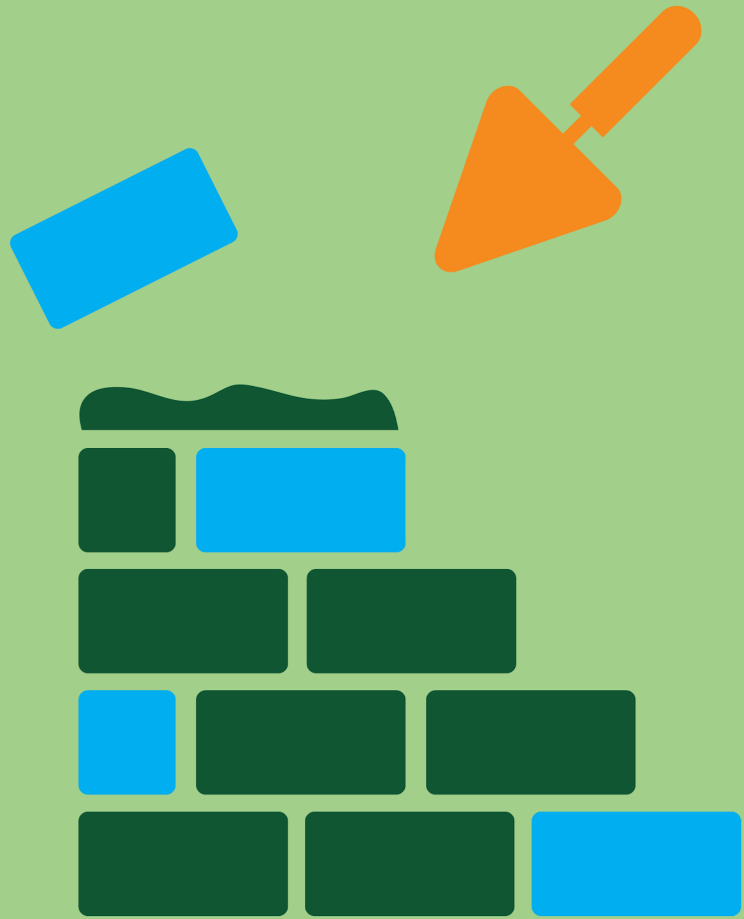
THE CLIMATE IMPACT OF THE DANISH BUILDING SECTOR

A Catalogue of the most important areas for an accelerated green transition of the building sector



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The Climate Impact of the Danish Building Sector - a catalogue of the most important areas for an accelerated green transition of the building sector

Authors: Nethe Veje Laursen, Erik Trang, Michael H. Nielsen og Søren Dyck-Madsen

Foreword

Buildings are an indispensable part of our society. Buildings enable our activities and contribute to growth, job creation and prosperity. Buildings accommodate our everyday lives, and we spend most of our time in buildings. It is where we live and where we work.

In Western parts of the world 90 percent of our time is spent indoors[1]. Therefore, the quality of buildings has a significant impact on our quality of life. At the same time buildings are one of the biggest sources of greenhouse gas emissions, it increases our use of resource and contribute to pollution. These side-effects occur as a result of the construction of a building, the production and transport of building materials during construction, energy consumption and material waste at the construction site, and energy consumption in the operational phase, i.e. heating, cooling and lighting in buildings.

The UN projects a population of almost 10 billion people in the world by 2050[2], who will all need a roof over their heads. Therefore, there is a need for sustainable buildings and construction on a global scale, as we are not able to forego buildings and we are not going to stop building and remodelling either. But by doing it smarter and more efficiently, the climate impact can be reduced. Denmark should lead the way to significantly more sustainable construction and buildings, and climate-friendly building operations, for the benefit of the climate, society, and the overall green transition.

To support Denmark on this journey, CONCITO has prepared The Climate Impact of the Danish Building Sector. It highlights the most important areas to focus on to enable an accelerated green transition of the building sector. The catalogue presents key areas where the building sector affects climate and identifies 18 focus areas that relevant stakeholders can work with here and now to reduce the climate impact of buildings.

CONCITO is an active participant in the work to make buildings and construction more sustainable and will follow up on this report with more detailed findings and specific recommendations in future papers and analyses.

The focus of the The Climate Impact of the Danish Building Sector is national, however, much is and can also be done at the European level It is not part of this analysis but it is no less important for that reason.

1 Ministry of the Interior and Housing (2021) – National strategy for sustainable construction (in Danish)
2 United Nations (2017) - World population prospects

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1. The Climate Impact of the Danish Building Sector

In order to reduce CO_2 emissions[3] it is important to focus on the building sector., The sector is a major contributor to both national and global CO_2 emissions.

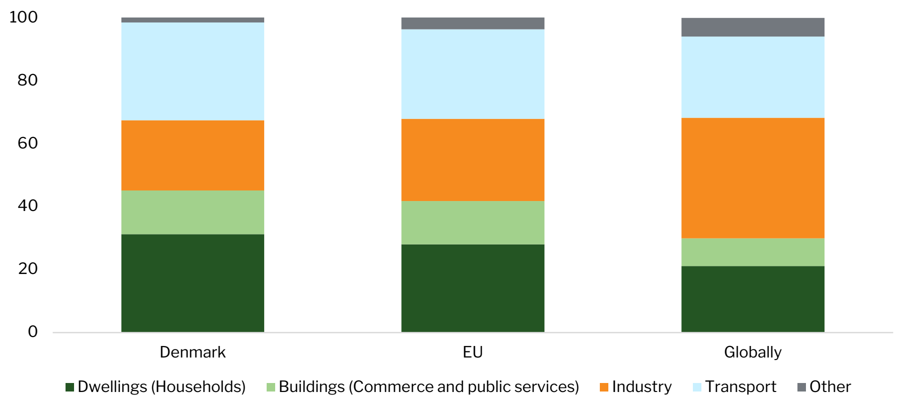
On a national scale, 45% of the energy consumption and 27% of energy-related CO_2 emissions is attributed to buildings[4]. It makes up 18 % of the total greenhouse gas emissions and excepts CO_2 emissions associated with the building process, and material consumption, including cement production. Cement production alone accounts for approx. 5% of Denmark's CO_2 emissions[5].

Within the European Union buildings represent 42% of total energy consumption, as depicted in Figure 1. Consequently, buildings contribute to 35% of energy-related CO_2 emissions and 28% of the EU's total greenhouse gas emissions[6]. Furthermore, cement production accounts for an additional 3% of the EU's CO_2 emissions[7].

Figure 1 illustrates the significance of buildings' climate impact on a global scale, and emphasizes their central role in the green transition, it is true for Denmark as well as abroad.

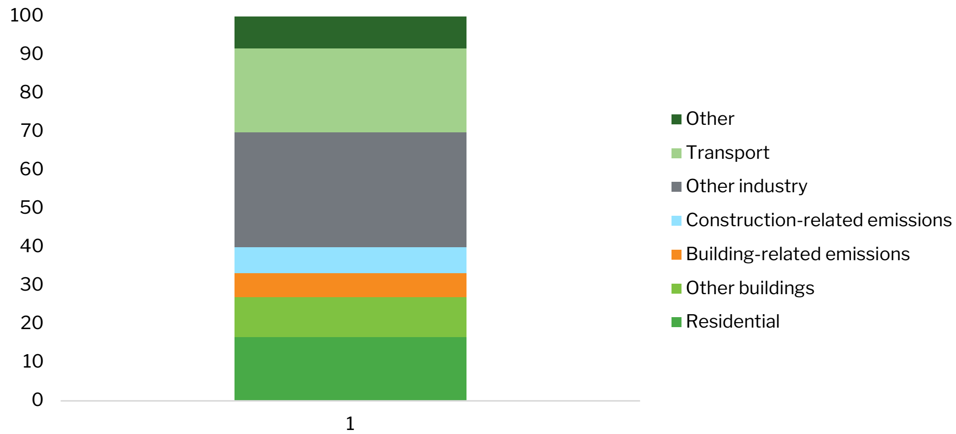
Globally, the operation of buildings is responsible for 27% of energy-related

Figure 1: Energy consumption by sector (Percent.)



Own calculations based on The Danish Energy Agency (2021) - Energistatistik 2021, Eurostat (n.d.) - Tabel NRG_BAL_S og IEA (2022) - Buildings

Figure 2: Global CO2 emissions



Building and construction-related emissions include emissions associated with the production of building materials such as cement, steel and bricks. Source: IEA (2022) - Buildings

3 For the sake of readability, CO_2 emissions are referred to as CO_2 equivalents throughout the report
4 The Danish Energy Agency (2021) - Energy in Denmark 2021. Energy consumption in buildings is defined as energy consumption in households and in commerce and public services
5 3: The Danish Energy Agency (2023) – Climate status and -projection 2023 (in Danish). KF23 Results – Numbers behind figures (in Danish) figure 6A.2 and figure 2.1
6 Eurostat (n.d) – Table NRG_BAL_S og TOTXMEMONIA
7 IEA (2022) - Buildings.

Facts regarding Denmark's Climate impact, the 70% emissions reduction target, and the relation to buildings

Denmark aims to reduce its greenhouse gas (GHG) emissions with 70% by 2030 compared to 1990. This target includes GHG emissions generated within the Danish borders only and can be seen as the climate impact from Danish *production activities*.

Danish consumption, which includes the utilization of imported building materials, is linked to GHG emissions occurring outside Denmark's borders. This is quantified separately as Denmark's consumption-based climate emissions.

When evaluating the climate impact of the Danish building sector, assessments often focus on the entire life cycle of buildings. This covers the climate impacts originating from building materials, construction processes, building operations, and eventual disposal, such that materials produced both within Denmark and abroad are included.

To exemplify, if the building sector in Denmark for instance reduces its consumption of carbon intensive materials, it might not necessarily directly contribute to the national 70% emission reduction target if the production of these materials remains unchanged within Denmark. However, such reductions in material consumption would lead to fewer emissions on a global scale.

CO_2 emissions[8] and the production of building materials contributes to 6% of energy-related CO_2 emissions. This is illustrated in Figure 2.

Thus, it is not an isolated Danish problem that buildings account for a significant portion of CO_2 emissions.

Besides its energy impact, the production of building materials for the building sector involves the extensive use of raw materials and chemicals, which has adverse effects on climate, biodiversity, and exacerbates resource scarcity worldwide. In Denmark, activities of the building sector are responsible for 40% of all waste generated[9].

The climate impact from imported building materials accounts for an estimated 9% of Denmark's consumption-based CO_2 emissions, when the emissions associated with their production overseas is included. In 2021 Denmark's consumption-based CO2 emissions stemming from the construction and renovation of buildings amounted to 5.6 million tons of CO_2 emissions, approximately half of these emissions occurred abroad[10].

To align with both national and international climate targets, Denmark must reduce its CO_2 emissions, significantly, not at least to reach the target of 70% reduction in CO_2 emissions by 2030. Given its substantial climate impact, the building sector has a central role in achieving these reductions by effectively mitigating the climate impact of buildings.

Consequently, there are compelling reasons to prioritize a political focus on the reduction of CO_2 emissions related to the building sector throughout the entire life cycle of buildings. This entails addressing the climate impact of building materials, CO_2 emissions linked to energy consumption and construction waste, as well as enhancing energy efficiency during building operations.

A transition to circular processes is imperative to obtain a more sustainable balance between the resources we extract and those we return to nature. Achieving this necessitates a focus on reusing and recycling building materials, creating new materials from recycled sources, and extending the lifespan of existing buildings to minimize the consumption of new resources. These various aspects require both attention and action and must be addressed prompting CONCITO to recommend the following 18 focus areas:

8 The Danish Environmental Protection Agency (2022) – Waste statistics 2020 (in Danish)
9 The Danish Environmental Protection Agency (2022) – Waste statistics 2020 (in Danish)
10 The Danish Energy Agency (2023) – Global Report 2023

Recommended Focus Areas for Climate Mitigation in Danish Building Sector:

Climate Requirements in the building sector

- Collect and provide access to data from mandatory life cycle assessments (LCA) to support future regulation
- Swift enhancement of the climate requirements of 12 kg CO_2e/m^2/year within the Danish Building Regulations for new buildings. Enhancement will encourage innovation to reduce CO_2 emissions in the building sector
- Expand climate requirements within the Danish Building Regulations to encompass more phases of the construction process e.g., the execution phase

Construction Site Emissions

- Systematically gather data on the climate impact of construction sites
- Promote the adoption of electrically powered construction equipment, fostering market maturation where needed
- Develop a plan for the timely implementation of electrical and district heating infrastructure at construction sites

Renovations or New Construction

- Mandate a comparison of the climate impact between demolition and new con-struction versus renovation and transformation prior to granting demolition permits
- Develop a LCA model for renovation and rapidly incorporate climate requirements for renovation into the Danish Building Regulations

The Climate Impact of Building Materials

- Accelerate the accumulation of knowledge and documentation regarding the technical properties of new materials and their structural applications
- Establish requirements for the sustainable certification of bio-based resources used in construction
- Promote the use of sustainable building materials, emphasizing reuse and recycling
- Support the development of accurate environmental product declarations (EPDs) for integration into LCA tools

Energy Consumption and Efficiency

- Formulate a national strategy for efficient energy utilization, giving due importance to low energy consumption in buildings, also as power and heating sources become greener
- Set a national objective for the rapid phase-out of oil, gas, and wood pellet boilers
- Restrict the consumption of biomass for energy production, including district heating

Buildings of the future

- Modify the Danish Building Regulations to incentivize the construction of buildings with fewer and more flexible square meters, thereby reducing material and energy consumption
- Promote mobility within the housing market
- Design new and renovated homes with fewer and more efficiently utilized private square meters

2. Climate Requirements in the Building Sector

One way to compel the building sector to proactively reduce its climate impact is by implementing climate requirements introducing limits to CO_2 emissions from a building during its construction, operation, and end-of-life phases. The introduction of climate requirements for the building sector will create a demand for more climate friendly building materials, thereby fostering innovation and sustainable development within the industry.

Starting from January 1, 2023, the Danish Building Regulations have mandated that major new buildings (exceeding 1,000 m²) must not exceed an emission threshold of 12 kg CO_2e/m²/year over a 50-year lifespan, as determined by a life cycle analysis (LCA)[11]. In 2025, the National Strategy for Sustainable Construction has outlined plans to expand this requirement to encompass smaller buildings. Furthermore, the climate requirements are expected to tighten progressively every two years until 2029 to reduce the climate impact of the building sector[12].

However, when applying the current LCA methodology, it appears that new buildings are already in compliance with the introduced climate requirement of 12 kg CO_2e/m²/year. Currently, half of new major buildings emit 8.8 kg CO_2e/m²/year. Even the upper quartile of new buildings falls below the current climate requirement, as depicted in Figure 3.

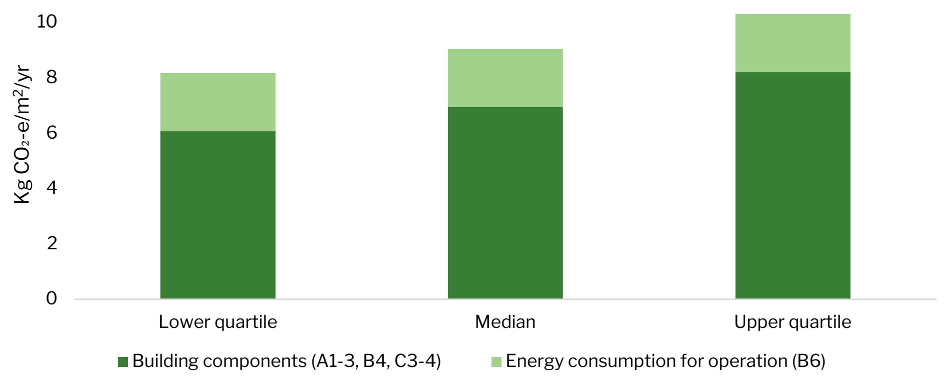
Given that new construction of major buildings already meets the existing climate requirement, the more stringent requirements proposed in the National Strategy for Sustainable Construction are simply not ambitious enough. It is unlikely that these plans alone will be sufficient in facilitating the required emissions reduction and a more sustainable development within an acceptable timeframe.

The climate requirement is assessed using a LCA. A through assessment of climate requirements should be based on a more comprehensive life cycle analysis, which encompasses all phases of a building project.

Yet, the current life cycle analysis methodology specified in the Danish Building Regulations does not cover all construction phases at present.

From a life cycle perspective, the climate impact from building materials makes up the largest share of the total climate impact from construction of new buildings[13]. This is currently included in the LCA assessments.

Figure 3: Climate impact from new buildings broken down by building components and operation.



Note: For operational energy an energy consumption of 37 kWh/m2 is assumed. It corresponds to compliance with the energy framework requirements for a residential building of 1000 m2 heated with district heating. Source: Data for building components is from Röck et al (2022) Towards EU embodied carbon benchmarks for buildings and own calculations based on Building Regulations and COWI (2020)- Updated emission factors for electricity and district heating (in Danish).

11 Building Regulations (in Danish) and Social and Housing Agency (2023) – Climate requirements (LCA) in buildings regulations (in Danish)
12 Ministry of the Interior and Housing (2021) – National strategy for sustainable construction (in Danish)
13 BUILD (2021) – Green transition in the building sector (in Danish)

Factbox: Methods for lifecycle assessments in the building sector (LCA method)

The lifecycle analyses are divided into phases. The life cycle phases are defined according to a European standard, where A denotes building materials and construction process, B denotes use and operation, C end of life and D deals with potentials for recycling and reuse.

The employed LCA methodology requires life cycle assessments to be carried out for the building materials, including raw materials and transport, i.e. phases A1-A3, replacement of building components (phase B4) and energy consumption for operation (phase B6), as well as waste treatment and disposal (phases C3 and C4). It does not include e.g. the construction phase (phases A4 and A5).

Source: Building Regulations (in Danish).

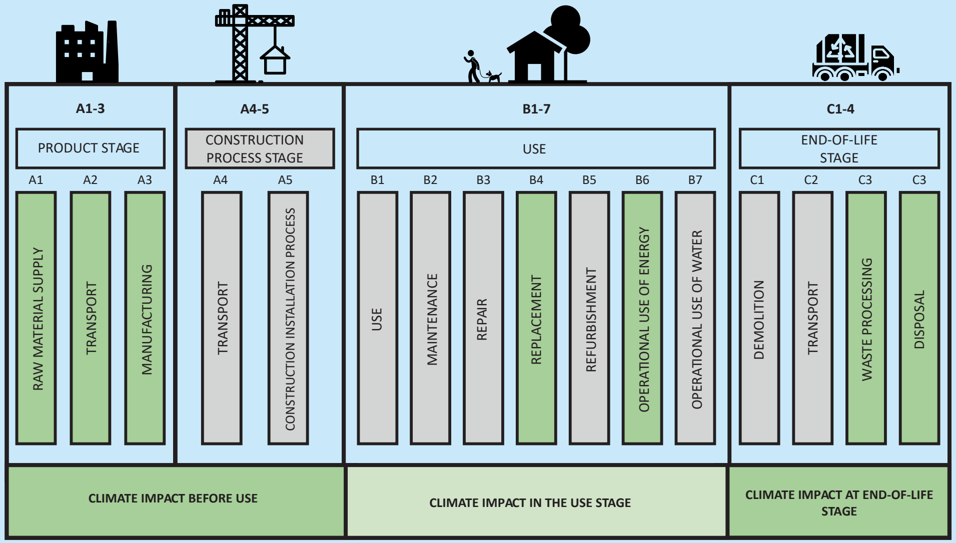
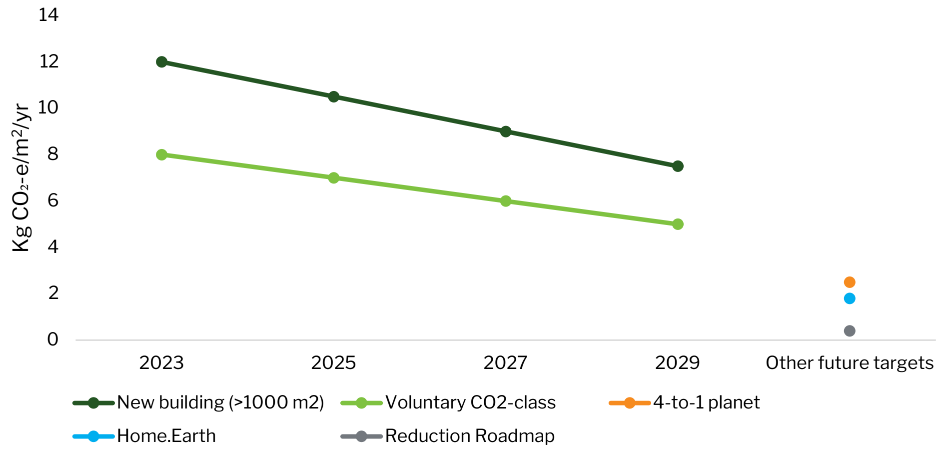


Figure 4: Current and future targets for the climate impact of new buildings



Note: Targets for new-buildings and voluntary CO_2 class are indicative.
Source: Own visualization based on Röck et al (2022) - Towards EU embodied carbon benchmarks for buildings,, Ministry of the Interior and Housing (2021) – National strategy for sustainable construction (in Danish), Home.Earth (2022) (in Danish), Reduction Roadmap (2022) and Realdania (2022) – Housing construction from 4 to 1 planet (in Danish)

As heating and power supplies are increasingly sourced from renewable energy, the relative share of building materials' climate impact of the total climate impact of a building will increase. Hence, building materials represent a central focus area for achieving sustainable construction practices.

The current approach to LCAs does not include the climate impacts from other important areas such as transportation, energy consumption, and material waste generated during the construction process, even though these sources account for a significant portion of emissions. In order to provide an accurate understanding of the full climate effects from construction of new buildings, it is essential to expand the scope of each LCA to include more phases.

Various actors in the building sector have put forward proposals regarding the extent and pace at which the climate impact from the building sector should be reduced. The degree of reduction is obviously related to these actors' own objectives and their interpretations of sustainable development within the building sector. It depends on several factors such as whether they measure against alignment with the Paris Agreement's goals, to comply with planetary boundaries, or towards specific reduction targets.

Figure 4 compares proposals for needed climate reduction from selected actors. The Reduction Roadmap project estimates that new housing construction should aim to emit only 0.4 kg CO_2e/m²/year by 2036 if Danish housing construction is to align with the Paris Agreement[14].

The property development firm Home.Earth estimates that emissions must be reduced to 1.8 kg CO_2e/m²/year to stay within planetary boundaries[15]. Meanwhile, Housing construction from 4 to 1 Planet advocates for lowering emissions to 2.5 kg CO_2e/m²/year to reduce the climate impact of new buildings by 75%, from todays approximately 10 kg CO_2e/m²/year[16].

It is evident that while the introduction of climate requirements for construction of new buildings is a step in the right direction, much more must be done to achieve sustainable and climate-neutral construction practices.

The path to sustainability is dependent on various underlying assumptions. It involves, among other things the size of the global carbon budget and Denmark's share of this budget. It also depends on assumptions on the planetary boundaries relation to resource consumption and environmental impacts of the building sector. Further, it depends on which parts of the construction phases is included in LCA calculations and the proportion of the total climate effect attributable to construction of new buildings in the future.

The overall conclusion is that actions outlined in the National Strategy for Sustainable Construction is not sufficient for a sustainable development of the building sector. It is a necessity to further reduce the climate impact from the Danish building sector. More stringent climate requirements will provide incentives to development of less carbon-intensive building materials, promote circular processes, and encourage a reevaluation of existing practices within the building sector.

Recommended Focus Areas

- Collect and provide access to data from mandatory life cycle assessments (LCA) to support future regulation
- Swift enhancement of the climate requirements of 12 kg CO_2e/m²/year within the Danish Building Regulations for new buildings. Enhancement will encourage innovation to reduce CO_2 emissions in the building sector
- Expand climate requirements within the Danish Building Regulations to encompass more phases of the construction process e.g., the execution phase

14 Reduction Roadmap (2022) (in Danish)
15 Guldager (2022) - If we are to continue living in the same area of square metres, we need a CO_2 cap of 1.8 kilos per square metre (Klimamonitor) (in Danish).
16 Realdania (2022) - Residential construction from 4 to 1 planet (in Danish)

3. Construction Site Emissions

As previously described, there are emissions associated with the actual construction work and onsite activities. These activities and emissions constitute an important part of a full life cycle assessment. However, they are not currently included in the LCA conducted to meet climate requirements in the Danish Building Regulations.

One of the reasons for this absence is the challenge in measuring these impacts accurately. To date, only limited data has been collected and published regarding the climate impact of construction sites. The average climate impact from construction sites has been assessed in a number of EU countries to 40 kg CO_2e/m^2/year, which corresponds to 0.8 kg CO_2e/m^2/year over a 50-year building lifespan, as depicted in Figure 5[17].

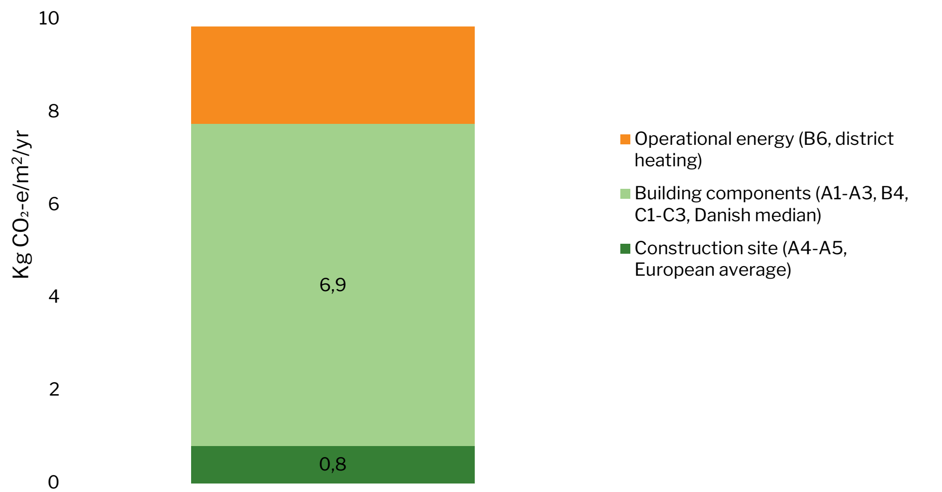
In a Danish context, this translates to approx. 9% of an average building's total climate impact over a 50-year life cycle. Thus, construction site emissions represent a substantial portion of the overall climate impact. This lends weight to the argument for including the construction site's climate impact in life cycle calculations. To credibly include the construction site's climate impact, it is imperative to systematically collect data and gain experience, enabling the establishment of better and ambitious climate requirements.

In 2022 the Danish building and infrastructure sector emitted 0.52 million tons of CO_2, which is mainly associated with the energy consumption of construction machinery[18].

The Danish Energy Agency (DEA) expects emissions to remain relatively stable towards 2030, with a slight decrease but slightly decreasing as shown in Figure 6.

This figure also illustrates the energy consumption in the building and infrastructure sector by fuel type,

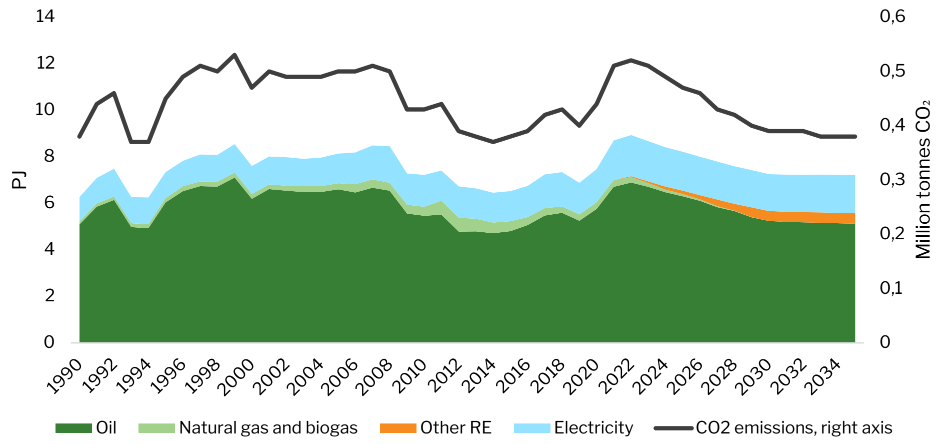
Figure 5: Climate impact from the construction site, life cycle assessment



Note: For operational energy an energy consumption of 37 kWh/m² is assumed. It corresponds to compliance with the energy framework requirements for a residential building of 1000 m² heated with district heating. Data for building components and the construction site are from Röck et al. (2022)
Source: Röck et al. (2022) - Towards EU embodied carbon benchmarks for buildings - Setting the baseline: A bottom-up approach and own calculations based on Building Regulations and COWI (2020): Updated emission factors for electricity and district heating (in Danish).

17 Röck et al. (2022) – Towards embodied carbon benchmarks for buildings in Europe
18 The Danish Energy Agency (2023) – Climate status and -projection 2023 (in Danish). KF23 Results – Numbers behind figures (in Danish) figure 6A.1

Figure 6: Energy consumption and CO_2 emissions on the construction site



Note: The figures includes emissions from energy consumption in construction projects and is therefore not limited to the construction of buildings, but includes also roads, bridges, tunnels, etc. TStated CO_2 emissions does not include emissions from the production of electricity.
Source: The Danish Energy Agency (2023) – Climate status and -projection 2023 (in Danish).

highlighting that many construction site emissions are linked to the industry's use of diesel fuel for excavation, construction work, internal transportation, and drying building structures.

To reduce CO_2 emissions it is necessary to switch to alternatives to diesel-powered machinery, mainly in form of electrically powered machines.

According to DEA, smaller battery-powered machines weighing less than 2.5 tons are considered available technology already today, while larger machines up to 12 tons still require further market maturation[19].

The adoption of smaller electric machines has already commenced, but uptake needs to be intensified. Achieving a broader shift to electrically powered machines necessitates a comprehensive plan for how to ensure availability of power supply to construction sites at the outset of construction.

For larger machinery it is essential to support market maturation, which entails making larger electric construction machines competitive in terms of both price and battery capacity. LCA requirements for the climate impact from construction process can incentivize development in this area.

If an area is specified for district heating, it is important to ensure roll out as early as possible, also on the construction site. This allows the utilization of district heating in drying of building structures, thereby, replacing diesel or gas-based methods.

Some actors within the building sector have proposed using biobased diesel (HVO diesel) as an option to reduce CO_2 emissions from construction sites. However, this will be a inappropriate approach.

Transport & Environment has estimated that the amount of agricultural land needed to meet European biofuel consumption could have absorbed twice as much carbon as the biofuels are assumed to displace if left as natural habitat[20].

Recommended focus areas

- Systematically gather data on the climate impact of construction sites
- Promote the adoption of electrically powered construction equipment, fostering market maturation where needed
- Develop a plan for the timely implementation of electrical and district heating infrastructure at construction sites

19 The Danish Energy Agency (2023) – Green Industry Analysis (in Danish)
20 Transport & Environment (2023) - Biofuels: An obstacle to real climate solutions, Brief

4. Renovations or New Construction

Preserving and renovating existing buildings is often the easiest and most cost-effective way of reducing the climate impact of a building instead of demolition and construction of a new building.

Older buildings often have inefficient building envelopes, resulting in high operational energy consumption and a correspondingly higher climate impact. In contrast, new buildings are designed with optimized building envelopes and lower operational energy consumption, making a new building seem like the more climate-friendly option.

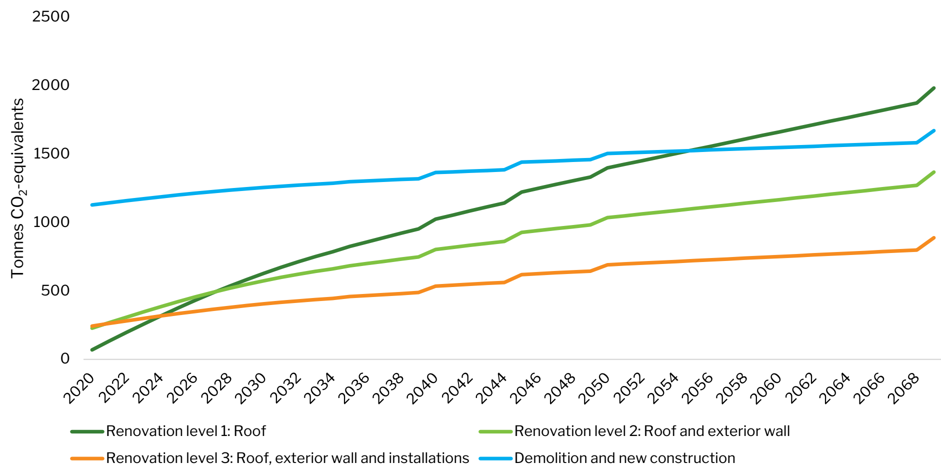
This perspective changes when considering all climate-related impacts, including those associated with the actual construction process. When evaluating renovation in relation to new construction from a climate life cycle perspective, renovation often emerges as the more climate friendly choice.

When existing buildings are renovated and transformed instead of being demolished and replaced, the lifespan of the built-in resources is extended. This reduces the demand for new building materials, which constitute a significant portion of the building sectors' climate impact and resource requirements. Simultaneously, renovating a building will lead to decreased operational energy needs, resulting in energy savings.

Furthermore, renovating existing buildings yields advantages beyond energy savings, including improved comfort, and enhanced indoor climate quality. In other words, an overall increase in building quality[21].

Considerations regarding the timing of CO_2 emissions are crucial from a climate perspective, as immediate reductions are necessary. This consideration also applies when choosing between renovation and new construction based on climate considerations. Ramboll[22] have conducted a comparison of the accumulated climate impact of renovation and new construction. The results are depicted in Figure 7 showing that renovation consistently has a lower climate impact during the construction phase, but higher emissions during the operational phase. This is seen in figure 7 by the convergence of new construction and renovations accumulated consumption.

Figure 7: Accumulated climate impact for three levels of renovation and new buildings

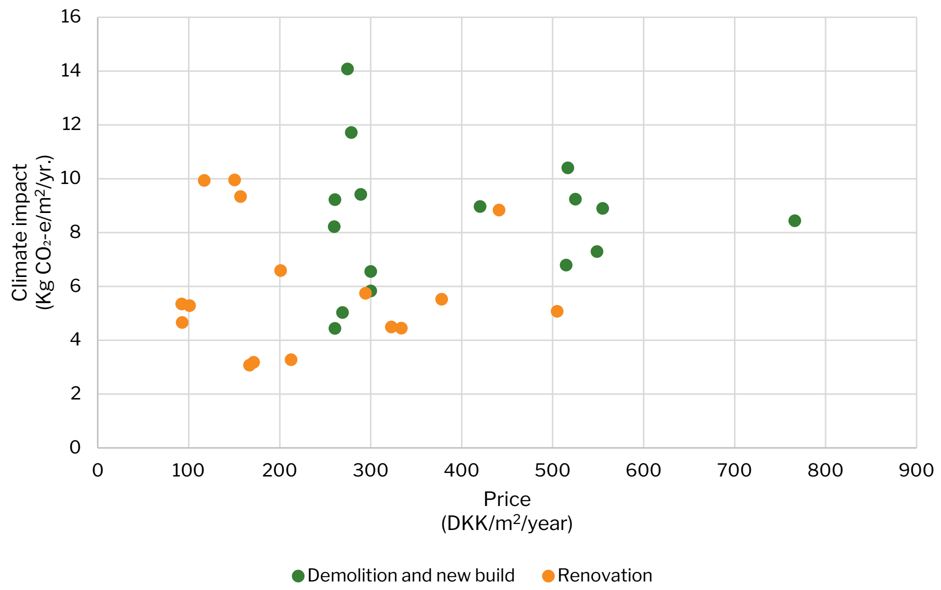


Note: Calculations are based on a commercial building. It shows a comparison of a situation where the building is demolished and a new one is built with three different renovation cases.
Source: Ramboll (2020) Analysis of CO_2 emissions and total economy in renovation and new construction (in Danish).

New buildings will have a high climate impact during the construction phase but a lower climate impact during operation. The rate of increase in emissions for renovations is higher

21 Buildings and Green Transition (2021) – The value of a good indoor climate (in Danish)
22 Ramboll (2020) – Analysis of CO_2 emissions and total economy in renovation and new construction (in Danish)

Figure 8: Climate impact and life cycle costs



Note: Comparison of the climate impacts vs. the tlife cycle costs of a) total renovation and b) demolition and new construction for 16 buildings. The further a building case lies along the x-axis, the more expensive the building is to own and operate. The further up the y-axis, the greater the climate impact from the building.
Source: Ramboll (2020) Analysis of CO_2 emissions and total economy in renovation and new construction (in Danish).

than that for new construction as older buildings tend to have higher energy consumption during the operational phase compared to new constructions.

The more improvements made as part of a renovation project, the lower the operational energy consumption, resulting in a reduced climate effect over the building's lifetime. This reinforces the argument in favor of renovating rather than demolition and new building construction.

In the same analysis, Ramboll compared CO_2 emissions and the total cost of ownership for renovation versus new construction. The findings consistently indicate that renovation is often both cheaper and has a lower climate effect than new construction[23]. This trend is illustrated in Figure 8.

It is expected that the current building stock will comprise 80% of Denmark's building stock in 2050[24]. Therefore, it is crucial that these existing buildings are renovated to meet current and future standards in a sustainable way. This entails not only enhancing the general condition of buildings but also reducing operational energy consumption.

The recently introduced climate requirements of the Danish Building Regulations do not encompass renovation of existing buildings, despite the substantial presence of existing buildings of the total building stock, both currently and as expected in 2050.

In both renovation and new building construction, mitigating the climate impact across all phases of a building process can be achieved by utilizing more climate-friendly materials, and focus more on reuse and recycling. Such initiatives have the potential to contribute to reducing the climate effects immediately.

Recommended focus areas

- Mandate a comparison of the climate impact between demolition and new construction versus renovation and transformation prior to granting demolition permits
- Develop a LCA model for renovation and rapidly incorporate climate requirements for renovation into the Danish Building Regulations

23 Ramboll (2020) – Analysis of CO_2 emissions and total economy in renovation and new construction (in Danish)
24 REBUS (2018) – Less loss of value in the refurbishment process – potentials of strategic partnerships (in Danish)

5. The Climate Impact of Building Materials

The journey toward more sustainable building sector demands a focus on building materials, from their production and handling to their usage throughout the building process itself. The building sector is a significant consumer of resources, largely reliant on non-renewable materials like sand and gravel[25].

To minimize the climate impact of building materials, a multi-faceted approach is needed. This involves increasing the reuse and recycling of materials, and increased focus on circular material flows involving the use of bio-based materials.

It is also necessary to adopt climate friendly methods for manufacturing of traditional building materials, as they will continue to play an important role in the building sector. A more climate friendly production could be achieved by implementing new production methods, or through the use of technologies like carbon capture and storage (CCS) where emissions from the production process are captured and stored. CCS is relevant for those materials where electrification of the production process is not feasible.

From a climate perspective, the direct reuse of building materials is preferable. If direct reuse isn't possible, innovative recycling techniques may be applied, potentially integrating with waste materials from other industries. This promotes a circular economy in the building sector, wherein one sector's waste becomes another's resource. For this to be fully realized, a circular system must be developed that allows materials to be reused multiple times.

However, there are challenges tied to the reuse and recycling of materials. An important challenge is the difficulty in documenting the technical specifications of a used material. Ensuring the quality of buildings requires thorough technical documentation covering aspects like fire resistance, acoustics, moisture, health, and structural integrity. This will naturally also apply to new types of recycle-based building materials.

Emerging bio-based building materials like straw-based products, new forms of wood, eelgrass products and others, will also often lack adequate technical documentation. This will mainly be because of lack of long-term studies making it difficult to document technical performance sufficiently.

Adoption of new materials will also require changes across the value chain of the building sector, involving new processes and practices affecting both contractors and future building occupants.

According to the OECD, global resource consumption is expected to nearly double between 2017 and 2060[26]. A main driver is demand for raw materials use for production of building materials like concrete.

Existing methods of cement production, a key component of concrete, contribute to about 7% of global CO_2 emissions[27] and roughly 5% of Denmark's CO_2 emissions[28].

The Danish Energy Agency anticipates a decline in Danish production towards 2030[29], with CCS expected to substantially contribute to lower emissions[30].

25 Danish Technological Institute (2021) - Circular construction will outperform linear construction by 2030 (in Danish)
26 OECD (2018) - Raw materials use to double by 2060 with severe environmental consequences
27 Buildings and Green Transition (2021) – The use of concrete in construction (in Danish)
28 The Danish Energy Agency (2023) - Climate status and -projection 2023 (in Danish). Sector note 6A (in Danish), figure 6A.2
29 As a result of Green tax reform (2022) (in Danish)
30 The Danish Energy Agency (2023) - Climate status and -projection 2023 (in Danish). KF23 sectoral assumptions memo Household and business energy consumption and process emissions (in Danish)

Concrete remains the most widely used building material globally and will most likely remain an essential part of future construction. As such, it is crucial to reduce our reliance on conventional concrete, whether by optimizing structures and foundations, substituting it with materials with lower climate impact, or innovating less carbon-intensive types of cement.

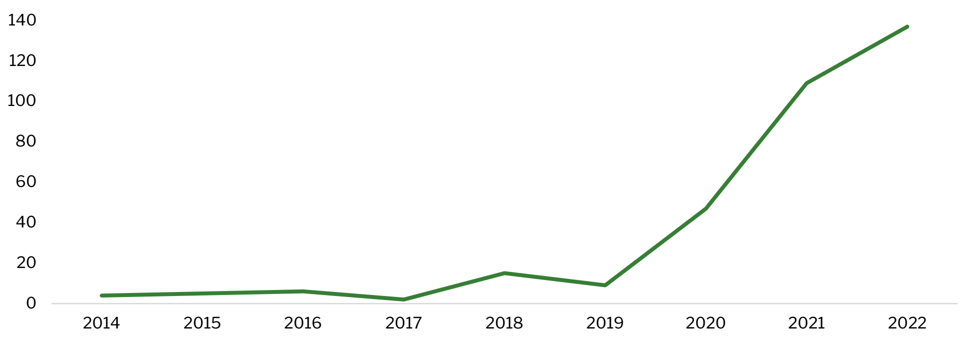
Demand for More Climate-friendly Materials

Climate requirements for new buildings leads to increasing demand for more climate friendly materials, including bio-based materials like straw and wood products. Yet, this increased demand has potential negative implications for nature's own carbon storages and for biodiversity. Looking at wood as example, it is a coveted resource globally, not only for the building sector but also in energy production, textile industry, medicine etc[31]. Increased demand for wood could strain the world's forests, which are vital for CO_2 absorption and biodiversity.

To conduct life cycle assessments as stipulated in the climate requirements for new buildings, it's essential to measure the climate impact of building materials more accurately. These measurements are usually detailed in Environmental Product Declarations (EPDs), regulated by a European standard. EPDs are thus the basis of the LCA of a new building, and the EPD help developers choose the optimal, climate-friendly mix of building material.

A way to assess the development in and demand for more climate-friendly building materials can be to look at the number of EPDs registered. As illustrated in figure 9 the number of registered EPDs in Denmark has grown from 39 in 2019 to over 200 in 2022[32], illustrating a growing demand.

Figure 9: Development of registered EPDs in Denmark



Source: EPD Denmark (n.d.)

Recommended focus areas

- Accelerate the accumulation of knowledge and documentation regarding the technical properties of new materials and their structural applications
- Establish requirements for the sustainable certification of bio-based resources used in construction
- Promote the use of sustainable building materials, emphasizing reuse and recycling
- Support the development of accurate environmental product declarations (EPDs) for integration into LCA tools

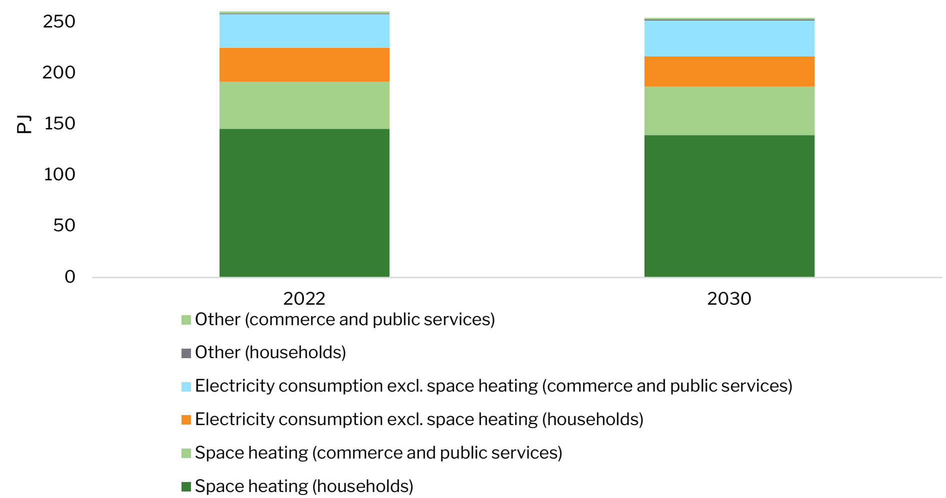
31 BUILD Report 2022:09 – Use of biogenic materials in construction (in Danish)
32 Danish Technological Institute (2022) – New agreement unites the Nordic region on climate documentation of construction products (in Danish)

6. Energy Consumption and Efficiency

Energy consumption for building operations has historically been a major contributor to the climate impact of buildings in Denmark. It continues to be an important element in LCA, even as an increasing share of energy derives from renewable sources.

Currently, energy consumption in buildings accounts for roughly 45% of the total energy consumption in Denmark. By 2030, this figure is projected to remain largely stable, as can be seen in figure 10. However, at the same time, a significant expansion in the total heated area of buildings is expected[33].

Figure 10: Energy consumption in buildings



Note: Energy consumption in buildings is approximated by energy consumption in households and the service sector, excluding data centers and transport (e.g. electric cars). It includes some non-building-related energy consumption such as lawn mowers and does not include space heating in manufacturing industries.
Source: Own calculations based on The Danish Energy Agency (2023) - Climate status and -projection 2023 (in Danish) and The Danish Energy Agency (2021) - Energy in Denmark 2021.

The reason it doesn't show in expected energy consumption is attributed to improvements in energy efficiency and changes in heat sources.

Denmark is already making significant strides toward a greener electricity and heating system. In the future district heating and individual heat pumps will phase out oil and gas boilers. By 2030, about 73% of Denmark's electricity and district heating is expected to be generated from renewable sources e.g., solar or wind, while the remaining 22% will be generated from biomass and biogenic waste[34]. This development will lead to a drastic reduction in CO2 emissions from buildings, as depicted in figure 11. Specifically, CO_2 emissions from buildings are expected to drop from approx.8 mil. tons in 2021 to less than 1 mil. tons by 2030.

The substantial expected decrease is mainly due to a reduction in the carbon intensity of electricity and district heating as fossil fuels are replaced with renewables.

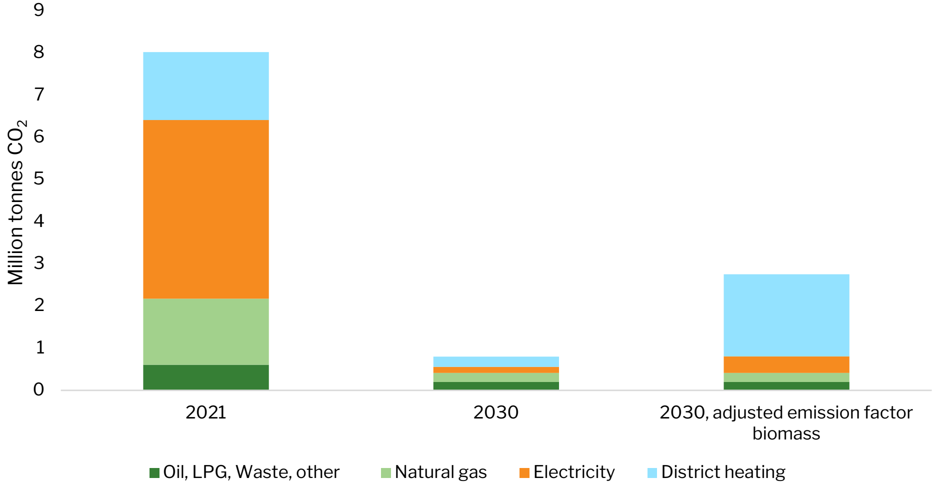
However, these projections assume biomass is a renewable energy source with zero-emissions. This is of special importance in the case of district heating where biomass is an important input and is expected to continue to be so. If biomass's carbon impact was accounted for emissions would only drop to around 3 million tons rather than 0,8 million tons, based on numbers from Ea Energy Analyses[35].

This difference arises from the fact that in the official calculations of Danish CO2 emissions burning biomass is treated as carbon neutral. However, even though biomass is considered a renewable form of energy, burning it does in fact emit CO2. The official figures do not reflect the full climate effects from biomass.

In the future production of electricity will be based on renewable energy sources. Using energy effectively will however continue to be important. The reliance on some amount of electricity produced on fossil sources will continue.

33 The Danish Energy Agency (2021) – Energy in Denmark 2021
34 The Danish Energy Agency (2023) - Climate status and -projection 2023 (in Danish). Sector note 8A (in Danish), figure 8A.3
35 Ea Energy Analyses (2021) - Optimised biomass use for electricity and district heating towards 2040 (in Danish)

Figure 11: CO2 emissions from energy consumption in buildings



Note: Energy consumption in buildings is approximated by energy consumption in households and service industries, excluding data centers. It includes some non-building-related energy consumption but excludes space heating in manufacturing industries. In 2021, the emission factor is 207 g CO_2/kwh for electricity and 15 g CO_2/TJ for district heating. In 2030, the emission factor is assumed to be 5 g CO_2/kWh for electricity and 2 g CO_2/TJ for district heating based on Energinet's Environmental report 2021 and The Danish Energy Agency's Climate status and -projection 2023. In the rightmost column, the emission factor for biomass burning is adjusted according to Ea Energy Analyses (2021), where emissions from biomass are estimated to 35 kg CO_2/GJ for woody biomass and 15 kg CO_2/GJ for straw relative to leaving the biomass in the forest or ploughing it into fields. In the middle column, biomass and biogas are considered CO_2-neutral.
Source: Own calculations based on The Danish Energy Agency (2023) - Climate status and -projection 2023 (in Danish) and The Danish Energy Agency (2021) - Energy in Denmark 2021, The Danish Energy Agency (2021) - Key figures on energy consumption and supply (in Danish), Ea Energy Analyses (2021) - Optimised biomass use for electricity and district heating towards 2040 (in Danish), Energinet (2021) - Environmental report 2021

Therefore, energy savings in residential and commercial buildings will still contribute to CO_2 reductions.

Efficient use of energy will reduce the need for scaling up renewable energy production, thereby limiting the demand for grid enhancements. Additionally, as renewable electricity becomes more essential for producing export goods like green hydrogen, which can be exported. The case for energy efficiency simply grows stronger.'

Heating needs of buildings

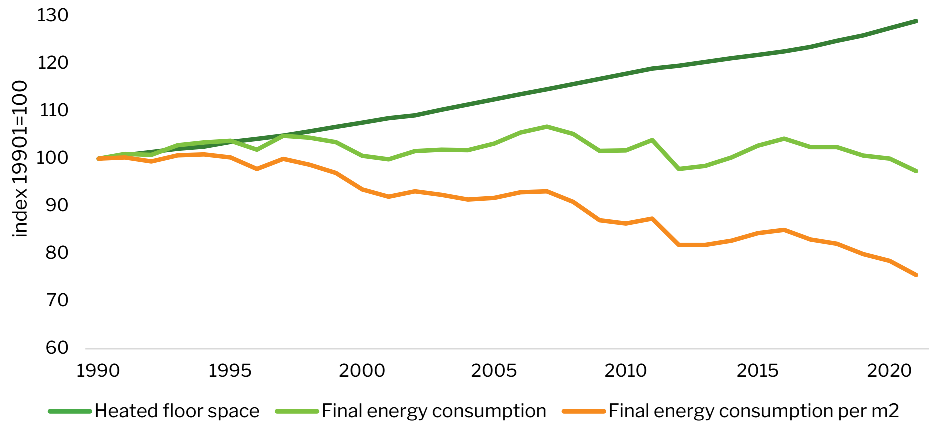
Space heating accounts for the largest part of energy consumption in buildings as shown in figure 12. For the past 30 years the energy consumption for space heating has remained relatively constant. However, due to population growth and a trend towards more square meters per person, the size of the area needing heat has grown by 30%.

Over the same period energy consumption per square meter for heating has actually decreased by 24%. This is partly due to lower heating needs as well as more energy-efficient heat sources like heat pumps, has replaced oil and gas boilers. This development emphasizes the effectiveness of energy efficiency improvements.

Following the 2022 ban on Russian gas imports there has been political attention on replacing oil and gas boilers with district heating and heat pumps.

In 2022 335,000 households primarily used fossil gas-fired boilers for heating, 65,000 used oil-fired boilers, and 108,000 relied on biomass boilers according to the Danish Energy Agency.

Figure 12: Energy consumption for space heating in households



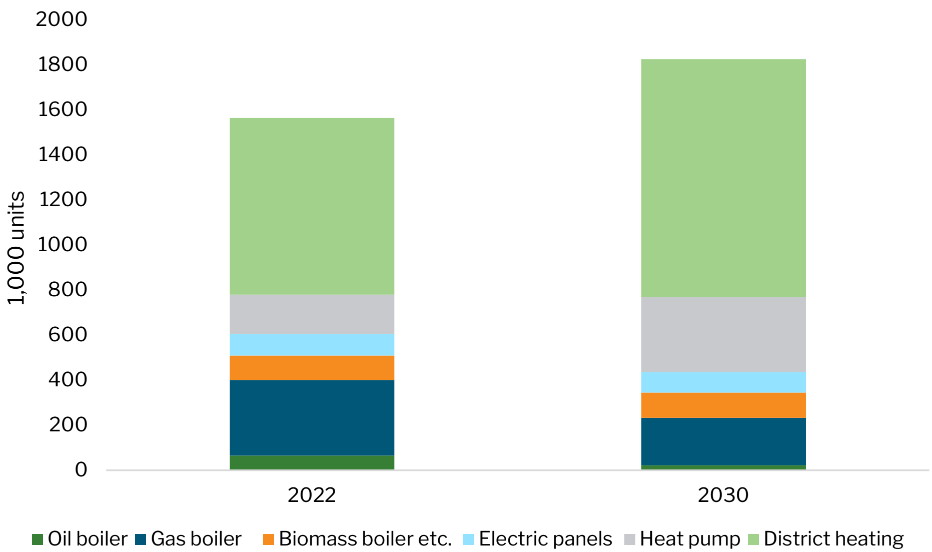
Source: The Danish Energy Agency (2021) - Energy in Denmark 2021.

This is depicted in figure 13. These numbers are expected to decline sharply towards 2030.

Biomass boilers, such as those using wood pellets, not only contribute to local environmental pollution, but also have a notable climate impact. Given that biomass is a limited global resource, it's crucial to transform to more efficient heating solutions.

The Danish Council on Climate Change suggests that by 2030, it's feasible to phase out all gas boilers in favor of implementing a mix of approx. 60% heat pumps and 40% district heating[36].

Figure 13: Types of heating in residential buildings



Source: The Danish Energy Agency (2023) – Climate status and -projection 2023 (in Danish).

Recommended focus areas

- Formulate a national strategy for efficient energy utilization, giving due importance to low energy consumption in buildings, also as power and heating sources become greener
- Set a national objective for the rapid phase-out of oil, gas, and wood pellet boilers
- Restrict the consumption of biomass for energy production, including district heating

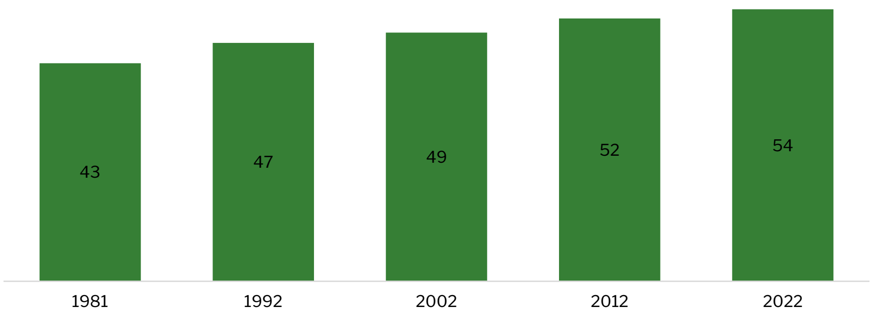
36 The Danish Climate Council (2022) – From gas towards green heating (in Danish)

7. Future Buildings

To reduce the climate impact of buildings it is obvious to address the amount of square meters build. Fewer square meters reduce the climate impact, as fewer building materials for construction and renovation are required, and it consumes less energy during its operational lifetime. There is no sign that it is a path Denmark will take as of now. Danes have gone from an average living space per person of approx. 43 square meters in 1981 to an estimated 54 square meters per person in 2022, as can be seen in figure 14. There has been a trend towards larger living spaces per person and increasing income levels making it possible for households to own more than one home.

The increase in square meter usage is particularly driven by the ever-increasing size of new detached houses, as the average newly built detached house today is 213 square meters – in 1962 it was only 119 square meters[37].

Figure 14: Average floor area per person



Note: The figure indicates gross floor area.
Source: StatBank Denmark, Table BOL106, Bolius (2023) – What is the size of an average house, terraced house, apartment and holiday home in Denmark? (in Danish) and Kommunernes Landsforening (2019) – Development in the average dwelling size (in Danish).

Looking at the numbers, it looks like the average size new house has decreased since 2010, from 156m2 to 113 m2. However, this is primarily due to a sharp increase in the number of newly build apartment buildings, which decrease in individual size, while at the same time, the number of new build detached houses remains largely unchanged but have grown in individual size[38].

There are are are several reasons to especially detached houses are getting bigger. First and foremost it is what that is in demand in the market, and therefore also what is interesting for financing institutions. It seems new homes need to be a certain size to be interesting as investment.

It is also an important fact that the regulatory framework in Denmark, which focuses on CO_2 emissions per square meter, inadvertently incentivizes the construction of larger homes, as climate intensive rooms as bathroom and kitchen will be rather similar for all building sizes.

Thus, larger buildings have a lower climate impact per square meter since the building envelope's size increases at a slower rate than the building volume.

Efficient Use of Existing Buildings

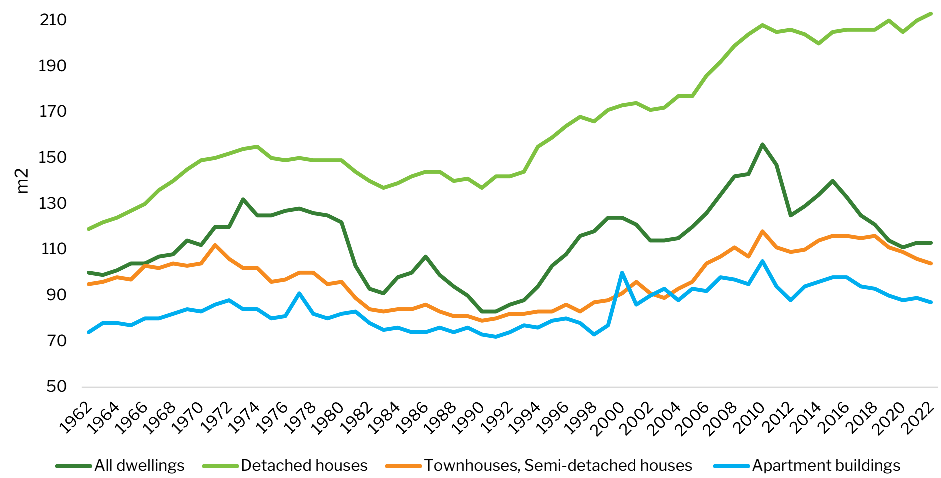
One effective way to counteract this trend towards ever-larger homes is to encourage the efficient use of existing buildings. For instance, as family situations change—such as when children leave home—is should be supported to move from larger homes to smaller, more suitable one.

Such development could be stimulated with availability of smaller, senior-friendly homes in local areas to make moving a viable option. To utilize the full potential for existing buildings, mobility has to be supported with buildings and homes that appears attractive and makes it an active choice to relocate to fewer square meters.

This way it will be possible to limit the continuous increase in square meter

37 Bolius (2023) – How big is the average detached house, terraced house, apartment and holiday home in Denmark? (in Danish)
38 Statistics of Denmark (2022) – BOL102: Dwellings by type of occupant, region, time, year of construction and use (in Danish)

Figure 15: Average area for new buildings



Source: StatBank Denmark, table BYGV06.

usage and create better awareness of the square meter usage.

For new constructions, the focus should be on creating smaller and smarter spaces that are flexible and adaptable to changing needs over time. Shared community areas could make up for reduced private space, offering benefits of both social interaction and sustainability. New buildings should be constructed using more bio-based materials, recycled materials and incorporate more recycled materials. Users of buildings has to get used to a different expression of building than previously.

This will require a cultural shift in our perceptions of what constitutes a 'good home'. However, it also requires regulation that support the movement towards more sustainable homes.

Local authorities can play a significant role in steering development in a more sustainable direction. Urban planning can prioritize renovations over new constructions and favor smaller, more efficient homes. Incentives could be provided for renovations that improve energy efficiency or repurpose existing buildings, thus extending their lifespan and reducing the need for new materials[39].

Recommended focus areas

- Modify the Danish Building Regulations to incentivize the construction of buildings with fewer and more flexible square meters, thereby reducing material and energy consumption
- Promote mobility within the housing market
- Design new and renovated homes with fewer and more efficiently utilized private square meters

39 CONCITO and Capital Region of Denmark (2023) - Analysis of the CO_2 emissions for different types of urban development (in Danish)

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DENMARK'S GREEN THINK TANK

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info@concito.dk

Læderstræde 20,
1201 Copenhagen
Denmark

www.concito.dk/en