

# Energy renovation of buildings

Realising the untapped  
potential of the built  
environment

## INSIDE THIS WHITE PAPER

The Danish governance system for green buildings

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Benefits across the triple bottom line

Smart energy systems and data use

Inspiring energy efficient solutions

## ENERGY RENOVATION OF BUILDINGS

Realising the untapped potential of the built environment

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### FRONT PAGE PHOTO

Schmidt Photography

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# Executive summary

As buildings account for almost 40% of global energy consumption, they represent a pressing, but also promising, action area in the green transition. It is predicted that 85-95% of the European building stock that will exist in 2050 has already been built. Thus, it is vital that we realise the potential for energy efficiency in our current buildings.

## **World class solutions for energy efficient buildings**

Targeting the energy consumption of buildings is a key priority for any country or community striving to reduce CO<sub>2</sub> emissions. Promoting energy efficient buildings has long been a cornerstone of Danish green ambitions, and the innovative solutions developed by both the public and private sector have made Denmark a global leader in this field. Denmark has one of the most comprehensive regulatory frameworks for ensuring energy efficiency in buildings. Among its key components are a strict building code, energy labelling, targeted information campaigns and, crucially, involvement of relevant industries.

With initiatives such as public-private partnerships, Denmark presents a unique way to harness the strength of both public and private resources to support energy efficient buildings. Danish companies provide many world class solutions and technologies for insulation, windows, data control systems and architecture that make sustainable energy renovation projects possible.

## **Sustainable energy Renovation**

Renovating and retrofitting existing buildings are indispensable tools when greening the built environment, as well as impactful paths to increased sustainability – not only in an environmental sense, but also economically and socially. While renovating a building can result in lower CO<sub>2</sub> emissions, it can also lower heating and electricity costs as well

as increase the value and lifespan of the building. The business case for energy renovation becomes even stronger when considering the benefits an improved indoor climate and functionality can have for residents. Taking a broader view, pursuing energy renovation programmes can play a critical role in pushing our common energy systems towards a low-carbon future by reducing energy demand.

To reap the benefits of energy renovation across the triple bottom line, it is important they are devised in a collective and holistic manner. When assessing the feasibility of renovation projects or developing measures to encourage them, environmental, economic, and social considerations should drive the process.

## **About this white paper**

This white paper provides tangible pathways to realise the untapped energy efficiency potential in the built environment. From governance tools and meaningful partnerships to the implementation of technical installations and successful repurposing, it encompasses a broad range of perspectives and concrete cases on how to promote, enable and support energy renovation efforts. Sharing experiences and information is essential to further accelerate energy renovations globally. In this spirit, we hope this publication can inspire energy efficient solutions that will advance a green transition of the global building stock to the benefit of both the planet and the people who inhabit it.

# Leading energy efficiency in buildings by example

BY DAN JØRGENSEN, DANISH MINISTER FOR CLIMATE, ENERGY AND UTILITIES

Denmark has years of experience reducing greenhouse gas emissions in the energy sector and we aim to support the global transition to a carbon-neutral world. We will continue to develop technical green solutions not only for Denmark but for the whole world.

We strive to lead by example. In 2020, the Danish Government and a broad parliamentary majority agreed on one of the world's most ambitious climate acts. With a target that aims to reduce greenhouse gases by 70 percent by 2030 compared to 1990 levels, we set the bar high, and it was clear that rapid action was needed.

Since then, we have made concrete policy decisions and put forward policy proposals that take us more than two thirds of the way to reaching our target. And the Danish government produced an overarching road map aimed at ensuring that we achieve the remainder. The roadmap outlines 24 initiatives, addressing every single sector, to be implemented by 2025, by which all necessary decisions will have been made to ensure achievement of the 70 pct. target.

The building sector – for both new and existing buildings – is of great significance. Construction and use of buildings is responsible for approximately 40 percent of Denmark's overall energy consumption and accounts for about 30 percent of our CO<sub>2</sub> emissions. Therefore, if we are to meet

our climate goals, we need to ensure we build and renovate in a highly energy-efficient manner.

Designing energy-efficient solutions for existing buildings is of particular importance, as approximately 85 percent of the buildings we will live in by 2050 already exist today. Fortunately, we already have many of the important tools needed to use energy more efficiently. In Denmark, we have particularly focused on expanding the district heating network, replacing old oil or gas boilers with heat pumps, ensuring that new buildings are as energy-efficient as possible and increasing the pace of energy-efficient renovation of existing buildings. Recently, the Danish government proposed a plan to accelerate the phase-out of natural gas even more by increasing renewable gas production and expanding the rollout of district heating and installation of green heat pumps.

Many of the available solutions to increase energy efficiency in buildings are described in this White Paper. I hope they can serve as inspiration for you and can contribute to greening the construction sector.



**Dan Jørgensen**  
Danish Minister for Climate, Energy and Utilities

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# Clean, digital, and efficient buildings in Europe

Three-quarters of Europe's buildings are energy inefficient by modern standards. Accounting for more than one-third of EU's CO<sub>2</sub> emissions, they are largely heated by fossil fuels. Reducing energy demand via renovation will aid in reaching net zero emissions by 2050.

Comfort, safety, and affordability are the pillars of our vision to decarbonise our buildings by 2050. The world we are currently living in is in need of houses that are renovated to unprecedented efficiency levels. The remaining energy consumed in the buildings will soon be fuelled primarily by renewable sources. Various appliances will need to interact with the grid, generators and common points of use. Thus, a house, a neighbourhood, and a city, must all strive towards reaching a balance of generation and consumption, which will allow for a flexible and dynamic sustainable transition.

We already have many examples of the necessary technologies and solutions here in the EU. As they continue to develop over time, they will also need to be used more widely. The largest challenge still lies with heating and cooling. Buildings in total generate around 36% of energy-related greenhouse gas emissions, with the heating and cooling sectors responsible for 80% of this figure. Reducing energy expenditure on heating therefore also has a direct impact on energy poverty and supports people's health and wellbeing.

Focusing on energy-efficient renovation policy is also important to ensure that the upgrades improve security of the energy supply and correspond to the limitations of the energy system's capacities. To be successful, a refurbishment project must conserve energy and resources to assist in lowering the carbon footprint of buildings over the course of its life cycle. Both the public sector and companies will need to be increasingly attentive towards the needs of the consumers to secure a just transition and reach higher standards of energy performance, quality of life and aesthetics.

The European Commission proposes to remove the existing barriers within the conventional construction sector and rebuild ties between the different stakeholders on the basis of transparency, exchange of data and affordability. In 2020, the Renovation Wave announced a roadmap to get this off the ground, and in 2021, the recast Energy Performance of Buildings Directive (EPBD) introduced upgraded energy performance and information standards for buildings.

The Member States will continue to set their own path towards a common European objective to decarbonise Europe's building stock, while the European Commission will be ready to assist them in every way necessary.



**Kadri Simons**  
EU Commissioner for Energy



The worst-performing 15% of the EU building stock will have to be upgraded from Energy Performance Certificate (EPC) label G to at least label F by 2030, public and non-residential buildings leading the way by 2027. Residential buildings should be renovated from G to at least F by 2030, and to at least E by 2033.



The obligation to have an energy performance certificate is extended to buildings undergoing major renovation, buildings for which a rental contract is renewed and all public buildings.



Buildings or building units which are offered for sale or rent must have an energy performance certificate, and the energy performance class and indicator should be stated in all advertisements.



National Building Renovation Plans will be fully integrated into National Energy and Climate Plans to ensure comparability and tracking of progress – they will need to include roadmaps for phasing out fossil fuels in heating and cooling by 2040 at the latest.



A Building 'Renovation passport' will give access to information and lower costs for consumers to facilitate their planning and a step-by-step renovation towards zero-emission level.



Member States are invited to include renovation considerations in public and private financing rules and to establish appropriate instruments, in particular for low-income households.

FIGURE 1

## How the revised Energy Performance of Buildings Directive will boost energy renovation.

The Renovation Wave strategy uses regulation, funding, and technical assistance across the entire renovation value chain to meet its aim of at least doubling renovation rates within the next ten years and ensure that renovations lead to higher energy and resource efficiency. As part of the strategy, the Energy Performance of Buildings Directive (EPBD) was revised in 2021. It upgrades the existing regulatory framework to reflect higher ambitions and more pressing climate and social action needs.



## Renovation classes

In addition to energy requirements for specific building components, The Danish Building Code provides energy performance frameworks called renovation classes, as a way in which to satisfy energy efficiency standards. Instead of having requirements for achieving heat savings by re-insulating per building element and with accompanying cost-effectiveness calculations, the energy performance framework gives developers the freedom to carry out other energy saving measures that in total bring the building's energy demand down to sustainable levels

Photo credit: Schmidt Photography

## CHAPTER 2

# Regulating energy efficiency in buildings

Designed to realise the potential for energy savings and reduction of greenhouse gasses in both new and existing buildings, Denmark has one of the strictest building codes in the world.

Denmark has strict building regulations regarding the construction of new buildings. However, the annual building rate only comprises approximately 1-2% of the total building stock. Therefore, regulating the energy performance of existing buildings plays a key role in the green transition.

The Danish government has set ambitious energy policy goals. By 2050, the energy supply will be based solely on renewable energy sources. However, this does not negate the importance of reducing the energy consumption in buildings and the focus on energy efficiency. In Denmark, approximately 25% of the energy consumption is used for space heating and hot water in buildings. Therefore, realising energy savings in buildings is a significant area of attention in energy policies.

### **The building code as a driver for innovation**

The Danish Building Code, BR18, is one of the main policy instruments to achieve energy savings. The code also contains regulations regarding the energy performance related to major renovations of buildings. For example, if the renovation of a building includes the replacement of a window, a ventilation system or a roof, the building code defines minimum standards for the energy performance of the new

component. The code therefore guarantees that the existing building stock continuously becomes more energy efficient. This is reflected in the energy statistics, which show that the energy consumption of buildings has been declining for many years. At the same time, the Building Code ensures that energy savings are implemented when it is economically feasible for the owners. Conducting energy renovations in buildings is generally most cost-efficient when carried out in connection with major maintenance work and other changes. Therefore, another central aim of the regulatory efforts is to encourage building owners to utilise building renovations as an opportunity to carry out energy savings programmes.

The building code is revised every five years to encompass and align with new technological developments taking place in the construction industry. Whenever changes are made, it is preceded by an extensive consultation process with industry to ensure ambitious and realistic changes. The changes are announced several years prior to implementation, enabling the industry to develop new solutions and invest in the necessary production apparatuses. In this way the building code is also used to incite innovation in the industry.

# How the Danish EPCs drive energy renovation

New revisions to the Danish Energy Performance Certificates (EPCs) and a focus on digitalisation has increased the number of certificates and has made them easier to understand for the building owners that consult them.

## Creating user-friendly EPCs

Energy performance certificates or Energy Labelling has been used in the Danish building sector since 2006. About half of the building stock in Denmark has an EPC. The certificate assigns an energy rating on a scale ranging from A (high energy efficiency) to G (poor energy efficiency) and lists cost-effective measures for improving the energy performance of the building and the savings potential related to the measures.

In 2021, the layout of the Energy Labelling Report was redesigned to make it easier to understand for the house owners. At the same time, a new funding scheme was introduced, making it a requirement to have an EPC in order to receive funding. This has resulted in a steep increase in the number of EPC produced annually; in 2020 approximately 68,000 energy labels were issued, and that number rose to roughly 81,000 in 2021.

## Responsibility and public availability

The responsibility for implementing the EPC lies with the Danish Energy Agency (DEA), including the daily operations, supervision, quality assurance and future development of the scheme. All EPCs are registered in a central database administered by the DEA and are displayed on its public website [www.sparenergi.dk](http://www.sparenergi.dk).

The EPC of single-family houses constructed less than 25 years ago can take place without an on-site visit to the building. For public buildings, office buildings and buildings used for administration, the EPC must be based on the calculated energy consumption. The validity of an EPC is 10 years.

All public buildings with more than 250 m<sup>2</sup> of useable floor area are required to have a valid EPC, which must be displayed publicly. All the certificate's other key information is made available to the public through the central web-based information server [www.boligejer.dk](http://www.boligejer.dk) and on the site [www.sparenergi.dk](http://www.sparenergi.dk).

## Increasing the value of houses with EPCs

The DEA has conducted a study on the relationship between house prices and an EPC's rating. One of the key results was that the EPC rating has a clear and significant influence on the house price and the buyer's willingness to pay a higher price for a higher energy rating. For example, in the case of a 100 m<sup>2</sup> house with a C-label rating compared to a D-label rating house, it was found that it capitalised into a willingness for the house owner to pay a premium of EUR 6,000 for the higher rated house.

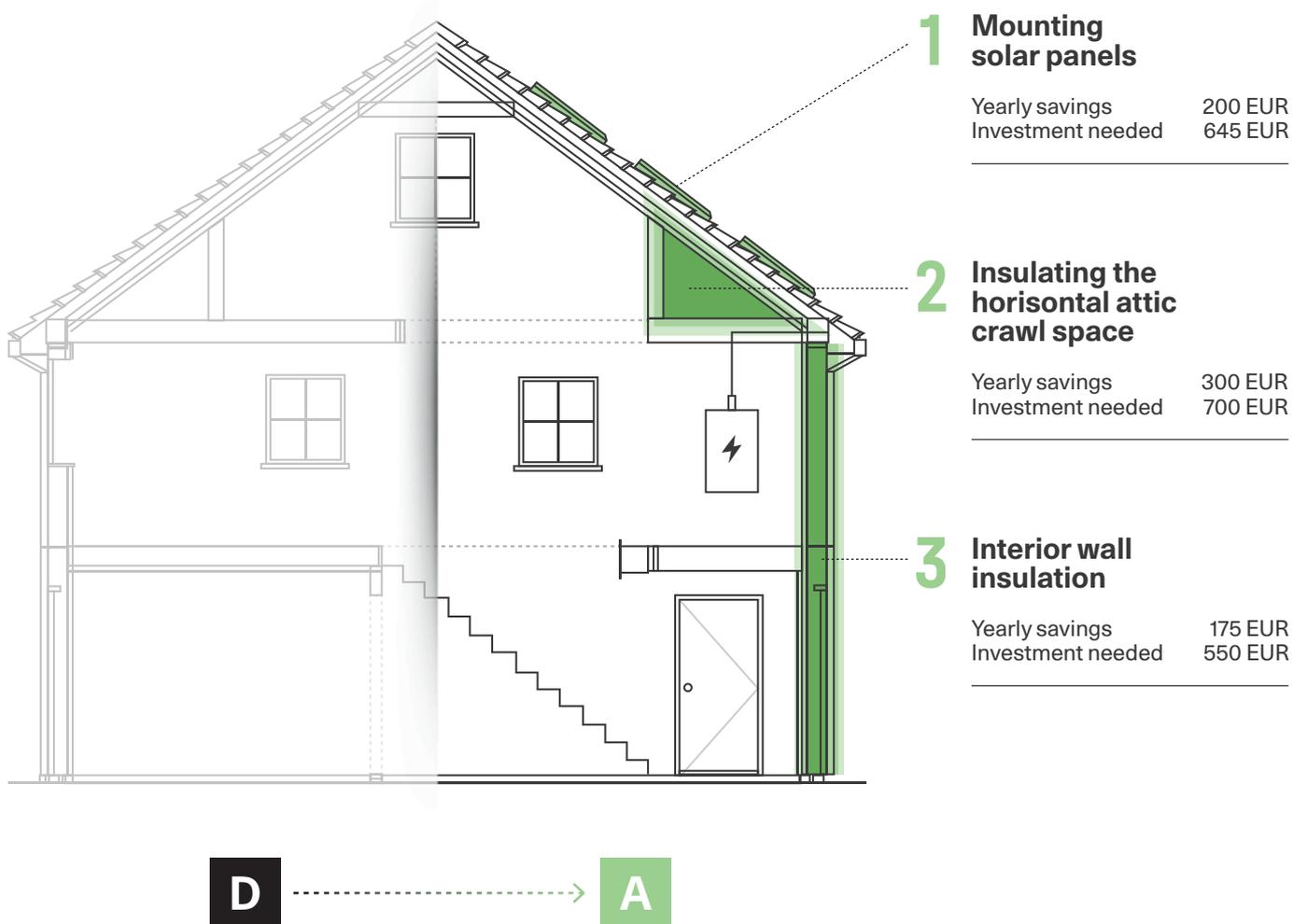


FIGURE 2

## The new layout of the EPC

The new layout of the EPC makes it easy for building owners to improve the energy performance of their building in a cost-effective manner. The certificate highlights the most potential filled measures to lower both the energy bill and the CO<sub>2</sub> emissions of the building. Users are clearly shown how much of their current energy expense they could save and what energy label they could upgrade their building to by following the report's recommendations. Each proposal is followed by step-by-step instructions on how to implement it, how long it will take and how the investment will result in yearly savings.

# High quality information for building owners

A key measure to achieve Denmark's climate goals is easy-to-understand, high quality information about the energy renovation of buildings to both building owners and craftsmen. For this, the Danish Energy Agency has created several platforms.

## **SparEnergi.dk**

SparEnergi.dk is a one-point entry to all information from the Danish Energy Agency (DEA) regarding energy renovations and retrofitting buildings. Hosted by the DEA, the free and open web platform provides information about how to renovate buildings and save energy for building owners in both residential, commercial, and public buildings.

The platform contains information about how to change the heating system, how to upgrade insulation, replace windows, and much more. There are also examples and cases, guides, and calculation tools. Moreover, the platform provides information on energy labelling and is a joint platform for all the agency's campaigns and initiatives aimed at end users. The purpose is to create synergies between the various initiatives, making it easy for the users to find cohesive content.

## **Targeted campaigns**

To make energy efficiency information effective, it is necessary to target information and messaging to relevant groups. It is also important to know when building owners are seeking information. This is often in connection with either selling or buying a house, or the decision to start a major refurbishment of the home.

Not all people are driven by the same motivating factors when it comes to reducing energy consumption. Some homeowners are motivated by the possibility of monthly savings, while others may be driven by an enhanced indoor

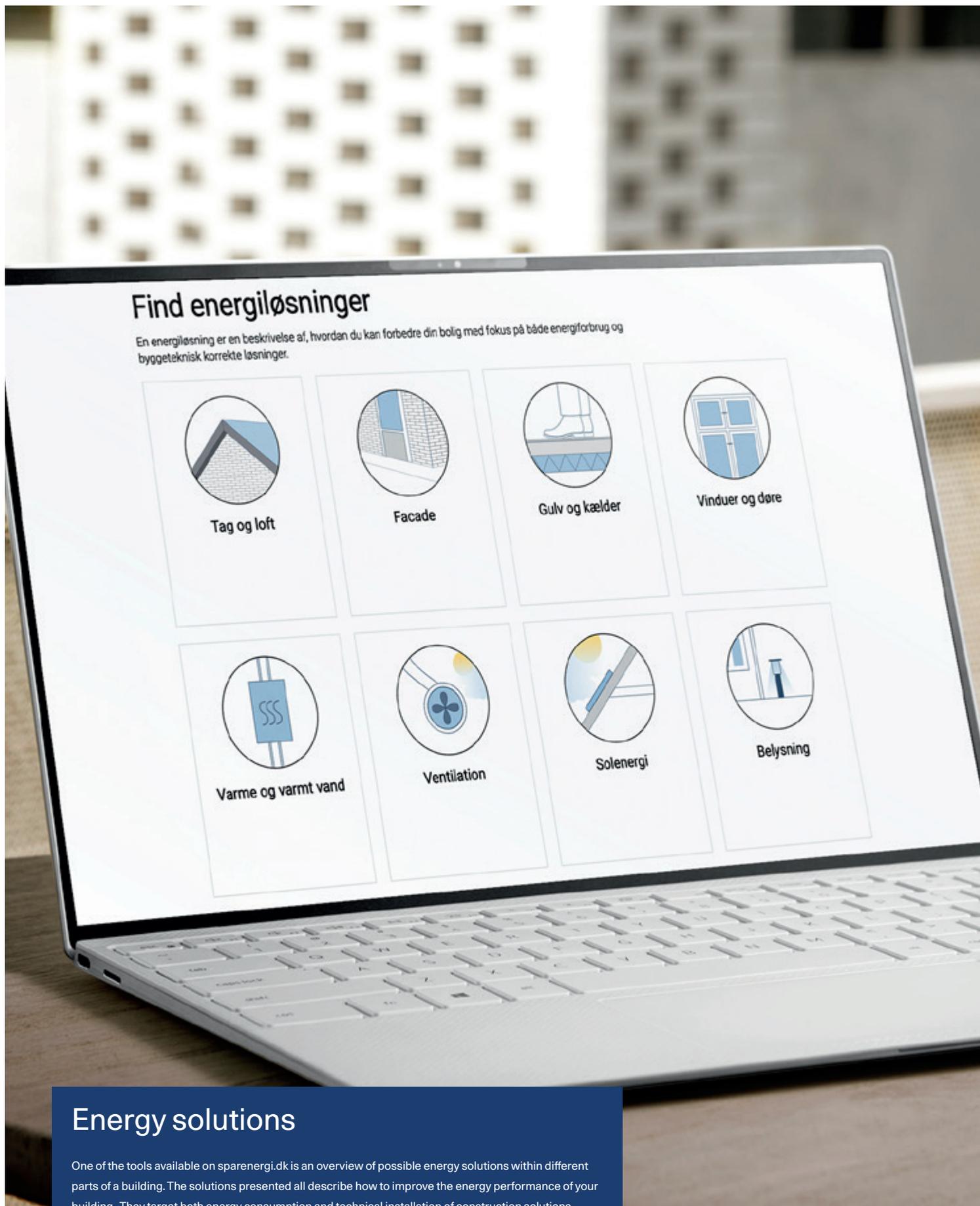
climate and better comfort, or the importance of reducing CO<sub>2</sub> emissions and benefitting the environment. The differing motives and needs are kept in mind on the platform, enabling more accurately targeted and thus impactful campaigns.

## **Evaluating our impact**

An evaluation carried out in 2016 showed that the platform contributes positively to promote energy savings among households and public and private companies in Denmark. It also revealed that the platform is particularly used in the preparatory information-seeking and clarifying phases before the user may take action in the form of energy saving renovations, purchases and behavioural changes. It is also in these phases that the evaluation shows the greatest need and opportunity to make a positive impact.

## **Information to installers and craftsmen**

To realise the expected energy savings when renovating buildings, craftsmen and installers must be well informed and trained. Therefore, the DEA also supports a similar platform ([www.byggeriogenergi.dk](http://www.byggeriogenergi.dk)) and The Knowledge Centre for Energy Savings in Buildings that is aimed at craftsmen and installers. Here, the content is more technical and focuses on showing examples and tools. The knowledge centre collects and systematises knowledge about energy savings in buildings and disseminates it to the construction industry. The overall goal is to help realise greater energy savings in the existing building stock.



## Find energiløsninger

En energiløsning er en beskrivelse af, hvordan du kan forbedre din bolig med fokus på både energiforbrug og byggeteknisk korrekte løsninger.



Tag og loft



Facade



Gulv og kælder



Vinduer og døre



Varme og varmt vand



Ventilation



Solenergi



Belysning

## Energy solutions

One of the tools available on [sparenergi.dk](http://sparenergi.dk) is an overview of possible energy solutions within different parts of a building. The solutions presented all describe how to improve the energy performance of your building. They target both energy consumption and technical installation of construction solutions. Under each solution, you can find information on its potential benefits as well as contact details on local craftsmen, who can help you implement it in your own building.



Photo credit: Kim Toft Jørgensen

## A one-stop-shop approach to energy renovation

With ProjectZero, the city of Sønderborg in Denmark has shown how one-stop-shop efforts focusing on both the supply and demand side of energy renovations can encourage local investment. When the project started in 2010, the 18,600 owner occupied homes in Sønderborg had a large carbon footprint. Most of them were built before the oil crises of the 1970s and were supplied with oil and natural gas. In collaboration with local craftsmen, banks, realtors, energy consultants and district heating companies, ProjectZero launched several initiatives targeting energy inefficient buildings. They ranged from educating craftsmen in energy consultancy and guiding homeowners through potential renovation projects, to introducing accessible loans to finance energy saving efforts and coordinating communication and monitoring efforts amongst stakeholders in the building and renovation market.

Out of the 1,600 homeowners that received guidance, 60% of them subsequently invested an average of DKK 150,000 (EUR 20,162) in energy renovations. The employment and skill level in the construction industry has also increased significantly. Sønderborg's experiences have become a steppingstone for other locally coordinated energy efficiency projects in both Denmark and internationally. Looking to the future, ProjectZero is now focusing on integrating the knowledge obtained in local vocational education institutions to ready the construction industry for the next wave of energy efficient renovation.

### CONTRIBUTORS

ProjectZero

### LOCATION

Sønderborg



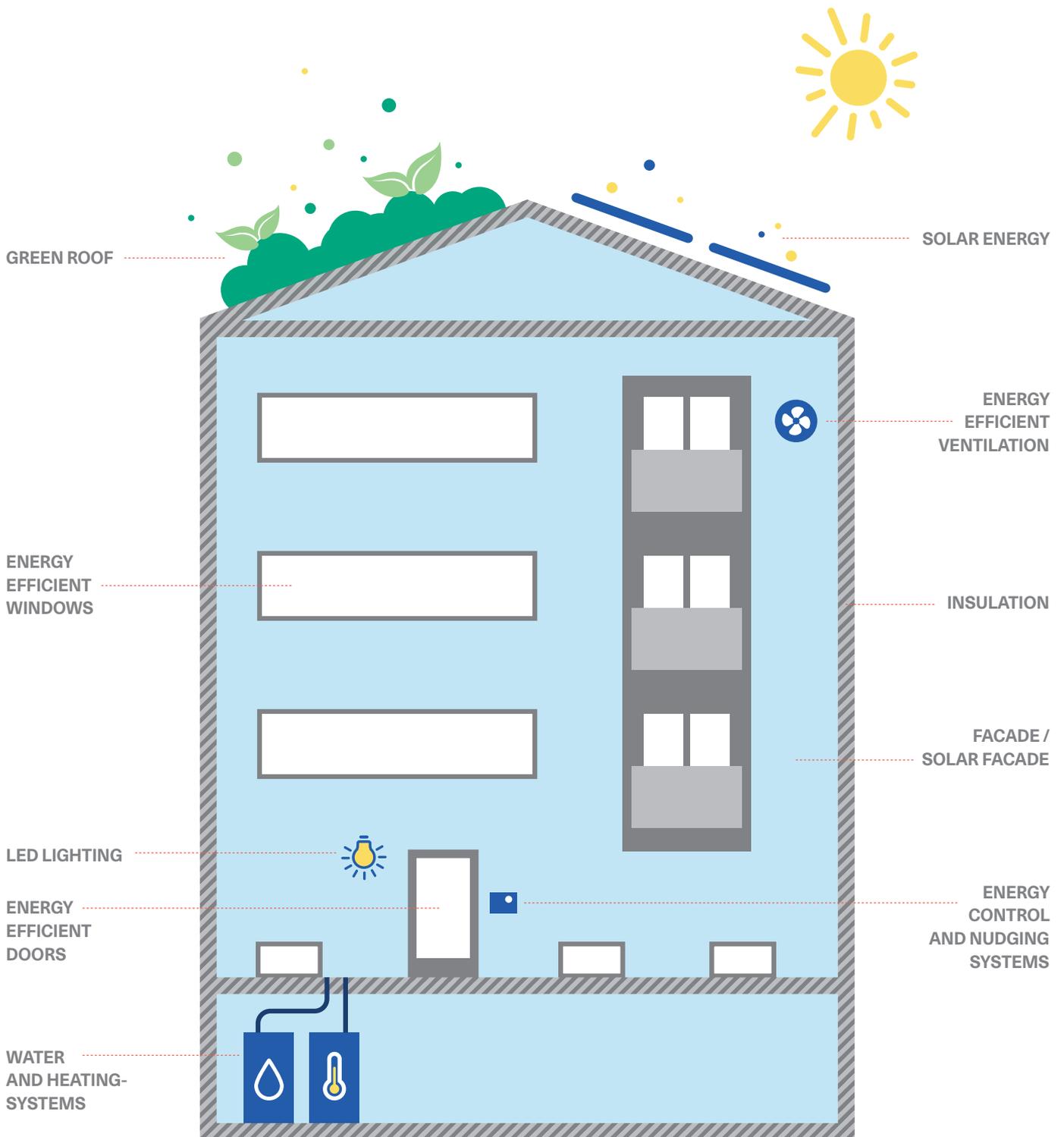


FIGURE 3

## What an energy efficient building might look like

There are many ways to tap into the energy efficiency potential of a building. Solutions can target anything from switching to more renewable energy sources to improving the indoor climate via insulation and ventilation to installing energy control systems. Pursuing multiple solutions simultaneously will often be the most impactful, beneficial and sustainable way to perform energy renovation.

# Constructing green partnerships and strategies

Involving the private sector to support and drive green initiatives is a hallmark of Danish climate governance. When it comes to energy renovation of buildings, recognising and utilising the experience of the construction industry is key.

Thinking strategically about construction as both a practice and an industry is essential to achieving energy efficiency in buildings through renovation. In Denmark, this is reflected in multiple efforts initiated by the government with support from, and in synergy with, the industry.

## **Partnering with the industry**

The private sector plays an important role in the green transition of our societies. Partly via efforts to reduce emissions in value chains, and partly by developing new sustainable products and practices. Building on the Danish tradition for public-private partnerships, the Danish government has established 14 climate partnerships that represent different sectors of the country's economy, each of which has been tasked with proposing solutions as to how their individual sector could contribute to CO<sub>2</sub>e reductions in a just way.

Among them is the Climate Partnership for Construction. The partnership has proposed 14 concrete initiatives related to energy renovations, focusing on achieving heat savings through increased renovation rates and public investments, renovating social housing units, packaging energy renovation solutions for homeowners and activating energy labelling as an enabling energy savings tool. If implemented by 2030, the partnership's recommendations on energy renovations can contribute to reducing CO<sub>2</sub> emissions 729,000 tonnes annually.

## **National strategy for sustainable construction**

The sentiment of the partnership is reflected in the National Strategy for Sustainable Construction adopted in 2021. The strategy centres around five focus areas: 1) More climate-friendly buildings and construction; 2) Durable, high-quality buildings; 3) Resource efficient buildings; 4) Energy-efficient, healthy buildings and 5) Digitally supported construction. These are all areas where energy renovation has a potential role to play. The strategy clearly states that economically and environmentally feasible energy renovations are a powerful tool to achieve energy savings in a way that is healthy for both the planet and its people.

To support renovation efforts, the strategy includes initiatives on targeted, digital measures to streamline energy as well as subsidies to help realise energy savings. The initiatives will make it easier to identify and realise energy saving potentials in both public and private buildings. Additionally, the strategy entails developing Life Cycle Assessment requirements to be phased into the national building code as a requirement by 2023. In line with recommendations from the IEA, the requirements will enable smarter and more sustainable construction and renovation choices. Choices that will reduce the climate footprint of construction and support the industry in its aim to build more sustainably and promote green solutions.



## Benefits of climate partnerships

The benefits of climate partnerships between private and public actors are manifold and tangible. The ability to demonstrate these benefits is a critical first step to unlocking the potential of future green partnerships all over the world

### Engagement

The private sector emphasises their commitments to establishing long-term climate targets

### Innovation

New technological solutions and business models are unlocked in the process of establishing new partnerships and developing recommendations

### Acceleration

Decarbonisation and the development of new technologies are accelerated through concrete initiatives and increased awareness

### Co-creation

Collaboration and co-creation across public and private sectors as well as businesses and industries towards one common goal

# The trajectory of energy renovations in Denmark

Since 1990, significant improvements to the energy efficiency of buildings and reductions in CO<sub>2</sub> emissions have been achieved in Denmark. However, with ambitious national and EU goals on the horizon, much more must and can be done in the built environment.

From 1990-2020, the energy consumption for space heating per household in Denmark was reduced by 15% and consumption per m<sup>2</sup> was reduced by 22%. This was achieved in large part through the strict energy efficiency requirements for new buildings and major renovations in the Danish Building Code. Moreover, despite an increased total building area, the total energy consumption of state-owned buildings was reduced by 14% from 2006-2020. The transition to renewable energy production has also visibly reduced CO<sub>2</sub> emissions in these buildings. For example, CO<sub>2</sub> emissions per kWh electricity has been reduced from 929 to 211 grams CO<sub>2</sub>.

## Targeting energy efficiency

The EU Energy Renovation Wave and Danish targets for energy efficiency and CO<sub>2</sub> reductions will accelerate improvements in the energy efficiency of buildings. The EU goal is to reduce greenhouse gas emissions by 55% in 2030 and by 80-95% in 2050 when compared to 1990. The EU Commission also proposes to raise targets for improvements in

energy efficiencies across all sectors to 36% in 2030. The Danish goal for CO<sub>2</sub> reductions is 70% in 2030 and climate neutrality in 2050. In the coming years, a crucial focus will be on unlocking the remaining energy saving potential in Danish buildings, not least in buildings built before 1980.

## A resourceful industry

The Danish construction industry possess much of the necessary skill and knowledge to support energy renovation in buildings both in and outside of Denmark. More than 40% of the industry's production in Denmark targets international markets. The activity in the construction sector is currently at a high level: the annual turnover for renovation of existing buildings was 13,441,111 million EUR in 2020, accounting for one-third of the sector's total activity, with energy renovations playing a key part. Crucially, the sector works closely with energy authorities on the design and implementation of requirements and other incentives for energy efficiency.

## How to make existing Danish buildings energy efficient:

- Conversion of 400,000 gas boilers and 100,000 oil boilers to sustainable solutions such as individual heat pumps and district heating.
- Upgrading the worst-performing buildings. Around 30% of energy labelled buildings currently possess energy labels from E-G.
- Energy improvements such as energy efficient windows and improved insulation when buildings are being renovated
- Ensuring optimal operation and efficiency of technical systems such as heating and ventilation
- Energy efficiency requirements for new buildings and major renovations will be continually updated to cost-optimal levels
- Maximum life cycle CO<sub>2</sub> will be phased in from 2023 for new buildings and for renovation of existing buildings at a later stage, taking the embedded energy of building materials into account

Source: The Danish Construction Federation

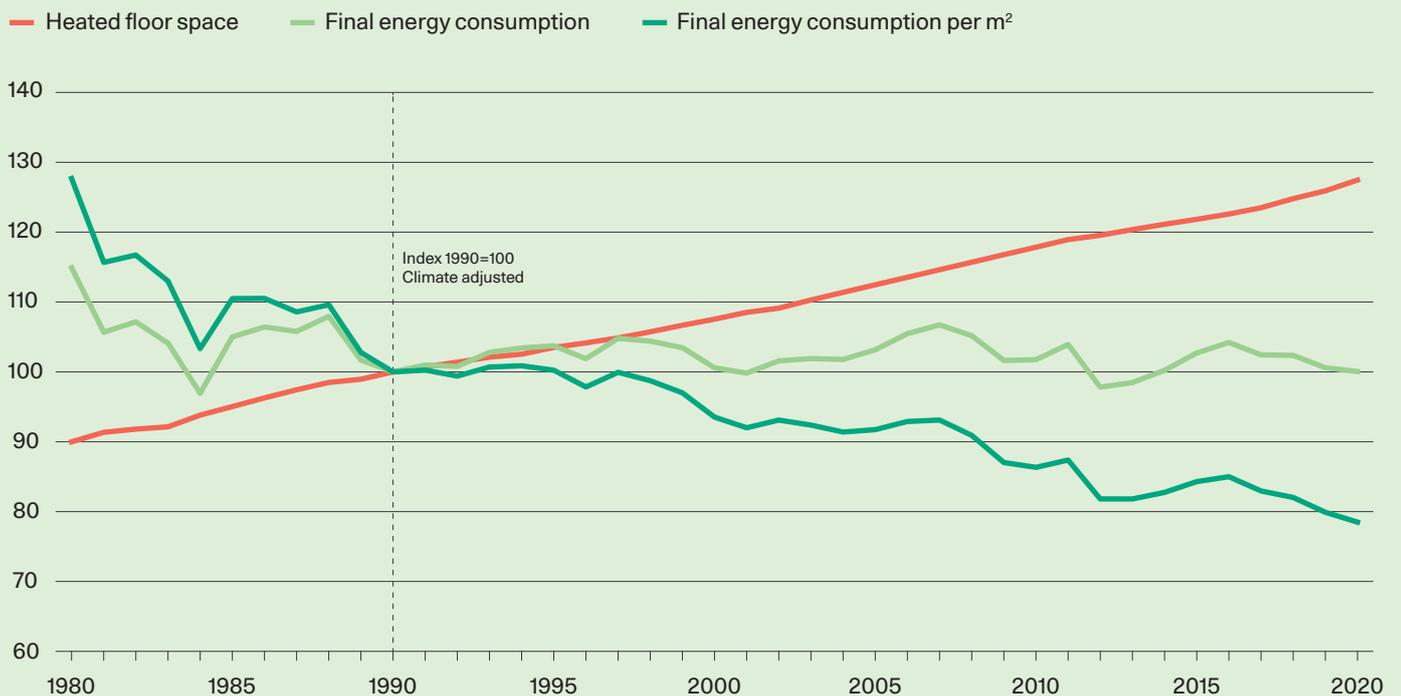


FIGURE 4

## Energy consumption for space heating: 1990-2020

The period 1990 to 2020 shows a notable decrease in the energy consumption for space heating per m<sup>2</sup> in Danish households and a decoupling of the total energy consumption from the growth in total household area. The decline can be explained partly by upgrades in the insulation of older homes, partly by replacing old oil burners with more efficient natural gas boilers and district heating installations. Furthermore, requirements for new homes in Danish building regulations mean that their energy consumption per m<sup>2</sup> is lower than existing homes.



Photo credit: ROCKWOOL

## Circular, fire-safe construction reduces waste

Deep renovations of multi-family housing can result in energy efficient, fire-safe, and sustainable buildings. A residential project in Germany is a prime example of this.

Transforming an outdated housing cooperative into modern, environmentally friendly, and comfortable spaces while making significant energy efficiency improvements was the combined goal of this project. In addition to safe and modern buildings, the aim was also to significantly limit the amount of construction waste that was sent to landfill, thus ensuring broader benefits to the community at large.

The housing cooperative owner selected the best possible building materials for the renovation project, carefully considering the need for thermally efficient buildings that would also be durable, provide additional fire protection, and ultimately boost the long-term value of the complex. In the end, they chose an ETICS system based on ROCKWOOL's 100% non-combustible stone wool insulation. An added benefit to this choice was the ability to utilise the Rockcycle program, whereby any cutaway waste pieces of insulation would be collected and returned to the factory allowing the material to avoid being landfilled. Instead, it could be reused in the production of new stone wool products.

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### LOCATION

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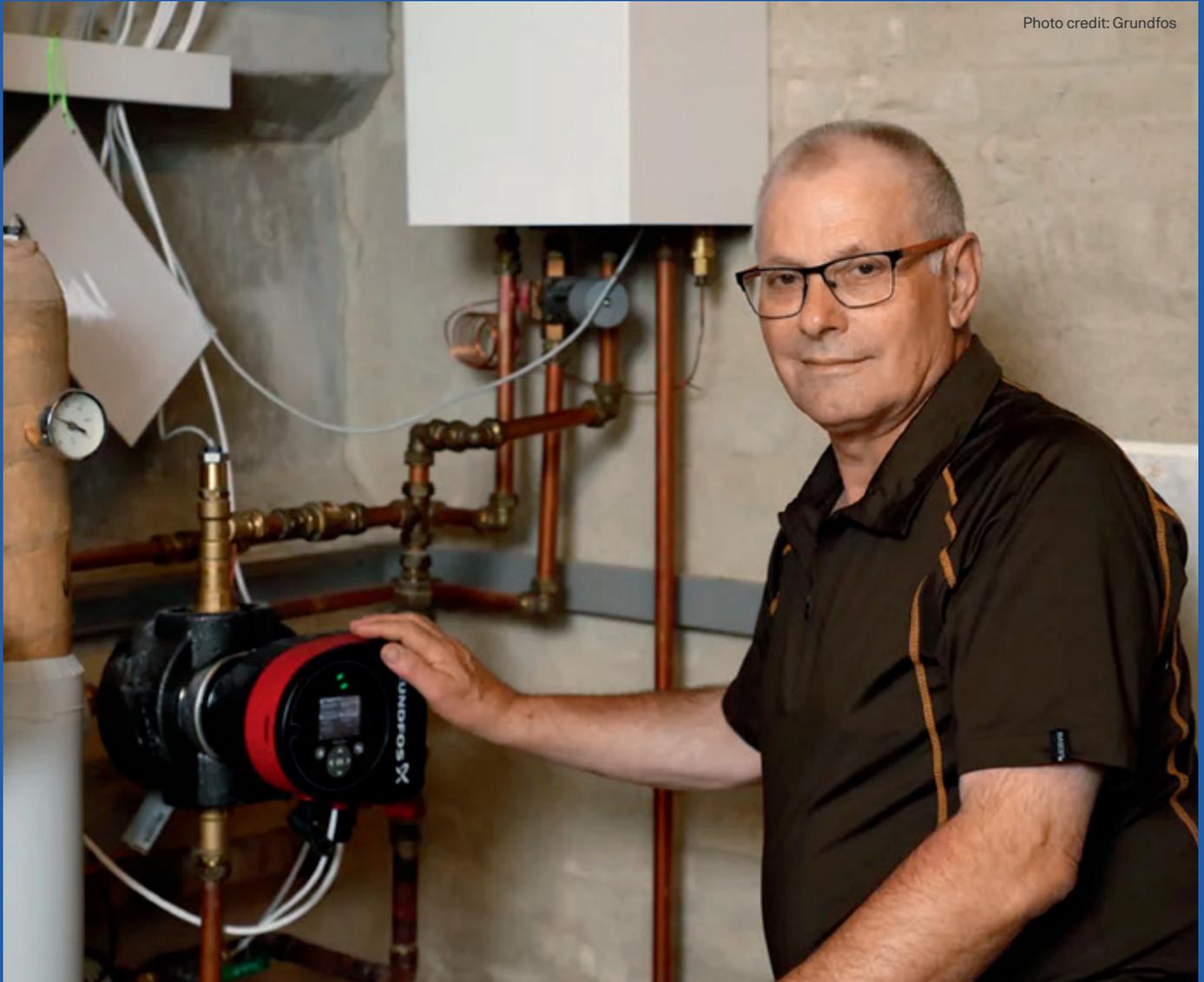


Photo credit: Grundfos

## Holistic maintenance of heating systems

Technologies that optimise the energy consumption of buildings are central to renovation efforts. Grundfos presents one such solution with BuildingConnect, a customisable control and maintenance solution for heating systems. BuildingConnect targets smaller commercial buildings looking to achieve better energy performance – such as Østergaards Hotel in Herning, Denmark.

When Østergaards Hotel needed to refurbish their heating pumps and equipment, BuildingConnect offered them an approach to understanding the building's heating system holistically. The solution is not only geared to monitor, control, and optimise the system's performance, but also encourages proactive maintenance, allowing users to predict and solve issues before they occur. It enabled Østergaards Hotel to see real-time trend curves for specific time periods, use the data to improve efficiency levels and, crucially, change set points and obtain detailed information on heat, flow and return temperatures.

Installing BuildingConnect in connection with their renovation has proven to be a sustainable and impactful investment for Østergaards Hotel, both in terms of energy efficiency and economic savings: Nearly 75,000kWh, equal to the yearly consumption of four Danish households, and 50,000DKK (6.720 EUR) was saved within the first seven months. The solution is a clear example of how pairing renovation with effective energy system surveillance can reduce both Co2 emissions and the energy bill significantly.

### CONTRIBUTORS

Grundfos

### LOCATION

Østergaards Hotel, Herning



# Smart energy systems and building renovations

The energy renovation of existing buildings will not only decrease energy demand. It will also lead to further efficiencies in the energy supply as well as the integration of renewable energy through district heating and individual heat pumps.

## The approach to future energy systems

Amongst the many private and public stakeholders working throughout the world to decarbonise the energy sector, there is growing recognition that in the case of buildings, one must take an integrated approach. Savings, heating, cooling, electricity, transport, and gas cannot be seen as separate elements. These sectors need to be integrated. Here, energy efficiency in buildings plays a vital role.

Savings in heating demand enables lowering the temperature of the heat supply, which benefits both district heating systems and individual heat pumps. Moreover, energy savings and an expansion of district heating will make utilising waste heat from industry, data centres and power-to-x technologies as well as heat from geothermal and solar ther-

mal energy more affordable. Recent research shows that expanding district heating to cover 63-70% of the Danish heating market is feasible both economically and regarding energy efficiency. Paired with sector integration, this leads to more affordable thermal storage options that can support the integration of wind and solar energy.

To realise the potentials of existing and new buildings, one must consider the way energy systems around buildings are transformed. When identifying affordable paths to decarbonisation, an integrated Smart Energy System approach is key. This approach relies on the beneficial synergies between savings, energy efficiencies, and interactions between energy sectors, combined with an integrated use of storages and existing infrastructures.

## Proposals for energy savings in Denmark in the future

- District heating should be expanded further to replace individual boilers
- Large-scale heat pumps, geothermal, waste incineration, and biogas should be supported inside district heating areas
- New supply systems with low temperature district heating from solar thermal
- Efficient ground-source heat pumps supplemented with solar thermal

### Supply level as an enabler

The contribution of the building sector is essential to establish smart energy infrastructures and a fully renewable energy system. Recommendations to increase energy savings activities and support behavioural changes in the operation of buildings go hand in hand with supply level recommendations.

It is essential that heat savings in existing buildings are implemented in conjunction with general renovations and refurbishments. Otherwise, the cost of achieving demand savings is excessive and transitioning to a renewable energy

system by 2045 risks being affected by that cost. For the building stock in Denmark today, approximately 32-40% savings can be recommended for space heating, including hot water. Although new buildings pose a smaller challenge overall in terms of energy efficiency, it is key that recommendations facilitate savings to a level at which the supply of renewable energy becomes cheaper. A high level of energy savings combined with district heating and individual heat pumps significantly reduces peak electricity demands compared to a strategy with only individual heat pumps. About 30-35% coverage with individual heat pumps can be recommended in Denmark.

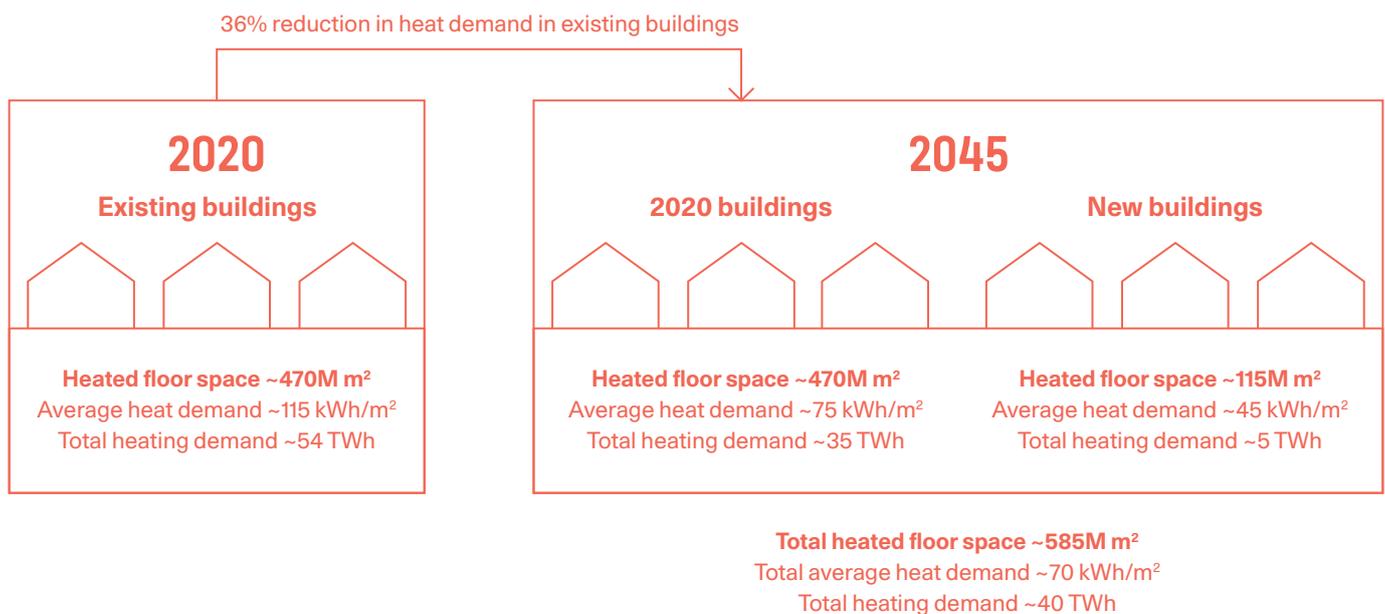


FIGURE 5

## Crunching the numbers on heat demand

If the recommended reduction in heat demand in existing buildings are implemented, it will significantly lower the total heating demand in Danish buildings by 2045 - even with the expected expansion of the building stock. These reduction are most sustainably achieved if targeted in connection with general renovation efforts.



Photo credit: Danfoss

## Energy-efficient district heating with Leanheat

Optimising district heating infrastructure is key in energy efficiency efforts. Moreover, the customer side is often not integrated in the network's operation. Customer heating systems are mostly local, static, based on the outside temperature and lack the possibility to provide feedback to the energy supplier.

In Hanover, Germany, a municipal energy service provider recognised the potential for improving energy efficiency while also enhancing the user experience and customer comfort. They choose Danfoss as the solution provider and equipped 24 properties with the intelligent control software, Leanheat Building, part of the Danfoss Leanheat software suite. It integrates buildings into the optimisation of the district heating system and dynamically adapts heat control and flow to actual customer demand based on continuous real-time measurements and AI. This enables flexibility and lower return temperatures in the district heating network. Thus, efficiency potentials on both the grid and the building side are optimally exploited.

Installing Leanheat reduced energy consumption in the properties by 5-9% and reduced peak loads by almost 20%. Thanks to remote access to sensor data, service technicians were also able to identify and solve technical more quickly, which increased customer satisfaction. The data provides the supplier with information about weak points in the network, while also informing the building owner about possible potentials for improvement to the properties.

### CONTRIBUTORS

Danfoss

### LOCATION

Hanover





Photo credit: Nicolas Weldingh

## Setting data free to support energy efficiency

It is crucial to explore data as enabling knowledge in the green transition. Finding ways to release consumption data publicly to help relevant actors target energy efficiency efforts is a major challenge, but also a potential-filled avenue. This is the realm of possibility Bygningshub.dk taps into.

In April 2022, headed by The Danish Energy Agency and the Agency for Data Supply and Efficiency, the site Bygningshub.dk was launched. It offers building owners and administrators, service providers and authorities better and more accessible data to improve energy efficiency in buildings. The site is part of an experiment in Aarhus municipality to release data on electricity and heat consumption that can be combined with data from The Building and Housing Register as well as data on local weather conditions and energy labelling. Visitors can access data from large buildings with multiple users. The data on electricity and heat consumption is provided by Energinet and Kredsløb, a local district heating provider. It is anonymised by aggregating the data of all consumers in each building so that the requirements for protection of personal data in the EU Personal Data Regulation (GDPR) are met. Thus, the experiment is an exercise in clever data supply, protection, and use – all to optimise the energy performance of buildings.

The test period runs to the end of 2022, and the experiences will subsequently be evaluated to decide whether to make Bygningshub.dk a national platform.

### CONTRIBUTORS

The Danish Energy Agency, The Danish Agency for Data Supply and Efficiency, Aarhus Municipality, Kredsløb, Energinet

### LOCATION

Aarhus Municipality





## Leadership in the green transition

The politicians and CEOs participating in the DK2020 project have taken part in several masterclasses. Here, they have been redied to create and implement Paris compatible action plans with input from both national and international green actors.

Foto: Claus Fisker

## CHAPTER 8

# Municipal energy efficiency in buildings

Buildings account for much of Europe's energy consumption and CO<sub>2</sub> emissions. Danish municipalities are proof of how important it is to support local authorities and grant them freedom to lead energy saving efforts that create sustainable buildings.

Energy efficiency in the built environment is a good place to target climate action. More than a third of Denmark's CO<sub>2</sub> emissions stem from buildings – both old and new. We also know that the lifespan of a building is long, making it common sense to care for, preserve and improve the buildings we already have.

**DK2020 action plans**

Danish municipalities are working together to realise the energy saving potential in buildings through efforts such as DK2020. In this unique initiative, 95 of Denmark's 98 municipalities are committing themselves to create local climate action plans to help Denmark reach the goals of the Paris Agreement. It is important to engage local governments on their own terms, as each municipality faces different barriers in the green transition.

In the climate plans, the municipalities set goals for implementing energy efficiency measures in their own buildings in line with EU ambitions. They also prioritise helping regular citizens do the same, as they play a vital role in greening buildings. In Denmark, 87% of all buildings are owned by private homeowners.

The municipal climate action plans highlight the necessity of combining energy renovations with other efforts to save energy. A smart climate strategy for buildings starts with planning the activity in the buildings during the day, so each square meter is optimally utilised. Similarly, increasing the use of data-driven energy management is an important tool in optimising energy performance and communicating with the grid. As such, making these data available to all building owners is crucial.

**Collaborative knowledge sharing**

The knowledge and experience gained by the municipalities in their work on energy efficiency in buildings is shared with numerous key actors, including state legislators. In addition, the municipalities collaborate with private suppliers to develop product manuals and share showcases on the use of different behavioural methods and advanced technologies such as energy management systems, IoT solutions, and advanced analyses of energy consumption. The variety of tools available to achieve energy efficiency shows the importance of being able to apply the right solution locally and share experiences so others can learn from them. This, among other things, is what Danish municipalities are trying to achieve in their climate collaborations.

Photo credit: Martin Heiberg



## Energy renovation towards a CO<sub>2</sub> neutral capital

The goal of the CPH 2025 Climate Plan is to make City of Copenhagen CO<sub>2</sub> neutral by 2025. To fulfill this ambition, efforts to lower the energy consumption of municipally owned buildings are vital. Such efforts have been a cornerstone of the municipality's work for over a decade - and they have paid off. Since 2010, the municipality has lowered the energy consumption of its buildings by 21%, despite an increase in the total square metres owned.

The City of Copenhagen has multiple initiatives to ensure that sustainable renovations of the municipality's buildings are executed in a prudent manner. For instance, they've established central energy surveillance and automatic maintenance systems on a large part of the property portfolio, which has helped guide energy savings and renovation projects. The schools of Copenhagen have been a priority target for these kinds of energy renovation. Improving the performance of the buildings that house the next generation is a sustainable investment in several ways.

Moreover, the municipality has worked strategically with requirements and certifications whenever construction or renovations have been carried out. Since 2021, it has been a municipal aim to have all major renovation and preservation projects be granted (at least) a DGNB Silver certification. Additionally, the municipality is working to renew a vast amount of its building's energy labels by 2023 to provide a better basis for prioritising future maintenance of the property portfolio.

### CONTRIBUTORS

City of Copenhagen

### LOCATION

Copenhagen



Photo credit: Brian Jensen



## Impactful municipal energy efficiency initiatives

Middelfart municipality on Funen, Denmark, has launched multiple initiatives to improve energy efficiency across both public and privately owned buildings. Firstly, all buildings owned by the municipality are being assessed to identify how to use the square metres as cleverly as possible in terms of reducing expenses and energy consumption. It is an exercise in prioritising and being flexible in accepting various forms of use of the buildings at different times of the day. These efforts will be followed by energy optimisation and timely renovations.

Homeowners are also key players, as they can transform their own homes into energy efficient buildings. This potential is addressed by the municipality's Energy Coaching initiative, which combines classic energy consulting with an anthropological and holistic approach to sustainability in the home. The work with homeowners is further intensified through a task force for energy savings in buildings. Here, local experts and politicians have been tasked with creating and implementing a master plan for energy savings and renovations in buildings for the whole municipality.

Lastly, the municipality collaborated with a local evening school as well as local engineers and companies to educate homeowners on retrofitting and renewable energy options for homes. An evaluation of the initiative showed that the participants subsequently made investments in renovation projects totaling nearly EUR 268,000, thereby demonstrating the importance of knowledge sharing.

### CONTRIBUTORS

Municipality of Middelfart

### LOCATION

Middelfart, Denmark



# DGNB – a systematised approach to sustainability

The DGNB standard is a pillar in the Danish transition to a greener and more holistic approach to the built environment. Targeting the triple bottom line, DGNB guides actors to sustainable construction and renovations of buildings and urban districts.

DGNB is an international sustainability certification standard that aims to promote sustainability in the built environment by providing a systematised approach to evaluating sustainability. In Denmark, the framework was chosen as the industry standard for sustainable construction in 2010 by a unified construction sector and has later been adapted to Danish conditions and requirements. Importantly, it is possible to certify both existing buildings and new buildings as well as urban areas.

In practice, DGNB has two primary functions. Firstly, it serves as a benchmark for sustainability, meaning that a DGNB certification can be used to highlight and disseminate sustainable efforts made in the individual building and in the construction industry in general. Secondly, DGNB functions as a tool for organising sustainability efforts in construction process and making the most appropriate decisions throughout the development or renovation of the individual and unique building or urban area. Through a DGNB certification, stakeholders obtain a structured and systematic review of all parameters of the project as it is planned and executed.

## **Triple bottom line**

The DGNB system is based on the three central sustainability areas of environmental, economic, and socio-cultural issues, which are weighted equally in the evaluation. The

DGNB System also accounts for the location and the technical and procedural quality based on a holistic approach.

In contrast to other sustainability certifications, it is the holistic view of sustainability that characterises DGNB. Sustainability in DGNB's perspective is both about scoring highly on the individual parameters, but also about ensuring a balance between them. Thus, the DGNB guides and encourages an approach to construction and renovation, where the three areas of sustainability are in harmony, ensuring both environmental, economic, and social gains.

## **Market forces drive the transformation**

The general support from the industry has been crucial to the success of DGNB in Denmark. Notably the number of Danish DGNB certified and pre-certified projects has increased from 20 projects in 2017 to 97 projects in 2021. The progress and recognition of DGNB is a result of the industry's acceptance and use hereof. Ambitious market forces have transformed the framework from an unknown asset into a competitive advantage that drives change and aids the green transformation across the industry. The system has been continuously developed since its conception and is now not only considered the most advanced in the world, but also recognized internationally as the Global Benchmark for Sustainability.

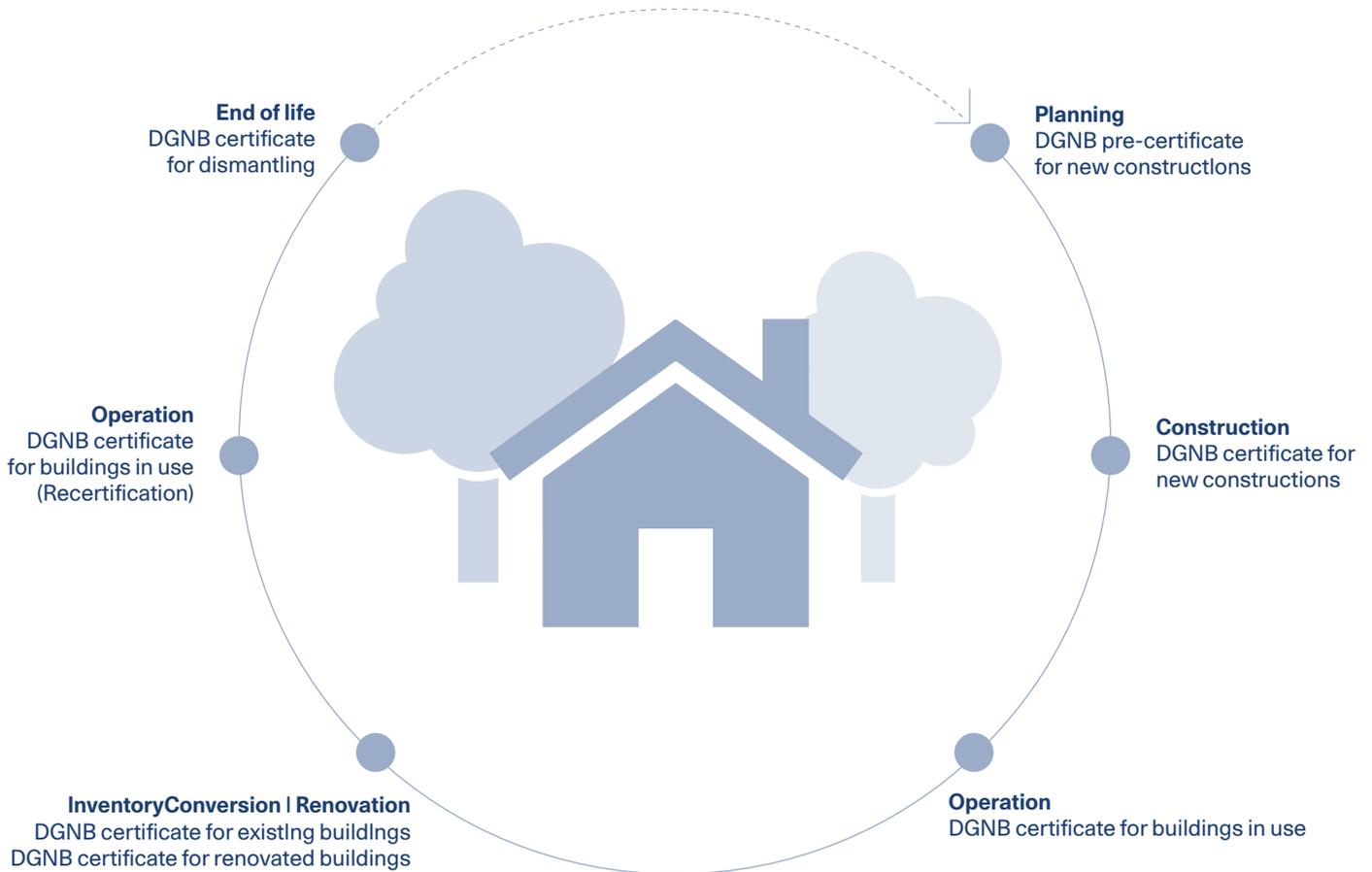


FIGURE 6

## DGNB criteria throughout a building's life cycle

The base of the DGNB criteria is the three-pillar model of sustainability: environmental quality, economic quality and socio-cultural and functional quality. In some places, like Denmark, criteria for technical, process and area quality are also utilized. Every building, from planning to demolition, goes through different phases in its life cycle, which are linked to different requirements and conditions. Each phase has accompanying versions in the DGNB system, which encompasses the relevant aspects of the given phase. Some also specify criteria across different building types (hotel, office, home etc.). DGNB certification can thus be applied to both new and existing buildings as well as to renovation and buildings in use.



Photo credit: The Technical University of Denmark

## Renovating in a sustainable, ambitious manner

DTU Skylab is The Technical University of Denmark's living laboratory for innovation and entrepreneurship. Here, the latest technology and science is coupled with an ambitious community, where students, researchers and business partners meet to develop visionary solutions.

DTU Skylab is a robust and adaptable building. The flexibility of the established technical floor and the considerable ceiling heights make it possible to change installations according to future needs, thereby enabling a long service life. At the same time, the robust materials function as a resource bank that can be reused in new construction at the end of their service life. Similarly, the building's robust materials, easy-to-clean surfaces, and energy efficient installations amount to low life cycle costs. Moreover, because the building is built against an existing building, the consumption of resources for establishing and heating an additional facade is avoided. In addition, instead of adding solar cells on the building itself, the building is connected to DTU's central solar cell system, on the rationale that larger plants are cheaper to establish and maintain than multiple smaller plants and provide a better economy.

With a DGNB score of 68.2% balanced across all categories, DTU Skylab has achieved DGNB Gold, reflecting the sustainable nature of the building. Furthermore, the high architectural quality means that DTU Skylab is the first building in Denmark to be awarded DGNB Diamond certification.

### CONTRIBUTORS

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### LOCATION

Lyngby, Denmark





Photo credit: Monomal

## From farm to aesthetic and sustainable home

Rødbøgegaard, a farm built in 1780 in Northern Zealand, Denmark, has undergone a transformation from agricultural property to a modern living space with an adjoining atelier. The farm was worthy of preservation, making the challenge one of changing the function, while preserving the feel and character of the original place. This required purposeful interplay between architectural design and a sustainable approach to renovation.

Energy efficiency concerns played a key role in the renovation process. The farm is now insulated and supplied with geothermal heat, which is laid out the adjacent field. Roofs, windows, and doors have been replaced. The living spaces were strategically designed, orienting them towards to the four cardinal directions to optimise their function, as well as energy gains. Large windows ensure contact between the inside and outside space and create unique daylight conditions, as well as utilise the heat on the concrete floors.

The renovation has yielded both environmental, economic, and social benefits. By optimising energy efficiency on both the heating, water, and electricity, implementing modern and creative architectural solutions, the farm's worth has increased fourfold. The farm's new character has also contributed to the local community both aesthetically and functionally. Sustainable on many levels, Rødbøgegaard can be an inspiration on how we might care for the many run-down agricultural properties all over Europe going forward.

### CONTRIBUTORS

Monomal

### LOCATION

Havreholm, Denmark

# Investing in and financing energy renovations

In order to realise the untapped energy efficiency potential in our buildings, energy renovations must be made feasible through green investment, accessible financing models and holistic solutions.

Investment and financing are crucial arenas of action in all efforts to accelerate the green transition of our societies. This is especially true for energy renovations of the built environment. In Europe, renovations of buildings with a consistent focus on energy efficiency is one of our most effective ways to reduce CO<sub>2</sub> emissions. According to the EU Energy Efficiency Directive, member states are required to renovate at least three% of the total floor area of all public buildings annually. However, given that the renovation requirement does not include energy renovations by default, it takes focus, expertise, and funding to realise a building's full energy saving potential. Those same resources are needed in the renovation of private buildings and homes, where the gap between the incentive to renovate and funding might seem especially difficult to bridge in the short term. Thus, the financial backbone must be secured, guaranteed, and integrated in any renovation project.

## Accessible financing models

Whether you are a private house owner or a public entity with a large building portfolio, accessible funding is vital in ensuring that supranational and national recommendations are translated into action. The structuring of loans is a key component. Here, working with options such as fixed rates and loans without collateral can make the decision to go through with energy renovations more viable. On the

funding side, financing based on guaranteed savings, in line with the ESCO model, is a way to take long-term responsibility for the solutions implemented. In the big picture, such models help push the general behaviour of the green investment market towards recognising the responsibility of financing organs in the green transition. By strategically enforcing sustainability and energy requirements, they play an important role in both financing and incentivising energy renovations.

## Holistic benefits

As with most areas of the green transition, it is beneficial to take a holistic approach to financing energy renovations. For instance, by offering one-stop solutions that include advisory, professional project and funding management, contracting, financing, and follow-up monitoring, energy renovations can be made more feasible and well-tailored. The benefits of investing in holistic building renovation extend beyond the environment. The IEA's sustainable recovery report found that, per euro invested, building renovation is our biggest job creator with 12-18 local jobs for every million invested. The EU Commission estimates the potential for an additional 160,000 green jobs in the construction sector in the EU by 2030. Thus, investing in and financing energy renovation is also good business.

## The impact of holistic energy renovation of office buildings

80 MILLION

people working in offices in Europe can benefit from healthier work environment

12%

increase in employee productivity

€500 BILLION

gross value added across the EU

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FIGURE 7

### Investing in renovation is good, green, and healthy business.

Offices account for 23% of the total floor area of the EU's non-residential building stock and house 80 million workers. Thus, investing in renovation of office buildings can be impactful, both for the environment, the workers, and the economy. By providing an energy efficient, comfortable, and healthy workspace, holistic renovation of a typical office can lead to a 12% increase in employee productivity. At a European scale, that could be worth up to 500 billion euro annually.

These types of benefits extend beyond offices. For hospitals, optimising the indoor environment can reduce average time spent in hospitals by 11%. Across 90 million patients annually, that is a societal benefit worth around 42 billion euro. For schools, optimizing the indoor climate heightens student performance, letting them achieve the same learning results two weeks faster per year.



Photo credit: Sustain

## Financing energy savings in Kalundborg

When the EU required renovation of the public housing department FOB Kalundborg in northwestern Zealand, Denmark, was due the managing board was ready to think out of the box. By incorporating energy efficiency through an additional investment, the renovation of FOB Kalundborg enabled more than a doubling of the energy savings planned in the original industry standard renovation.

The FOB Kalundborg renovation project's expected CO<sub>2</sub> savings were doubled by an external financing of just 8% of the total renovation budget. The additional investment enabled the replacement and re-insulation of technical installations. Furthermore, intelligent management was installed, which helps to reduce energy consumption and to ensure a better indoor climate for the tenants. The additional investment also paved the way for new and energy-friendly windows, and for optimal insulation of facades, exterior walls, and gables. In total, the project has realised savings on heating, electricity, and water, amounting to a reduction of approximately 600 tonnes of CO<sub>2</sub> per year.

The savings were made possible by the ESCO 2.0 financing model developed by the Danish energy efficiency contractor and advisory company Sustain. ESCO 2.0 is a holistic one-stop solution for energy renovations of buildings and public housing by bundling independent advisory services, A-Z energy renovation and project management, a savings guarantee, and external financing from the green investment and pension fund PKA.

### CONTRIBUTORS

Sustain, FOB Kalundborg,  
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### LOCATION

Kalundborg, Denmark



Photo credit: Boligforeningen Ringgården



## A new, efficient kind of photovoltaic installation

Something special has been going on in Trigeparken, a public housing complex just north of Aarhus. Hidden behind scaffolding, a radical renovation project has given six apartment blocks a massive lift both architecturally and in terms of energy efficiency.

The blocks are part of the large-scale, EU funded climate project READY. The project aims to develop and test green technologies and set new, climate-friendly standards in a collaboration between the municipality, Ringgården housing association, Aarhus University, and a number of private companies.

As part of the READY project, three of the six apartment blocks have been fitted with a new type of photovoltaic installation that can produce around three times as much energy as traditional solar cells. Where traditional solar cells can absorb about 20% of the energy in sunlight, the new PTVT panels, developed by Racell Sapphire, can absorb up to 90%. For the residents, the renovation means that their energy costs will be significantly lower than before. Then, READY comes as a bonus. The photovoltaic installation is expected to supply electricity to the individual homes as well as to common areas and laundries.

Public housing has immense potential when it comes to the green transformation, so housing associations all over Denmark have a crucial role to play in testing and implementing sustainable energy solutions.

### CONTRIBUTORS

Aarhus municipality

### LOCATION

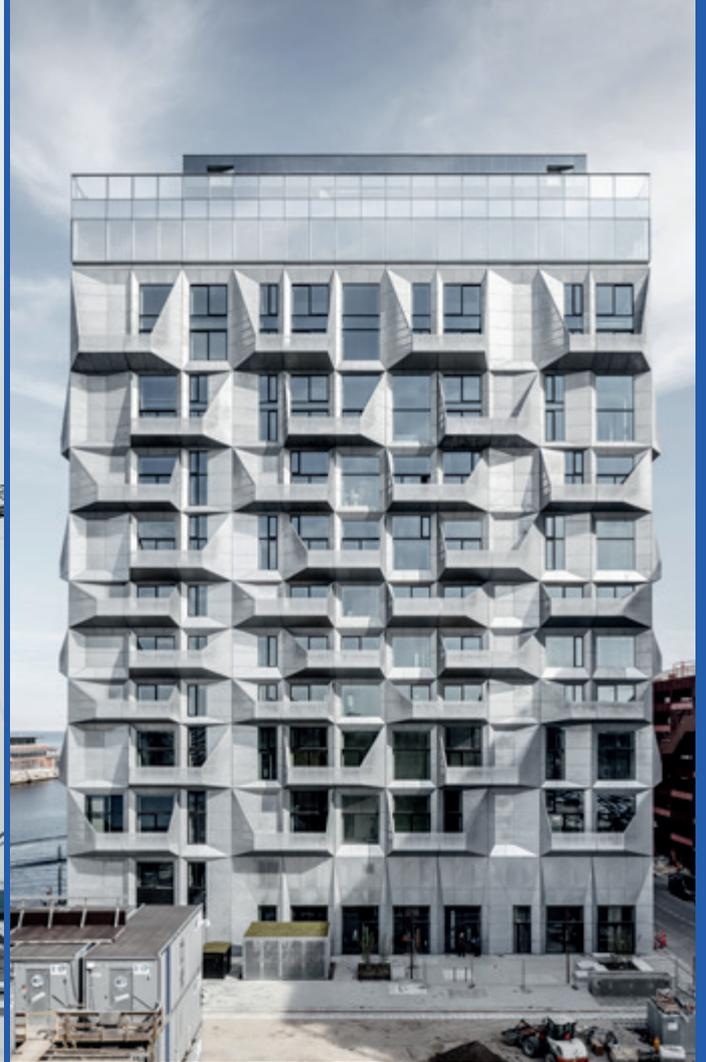
Trigeparken, Trige, Aarhus



Photo credit: Rasmus Hjortshøj



Photo credit: Rasmus Hjortshøj



## Architectural transformation as resource

The Silo is a sustainable centrepiece of Copenhagen's redeveloped North Harbour. The old grain storage silo from 1962 was transformed in 2017 and now houses both apartments and public spaces.

The original silo's inherent qualities made it a resource to be reimagined, rather than industrial waste. 2,740 m<sup>3</sup> of concrete was reused in the renovation, the equivalent of 380 tonnes of embedded CO<sub>2</sub>. Leftover concrete from windows, decks and doors has been reused to make seating and podiums in the area surrounding the building and is a characteristic detail in the interior of the apartments. The old silo was not isolated. The upgrade to current energy standards was achieved by maintaining the silo's rawness inside and fitting the outside with a well-insulated façade clad in galvanized steel elements, thereby creating an efficient sculptural overcoat. After securing the roof and the bays, the establishment of new technical installations followed.

To repurpose and preserve structures in built environments is a commitment to sustainability. Not only in terms of the materials and CO<sub>2</sub> emissions saved, but also in terms of caring for the cultural heritage by emphasising the value of aesthetic and lasting design. The Silo's mix of private and public functions is also an expression of social sustainability. The renovated building does not just take up space but gives back to its surroundings by providing new, shared, and accessible areas for the community.

### CONTRIBUTORS

Cobe

### LOCATION

Copenhagen



Photo credit: VELUX



## Healthy homes for people and the planet

Living Places is a new way of thinking about how to build in the future. The project explores how the building industry can support the health of the people and the planet through building design that is scalable, affordable, and commercially viable. It arose by looking at the most common Danish home, and asking how materials, construction, utilities, and architecture could be rethought towards building homes with less impact on the planet. The goal is to build within the Science Based Targets Initiative limit of 1.5 degree rise in global temperatures.

To document the environmental impact of a building's life cycle from design, manufacturing, use and maintenance, to renovation and demolition, a Life Cycle Assessments calculator was developed, enabling an assessment of materials already in the design phase. The buildings will be built of materials with low or positive CO<sub>2</sub> impact and a focus on design for disassembly, reuse, and recycling of materials such as wood fibre insulation material and screw pile foundations.

The blueprint for Living Places considers the elements of sustainable living in a holistic manner; daylight, biorhythms, acoustics, air quality, thermal environment and the relation to the surrounding nature are all interwoven and incorporated in the design. The prototype concept footprint is below 4 kg CO<sub>2</sub> eq/m<sup>2</sup>/year for the 50-year standard viewing window. The first example of Living Places will be built for the World Capital of Architecture in Copenhagen in 2023.

### CONTRIBUTORS

VELUX

### LOCATION

TBD



Learn more about Danish energy solutions,  
find more cases from around the world and  
connect with Danish experts at:

[www.stateofgreen.com](http://www.stateofgreen.com)



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