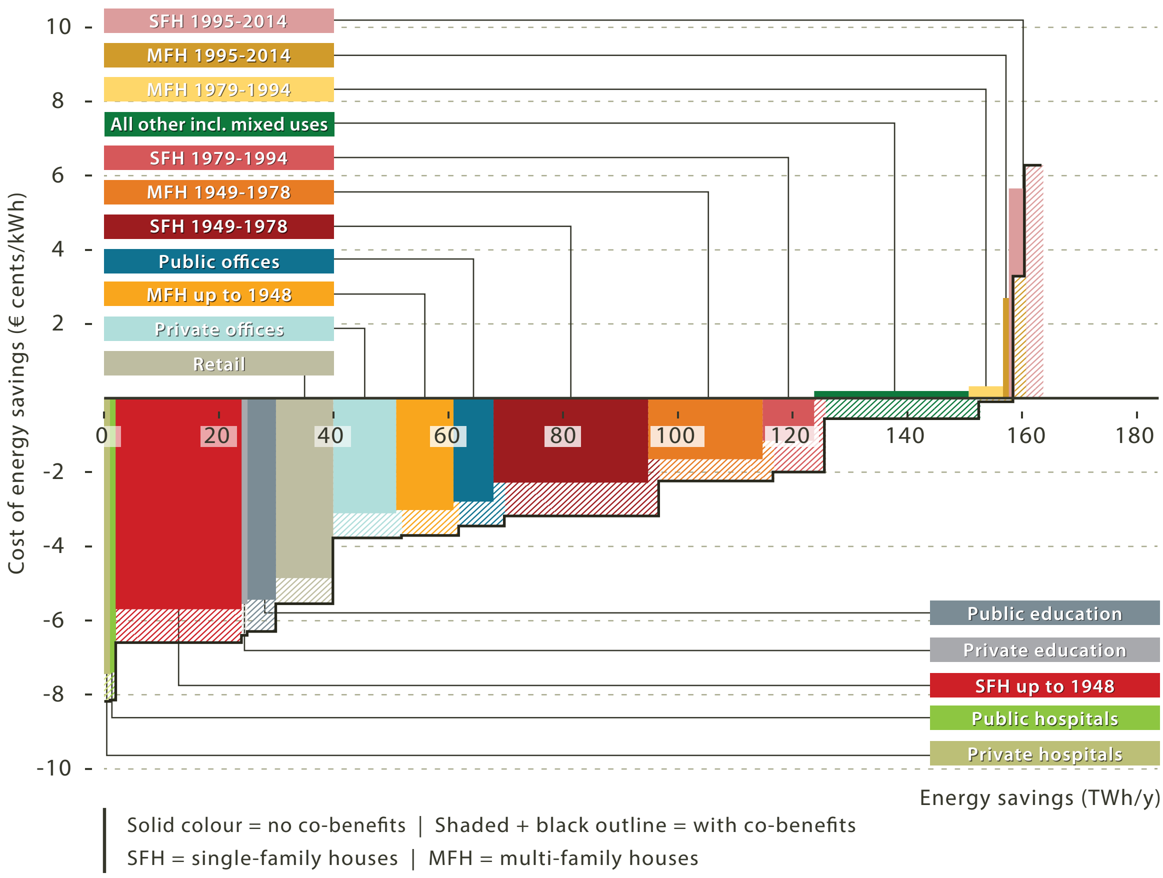
This scenario shows the impact of a policy focused purely on high energy prices, achieved for example through energy taxation and/or carbon pricing. At the same time, this scenario can also be understood to reflect the possibility of future increases in the market price of energy.

Market distortion occurs if consumers do not pay the full price of energy. Subsidies for fossil fuels can arise at various stages of the supply chain, through support for extraction industries, generation, or even at point of use. Other distortions occur if the energy price does not reflect the full environmental externalities associated with energy use. According to a 2015 International Monetary Fund report[40], the value of fossil fuel subsidies in Germany amounts to US$ 683.85 per person per annum.

High energy prices make energy efficiency retrofits a much more attractive investment for nearly all building categories. The resulting total energy savings of 163 TWh/year (or 165 TWh/year with co-benefit) are quite similar to those achieved in the High Subsidy scenario, though the net savings are far greater – €3.8 billion, compared to €1.2 billion.

Compared to the High Subsidy scenario, an additional building category, single-family houses from the period 1979-1994, is now cost-effective. It is noteworthy that the 'other sectors', non-residential and multi-family houses 1979-1994, are only just above the line, so a small increase in support (e.g. subsidy) for these building categories could dramatically increase the level of cost-effective savings. In any case, a bundling approach would achieve the full savings potential while still leaving a large surplus.

Figure 20: ESCC– High Energy Prices scenario



[40] http://www.imf.org/external/pubs/ft/survey/so/2015/NEW070215A.htm

Table 10: Savings – High Energy Prices scenario

Subsidies	Transaction costs	Discount rate	Cost decrease to 2030	Energy price increase to 2030
Medium	Medium	Medium	Medium	Medium
10-25%	5%	4%	6-25%	2.6% p.a. (equivalent to a total increase of 50%)

All building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	163	165
Net financial savings (€bn)	3.8	5.1
Total investment (€bn)	361	375
…of which subsidies (€bn)	65	69

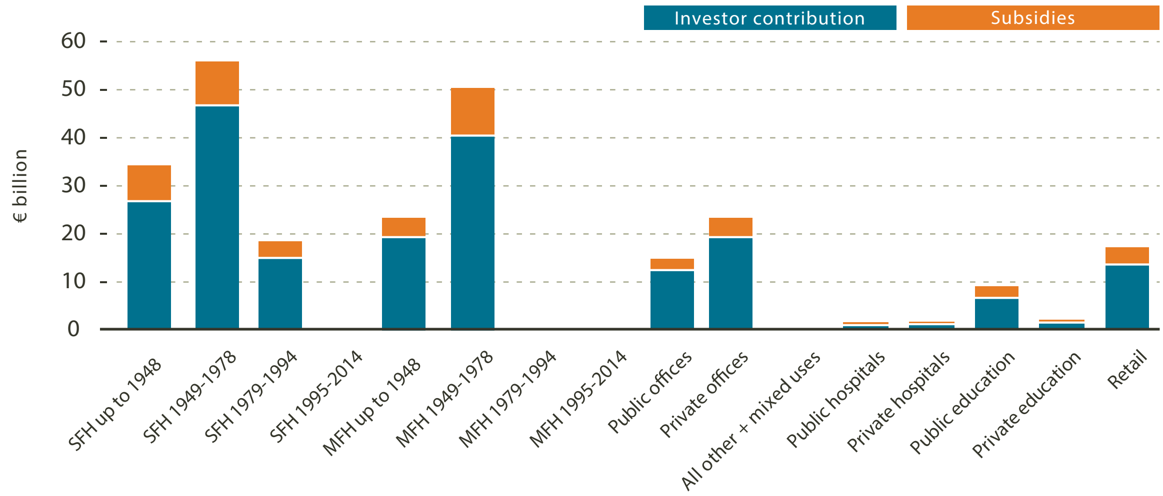
Cost-effective building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	125	160
Net financial savings (€bn)	4.1	5.3
Total investment (€bn)	242	360
…of which subsidies (€bn)	44	68

Analysis for the case of cost-effective building categories

The three graphs below illustrate:

- (Figure 21) Cost-effective investment is now triggered for 12 out of the 16 sectors, rising to 14 with the inclusion of co-benefits.
- (Figure 22) The average renovation depth is quite similar to the High Subsidy case, with the deepest renovation being cost-effective in 80% of non-residential buildings and 40% of residential buildings.
- (Figure 23) The addition of single-family houses (1979-1994) means there is a somewhat higher floor area renovated than for the High Subsidy scenario. When co-benefits are included, two significant building categories become cost-effective: multi-family houses (1979-1994) and the "other non-residential" category.

Figure 21: Investment in cost-effective building sectors (top – without co-benefit; bottom – with co-benefit)



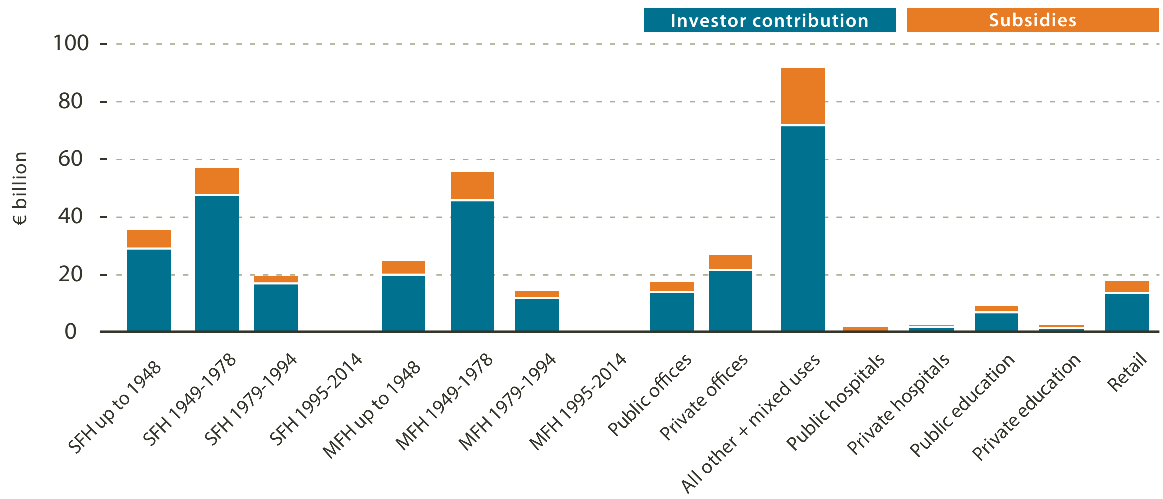
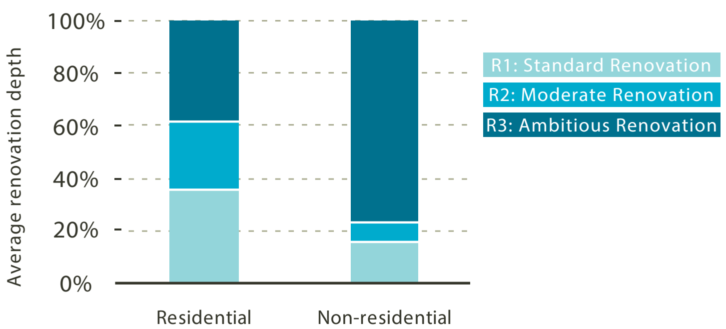


Figure 22: Average renovation depth (left - without co-benefit; right - with co-benefit) – High Energy Prices scenario



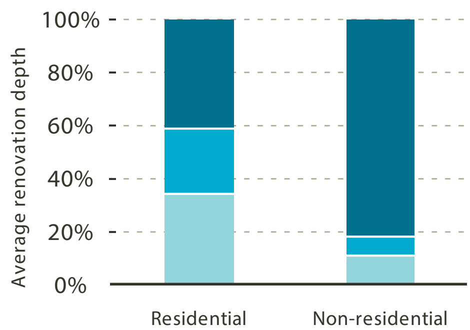
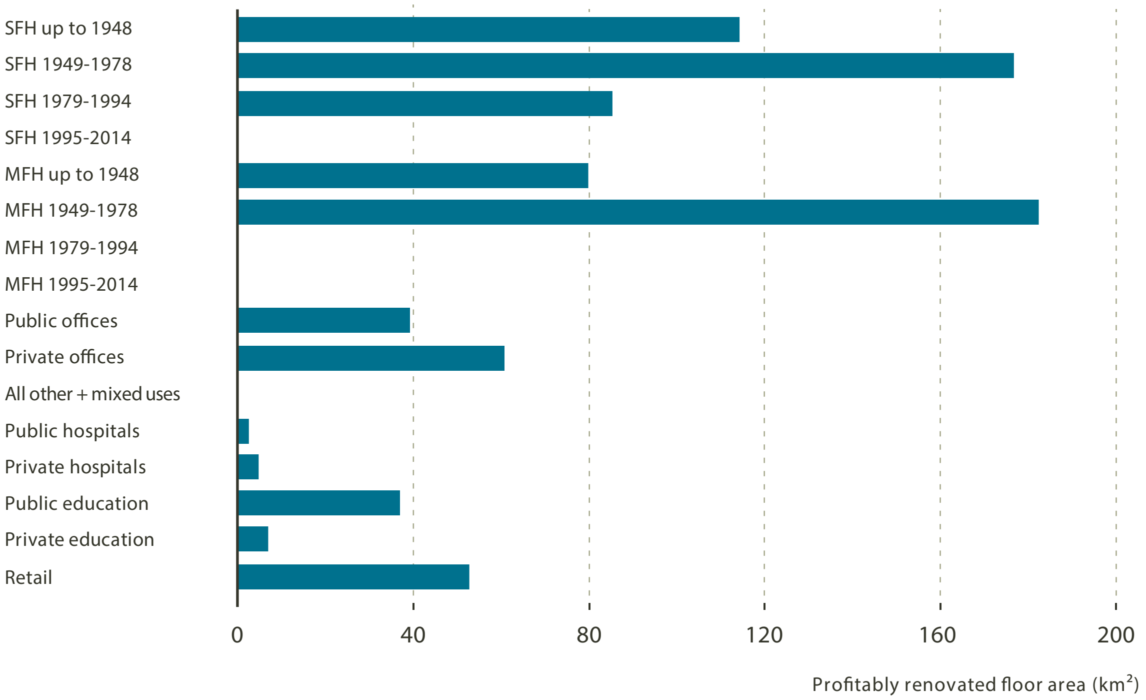
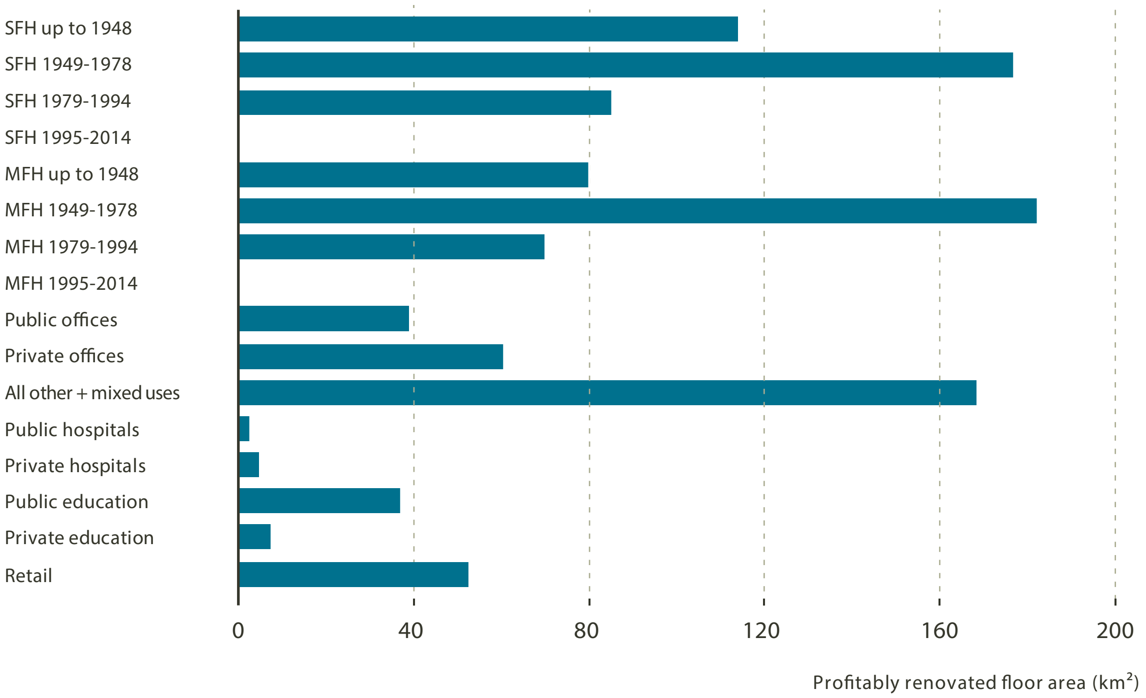


Figure 23: Profitably renovated floor area (top - without co-benefit; bottom - with co-benefit) – High Energy Prices scenario





Scenario 4: Soft Measures

In this scenario, we have removed subsidies and instead assumed the most favourable cases for: transaction costs, learning curve and discount rate. In practical terms, this means taking actions such as:

- Making the process of arranging and financing renovation measures much easier;
- Accelerating cost reductions through R&D; and
- Reducing the cost of borrowing.

Our analysis has shown that the combined impact of these measures is generally not as attractive to investors as the prevailing situation with existing subsidies. Across most parameters (cost savings, cost-effective measures, etc.) this scenario produces less attractive conditions for energy savings than the Business as Usual scenario, except for a slight increase in the level of cost-effective savings, from 60 TWh/year in the Business as Usual to 68 TWh/year in this Soft Measures scenario.

Figure 24: ESCC – Soft Measures scenario

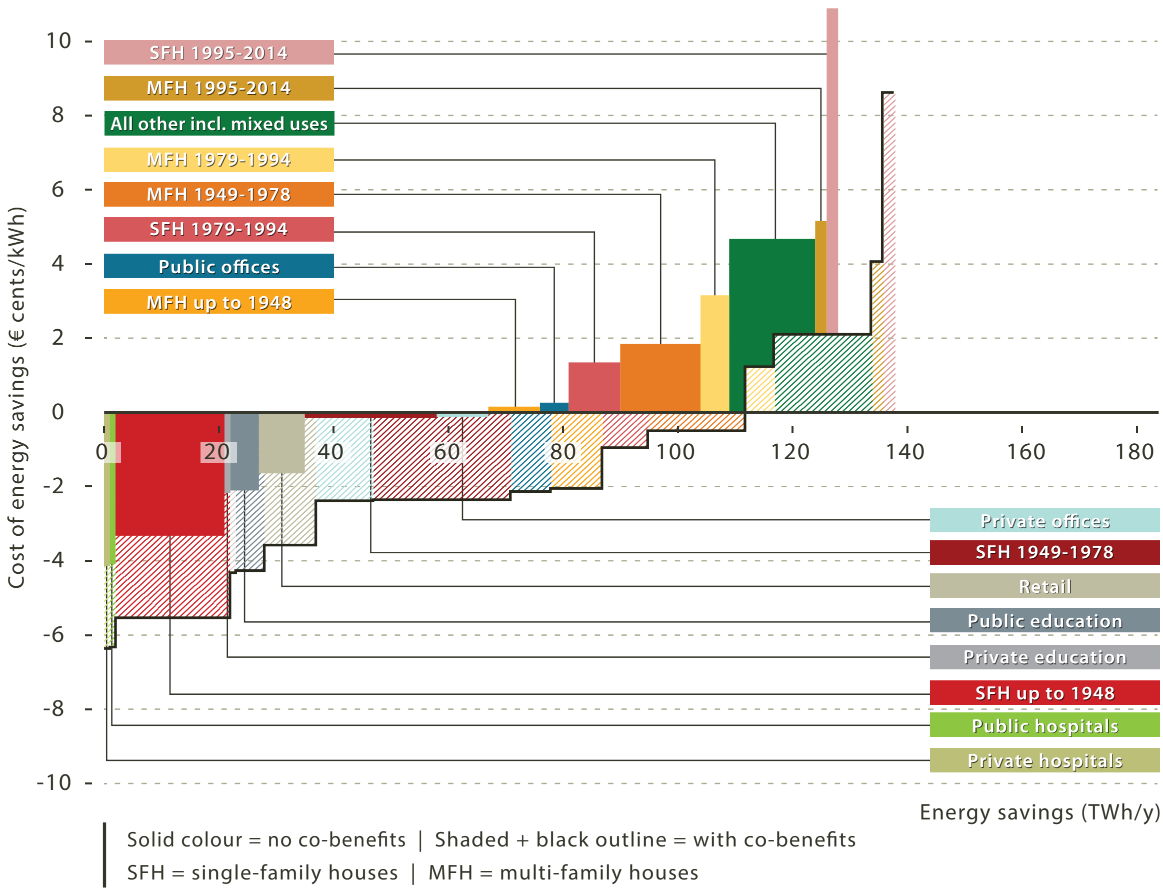


Table 11: Savings – Soft Measures scenario

Subsidies	Transaction costs	Discount rate	Cost decrease to 2030	Energy price increase to 2030
Nil	Low	Low	High	Medium
0%	2.5%	2%	9-38%	1.1% p.a. (equivalent to a total increase of 19%)

All building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	129	139
Net financial savings (€bn)	-0.7	2.4
Total investment (€bn)	216	232
…of which subsidies (€bn)	-	-

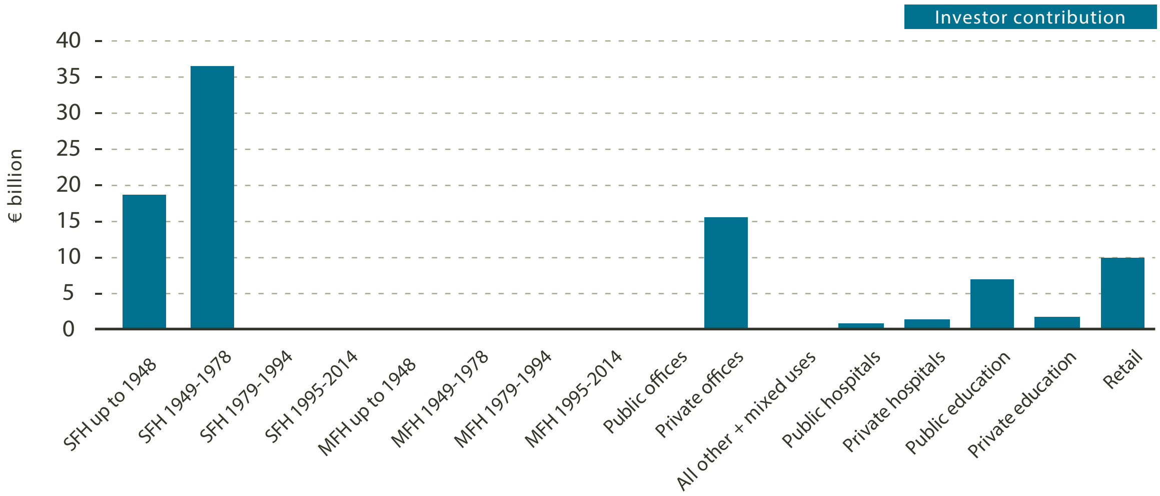
Cost-effective building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	68	112
Net financial savings (€bn)	0.9	3.1
Total investment (€bn)	89	168
…of which subsidies (€bn)	-	-

Analysis for the case of cost-effective building categories

The three graphs below illustrate:

- (Figure 25) Unlike the other scenarios, there is no subsidy in the investment plot. Eight of the 16 building categories are cost-effective, though the only residential building category where cost-effective investment is triggered is single family homes built up to 1978. With co-benefits included, an additional four significant building categories become cost-effective.
- (Figure 26) The renovation depth is the lowest of all five scenarios. Only around 5% of residential buildings, and 30% of non-residential buildings, attract the most ambitious renovation depth (R3). However, when co-benefits are included, the proportion of R3 renovations roughly doubles.
- (Figure 27) The floor area which could be renovated in a cost-effective way is somewhat greater than in the Business as Usual scenario, as a result of the replacement of multi-family homes built up to 1948 with the much larger category of single-family homes constructed between 1949 and 1978. This shows that soft measures are an important tool to trigger renovation activities, even in the absence of the direct fiscal stimulus of a subsidy.

Figure 25: Investment in cost-effective building sectors (top – without co-benefit; bottom – with co-benefit)



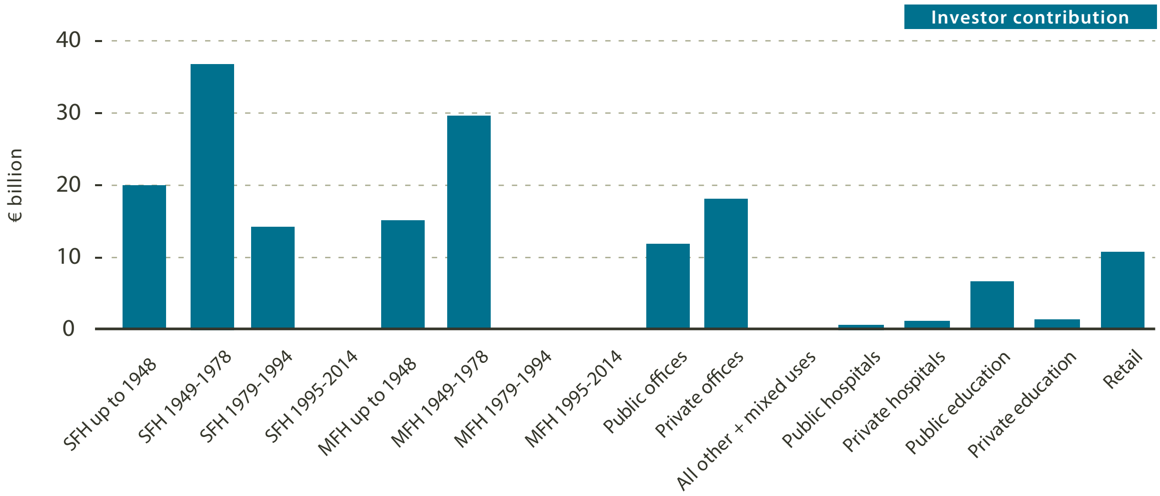
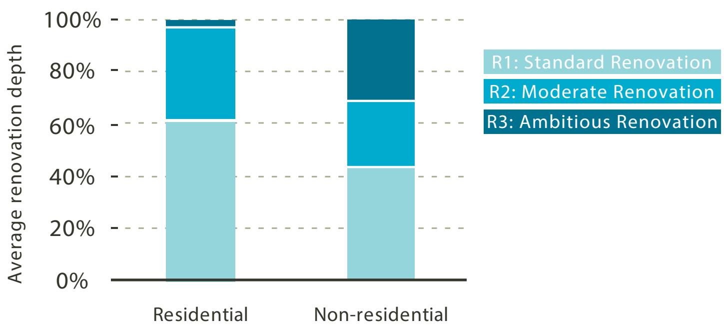


Figure 26: Average renovation depth left - without co-benefit; right - with co-benefit) – Soft Measures scenario



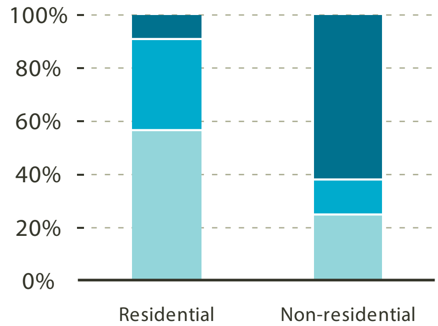
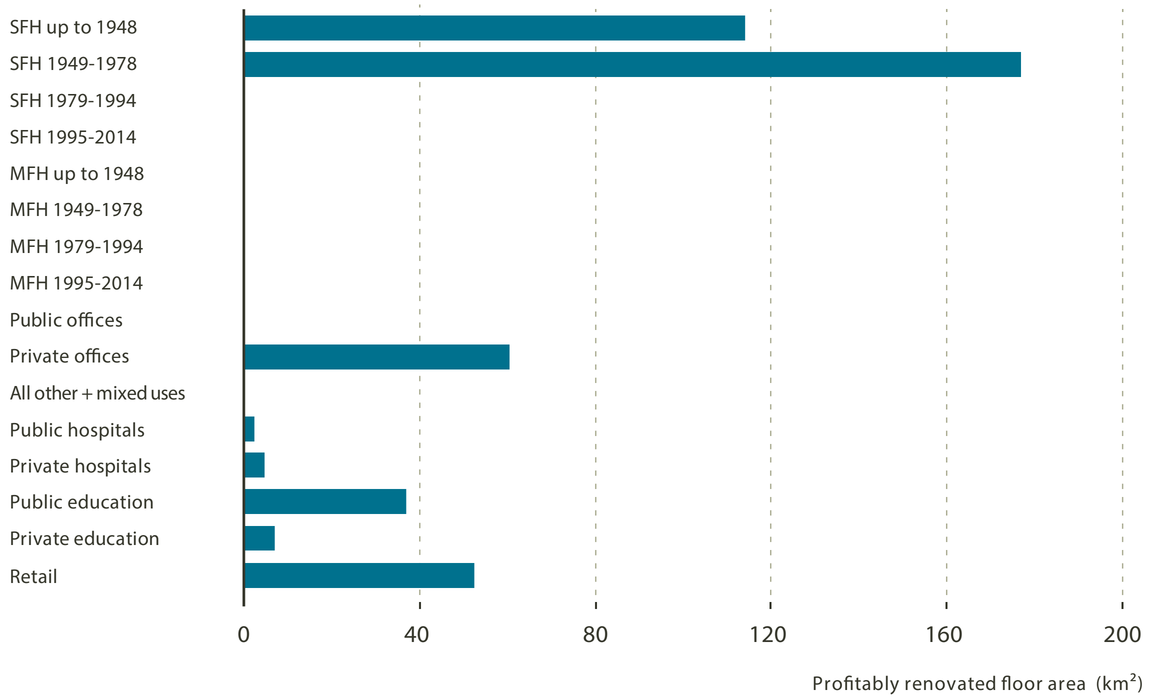
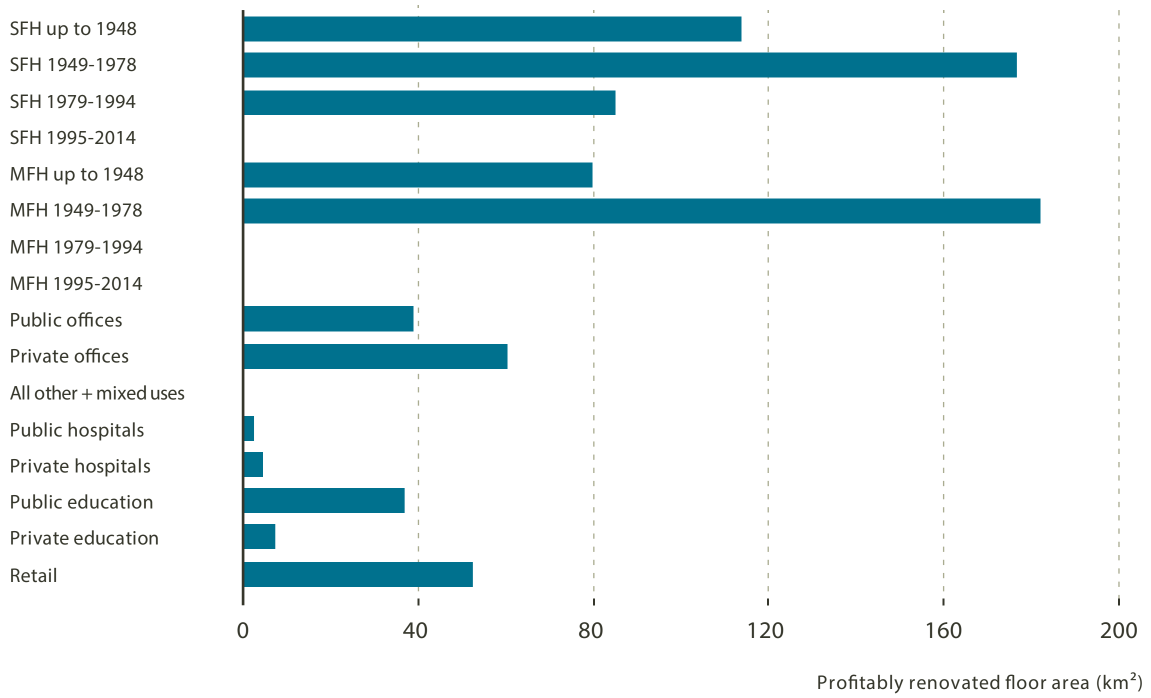


Figure 27: Profitably renovated floor area (top – without co-benefit; bottom – with co-benefit) – Soft Measures scenario



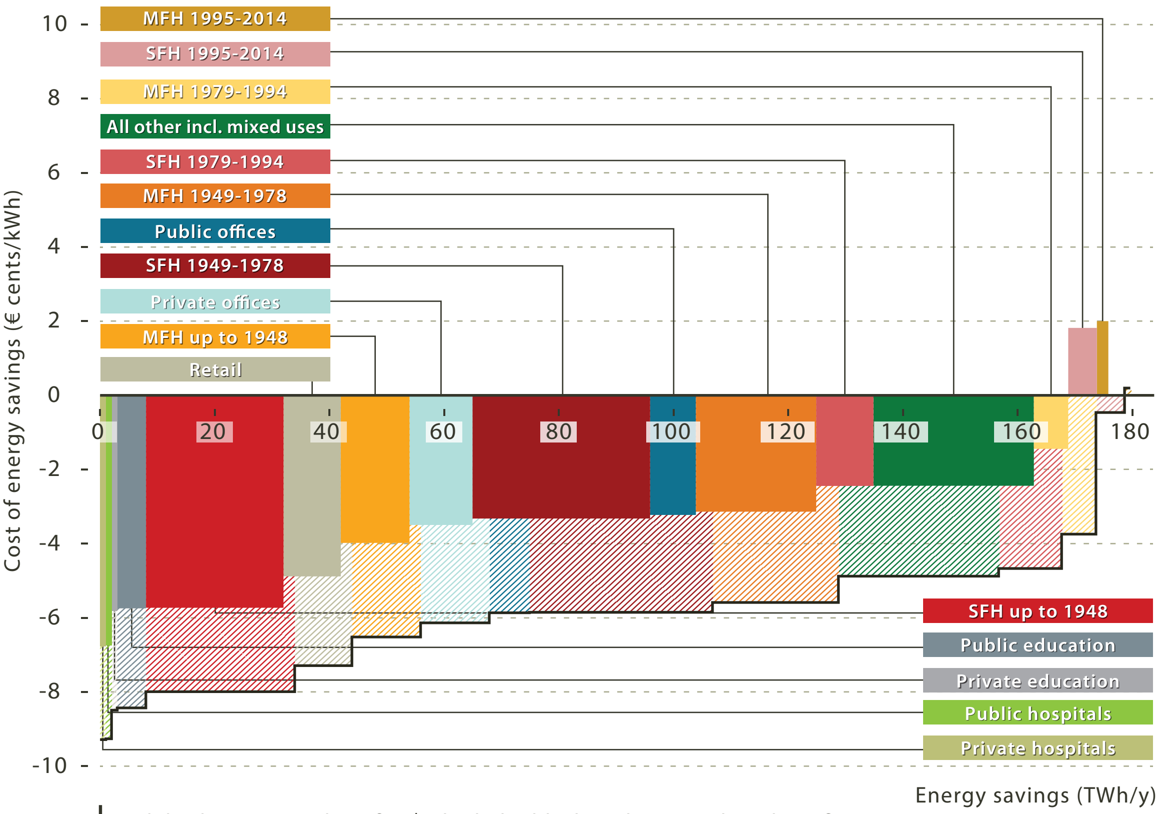


Scenario 5: Best Case

The Best Case scenario combines high subsidies, high energy prices and the package of soft measures to deliver the best possible economic conditions for building renovation. As would be expected, this combination of policy measures leads to the highest savings of all scenarios, with all except two small building categories being cost-effective. The two which remain not cost-effective are the newest residential buildings (SFH and MFH) constructed since 1995 – these buildings should not, in any case, require major renovation prior to 2030 as they will only be a maximum of 35 years old by then.

Excluding these two sectors, total energy savings of 170 TWh/year would be achieved in this scenario, delivering net benefits of €6.2 billion, rising to €10.7 billion if the full value of the comfort co-benefit is taken into account.

Figure 28: ESCC – Best Case scenario



Solid colour = no co-benefits | Shaded + black outline = with co-benefits
SFH = single-family houses | MFH = multi-family houses

Table 12: Savings – Best Case scenario

Subsidies	Transaction costs	Discount rate	Cost decrease to 2030	Energy price increase to 2030
High	Low	Low	High	High
20-40%	2.5%	2%	9-38%	2.6% p.a. (equivalent to a total increase of 50%)

All building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	176	181
Net financial savings (€bn)	6.1	10.7
Total investment (€bn)	448	489
…of which subsidies (€bn)	120	132

Cost-effective building categories	Without co-benefit	With co-benefit
Energy savings (TWh/year)	170	179
Net financial savings (€bn)	6.2	10.7
Total investment (€bn)	427	484
…of which subsidies (€bn)	114	131

Analysis for the case of cost-effective building categories

The three graphs below illustrate:

- (Figure 29) Cost-effective investment is triggered for 14 out of 16 building categories, with only the newest residential stock (SFH and MFH 1995-2014) not included. Adding in the value of co-benefits makes SFH 1995-2014 cost-effective.
- (Figure 30) Ambitious renovation predominates, with 90% of the non-residential stock and 60% of the residential stock achieving R3, increasing to 80% when co-benefits are included.
- (Figure 31) This scenario delivers the highest level of renovation activity across a wide range of building categories. In total, over one billion m^2 of floor area would be renovated cost-effectively under this scenario to 2030. Only MFH 1995-2014 are excluded when the co-benefit is added into the analysis.

Figure 29: Investment in cost-effective building sectors (top – without co-benefit; bottom – with co-benefit)

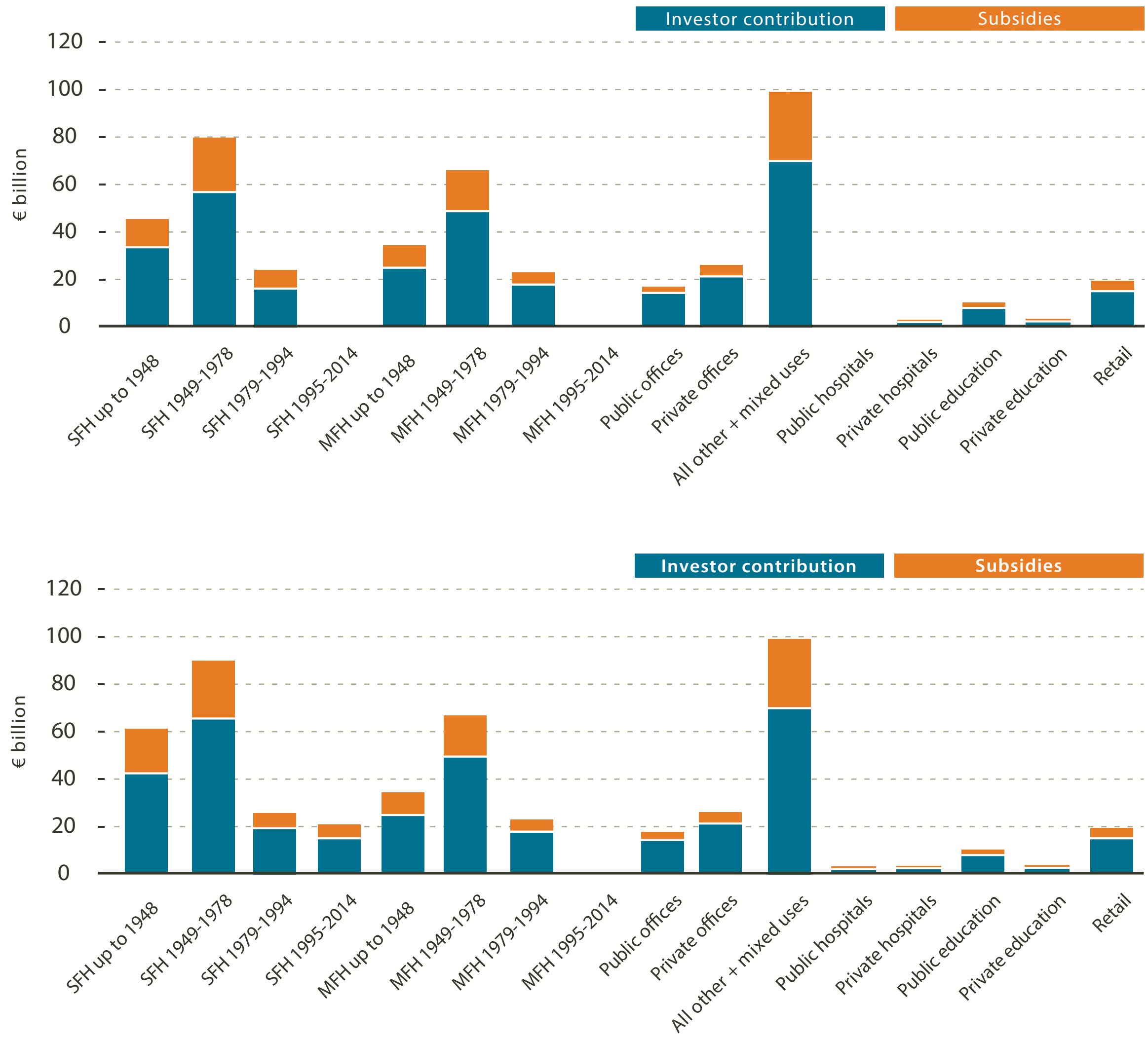


Figure 30: Average renovation depth (left - without co-benefit; right - with co-benefit) – Best Case scenario

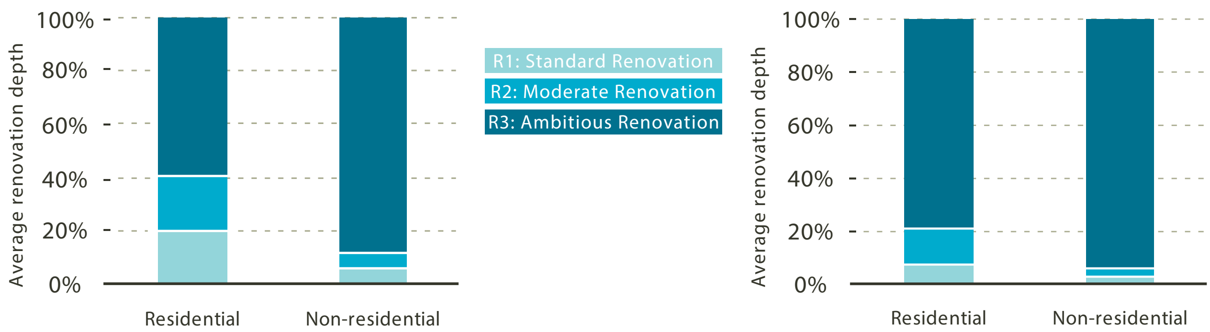
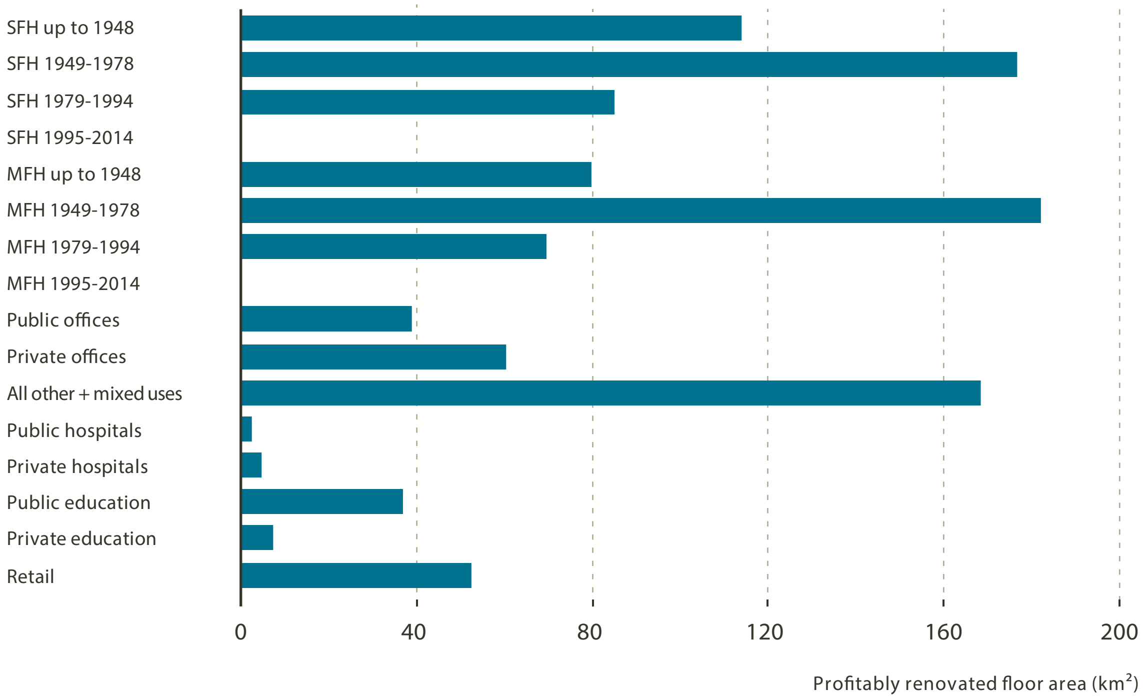
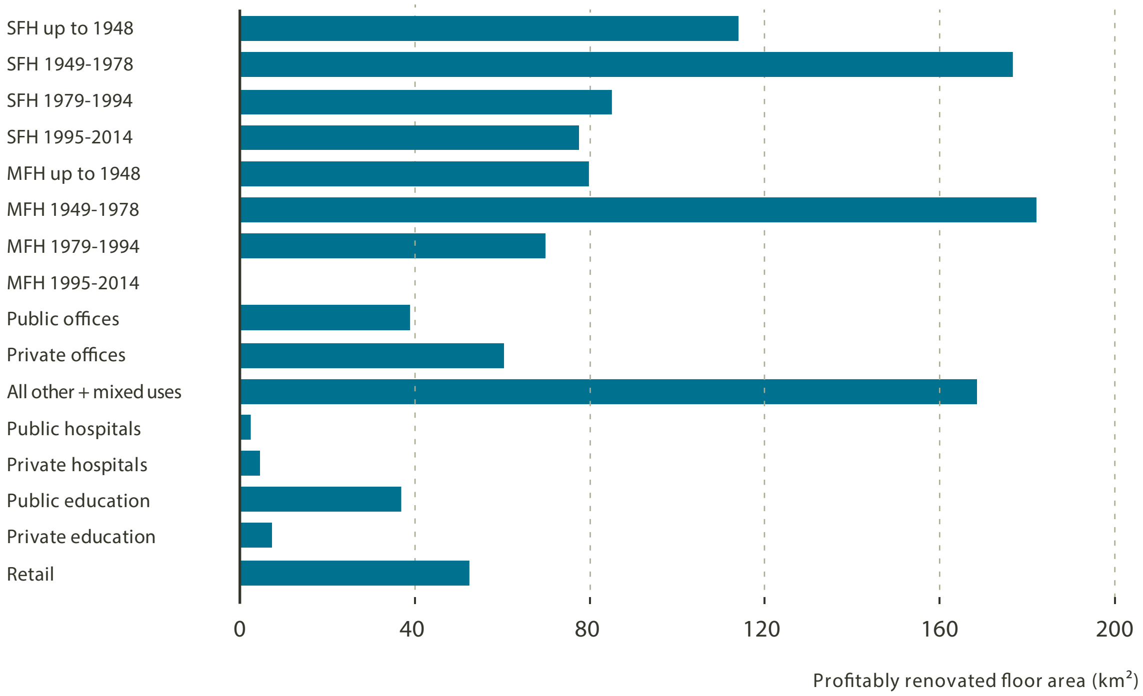


Figure 31: Profitably renovated floor area (top - without co-benefit; bottom - with co-benefit) – Best Case scenario





Comparison of all scenarios

The graphs below present the outline of the ESCC plots of the five scenarios described above. The top plot is without the inclusion of the comfort co-benefit, whereas the bottom one includes comfort. While this form of visualisation does not enable the different building categories to be distinguished, it enables a quick comparison of the scenarios that have been examined.

The lower a curve is located, the more cost-effective the scenario, while the further it extends to the right, the greater the energy savings achieved. It can be seen that reliance on soft measures alone (light purple), without any subsidy, would generally be a less attractive option than the Business as Usual scenario (blue), though it does produce slightly higher cost-effective savings and hence cost-effective potential for renovated floor area.

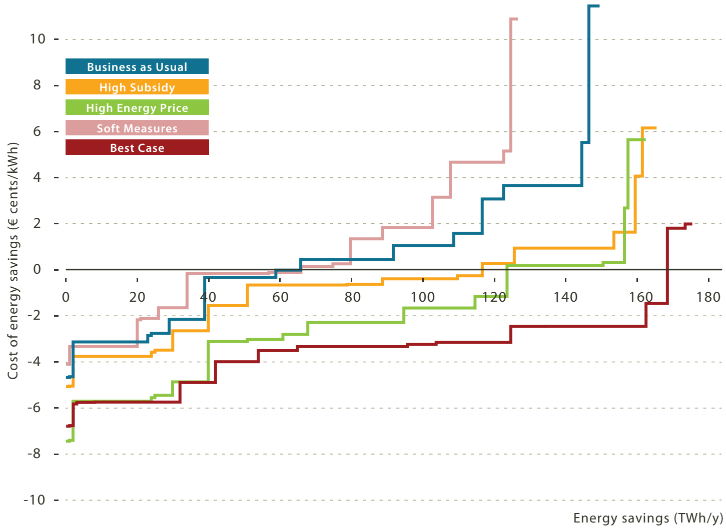
The application of either high subsidies (orange) or high energy prices (green) has a considerable impact, with most building categories becoming cost-effective. Between these two, the price lever has a bigger impact on cost-effectiveness, even though the resulting cost-effective energy savings are similar.

As expected, the Best Case scenario (red) provides both the greatest economic return and highest energy savings for investors.

The impact of including the comfort co-benefit can immediately be seen in the bottom graph, with all curves shifting down and to the right.

The economic parameters used in each scenario are presented in Table 13.

Figure 32: Comparison of scenarios (Top: without co-benefit; bottom: with co-benefit)



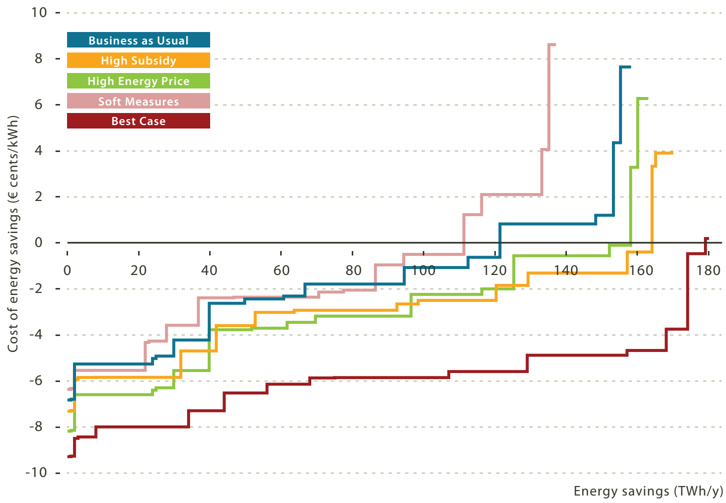


Table 13: Economic parameters used in each scenario

	Subsidies	Transaction costs	Discount rate	Cost decrease to 2030	Energy price increase to 2030
Business as Usual	10-25%	5%	4%	6-25%	1.1% p.a. (equivalent to a total increase of 19%)
High Subsidies	20-40%	5%	4%	6-25%	1.1% p.a. (equivalent to a total increase of 19%)
High Energy Prices	10-25%	5%	4%	6-25%	2.6% p.a. (equivalent to a total increase of 50%)
Soft Measures	0%	2.5%	2%	9-38%	1.1% p.a. (equivalent to a total increase of 19%)
Best Case	20-40%	2.5%	2%	9-38%	2.6% p.a. (equivalent to a total increase of 50%)

In the following tables, a summary of the most significant results is presented to allow comparison across the scenarios, and also to see the impact of including the co-benefit. The first pair of tables (in blue) shows the case for all building categories, while the orange tables underneath show the cost-effective building categories.

The impact of the co-benefit can most readily be seen in the Business as Usual and the Soft Measures scenarios, where, for all building categories, the overall financial impact shifts from being negative to positive. The impact of including the co-benefit is even more pronounced for the cost-effective results (in orange) with, in the Business As Usual case, a more than doubling of investment and resulting energy savings.

Table 14: Financial and final energy figures – all building categories

	WITHOUT CO-BENEFIT				
	Business as Usual	**High Subsidies**	**High Energy Prices**	**Soft Measures**	**Best Case**
Total energy savings (TWh/y)	150	167	163	129	176
Net financial savings (€bn)	-0.8	1.2	3.8	-0.7	6.1
Investments (€bn)	304	405	361	216	448
…of which subsidies (€bn)	50	106	65	0	120
Subsidies as % of total investment	16.4%	26.2%	18.0%	0%	26.8%

WITH CO-BENEFIT					
	Business as Usual	High Subsidies	High Energy Prices	Soft Measures	Best Case
Total energy savings (TWh/y)	160	171	165	139	181
Net financial savings (€bn)	2.8	5.0	5.1	2.4	10.7
Investments (€bn)	352	445	375	232	489
…of which subsidies (€bn)	65	117	69	0	132
Subsidies as % of total investment	18.3%	26.3%	18.4%	0.0%	27.0%

Table 15: Financial and final energy figures – cost-effective building categories

WITHOUT CO-BENEFIT					
	Business as Usual	High Subsidies	High Energy Prices	Soft Measures	Best Case
Total energy savings (TWh/y)	60	118	125	68	170
Net financial savings (€bn)	1.2	1.9	4.1	0.9	6.2
Investments (€bn)	97	254	242	89	427
…of which subsidies (€bn)	19	65	44	0	114
Subsidies as % of total investment	19.3%	25.6%	18.2%	0.0%	26.7%

WITH CO-BENEFIT					
	Business as Usual	High Subsidies	High Energy Prices	Soft Measures	Best Case
Total energy savings (TWh/y)	122	165	160	112	180
Net financial savings (€bn)	2.8	5.0	5.1	2.4	10.7
Investments (€bn)	235	426	360	168	484
…of which subsidies (€bn)	41	113	68	0	131
Subsidies as % of total investment	17.4%	26.4%	18.9%	0.0%	27.1%

As noted earlier, the two scenarios Soft Measures and Business as Usual deliver the lowest level of impact. High Energy Prices and High Subsidies both deliver significant improvements across the board, while the most attractive scenario, Best Case, shows what could be achieved if market conditions were transformed in favour of deep renovation.

A comparison of total energy savings across the five scenarios is presented in Figure 33. Total energy savings (blue bar) vary across the scenarios, since the depth of renovation triggered (R1, R2, or R3) depends on the cost calculation. Under more favourable economic conditions (such as High Subsidies, High Energy Price, or Best Case), there is a shift towards the most ambitious R3 renovation depth. This is demonstrated clearly in Figure 34. This figure also shows the missed opportunity in terms of savings if the prevailing economic conditions, as modelled in the Business As Usual scenario, continue. Less than half of the potential savings are currently economic.

Figure 33: Comparison of energy savings across the five scenarios

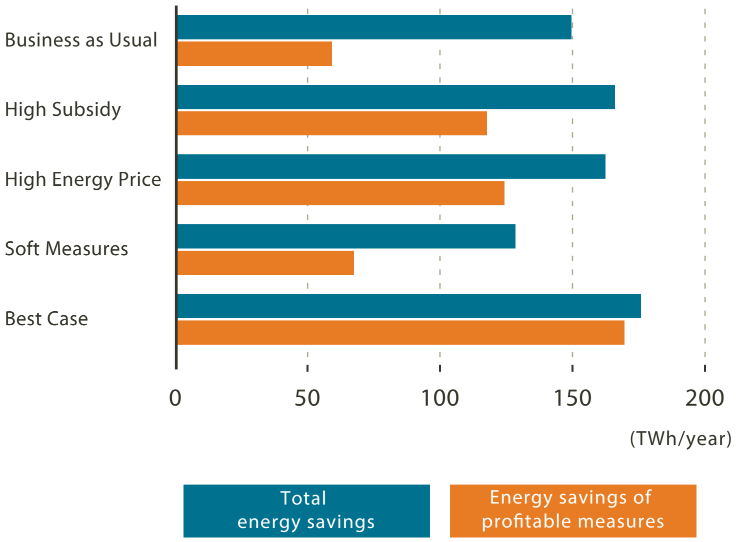
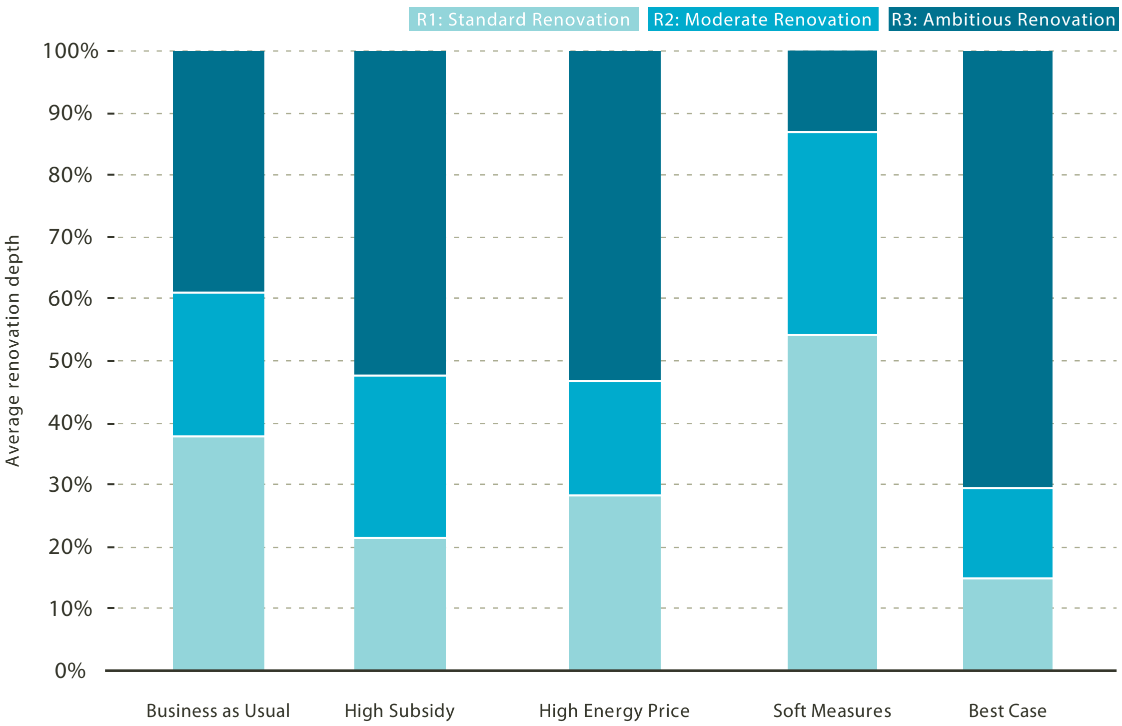


Figure 34: Comparison of the resulting renovation depths across the five scenarios (profitable building categories)



As would be expected, the level of investment is closely related to the energy savings. Figure 35 presents the investment requirements and related subsidy contributions, assuming investors only address those building categories for which renovation is cost-effective. As previously discussed, investments (and energy savings) increase considerably if co-benefits are included, or if a bundling approach is adopted.

Figure 35: Comparison of required investments and subsidies across the five scenarios (cost-effective building categories)

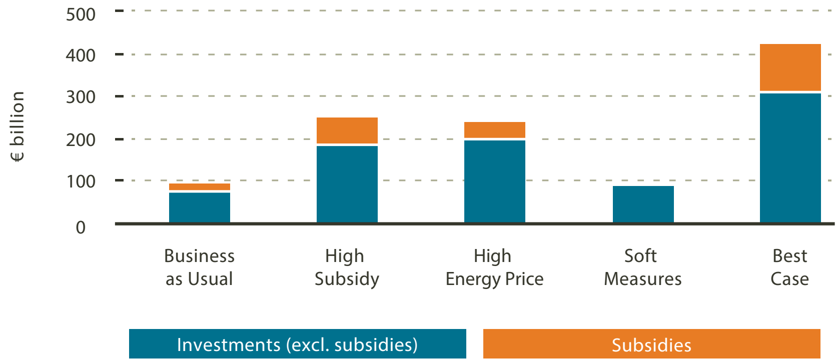
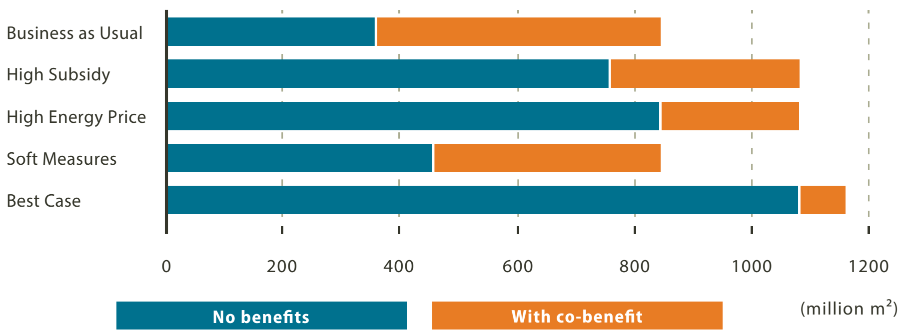


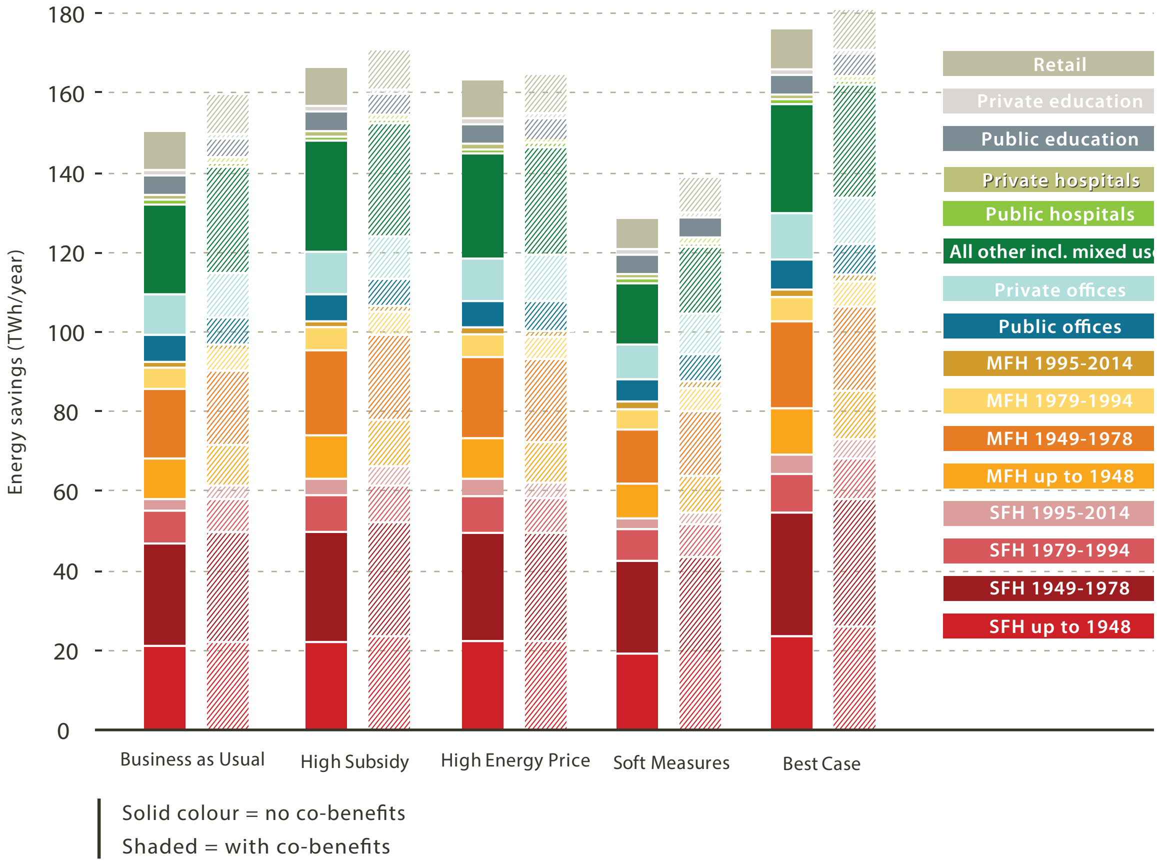
Figure 36 compares the renovated floor area across the five scenarios, showing the large increase achievable by including co-benefits in the economic appraisal.

Figure 36: Comparison of the extent of renovations across the five scenarios (profitable building categories)



Finally, Figure 37 compares the energy savings by building category across the five scenarios both with and without the comfort co-benefit. The categories with the largest energy-saving potential are mostly residential buildings, both single-family and multi-family houses, particularly those constructed prior to 1979. In the non-residential sector, offices (both private and public) as well as retail buildings offer the largest potential. Also, given the significant heterogeneity in the non-residential sector, there is a large category of "other" buildings (dark green bar) comprising buildings such as warehouses, transport facilities, factories, restaurants and many others.

Figure 37: Energy savings across all building categories by scenario (TWh/year)



4 DISCUSSION

Understanding which economic levers have the biggest impact on the cost-effectiveness of building renovation for potential investors is a vital part of the decision-making process for policy makers. The analysis underpinning this report provides the basis for comparison of the options that will enable the optimisation of the German national building renovation strategy.

The economic factors considered in this study are:

- Subsidies
- Transaction costs
- Discount rate
- Learning and cost reduction
- Energy-price increase
- Co-benefit of increased comfort

By varying one or more of these parameters, the theoretical impact of policy measures can be readily determined in an easy-to-visualise format and at a level of disaggregation by building category that is essential to tailor the right policies to the right building sectors. For example, the fact that the newest residential buildings constructed since 1995 – both single-family houses and multi-family homes – are not cost-effective, even under the Best Case scenario (without co-benefit), should not be of great concern, since these buildings would, for the most part, not warrant renovation prior to 2030.

In summary, the following overall observations can be made:

- The level of ambition of renovation is heavily influenced by policies rather than by the market. Without the right policy signals, there is a serious risk that the building owners and investors will continue to focus on shallow renovations, effectively locking out the potential for the full energy potential to be realised, and, with it, a loss of economic benefit to building owners and the wider German economy. In the worst case, over half of all renovations could be shallow, whereas in the best case, over 70% could be deep;
- Total annual energy savings of up to 180 TWh could be achieved by 2030, through a dedicated programme focused on deep renovation. This represents approximately 16% of current energy use in the building stock;
- Non-residential buildings are generally more cost-effective to renovate than residential buildings;
- Among residential buildings, those constructed up to 1948, both single-family and multi-family, are the most cost-effective to renovate;
- The energy-saving potential across all non-residential buildings is broadly equivalent to that across single-family houses of all age categories;
- Including the value of the comfort co-benefit has a big impact on all building sectors and across all scenarios;
- The least cost-effective building categories to renovate are the newer residential buildings, built to higher energy-performance standards. One would not expect these new buildings to be renovated in substantial numbers in the period up to 2030;

- Total investment requirements over the period up to 2030 vary considerably, between €100 billion and €500 billion, depending on the scenario, subject to whether the co-benefit is included, and whether all buildings or only the cost-effective sectors are considered. This shows the big impact on investment – up to a factor of five – that choice of policy levers can have on the market for building renovation;
- Establishment of a fund which bundles investments with varying cost-effectiveness can substantially increase the overall level of renovation;
- The greatest level of energy savings, and financial return to investors, would be achieved through a combination of financial/fiscal measures such as subsidies and energy prices, together with soft measures that reduce costs for investors by creating more favourable market conditions.

5 RECOMMENDATIONS

The analysis in this report demonstrates that additional policy measures are required if the full potential for energy saving in the German building stock is to be achieved. Given the right market conditions, the cost-effective potential for renovation can be more than doubled. For this to be achieved, we put forward for consideration the following recommendations.

Setting an appropriate strategic context

- Society benefits when individual building owners and investors undertake building renovation work. Employment is created, air quality is improved, buildings become healthier and more productive, while energy security is enhanced and carbon emissions are reduced. For these reasons, the national policy focus needs to shift towards maximising the energy savings achieved in the building stock by stimulating comprehensive, deep renovation. Sub-optimal levels of insulation, or the installation of less efficient building components and equipment, effectively limit the energy-saving potential for the foreseeable future (the so-called "lock-in effect"), and are often more expensive when considered over the lifetime of the measures.
- Designing an appropriate policy landscape to deliver a deep renovation of the German building stock requires due consideration of the full spectrum of factors that currently limit uptake. In the context of developing the national building renovation strategy, a comprehensive, holistic analysis should therefore be undertaken as to how to stimulate the market.
- Investor confidence will be strengthened by providing clear short- and mid-term policy targets within a long-term framework that provides maximum investment security for decisions in the real-estate and energy renovation market in order to lower the investment risk and hence the discount rate.

Providing the right economic signals

- Among the many significant barriers to a thriving renovation market is the absence of sufficiently strong economic signals and appropriately tailored financial instruments. Policies to stimulate deep renovation could, for example, include feed-in tariffs for saved energy, conditional on achieving an ambitious level of energy saving. Further incentives for deep renovation could be provided at property-sale transactions where the associated tax could be reduced if the future owner invests to renovate the property.
- Energy price signals play an important role in motivating investors to cut their energy costs. Eliminating fossil fuel subsidies across the energy-supply system and reflecting the true externalities of energy use (for example, through carbon pricing) will provide stronger incentives for building owners to invest in energy-saving measures. Fully cost-reflective energy prices, with appropriate safeguards for those in economic difficulty, are also more justifiable and rational from a societal perspective. There is scope to increase the taxation of energy used in buildings. For example, the six cent/litre tax rate on heating oil in Germany is considerably below the EU average of 18 cents/litre. Indeed, seven Member States have a rate that is over 30 cents/litre[41].

Focusing financial support where it is most needed

- The well-established financial support system run by KfW could be further developed to stimulate renovation of certain building types which show high energy-saving potentials but are not renovated due to a limited return on investment. Consideration should be given to the stratification of the support programmes in order to encourage greater uptake among particular building types and owner profiles. For example, larger subsidies could be offered to building categories for which deep renovation is

[41] Source: Forum Ökologische Steuerreform (FÖS)/ Green budget Germany, 2015.

marginally not cost-effective. Rented properties, where rent increases are not feasible or not desirable from a societal perspective, might benefit from specific support measures which recognise the limited economic justification for landlords to invest in improving the energy performance of their properties, since they do not receive the resulting cost savings.

- Another way to address the varying cost-effectiveness of different building categories could be in the form of an investment fund, which bundles projects with differing economic performances to lower the average investment risks. Such an approach is common in equity management and could be extended to renovation-project financing. Such an "investment bundling" could provide safe and stable returns to investors while giving owners access to necessary capital.

- Deep renovation of commercial properties is often limited due to tenant laws and split incentives/benefits, rather than by the low economic viability of the investment. This barrier could be overcome through different means, such as mandatory upgrades on a particular timescale or at certain trigger points (e.g. sale, new lease) to achieve certain performance levels.

- Buildings with an important societal function and with resulting societal benefits, such as schools and hospitals, should receive preferential treatment with the help of appropriate support measures to create viable investment cases for deep renovation. First steps in that direction have been made with the new KfW-programmes for non-residential buildings and respective funding strands of the NKI, the national climate initiative. These need to be strengthened to ensure the focus is on achieving deep renovation.

- A programme for the development of accurate modelling and financing tools to increase the effectiveness of subsidy distribution should be encouraged by the government. The return on investment in such a research programme would be an even more intelligent, streamlined, automated process to make use of public finances and increase the effectiveness of funds in reaching renovation targets and in triggering renovations.

Providing the right support infrastructure and systems

- Building owners and investors need the right encouragement, information, support and incentives to choose the deep renovation option, particularly when undertaking other maintenance work on the property, as the additional cost of improving the building's energy performance at this time can be minimised. Such support could come in the form of impartial information centres or one-stop-shops, which guide the owner/investor through the whole process, reducing transaction costs and helping to make the right choice. In certain places in Germany, local or regional energy agencies are already playing that part and should be further supported and strengthened in their endeavour.

- For building owners and investors, encouraging the inclusion of co-benefits such as increased comfort and property values in the economic appraisal can have a big impact on the cost-effectiveness of deep renovation. Advice centres and one-stop-shops could offer free software that includes co-benefits in the economic appraisal. The existing dena calculation-tool for renovation could be modified to take co-benefits into account.

- Policy measures could increasingly stimulate deep renovation of urban quarters with an identical building typology. Building-type specific renovation packages, which could (partially) be pre-fabricated, would be more cost-effective if deployed in large numbers. Prefabrication could reduce disruption time for building occupiers. Such approaches are successfully implemented in the Netherlands[42]. Such a "geographical bundling" would contribute to the renewal and upgrading of urban quarters without stimulating gentrification.

- Efforts to improve skills within the workforce through qualification and vocational training programmes should be continued and enhanced.

- The already significant level of R&D support should be maintained in order to speed up learning curves and the process of cost reduction.

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[42] http://energiesprong.nl/transitionzero/

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