November 2023

3keel

Global Retrofit Index Interim Report:

Assessing progress on the path to net zero

in association with

Kingspan

Report Information

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Foreword

The energy used to run buildings accounts for over a quarter of total global energy-related greenhouse gas emissions (IEA, 2023). Improving the energy efficiency of the world's building stock through retrofitting is therefore central to our fight against climate change. The upgrade of existing buildings not only decarbonises the global economy, but can simultaneously create jobs, improve living standards and health outcomes.

The results of this follow-on study to the 2022's Global Retrofit Index demonstrate a concerning stagnation of progress, even amongst some of the higher performing G20 nations. The six countries analysed are largely failing to take the steps required to reduce emissions from their existing building stocks and meet national climate goals. In fact, reductions in emissions from buildings over the past decade are now stalling and retrofitting rates are lagging far behind where they need to be.

The minor improvements to existing buildings which are being carried out are not resulting in sufficient uplift to energy efficiency ratings. Our assessment of residential buildings' ratings in the UK, France and Ireland shows that most homes are still rated in the middle bands and therefore not efficient enough to significantly reduce emissions in line with net-zero scenarios. This underscores the importance of deep, whole-building retrofits in order to drive down emissions.

However, it is important to acknowledge that widespread retrofitting represents a complex challenge given the need to make multiple changes to millions of buildings with varied ownership. Our study has therefore identified five key elements that should be present in a successful retrofitting framework. If implemented in a coordinated manner, these elements can drive the decarbonisation of building stocks effectively, affordably and at scale.

There are reasons for optimism, as exemplified in the case studies featured in this report. Innovative solutions which overcome financing and coordination barriers to retrofitting are emerging. We now need decisive government and private sector action to implement such solutions, rapidly scale retrofitting, and drive down building emissions globally.

Olwen Smith

Principal Consultant, 3Keel

Foreword

It's clear that if we're to stand any chance of meeting the Paris Agreement objectives of limiting global warming to 1.5˚C then decarbonising the built environment isn't just an option – it's essential. Given that approximately 80% of buildings that will be standing in 2050 have already been built, retrofitting existing global building stock is a critical lever on the path to net zero.

Since 2022, Kingspan has partnered with environmental consultants 3Keel to produce the Global Retrofit Index; this being a second, follow-on publication. The research assesses the ambitions, policies and progress of major economies in decarbonising the built environment. It also identifies innovative and effective technologies and solutions for lowering carbon emissions of domestic and commercial properties across the world.

Whilst it is encouraging this year's study has revealed that five of the six countries reviewed (UK, USA, France, Germany, Netherlands and Ireland) have reduced emissions from their building stock over the past decade, it is unfortunately set against a concerning backdrop of projections that suggest none are aligned with an emissions reduction pathway that supports their climate commitments. The striking analysis contained in this report reveals that the progress of these major economies is in fact plateauing, or in the case of the USA, showing an upward trajectory.

Simply put, over the coming years accelerating the rate of retrofitting must be prioritised if we are to avoid veering wildly off track and putting the net zero scenario in complete jeopardy.

It's important to remember that we already have the knowledge, solutions and technologies, available to us today, to significantly improve energy performance in buildings. To enact lasting change we must find the key to unlocking investment, expanding the skilled workforce and driving positive behavioural change among the broader public, businesses and governments.

It is vital that policymakers and the construction industry continue to work together to facilitate change and bring forward workable ideas. We hope this study is a useful tool in equipping leaders and industry decision-makers with new data, analysis and suggestions for a realistic retrofitting framework that can shine a light on a potential path forward.

Bianca Wong
Global Head of Sustainability, Kingspan Group

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Key Takeaways

Retrofitting has been recognised as a critical lever in decarbonising the global building stock and achieving the targets set by the Paris Agreement, with the operation of buildings responsible for 26% of global energy-related emissions (IEA, 2023).

1. Retrofitting represents a significant challenge. Current retrofitting rates amongst even the higher performing G20 countries, assessed in this report, are well-below what is needed to align with their national climate targets and reach net zero by 2050.

2. Governments are falling short in their ambition for, and action on, retrofitting with reductions in building stock emissions plateauing across major economies including the UK, Germany and France. An upward trend in the USA presents an even more concerning picture.

3. Improvements in EPC ratings have stagnated across the UK, France and Ireland with the vast majority of certificates issued still rated as ‘D’ or ‘C’ and therefore not energy efficient enough to deliver the required decarbonisation. Similarly, Germany's residential building stock continues to be over-reliant on fossil-fuel heating.

4. Many of the solutions to retrofitting and decarbonising buildings already exist, but implementation remains limited. Common barriers include unlocking private investment, an insufficiently sized and skilled workforce and limited awareness amongst citizens and building owners.

5. Better data is needed to continue tracking global progress on retrofitting and ensure accountability. Governments should publish information on building energy use and emissions, rates of low carbon heating and energy efficiency data.

6. Retrofitting offers significant opportunities and benefits beyond meeting climate targets, including job creation, reductions in social inequality, and improved health and quality of living.

Executive Summary

Assessing retrofitting progress across the G20

Retrofitting the existing global building stock has been recognised as a critical lever on the path to decarbonising the built environment and achieving net zero by 2050. It also offers the opportunity to deliver significant economic, social, and health advancements. Not only does investment in retrofitting drive the creation of 'green' jobs and the upskilling of the workforce, but it also benefits the most vulnerable in society, who typically live in the least energy efficient homes.

In recognition of these opportunities, but also the significant challenge that retrofitting poses, the Global Retrofit Index (GRI) was published in late 2022. The GRI was designed to assess and rank the performance of G20 countries in meeting the retrofitting challenge, with the intention of both understanding progress across some of the world's largest economies and identifying key learnings. Each country was assessed across three key areas: (1) the need for retrofits of existing building stock; (2) recent building emissions progress; and, (3) relevant government policies.

The GRI clearly identified that many of the world's largest economies were failing to retrofit their building stocks at the required scale or rate, with the index's higher performers achieving scores well below what was considered 'good'. For example, the top ranked country, Germany, received a score of only 62/100.

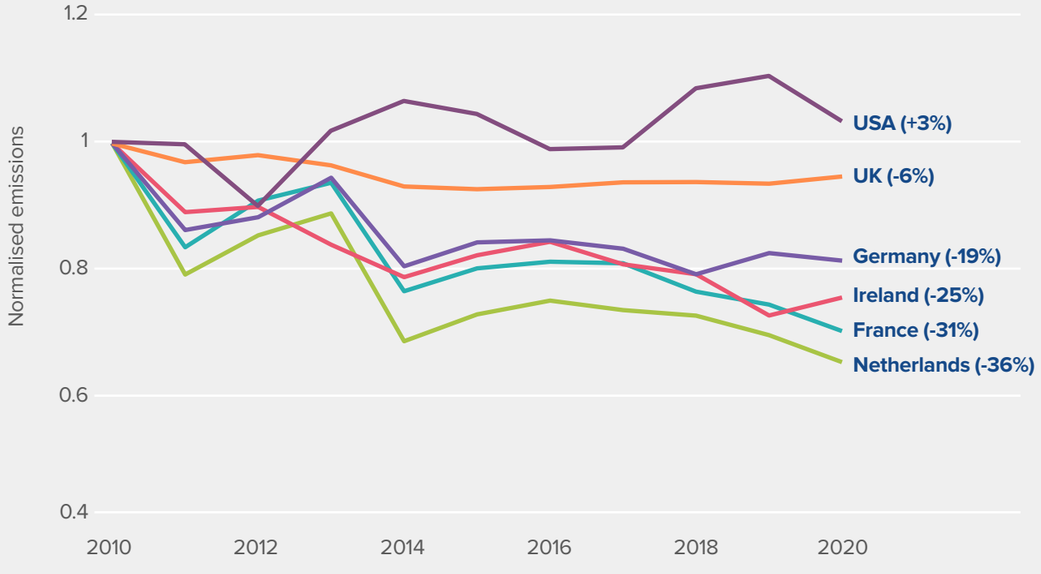
A deeper analysis of higher performing countries

In light of this lacklustre performance across the G20, where the higher performers were frequently European countries, this report serves as a follow-up to examine in greater detail the data, and context, underlying the performance of higher-scoring countries in the GRI. The focus is therefore on understanding both where these countries are successfully delivering on retrofitting, and the key elements behind the success, as well as where they are falling short and failing to meet commitments. With an eye to the future, it is also important to understand whether these higher performers are just starting to ramp up activity on a positive pathway towards net zero, or simply benefitting from legacy tailwinds.

The countries that have been assessed in this year's report are: the United Kingdom, France, Germany, Ireland, the Netherlands, and the world's largest economy: the United States. Ireland was not previously featured in the GRI, but has been included alongside its European peers as a relevant benchmark for the top performers in the European Union, where there is a shared policy framework, but significant variations between countries. The availability of relevant building stock data was also an important factor in the selection of countries for inclusion in this report.

Figure 4 - The comparative performance of building emissions reductions across 6 countries between 2010 and 2020

3Keel analysis of national inventory GHG emissions data published by respective governments (see report methodology for further detail)



Retrofit progress has stagnated

This new analysis has identified that, despite being higher performers in the GRI, the analysed countries' recent success is limited and not a guarantee of them delivering the levels of retrofitting required to rapidly decarbonise building stocks. Indeed, despite 5 of the 6 countries achieving emissions reductions in their building stock since 2010, current projections suggest that none of them are aligned with the emissions reduction pathways requried by their climate commitments. The United States is in an even trickier position with emissions from its built environment continuing to increase. This trend is expected to continue, in spite of the USA's commitment to deliver significant emissions reductions over the next decade.

Progress on retrofitting is therefore clearly off track.

However, there are signs of there being a positive uptick in the countries analysed, with recent government announcements of investment in retrofitting, such as in the USA and Germany, likely to have a significant impact in the coming years. Nevertheless, with common barriers such as insufficient skills in the workforce, a lack of private investment, and a lack of awareness amongst citizens, retrofitting will continue to pose a complex and significant challenge for national governments.

Elements of a successful retrofit framework

Recognising these barriers, the report also identifies five key elements that should be viewed as foundational for delivering a successful retrofitting framework:

- **1. Setting net zero building performance standards**
- **2. Developing a national retrofit plan**
- **3. Providing financial incentives and support**
- **4. Upskilling the workforce and scaling the supply chain**
- **5. Promoting best practice and data transparency**

Each of these elements is recognised as being crucial to enabling effective, affordable, and at scale retrofitting of national building stocks, and examples of their implementation are seen in the GRI's higher-performing countries. Real-world case studies of how these five elements are being implemented in practice have also been identified in the report. They provide further guidance on how barriers can be removed to allow the successful delivery of retrofitting.

Reviewing recent G20 retrofitting trends

Building on the 2022 Global Retrofit Index

In October 2022, the Global Retrofit Index (GRI), an in-depth evaluation of the state-of-play of retrofitting in G20 countries, was published. The report analysed and ranked countries' performance across three key areas: the need for retrofits of existing building stock, recent building emissions progress and relevant government policies.

The results of the 2022 GRI (see this report's appendix) clearly demonstrated that many of the world's largest economies are not taking sufficient action on building retrofits. Despite some progress in reducing building emissions, most G20 countries were found to be largely failing to take the steps required to eliminate operational building emissions at the speed and scale required to meet the goals of the Paris Agreement. Even the highest scoring country (Germany) only received a rating of 61.5 out of a possible 100, and three quarters of countries which were assessed scored below 50 or didn't publish sufficient data for evaluation.

Building on the results of the 2022 GRI, this report further explores retrofitting challenges and successes, with the aim of identifying solutions to the current, and significant, implementation gap. The report features deeper dive analyses of retrofit performance and policy in five European countries: France, the UK, Germany, Ireland, and the Netherlands as well as the world's largest economy: the United States. These countries were selected for analysis due to the relative age of their building stock (and thereby increased need for widespread retrofitting), as well as reasons of data availability. The third chapter of this report lays out five key elements of a successful retrofitting framework. Finally, a selection of retrofitting case studies are included, showcasing real-world examples of the latest innovations in policies, schemes and technical solutions.

The global context

During the year since the publication of the 2022 GRI, globally significant events have continued to influence the dynamics of the retrofitting challenge. Extreme weather patterns, including prolonged heat waves in North America, Asia and Europe, have prompted concern over the suitability of an ageing building stock to deal with the detrimental effects of a rapidly changing climate (EEA, 2022). Additionally, the ongoing war in Ukraine has given rise to volatile global energy prices, thereby increasing efforts to reduce consumption through the implementation of energy efficiency measures, most notably in Europe. This has not only further emphasised the importance of retrofitting in such regions, where the existing building stock represents the major decarbonisation challenge, but also highlighted the importance of zero-carbon compatible building standards in other regions, where new construction and forecasted growth in building floor space represents the primary decarbonisation challenge.

Despite a renewed focus on building efficiency in some regions, IEA figures show that globally emissions from buildings increased during 2021 and 2022, reversing the positive trend of reduction seen between 2018 - 2020 (see figure 2). To get back on track to the Net Zero Emissions Scenario, building emissions must fall by 9% per year on average until 2030, and more than halve by the end of the decade (IEA, 2023). This underscores the urgent need to significantly increase the retrofit rate across the globe. Widespread retrofitting will not only reduce emissions but can also provide key co-benefits including long-term cost

Figure 1 - League table showing GRI 2022 scores of countries analysed in this report (excluding Ireland)
Global Retrofit Index (3Keel, 2022)

Rank	Country	Existing stock (/25)	Retrofit performance (/25)	Retrofit policy (/50)	Total score (/100)
1	Germany	6.0	18.8	36.8	61.5
2	Netherlands	8.0	20.0	28.3	56.3
3	France	9.0	16.3	30.3	55.5
4	UK	8.0	16.3	28.5	52.8
=12	United States	7.0	7.5	14.3	28.8

savings, improved comfort, health benefits, increased building longevity and uplift in asset value (Brown, 2018).

Recent positive signals

In contrast to the overall global trend of increasing building emissions, there have been some encouraging signs of policy progress in major G20 economies since the publication of the GRI in 2022. Most notably, the USA's landmark policy package, the Inflation Reduction Act, was signed into law in August 2022. The package included allocation of nearly $9 billion to consumer home energy rebate programmes to electrify home appliances and perform energy efficient retrofits, with a focus on low-income consumers (White House, 2022a). In late 2022, the Biden administration also announced the first-ever Federal Building Performance Standard, setting a goal to cut energy use and electrify equipment and appliances in 30 percent of the building space owned by the Federal government by 2030 (White House, 2022b).

Across the Atlantic, in Europe, there has also been a sharper focus on improved building standards and retrofitting investment during the past year. At the EU level, a revision to the Energy Performance of Buildings Directive (EPBD) is in motion, seeking to increase the rate of renovation for the worst-performing buildings in each EU Member State (European Parliament, 2023). Large economies in Europe, such as France and Germany, have ramped up efforts to overcome financial and technical barriers to retrofitting. The German Federal government announced a €56.3 billion budget allocation between 2023 and 2026 for the retrofitting of buildings in the bottom 25% of energy performance (BMWK, 2022). However, recent opposition from the German government to tighter regulationin revisions to the EPBD, such as the prospect of mandatory renovations to ensure properties achieve minimum standards, have prompted concerns that the government's ambition is being watered down (Alipour, 2023). France saw a growing rate of retrofits in 2022, driven by the MaPrimeRenov programme, an energy efficiency

Figure 2 - IEA projection of a net zero scenario for global CO2 emissions from building operations
IEA (2023)

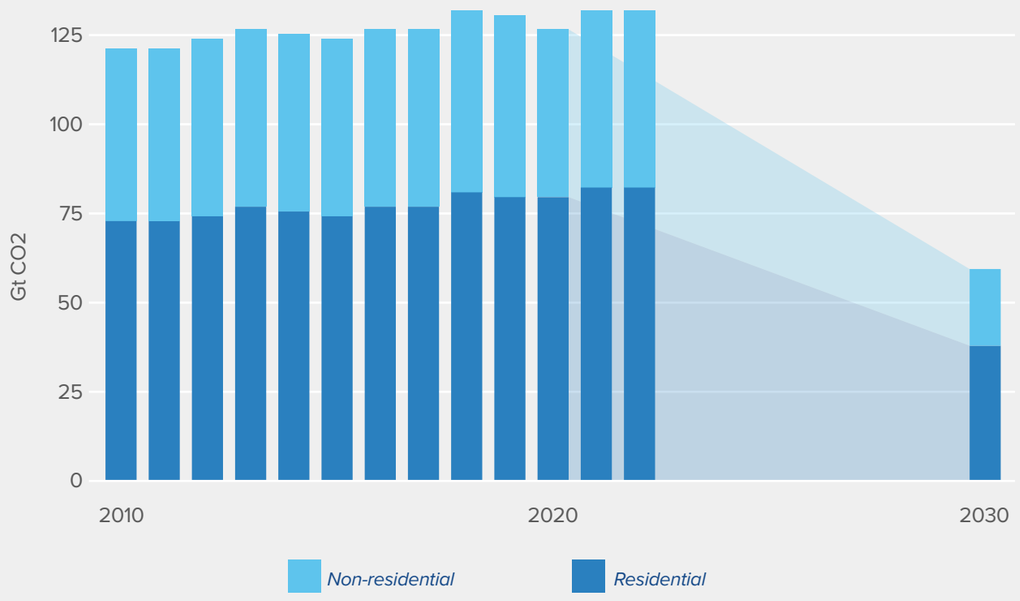
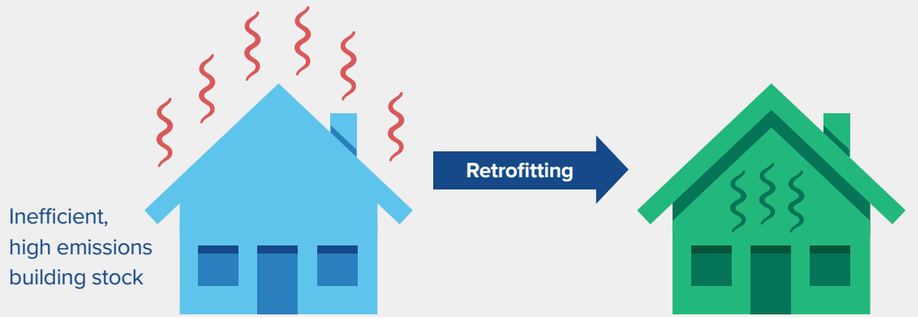


Figure 3 - Defining retrofitting
Retrofitting, as used throughout this report, refers to the deep renovation of existing buildings with new technologies and high energy efficiency measures in order to reduce their energy consumption and remove fossil-fuel reliant systems in order to make them compatible with a zero carbon built environment.



drive launched by the French government in October 2022, and measures to enforce minimum energy efficiency standards in private rental properties (Ministères Écologie Énergie Territoires, 2022).

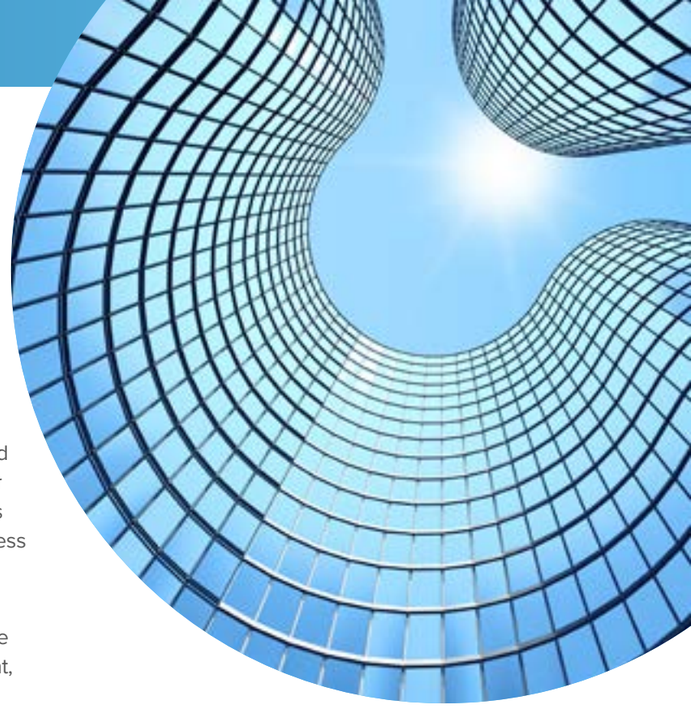
A small number of other G20 countries which the 2022 GRI report ranked as 'highly insufficient' in data availability and/or policy have also shown some improvement in their retrofitting plans over the past year. For example, in May 2023, Argentina launched its National 2030 Energy Transition Plan, which includes a goal to reduce energy demand by at least 8% by the end of this decade through energy efficiency measures including the retrofitting of residential and commercial buildings (Boletín Oficial de la República Argentina, 2023). In parallel, the country's first Energy Performance Certification (EPC) scheme, PRONEV, was introduced. India also enacted a new policy framework for energy efficiency in late 2022, which includes an updated Energy Conservation and Sustainable Building Code, now applying to both commercial and residential buildings (Bureau of Energy Efficiency, 2022).

Significant challenges remain

However, alongside these positive signals, instances of backsliding on retrofitting policy and implementation have also been observed in key G20 nations during the past year. The curbing of the Italian 'Superbonus 100' residential retrofit scheme due to criticisms that it was fueling inflation and fraud is a noteworthy example (Gazzetta Ufficiale, 2023). While in the UK, the government has recently moved to abandon its timelines for the tightening of energy efficiency standards, and scrapped its Energy Efficiency Taskforce, suggesting a lowering of ambition for retrofitting in the coming decade. Additionally, major global retrofitting blackspots persist: large economies such as China, South Africa and Indonesia continue to be found lacking in retrofitting policy frameworks and building emissions data disclosure.

It is evident that global retrofitting performance remains patchy and that a rapid acceleration of government and private sector action will be required to deliver the required levels of emissions reductions. This study seeks to build a better understanding of where such action should focus. Through analysis of retrofitting successes and challenges in a selection of countries with old building stocks, as well as the spotlighting of real-world case studies, the report provides actionable insights on how policy and finance levers can be employed to expedite the rate of retrofitting globally.

A closer look at retrofit performance by country



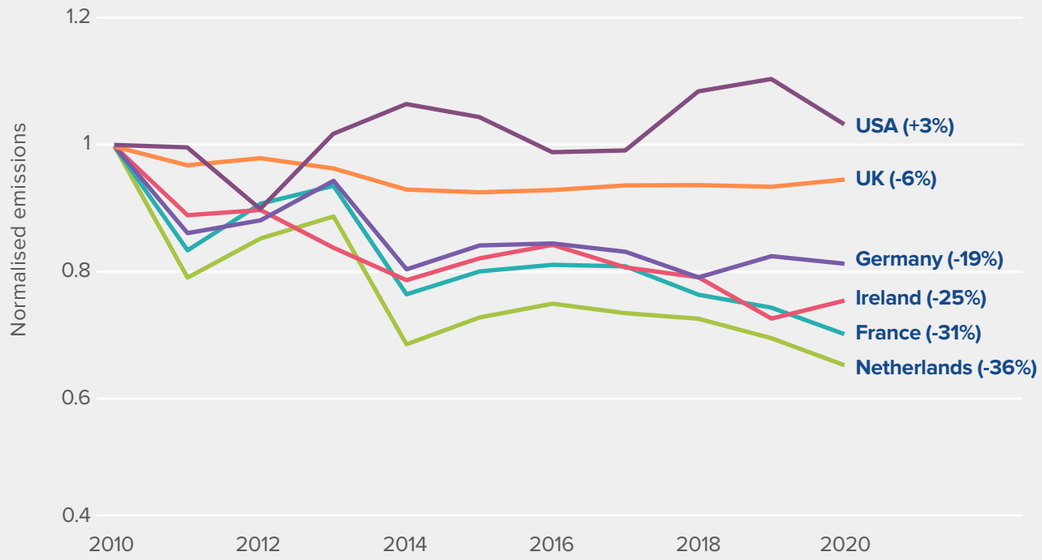
In this report, we build on the analysis conducted for the Global Retrofit Index in 2022 by looking more closely at the data, including both greenhouse gas emissions budgets and Energy Performance Certificate (EPC) databases, underlying the performance of some of the GRI's higher ranked countries. We have therefore examined Germany, the Netherlands, France, the UK, and the world's largest economy, the United States, to further understand current retrofitting trends, any commonalities behind their relative success, and the potential for progress in the coming decades.

We have also included Ireland within the analysis as a relevant benchmark for some of the top performers in the European Union. Ireland is of particular interest given that, despite its relatively young building stock, its homes are acknowledged as having relatively poor energy efficiency in comparison to its European peers.

The level of data made publicly available by the Irish government – which exceeds that of most other countries within the European Union and even some of those assessed within this study – has also made this comparison possible.

Figure 4 - The comparative performance of building emissions reductions across 6 countries between 2010 and 2020

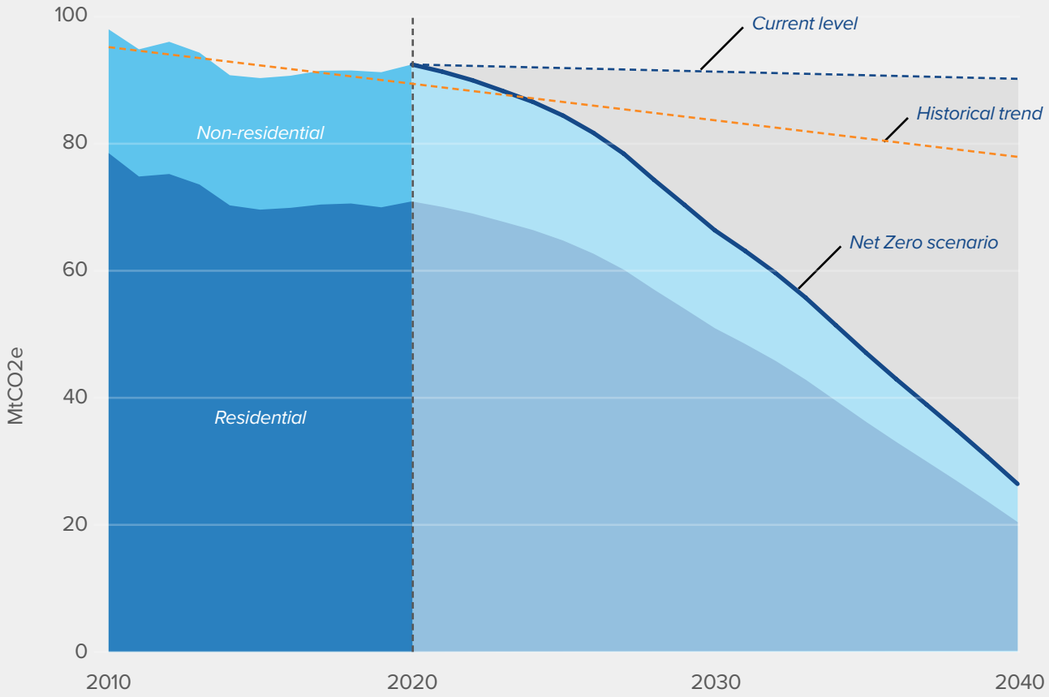
3Keel analysis of national inventory GHG emissions data published by respective governments



United Kingdom

Figure 5 - UK residential and non-residential building emissions 2010 to 2040

3Keel analysis of CCC (2020a) Sixth Carbon Budget analysis and data



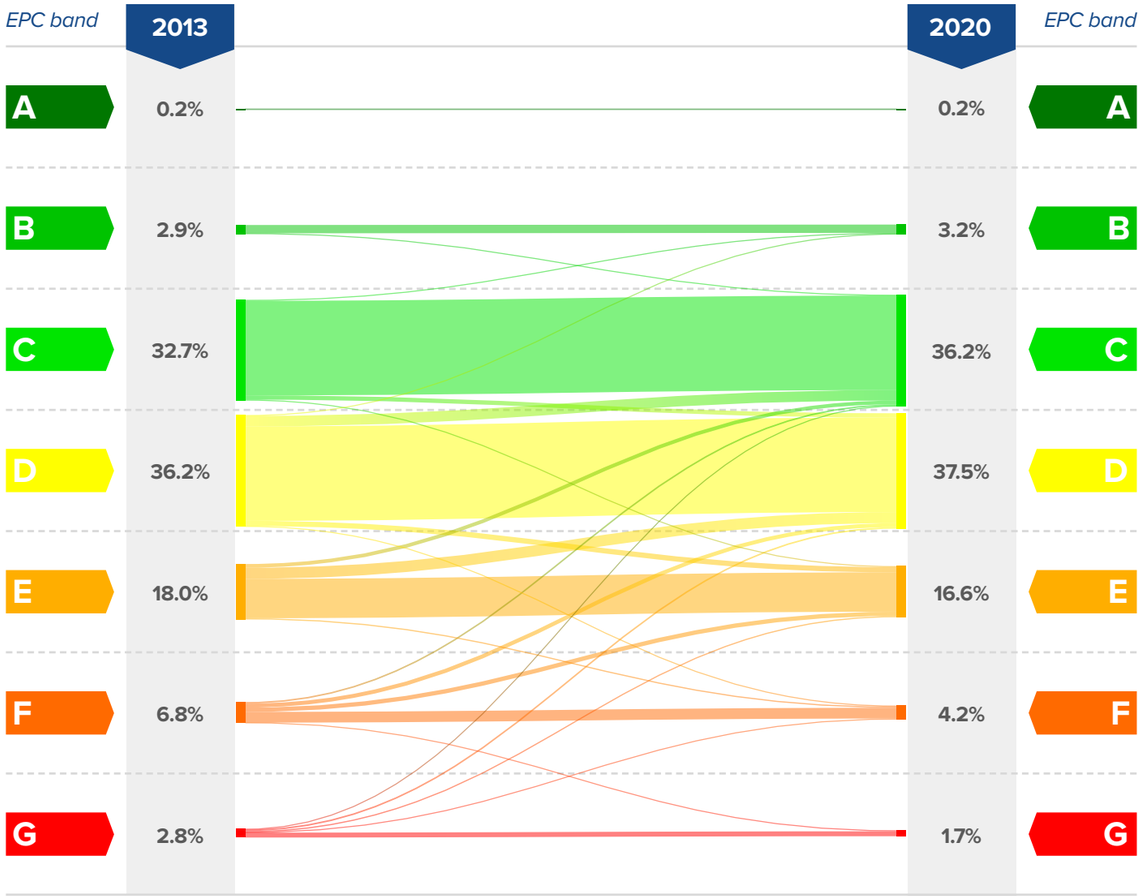
Greenhouse gas emissions from the UK's residential and commercial building stock have dropped by 6% over the last decade. Although when adjusting for the severity of winters, emissions have remained relatively stable since 2015 with the reduction largely achieved before this point. For direct emissions from the building stock, this stagnation can, in part, be explained by a significant drop in the numbers of energy efficiency retrofits completed in homes following a pull-back of policies that support such work by the UK Government in 2012 (CCC, 2022).

This drop to very low levels of retrofitting in the UK housing stock reflects a broader trend of relatively slow improvement in the energy efficiency of existing buildings, with an insufficient policy framework and supply chain unable to meet demand. This is evident in the changes to the UK's EPC data between 2013 and 2020 (see figure 6), with a general trend of improved performance lower down the ratings, but very little change at the top end. For example, the number of B rated EPCs has only increased by 0.3% in that period. While this trend initially seems to be broadly aligned with the UK Government's target for all homes to be EPC 'C' by 2035 (where practical, affordable, and cost-effective), concerns remain that the policy framework to support this goal is patchy and unlikely to deliver the target (Environmental Audit Committee, 2021). Further, recent uncertainty on the planned phase out date for gas boilers – 2035 – and whether this commitment will be kept contributes to a concerning picture on the potential for the UK to deliver the retrofitting required in the push for net zero (Quinn, 2023).

Indeed, the UK Climate Change Council's (2020b) projections for a 'balanced' pathway to net zero, highlight the importance of retrofitting, with much of the identified decarbonisation levers (over 90% of expected GHG emissions reductions) for the building stock reliant on the implementation of retrofits. Decarbonising space heating is

Figure 6 - The change in UK residential and non-residential energy performance certificates (EPC) (excluding new builds) lodged between 2013 and 2020

3Keel analysis of Department for Levelling Up, Housing & Communities (2023), and Energy saving trust (n.g.) data



the single biggest decarbonisation lever in the UK's building stock with 84% of GHG emissions in residential buildings driven by the associated fossil fuel use.

Retrofitting is fundamental to installing new fossil fuel-free systems, such as electric heat pumps, and yet this is an area where progress in the UK remains very slow. For example, in 2021, only 3% of boilers that needed replacing were replaced with heat pumps (CCC, 2022). This represents a broader trend of the UK's recent retrofitting levels. Despite the identification of timelines and solutions, progress has been hampered by implementation challenges.

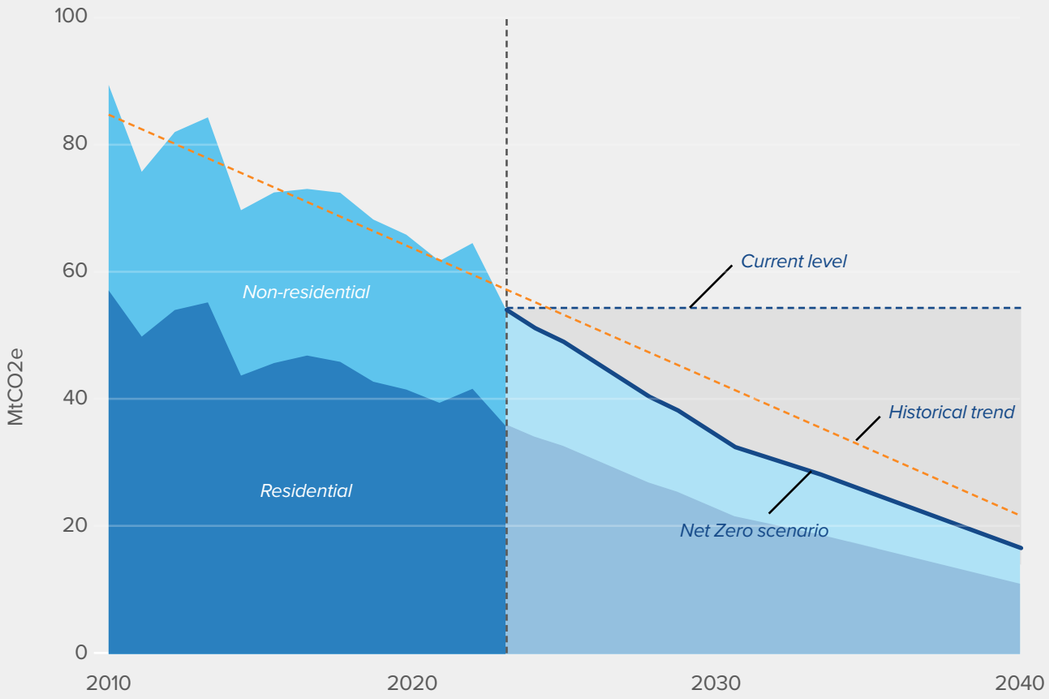
Recent decisions by the UK Government to relax energy efficiency standards for privately rented properties and to disband the Energy Efficiency Taskforce signal further backsliding (Wells, 2023). These steps will compound the challenge of aligning the country's building emissions with its national climate commitments over the coming years.

KEY TAKEAWAYS

- GHG emissions from the UK's building stock have dropped by only 6% in the last decade. This limited progress is, in part, explained by a withdrawal of government support in 2012 for residential energy efficiency improvements.
- Retrofitting is being relied upon as a fundamental decarbonisation lever in the UK. It is expected to represent over 90% of required building emissions reductions.
- Recent policy changes by the UK Government are not providing the long term certainty, or support, required by businesses, landlords and homeowners alike to invest in energy efficiency measures.

France

Figure 7 - French residential and non-residential building emissions from 2010 to 2040
3Keel analysis of CITEPA (2023) analysis and data



French building emissions reduced by approximately 31% between 2010 - 2020. Although when adjusting for the severity of winters, progress has in fact been far more gradual than this headline figure implies. This relatively slow progress reflects the fact that energy efficiency improvements and grid decarbonisation - so far largely reliant on the deployment of nuclear power - have been offset by an increase in the national building stock's heated floor space and the deployment of more air conditioning (HCC, 2019).

The majority of built environment emissions sits in the residential building stock, and some reductions – aligned with France's national climate targets – have been delivered. However, residential retrofitting has been very limited and well below the number committed to by the French Government. The French National Housing Agency estimates almost 66,000 whole building retrofits were completed in 2022, falling well below the national target for 370,000 retrofits per year between 2015 and 2030 (ANAH, 2023a; HCC, 2023).

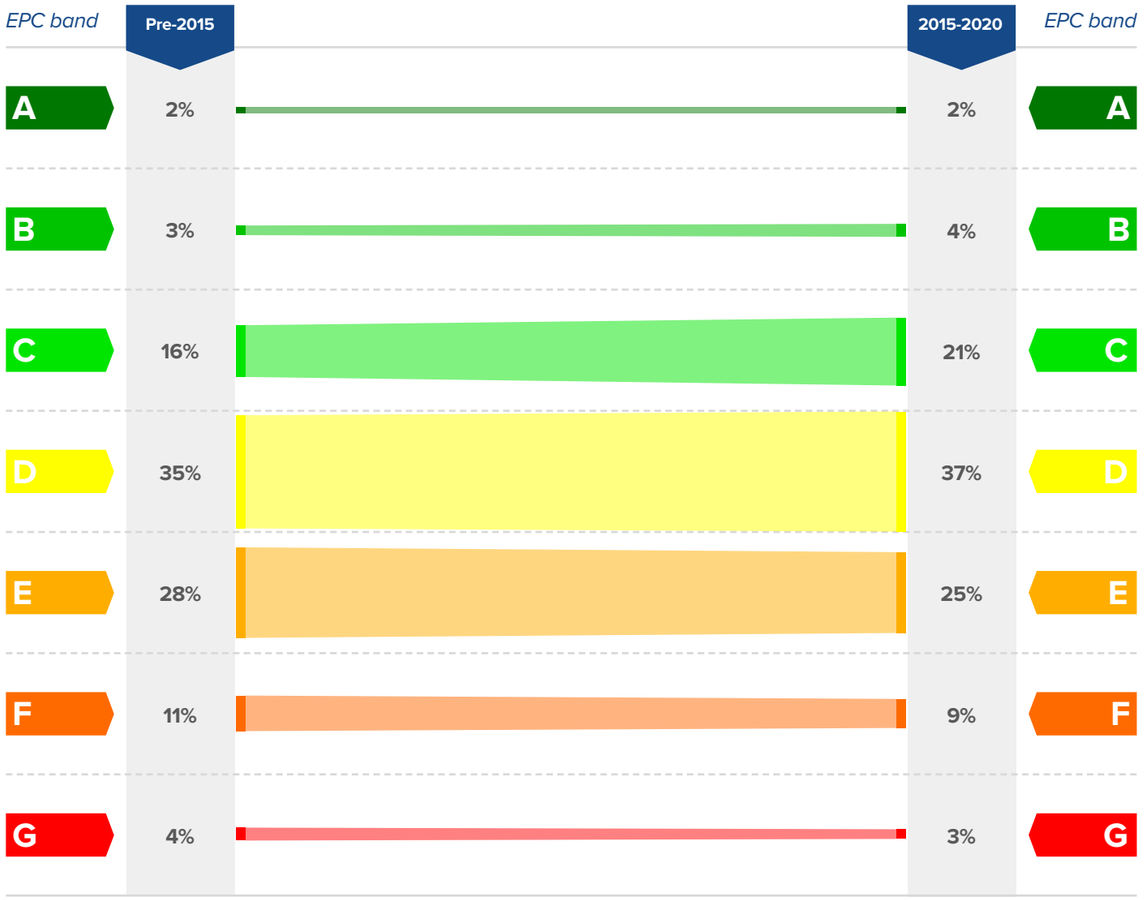
While there has been limited progress in the residential building stock, the commercial building stock has effectively stagnated with little to no reductions in emissions. This is largely the result of a lack of commercial retrofits, as well as a continued reliance on fossil fuels (HCC, 2023).

This general trend of minor, but relatively limited, reductions in emissions is mirrored in the EPC data available for the French building stock. Over the last decade, there has been an improvement in EPC ratings with a decline in the number of buildings at the bottom end of the ratings, and increases in the mid to higher ratings of 'D' and 'C' from 35 to 37% and 16 to 21% respectively (see figure 8). However, it is clear that this rate of progress will not be enough to deliver on France's net zero commitment (HCC, 2020).

For example, while the French MaPrimeRénov programme (see page 31) represents a successful policy to support retrofitting, it does not go far enough in terms of investment to enable the comprehensive, and deep, retrofits required to align with a net zero pathway (Vivier and Giraudet, 2022). However, it should be noted that significant increases in early 2023 to the amount of funds available to individual households could address some of these concerns (HCC, 2023).

Nevertheless, there remains a need for both a more robust policy framework and significant investment to deliver on France's retrofitting targets, with a particular focus on the commercial building stock where progress has been slowest to date.

Figure 8 - The change in French residential and non-residential energy performance certificates (EPC) (excluding new builds) lodged before 2015 and between 2015 and 2020
3Keel analysis of ADEME (2022) EPC data

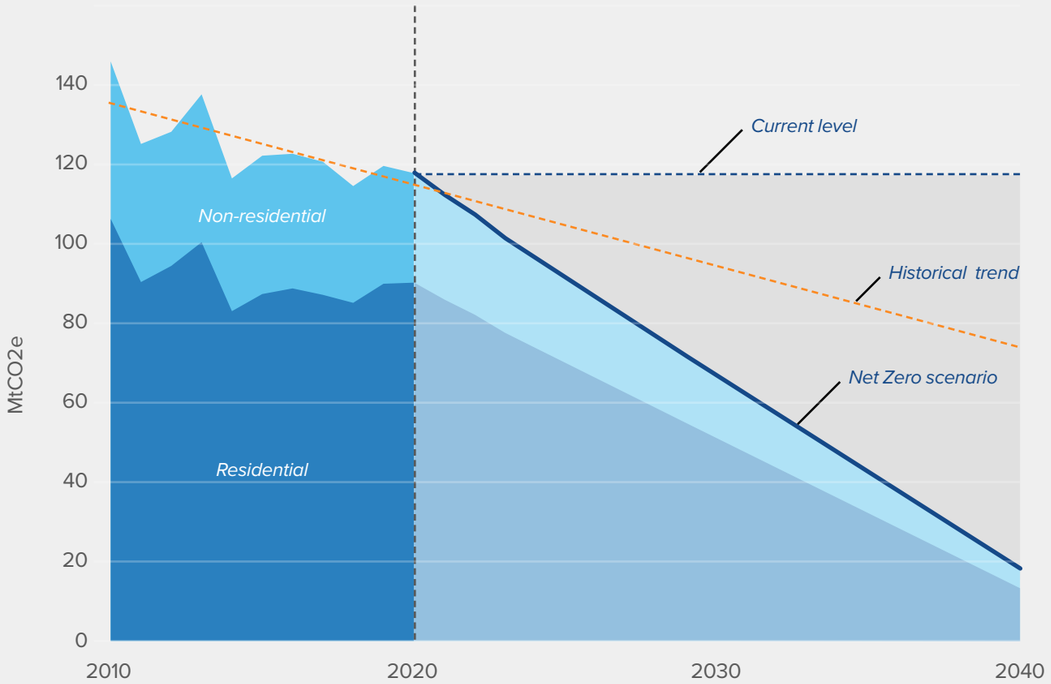


KEY TAKEAWAYS

- GHG emissions reductions in France's building stock have been counterbalanced by increases in both the use of (fossil fuel) space heating and air conditioning, meaning progress has been relatively limited.
- Current retrofitting performance is well behind target: only 66,000 whole building retrofits were completed in 2022 compared to a targeted annual average of 370,000 (ANAH, 2023a; HCC, 2023).
- While the government's MaPrimeRénov programme has demonstrated some success with fiscal support for residential retrofitting, it still has not been sufficient to support the retrofits required for a net-zero compatible building stock.

Germany

Figure 9 - German residential and non-residential building emissions from 2010 to 2040
3Keel analysis of Umweltbundesmat (2021) data



Greenhouse gas emissions in the German building stock have fallen over the last decade by approximately 19%, although as with France and the UK, this progress has stagnated in recent years. The current rate of reduction is not in line with the climate goals set by the German government, with the GHG emissions from buildings' heating systems alone exceeding the target for 2022 by 5.2 mtCO2e, and this gap is only expected to widen further in 2023 (Galvin, 2023).

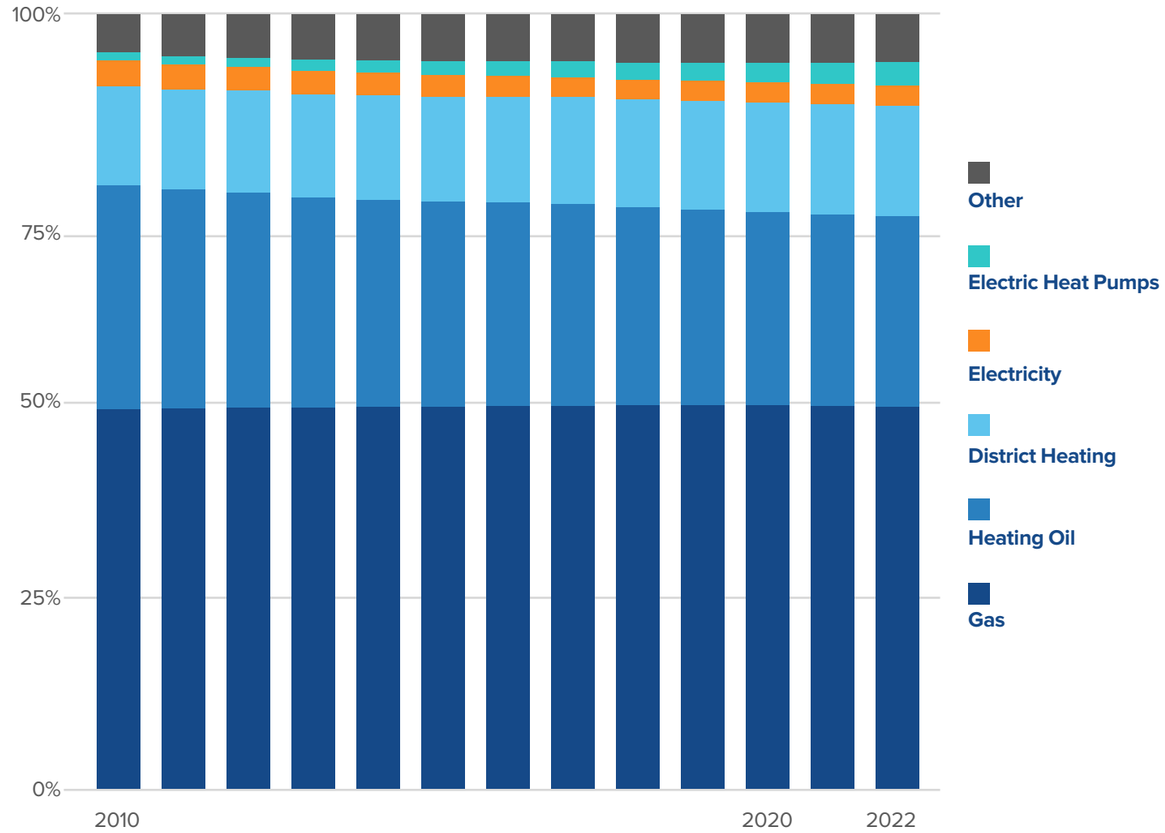
This lack of much-needed emissions reduction progress reflects both the fact that 75% of the building stock was built before energy efficiency standards were enforced by the German government, and the insufficient nature of the current policy framework to support retrofits (Galvin, 2023).

EPC data is not made publicly available by the German government. However, the data available on residential heating energy sources is a useful proxy for what we might expect to see in terms of energy efficiency trends across the building stock (see figure 10).

Since 2010 there has been a decrease in fossil fuel heating systems in Germany. However, this decrease has been marginal, with only a 2% percent increase in the deployment of district heating, electric heat pumps, and electric heating systems (BDEW, 2023). Furthermore, the potential impact of deploying electricity-based heating systems has been diminished by the carbon intensity of the German grid, with a continued reliance on fossil fuels, and particularly natural gas, representing a challenge for the country's plans for decarbonisation (Climate Transparency, 2022).

Retrofitting will be critical to delivering the decarbonisation of Germany's building stock. The German government has recognised this, and its policies have generally been regarded as forward-thinking. Yet, despite a generally favourable policy reputation, it is estimated that the average retrofit rate in Germany continues to languish around the EU average of 1% (BPIE, n.d.).

Figure 10 - The change in German residential heating sources from 2010 to 2022
Adapted from BDEW (2023) analysis and data



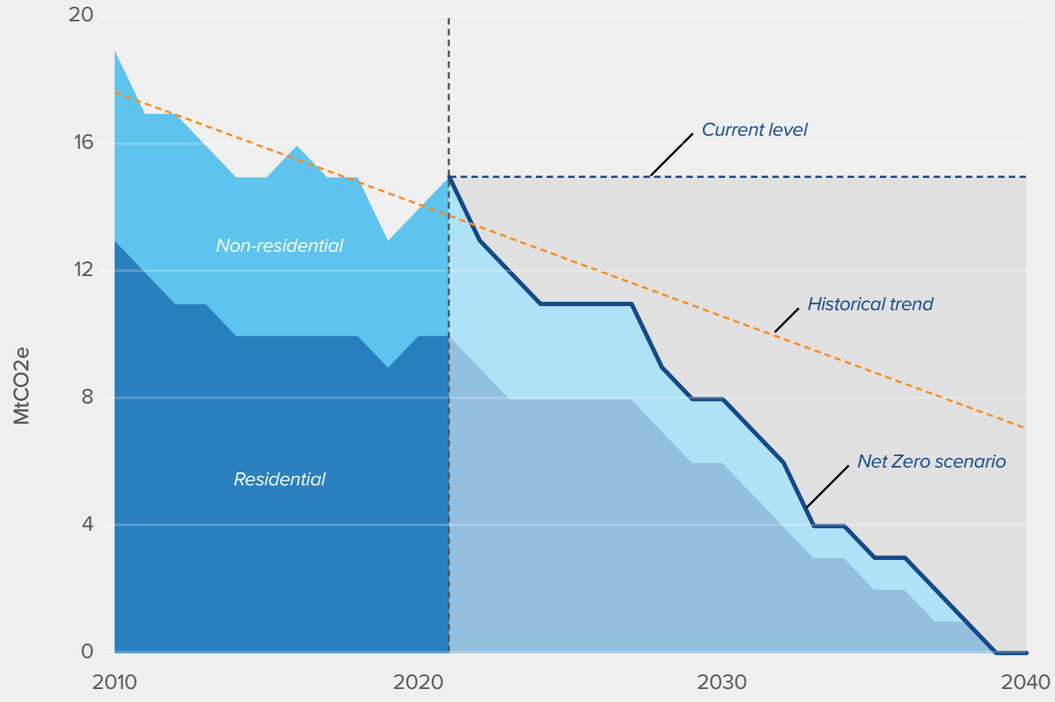
The recent announcement of €56.3 billion of funding in the federal budget to support building retrofits between 2023 and 2026 represents a significant development that will target the bottom 25% of buildings in terms of energy efficiency performance (BMWK, 2022; Kurmayer, 2022). However, granular details on how this funding will be spent have not yet been published. Its real-world impact will therefore be something to closely monitor in the coming years.

KEY TAKEAWAYS

- While GHG emissions in the German building stock have fallen over the last decade, they continue to exceed the trajectory set by the German Government's climate commitments.
- The residential building stock remains heavily reliant on fossil fuel-based space heating systems and, where decarbonisation progress has been very slow, significant levels of retrofitting are required.
- Recent federal funding pledges for €56.3 billion of investment offer hope of improvement, particularly in the most energy inefficient buildings, but implementation detail is lacking.

Ireland

Figure 11 - Irish residential and non-residential building emissions from 2010 to 2040
Analysis completed by O'Hegarty and Kinnane (2022, 2023)



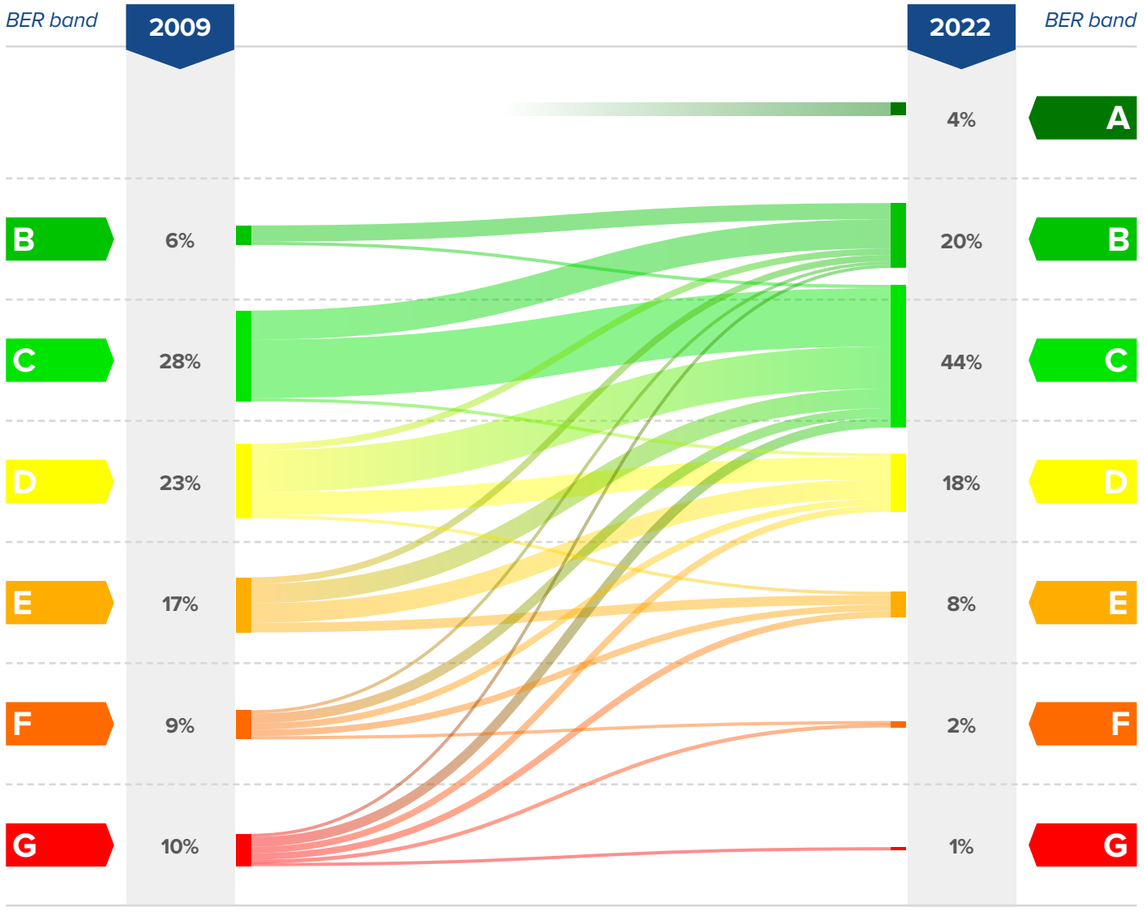
Ireland has achieved a reduction of approximately 25% in the greenhouse gas emissions from its building stock over the last decade. The majority of these building stock emissions reductions have been associated with the residential sector. However, compared to the EU average, the energy efficiency and carbon footprint of homes in Ireland remains poor, with Irish homes using 7% more energy and emitting almost 60% more carbon (SEAI, 2018). This not only reflects suboptimal energy efficiency performance, but also a significant reliance on fossil fuels for space heating (SEAI, 2018).

A particular issue, unique to the Irish building stock is the continued burning of peat to heat homes. Peat burning represented 6% of residential building energy use in 2019 (SEAI, 2020). This is a highly carbon intensive activity and, while it does represent a contentious issue, it must be urgently addressed if Ireland is to achieve its 2030 climate targets. In 2022, the Irish Government banned the sale of peat turf for use in heating systems and yet, illegal extraction and sales continue (Sheeran, 2022). Compounding this problem is the relative carbon intensity of the Irish energy mix, with Ireland having one of the lowest renewable energy contributions in the EU.

Despite having the youngest building stock in the EU, retrofitting has been identified as critical to decarbonising the Irish building sector as in the UK, France and Germany. The Irish Government has committed to delivering, on average, 75,000 retrofits in the residential building stock every year between 2026 and 2030 to achieve an overall target of

"The Irish government have earmarked 500,000 homes, and 1/3 of commercial buildings, for a deep energy upgrade by 2030. Ambitious targets that have not been matched by the same level of action. Only 7,566 homes were upgraded in the first half of 2023, and only 8,481 for all of 2022. This will equate to about 4% of the 2030 target, with only 7.5 years left to deliver the remaining 96%."
Dr. Richard O Hegarty - University College Dublin

Figure 12 - The change in Irish residential and non-residential building energy ratings (BER) lodged between 2009 and 2022
Figure based on Irish Central Statistics Office (2023) data



In Ireland, Building Energy Ratings (BER) are equivalent to EPCs elsewhere in Europe. In the figure, the data analysed is only available by segregated EPC ratings with no decimal places. Therefore, some smaller categories have not been presented in Figure 11 and this means that the total does not sum to 100%. See the report methodology for more information.

500,000 retrofits by 2030 (Government of Ireland, 2021). These retrofits must achieve a'B(2)' rating in the Irish EPC system. In 2021, 4,345 retrofits to this level were achieved and this figure increased to 8,481 in 2022. This retrofit rate increase was likely aided somewhat by the launch of the One Stop Shop residential retrofitting support scheme - see the case study on page 32 for further information (SEAI, 2023a).

However, this figure falls short of the government's target and the Irish data reflects this slow progress (see figure 12). While there has been a positive uptick with fewer homes in the lowest categories, most homes in Ireland continue to have ratings of 'C' and 'D', which is below the stated target of the Irish Government for homes to achieve a 'B(2)' rating.

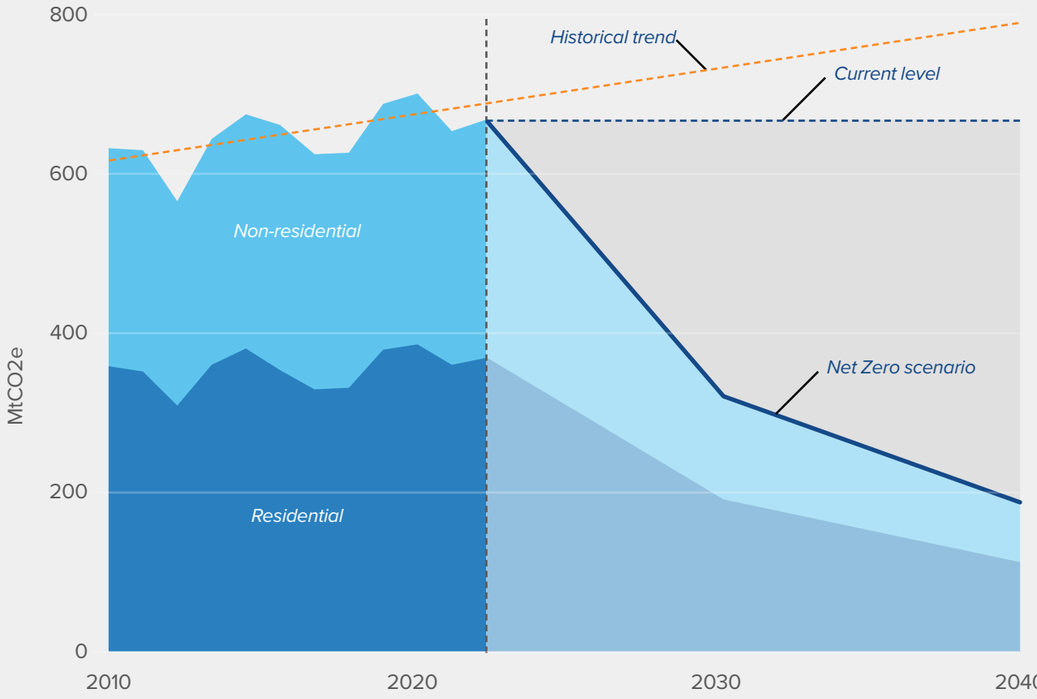
Significant action on retrofitting within a short time frame is therefore required for the Irish Government to meet its commitments and align with its pathway to a net zero trajectory.

KEY TAKEAWAYS

- While Ireland has made progress on reducing building emissions, its residential building stock remains poor in terms of energy efficiency performance compared to the rest of the EU.
- Reliance on fossil fuel-based heating systems represents a significant problem in Ireland, and retrofitting and grid decarbonisation will be crucial.
- Retrofitting progress has fallen below the ambitious targets that the Irish government has set, with the number of retrofits completed in 2022 just over 10% of the annual target. Whether innovative initiatives, such as the One Stop shops, can shift the dial in the coming years remains to be seen.

USA

Figure 13 - The USA's residential and non-residential building emissions from 2010 to 2040
3Keel analysis of US EPA (2023) GHG emissions data



In the US, emissions from the built environment have increased by 3% in the last decade and this trend looks set to continue. Future energy efficiency gains are expected to be counteracted by rising demand, which is set to ultimately result in a net increase in building emissions (Leung, 2018). The US's building stock is far off track for reaching net zero by 2050, and without major intervention is unlikely to align with such a trajectory in the coming years. Further, the average age of US buildings - in 2022, approximately 53 years for commercial buildings and in 2021, approximately 40 years for residential homes - emphasises that there will be a need for retrofitting in the US (Feldstein, n.d.; NAHB, 2021). As the world's largest economy and second largest GHG emitter, this is a concerning picture.

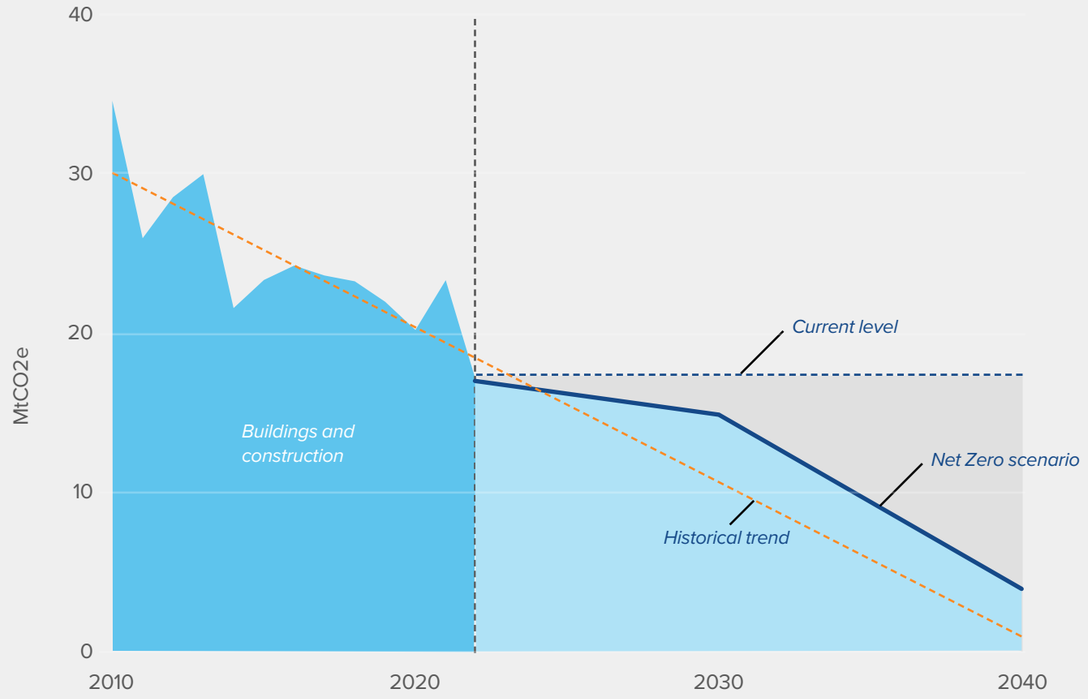
The Biden-Harris administration has recognised the importance of retrofitting the US's building stock with the Inflation Reduction Act (IRA) and announced numerous programmes to invest in retrofitting, including almost $9 billion of funding for home energy efficiency and electrification projections, and sought collaboration with states to address the issue (White House, 2023a; 2022c; 2023b; House Sustainable Energy and Environment Coalition, 2023). However, the levels of funding do not appear to be sufficient to meet the size of the challenge (Larsen et al., 2022).

KEY TAKEAWAY

➔ The USA is not on track in terms of retrofitting progress with building emissions having increased 3% in the past decade and expected to continue increasing towards 2050 without significant interventions.

Netherlands

Figure 14 - The Netherlands' residential and non-residential building emissions from 2010 to 2040
Figure based on PBL (2022) analysis and Centraal Bureau voor de Statistiek (2023)



Emissions from the Netherlands' building stock have decreased, by 36%, over the past decade and, based on modelling by the Netherlands Environmental Assessment Agency, this positive trend is likely to continue (PBL, 2022). However, it is also clear that the current projected building decarbonisation pathway based on adopted, and planned, policies will not meet the EU's Fit for 55 target (PBL, 2022).

As with the other EU countries, a major emissions source is space heating demand, particularly in the residential building stock. In 92% of households, as of 2018, this demand was met by natural gas-based heating systems (Centraal Bureau voor de Statistiek, 2021). This represents an exceptionally high reliance on natural gas. Recognising this, the Dutch Climate Agreement set the goal for all buildings to be heated without natural gas by 2050 with an intermediate target of 1.5 million gas-free dwellings by 2030.

However, progress against this goal has been slow. Much of the progress on reducing natural gas use so far has been the result of new builds using alternative systems, rather than any significant retrofitting activity (PBL, 2021). This means it is unlikely that the Netherlands will hit its 2030 target with current retrofitting rates expected to be simply too low to drive the decarbonisation of the building stock that is required (CE Delft, 2022).

KEY TAKEAWAY

➔ Despite recent progress on building stock emissions and retrofitting, the Netherlands is not expected to continue reducing its emissions in line with the historical trend. In fact, the Netherlands is not currently expected to meet its climate targets in 2030.

5 key elements of a successful retrofitting framework

The importance of retrofitting to the decarbonisation of the built environment and achieving national climate targets is well-established. However, the case for retrofitting goes beyond carbon reduction efforts. Retrofitting can deliver a wide array of economic, socio-economic, climate resilience and nature benefits (WGBC, 2023b). For example, not only does investment in retrofitting generate economic benefits through the creation of new jobs, it can also benefit occupiers with higher living standards, which often correlates with improvements in health (UKGBC, n.d.). This is particularly important as it is often the poorest in society living in the homes which are in the greatest need of retrofitting (UKGBC, n.d.; Smeeton, 2022).

Nevertheless, in looking more closely at the data available on the Global Retrofit Index's (GRI) high performing countries such as the United Kingdom, France, and Germany, it is clear that progress to date on retrofitting has been limited and that retrofitting rates are well-below what is required to achieve net zero and deliver the aforementioned co-benefits (3Keel, 2022; JLL, 2022).

We have therefore identified five key elements of a framework for delivering retrofitting that are foundational to such efforts and that countries must have in place to decarbonise their building stocks effectively, affordably and at scale. Each of these five elements have been individually recognised as crucial 'enablers' of retrofitting and they are typically identifiable within the high-performing countries in the GRI. Yet, their implementation is often far from perfect and consequently, this undermines the retrofitting agenda.

These five elements are:

- **1. Setting net zero building performance standards**
- **2. Developing a national retrofit plan**
- **3. Providing financial incentives and support**
- **4. Upskilling the workforce and scaling the supply chain**
- **5. Promoting best practice and data transparency**

1. Setting net zero building performance standards

Governments - national, regional, and local - should collaborate to create consistent and stringent building standards, and accompanying legislative implementation frameworks, to ensure that both existing, and new, buildings are required to meet net zero compatible standards.

As identified in the GRI in 2022, stringent building standards remain a foundational 'enabler' of any retrofitting action and will be crucial in driving action and allowing performance in the building stock to be better assessed, and monitored (IEA, 2021; IEA, 2022). The approach to implementation of building standards will need to be appropriate for the unique technical characteristics and challenges of both residential and commercial building stocks. Nevertheless, the overarching aim of the building standard system should be to provide a universal scoring system that reflects a building's performance, in terms of both its energy efficiency and carbon performance.

Alongside the development of such standards, it is important to set out an implementation pathway for

Empowering consumers and setting standards

The EU's mandatory implementation of the Energy Performance Certification (EPC) system demonstrates the strength of standard setting and how it can drive greater understanding of performance within the building stock.

The analyses in this report have been made possible by the EPC system and the publication of national-level data. Further, the EPC system has been credited with empowering consumers to understand the energy efficiency of their homes and how they can improve their performance, including the potential cost involved.

The success of the EPC system across the EU is also now providing the platform for further innovation to support retrofitting with, for example, the TIMEPAC consortium - an EU Horizon 2020 funded project - exploring how the EPC system can be evolved to match the information needs and retrofitting challenges of today (TIMEPAC, n.d.).

increasingly stringent standards to drive minimum performance within the building stock. Providing homeowners, landlords, and real estate developers with a clear and stable direction on building performance expectations is key to providing the market with a strong signal that action will be required (Cheslak, 2020).

2. Developing a national retrofit plan

Governments must also lead by developing and publishing national retrofitting plans that set out how, and at what rate, the country's building stock will be retrofitted to deliver Net Zero in 2050.

National retrofit plans should seek to draw together any existing policies and targets, set at the local, regional, and national level into a coherent framework and, where necessary, align them with the target for a zero-carbon building stock by 2050. Intermediate time-bound targets should also be set on the path to 2050 with appropriate metrics developed to promote transparency and enable the tracking of progress.

The EU's mandatory Long-term Renovation Strategies (LTRS) offer a good model for how this can be approached. EU member states are required to set out a national retrofitting roadmap with detail on supporting policies, measures and milestones for 2030, 2040 and 2050 as well as metrics to enable the tracking of progress (European Commission, n.d-a). Updates to these plans have also been required every 3 years. As a result, they have historically offered a clear and relatively up-to-date view on the retrofit plans of individual EU governments.

However, the LTRS are far from perfect and have faced significant criticism for not always providing the transparency and detail expected of national climate plans (BPIE, 2020; E3G, 2021). It is vital therefore that national retrofitting plans go beyond current approaches and provide the much-needed detail on what will be required to achieve the targets set. This means that they must include comprehensive planning on the regulatory, financial and policy framework that will be implemented to support the delivery of retrofitting (BPIE, 2013). The European Commission's proposal to replace the LTRS with more stringent 'Building Renovation Plans', that set targets instead of milestones and outline the investment needs of such targets, may deliver this in the EU.

3. Providing financial incentives and support

To deliver retrofitting at the speed and scale required, there will need to be significant investment by both building owners and governments. Unlocking this investment will be fundamental to increasing retrofitting rates, and governments will play a vital role.

Residential and commercial building stocks will require different approaches and solutions that are appropriate for their respective challenges (see Economidou, Todeschi and Bertoldi, 2019). For example, in the residential building stock, it is typically the affordability of retrofits that represents the biggest challenge to owner-occupiers. Government intervention through the provision of direct financial support, such as grants, or incentivisation, through tax breaks or sales tax cuts, will therefore likely be the most appropriate solution. Tax deduction systems for retrofitting costs in Germany and Denmark, and VAT rate reductions in France, offer good examples of how such support can be implemented (Economidou, Todeschi and Bertoldi, 2019). However, for the commercial building stock, and the challenges posed in funding large building retrofits, such interventions will likely be less appropriate. Given the difference in the scale of costs and the ownership model for many commercial buildings, government support through the provision of market-competitive credit or anchor investments to leverage private-sector funds may be more suitable.

The importance of financial support for the research and development of new retrofitting solutions, as well as their commercialisation and scaling, should also not be overlooked (Green Finance Institute, 2020). While many of the solutions required for building retrofits already exist, there will continue to be a need to innovate and scale technical solutions that drive ever lower GHG emissions, and ever greater energy efficiency. The appropriate government fiscal framework will therefore be vital to delivering both this support, and the broader support for retrofits that building owners require.

Innovative green finance mechanisms/instruments

Securing the investment required for deep building retrofits will represent the key 'unlocking' step to driving change in the building stock. Existing and innovative financial mechanisms/instruments will therefore have a key role to play. Typically, the suitability of different mechanisms/instruments will depend upon the use case, but there remains significant opportunity to embrace the rise of green finance as an opportunity to help finance retrofits.

For example, green bonds and sustainability loans, issued by companies, represent one way of adapting existing financial products to fund retrofits. The Canary Wharf Group has issued nearly £1bn of green bonds, under its own green bond framework, in order to fund its climate-related and environmental projects as a major urban land developer in London (Canary Wharf Group, 2021a; Canary Wharf Group, 2021b).

4. Upskilling the workforce and scaling the supply chain

To take advantage of investment and enable widespread retrofitting, it will be crucial for the supply chain and workforce to be scaled simultaneously. Otherwise, there is a risk that an implementation gap develops whereby other retrofit 'enablers' are in place, but labour or materials shortages cause bottlenecks.

This is not just a challenge of upskilling existing workers in the construction sector to ensure that they are able to deliver building retrofits. It is also a recruitment challenge, as it is clear that retrofitting will require a significant overall increase in the sector's capacity (City of London, 2023).

Sector-wide collaboration, and government support, is crucial to addressing this challenge. Initiatives, such as the Retrofit Academy in the UK, demonstrate the value of collaboration in delivering upskilling training to workers and sharing best practice to solve shared challenges in the supply chain (Retrofit Academy, n.d.; LGA, 2022). Governments have their own role to play by providing support to such initiatives, whether that be acting as the anchor investor or offering technical support and training (CAGBC, 2020).

5. Promoting best practice and data transparency

Indecision and a lack of clarity on the most appropriate options for retrofitting, including the technical suitability of solutions, can represent one of the most significant barriers to progress on retrofits (de Wilde, 2019). Providing clear and consistent direction on best practice and technical solutions is therefore important.

The construction sector and policymakers are well-placed to address this issue and should collaborate to develop industry standards and guidance that provide residential and commercial building owners with certainty on the available options. The World Green Building Council has begun efforts to identify and promote best practice, but more needs to be done (see WGBC, 2015; WGBC, n.d.; WGBC, 2023a). Solutions, such as Ireland's centralised 'One Stop Shops', offer examples of how this issue can be addressed at a local and national scale.

Accessing better data is also crucial to empowering building owners and enabling accountability. The GRI (2022) identified the lack of data as a major issue, and this remains the case. Governments must therefore take the lead on this and establish systems for generating and reporting granular, detailed datasets on national building stocks and make this publicly available. Such work should also align with efforts to implement, or update, building standards to ensure they include relevant data on energy performance.

Case studies

MaPrimeRénov - France

In October 2020, the French government introduced a large-scale scheme to support residential retrofitting called MaPrimeRénov. The initiative, run by France's National Housing Agency, provides households with financial assistance and a 'one-stop-shop' to support renovation projects which improve energy efficiency. It exemplifies a coordinated and holistic government approach to stimulating retrofitting by encompassing both financial and practical support elements.

The financial support included in MaPrimeRénov covers a wide array of retrofit measures, ranging from heat pump installation to combined solar systems and insulation. The scheme is intended to incentivise whole building action, with a €1,500 bonus available for those who undertake multiple measures, thereby increasing their EPC rating to an A or B (Service-Public.fr, 2023).

The programme is designed to be inclusive, offering different grant tiers depending on the applicants income, building type and ownership structure. The provision of higher subsidies to lower income households helps to ensure that the many benefits of retrofitting are accessible across socio-economic groups.

A notable feature of this scheme is its focus on simplification and support throughout the customer journey. MaPrimeRénov offers a user-friendly, online application process meaning homeowners can easily determine their eligibility and calculate the potential financial support that they can receive. Applicants are also provided with upfront quotes, energy audits, a directory of local installers, free consultations with local advisors as well as access to a 'renovation guide' (ANAH, 2023b).

MaPrimeRénov has seen widespread uptake since its launch. As of February 2023, approximately one million French households, primarily those in low-income brackets, had received funding from the scheme since its inception (CCC, 2023). The scheme looks set to continue stimulating the rollout of residential retrofits. In early 2023, the French Government confirmed a further €2.5 billion for the programme, which will fund both an increase in the grant amount available per applicant and an increase in capacity for advice provision (Service-Public.fr, 2023).

Key elements identified

1. Setting building performance standards
2. Developing a national retrofit plan
3. **Providing financial incentives and support**
4. Upskilling the workforce and scaling the supply chain
5. **Promoting best practice and data transparency**

One Stop Shop Services - Ireland

Through its National Retrofit Plan, by 2030 the Irish government made an ambitious commitment to retrofit 500,000 homes - or close to 30% of Ireland's housing stock - to an EPC of B2 in order to meet its target of a 40% reduction in residential building emissions (Department of the Environment, Climate and Communications, 2021).

In February 2022, as part of this plan, the Irish 'One Stop Shop' scheme was launched with the aim of accelerating the rate of residential retrofitting across the nation. This scheme provides an interesting example of efforts to reduce points of friction along the customer journey.

Behavioural challenges, including low levels of awareness and the complexity of bureaucracy, hidden costs and sunk personal time act as barriers to widespread adoption of retrofitting solutions in homes (SEAI, 2023b). To tackle these challenges, under the Irish One Stop Shop model, a registered service provider manages the entire retrofit process on behalf of a homeowner. This includes the initial property EPC assessment, the identification of required measures, the delivery of the retrofitting work and a final EPC reassessment at the close of the project. The ultimate goal of this coordinated and outsourced approach is to close the knowledge gap and reduce the administrative burden for customers (CCC, 2023).

While the One Stop Shop system does alleviate some of the frictions of the residential retrofitting process, it is not without its challenges. In Ireland, the recent increase in costs of building materials and labour has led to a financing gap, resulting in homeowners needing to self fund over half of the average cost of a full retrofit. Grants may need to be increased to ensure continued uptake by Irish homeowners.

Additionally, there have been reports of One Stop Shop service providers struggling to cope with demand due to a lengthy provider registration process (CCC, 2023). Almost one year after the launch of the Irish scheme only 12 One Stop Shop operators were fully registered, although it should be noted that 10 were identified as being close to completing the registration process (SEAI, 2023b).

Key elements identified

1. Setting building performance standards
2. Developing a national retrofit plan
3. **Providing financial incentives and support**
4. **Upskilling the workforce and scaling the supply chain**
5. Promoting best practice and data transparency

EU BIM-SPEED Project

The BIM-SPEED project, also known as the 'Harmonised Building Information Speedway for Energy-Efficient Renovation', was funded as part of the EU's Horizon 2020 scheme. A 4 year project, it was designed to support greater digitisation in the construction sector by enabling the use of building information modelling (BIM) when conducting residential building retrofits. It is a good example of how existing tools and new technological solutions can be adapted and combined to support retrofitting.

A building information model is effectively a digital representation, or 'twin', of a building and this use case has traditionally been regarded as particularly challenging, given that BIM is typically used for new buildings and infrastructure, rather than for existing buildings.

However, pilot projects by members of the 22-strong consortium of companies, research institutes, engineering and construction firms in BIM-SPEED had proven that BIM could be used with existing residential housing stock.

This project was therefore funded to develop the resources needed to enable the widespread use of BIM in residential building retrofits. The expectation is that the appropriate use of BIM in such projects could reduce their length by 30% and could result in energy use reductions of up to 60% by determining the most efficient retrofits (EU BIM SPEED, n.d.-b).

The principal outputs from the project were a cloud-based BIM platform and an accompanying set of inter-operable BIM tools that enable the use of BIM in residential retrofits, as well as 13 demonstrator projects. Each of these demonstrator projects tested the BIM platform, and its tools, in the real world in order to validate the approach and identify any potential challenges. For example, in the Netherlands, the retrofitting of four three-storey residential apartment blocks to remove the natural gas heating systems was used as an opportunity to test the validation process for the BIM to ensure it accurately reflects real world characteristics, rather than simply projections from original building plans (EU BIM SPEED, n.d.-a).

Key element identified

1. Setting building performance standards
2. Developing a national retrofit plan
3. Providing financial incentives and support
4. Upskilling the workforce and scaling the supply chain
5. **Promoting best practice and data transparency**

EEFIG DEEP Platform

The Energy Efficiency Financial Institutions Group (EEFIG) was set up in 2013 by the European Commission and United Nations Environment Programme Finance Initiative with the aim of accelerating private sector investment in energy efficiency. The De-risking Energy Efficiency Platform (DEEP) represents one of the tools EEFIG has developed in order to support this goal. It is an example of an innovative approach, by a governmental body, to enable the financing of retrofits through improved access to information which strengthens the business case for investment in retrofitting.

The EEFIG DEEP platform is an open-source database that holds anonymised historical data on energy efficiency projects in buildings and industry. This data not only captures the nature of the project and its various outcomes, but also key information on a project's financial performance, such as payback time and avoidance costs indicators.

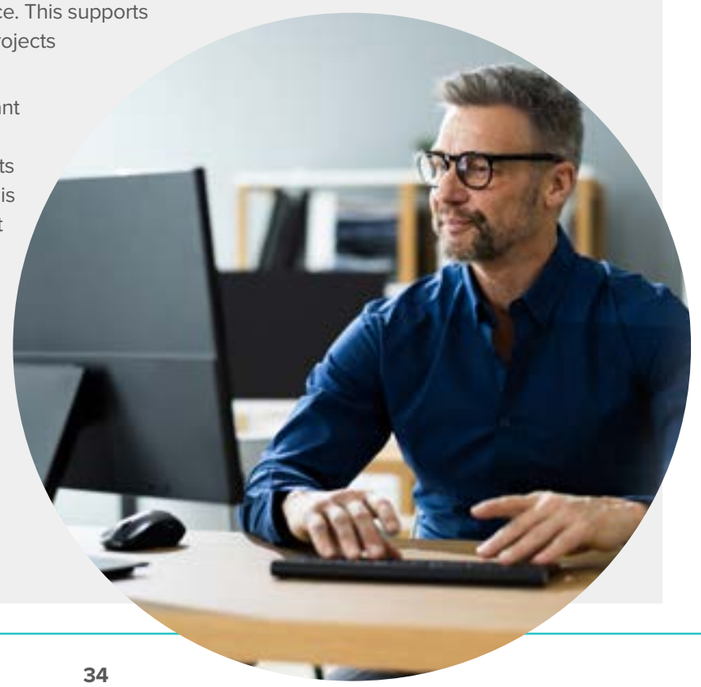
The intention of this platform is to provide financial institutions with pertinent data on the benefits and risks of energy efficiency investments. This evidence from the market is intended, in turn, to generate useful insights on the potential financial opportunity for such institutions, thereby accelerating their deployment of capital towards energy efficiency projects, such as the retrofitting of commercial buildings across the EU (European Commission, n.d.-b).

Further, once such investments have been made, the platform's data also enables the monitoring of their performance. This supports benchmarking exercises against comparable projects underway, or completed, elsewhere in Europe.

The EEFIG DEEP platform represents a significant resource for financial institutions and, as a live platform, it continues to add data and develop its functionality. A notable strength of the platform is the fact that it is open source, which means that data can be sourced from industry participants. The anonymized historical data is structured along major project characteristics, allowing for users to easily search for the most relevant data. So far, the platform includes approximately 38,000 projects, which have been submitted by more than 30 data providers (European Commission, n.d.-b).

Key element identified

1. Setting building performance standards
2. Developing a national retrofit plan
3. **Providing financial incentives and support**
4. Upskilling the workforce and scaling the supply chain
5. **Promoting best practice and data transparency**



Conclusions

Conclusion

Report background

Following the 2022 publication of the Global Retrofit Index which assessed G20 countries retrofitting performance and policy, this report has honed in on higher-performing countries with relatively old building stocks and good levels of building data availability. This focused approach enabled a deeper examination of data which directly relates to retrofitting - such as Energy Performance Certification (EPC) ratings - to draw insights on performance across the UK, Germany, France and Ireland, with additional analysis of the USA and the Netherlands.

Key findings

The study's analysis clearly illustrate that rates of retrofitting are lagging far behind what is required to meet net-zero targets. Across all six countries examined, a continuation of the trend of the past decade's building emissions levels will result in some overshoot by 2040. Glimpses of progress, such as the relatively steady decline of emissions from France's building stock, are offset by extremely poor performance in other large economies such as the USA where emissions are trending upwards.

Analysis of available EPC data in the UK, France and Ireland shows some uplift from the lowest building efficiency ratings over the past 5 - 10 years. However, there remains significant stagnation in the middle EPC bands with the vast majority of buildings still rated as D or C and therefore not energy efficient enough to deliver the required decarbonisation of these countries' buildings sector. Deep, whole-building retrofits which ensure modifications are coordinated and undertaken in the appropriate order to maximise efficiency will be necessary to push average EPC ratings to 'B' and above.

A number of governments of the countries analysed have set admirable goals to increase rates of retrofitting and have announced funding to support their efforts. For example, the German Federal government announced €56.3 billion to retrofit buildings in the bottom 25% of energy performance (BMWK, 2022), while France has increased the size of grants available to households through the MaPrimeRénov residential retrofit programme. Similarly, the Biden-Harris administration has pledged nearly $9 billion to consumer home energy rebate programmes to home appliance electrification and residential retrofits through the landmark Inflation Reduction Act (White House, 2022a). However, delivery against these ambitions has to-date been slow. In France only 66,000 whole building retrofits were completed in 2022 compared to a targeted annual average of 370,000 (ANAH, 2023a, HCC, 2023), while the USA has seen building stock emissions increase rather than decrease in recent years.

Barriers to rapid rollout of retrofitting

Retrofitting progress remains slow despite increasingly ambitious government targets and a variety of building upgrade funding programmes, indicating the existence of significant implementation barriers. These include systemic obstacles such as misaligned incentives between landlords and tenants, as well as shortages in the skilled workforce required to carry out retrofitting effectively (SEAI, 2023b). The upfront financial cost to homeowners is a also common deterrent to residential retrofits, and has been exacerbated by recent increases in inflation across the countries analysed (Which?, 2023). Confusion amongst homeowners regarding grant eligibility, as well as friction costs stemming from the need to liaise with numerous providers can also be barriers to the rapid rollout of deep residential retrofits.

Emerging best practice and government action

Overcoming such barriers and increasing retrofitting rates to decarbonise building stocks effectively, affordably and at scale requires action from government, industry and citizens, under a coordinated framework. This report identified five key elements of such a framework:

- **1. Setting net zero building performance standards**
- **2. Developing a national retrofit plan**
- **3. Providing financial incentives and support**
- **4. Upskilling the workforce and scaling the supply chain**
- **5. Promoting best practice and data transparency**

While industry actors and property owners do have roles to play in successful retrofit rollouts, governments hold the greater power to act on each of these five elements and thereby unlock action from the market.

Real-world examples of the five elements fundamental to accelerate retrofitting are provided through the case studies included in this report (see pages. 31 - 34). Schemes such as MaPrimeRénov in France and the Irish One Stop Shop demonstrate the importance of a coordinated approach which enables whole building retrofits of residential properties. While the EU's BIM-SPEED Project and EEFIG DEEP Platform leverage the power of technology and access to financial information to unlock retrofitting investment.

Outlook

If we are to stop the most catastrophic impacts of climate change, failure to decarbonise global building stocks is not an option. Retrofitting buildings not only reduces emissions but also brings co-benefits, including increased building longevity, improved comfort, health benefits, and uplift in asset value. It is therefore crucial that levels of public and private investment in retrofits rise dramatically in the coming years. Increasing financing for the rollout of retrofitting technologies - such as heat pumps - in the short term can help unlock further technological efficiencies and thereby drive down costs, improving affordability for lower-income households and for businesses.

Widespread retrofitting represents a uniquely complex challenge given the need to enact multiple changes to many millions of buildings with disparate owners. It is therefore incumbent on governments of high-emitting countries with old building stocks to urgently implement ambitious and coherent retrofit policies.

Report Methodology

It is important to note that each 'Net Zero scenario' shown in Figures 5, 7, 9, 11, 13 and 14 is subject to different underlying assumptions and models. They are intended to show one possible and plausible net zero scenario for each country and are not intended to be comparable.

It is also important to note that the EPC data used in this report reflects only the EPCs lodged in the respective national registers during the specified timeframe, and the data does not therefore represent the EPCs for the entirety of the existing national building stocks. Nevertheless, in the absence of such data, it represents the best available proxy for retrofitting activity and trends in national building stocks.

United Kingdom data analysis

Figure 5 - UK residential and non-residential building emissions 2010 to 2040

3Keel analysis of CCC (2020a) Sixth Carbon Budget analysis and data

This graph is adapted from analysis conducted by the Climate Change Council (CCC) for its Sixth Carbon Budget (2020).

The Net Zero scenario presented in Figure 5 is based on the data underlying the projected abatement pathway shown in figure 3.2.a of the Sixth Carbon Budget for both the UK's historical and future carbon budgets for residential and non-residential building stock emissions in the UK.

The proportional split between the unabated emissions in Figure 5 has then been estimated based on the historical split between direct residential and non-residential emissions, as published by the CCC in the Sixth Carbon Budget and presented in the Buildings Sector Summary Figure M3.2.

Finally, the 'historical reduction trend' line has been linearly extrapolated based on the trend in the GHG emissions data reported from 2010 to the most recent year of data available.

Figure 6 - The change in UK residential and non-residential energy performance certificates (EPC) (excluding new builds) lodged between 2013 and 2020

3Keel analysis of Department for Levelling Up, Housing & Communities (2023), and Energy saving trust (n.d.) EPC data

The data used in Figure 6 on the number and category of domestic and non-domestic EPCs issued is published by the respective national governments of England, Wales, and Scotland.

It has been used as the most appropriate proxy available for retrofitting trends in the existing UK building stock. Changes in EPCs typically reflect improvements, or a lack of, in energy efficiency. However, it should be noted that EPCs are only required for a property in the UK when it is built, sold or rented. Therefore, by its nature, the data on EPCs lodged in the UK only reflects properties that have been built, sold or rented in the selected period.

The data presented in Figure 6 is for 2013 to 2020, with this period selected to avoid EPC methodology changes in 2012 significantly impacting the underlying comparability of the data between years.

The data has then been processed as follows to produce the Sankey diagram in Figure 6:

- Any import errors or incomplete entries have been removed from the dataset.
- EPCs lodged for new builds have also then been removed from the dataset to better reflect both the state of the existing building stock and to avoid the potential for higher building energy efficiency standards in recent years skewing the underlying retrofitting trend in the UK's building stock.
- Building reference numbers have been used to identify how EPCs have changed for individual properties and to prevent any potential for double counting.
- Any change in EPC categories that represents less than 0.1% of the total EPC changes recorded in the dataset have then been removed to account for unexpected, and potentially anomalous, changes (e.g. a property with EPC A in 2013 moving to EPC G in 2020).

France data analysis

Figure 7 - French residential and non-residential building emissions from 2010 to 2040

3Keel analysis of CITEPA (2023) analysis and data

Figure 7 is based on an analysis of the data and projections published by CITEPA (Centre Interprofessione Technique d'Etudes de la Pollution Atmosphérique - the Interprofessional Technical Centre for Studies on Air Pollution) (2023) in the French National Low Carbon Strategy (Stratégie Nationale Bas-Carbone - SNBC).

The Net Zero scenario presented, and the associated GHG emissions budget, are based on the data and projections published in the SNBC. Historical GHG emissions data is used for the period to 2021 and SNBC RT-2 is used for the projected pathway for GHG emissions in France's building sector between 2022 and 2033. Beyond 2033, the Net Zero scenario assumes continued linear reductions aligned with France achieving net zero emissions in 2050. For the proportion between residential and non-residential GHG emissions, the split was assumed to be constant from 2022 with this calculated based on the most recent of year data available for historical (i.e. real world) emissions.

Figure 8 - The change in French residential and non-residential energy performance certificates (EPC) (excluding new builds) lodged before 2015 and between 2015 and 2020

3Keel analysis of ADEME (2022) EPC data

This analysis publicly available French EPC data (referred to as Diagnostic de Performance Energétique" (DPE)), published by ADEME (2022).

Given this dataset does not provide a unique building identifier for the EPCs lodged in the database, an alternative approach was taken to analysing this data in order to understand how EPCs have changed over time in France. The certificates lodged were still viewed as an appropriate proxy to show changes over time and so two distinct periods were used - pre-2015 (inclusive of 2015) and 2015-2020 - as suitable comparison points to demonstrate how the general trend in EPCs being lodged has changed. These larger time periods are also suitable in preventing any year to year abnormality skewing the data presented.

The French EPC dataset was filtered based on year lodged, as explained above. New builds were excluded to prevent their potentially higher ratings from impacting the trend of retrofits in existing buildings. Number of certificates lodged in the time period were then counted and the proportions for each rating calculated.

Germany data analysis

Figure 9 - German residential and non-residential building emissions from 2010 to 2040

3Keel analysis of Umweltbundesamt (2021) data

Figure 9 is based on an analysis of the data published by Umwelbundesamt (2021) and the German Federal Ministry of Justice (2019) in the Federal Climate Protection Act, published in 2019 and updated by amendment in 2021 to set the carbon neutrality goal for 2045 instead of 2050.

From the data provided, residential and non-residential GHG emissions were extracted with emissions associated with military buildings also excluded.

In line with the ambitions set in the Federal Climate Protection Act and the projections made by the German government, the Net Zero scenario presented uses the pathway set out by the German government for 2020 to 2030, which is a linear reduction in emissions. From 2030 onwards, the pathway has been extrapolated from this government data. The split between residential and non-residential GHG emissions was assumed to be constant from 2022, and this was calculated based on the most recent of year data available for historical (i.e. real world) emissions.

Figure 10 - The change in German residential heating sources from 2010 to 2022

Adapted from BDEW (2023) analysis and data

As the German government does not make its EPC data publicly available, it was not possible to create an equivalent sankey chart for Germany as with other countries in the report. It is expected that data gathered as part of the 2022 census may provide these insights, but it was not available at the time of writing.

An appropriate proxy for the EPC data was therefore identified and this is the data held by The Bundesverband der Energie- und Wasserwirtschaft e.V. (BDEW, 2023) on the change in residential heating sources between 2010 and 2022. Given the need to remove fossil fuel heating systems from residential buildings, and that this typically requires retrofitting, this data should capture any significant changes in Germany's residential building stock.

Ireland data analysis

Figure 11 - Irish residential and non-residential building emissions from 2010 to 2040

Analysis completed by O'Hegarty and Kinnane (2022, 2023)

FIgure 11 is based on the research and analysis conducted by O'Hegarty and Kinnane (2022, 2023). at University College Dublin. This research is ongoing and makes several assumptions to project a net zero scenario for Ireland. The pathway is based on an assumption of 500,000 retrofits of currently below EPC 'B' rated homes being delivered, with 50% achieving a 'B' rating and 50% achieving an 'A' rating.

Figure 12 - The change in Irish residential and non-residential energy performance certificates (EPC) lodged between 2009 and 2022

Figure based on Irish Central Statistics Office (2023) data

Figure 12 is based on the data published by the Irish Central Statistics Office (2023), which represents an analysis of building stock changes between 2009 and 2022. This data is only provided with no decimal places, and therefore does not provide much insight or granularity on the changes in EPCs lodged during this timeframe. As a result, the data presented in figure 12 only covers 97% of all EPCs lodged in this period. However, this has been considered sufficient to act as a proxy for changes in EPCs over time.

USA data analysis

Figure 13 - The USA's residential and non-residential building emissions from 2010 to 2040

3Keel analysis of US EPA (2023) GHG emissions data

Figure 13 represents an analysis of the GHG emissions data reported by the US EPA (2023) for the residential and commercial sectors in the United States. The net zero scenario has then been projected from this data as a linear reduction between 2021 and 2030, which is aligned with the US's NDC commitment for a 52% reduction by 2030 (below 2005 GHG emissions levels). It was not possible to identify a more sector-specific GHG emissions target for the US's built environment that sits underneath this national ambition.

Beyond 2030 and the US's interim climate target, a further reduction pathway has been modelled to 2040 based on the US's commitment to net zero. A 91% reduction in building emissions being achieved by 2050 has therefore been used as an appropriate pathway, based on the analysis conducted by Langevin et al (2023). Again, this pathway has been used as the United States has not provided sector-level climate targets and a pathway to absolute zero GHG emissions for the built environment is not considered credible.

Netherlands data analysis

Figure 14 - The Netherlands' residential and non-residential building emissions from 2010 to 2040

Figure based on PBL (2022) analysis and Centraal Bureau voor de Statistiek (2023)

Figure 14 is based on the data and analysis published by the Netherlands Environmental Assessment Agency (PBL, 2022) in its annual report - "Climate and energy outlook of the Netherlands 2022". Historical GHG emissions data is provided up to 2022. Beyond this point, the net zero scenario presented is based on the modelled pathway published in the report for the Netherlands achieving the EU's 55% GHG emissions reduction target by 2030. From 2030 to 2040, a linear reduction has then been separately extrapolated for this report to align with Netherland's stated ambition for a carbon neutral built environment by 2050.

References

ADEME. (2022). DPE Logements (avant juillet 2021). [Online]. Last Updated: 14 December 2022. Available at: https://data.ademe.fr/datasets/dpe-france [Accessed 1 November 2023].

Alipour, N. (2023). EU Buildings Directive: Germany signals readiness to stop tighter standards. [Online]. Euractiv. Last Updated: 18 September 2023. Available at: https://www.euractiv.com/section/politics/news/eu-buildings-directive-germany-signals-readiness-to-s [Accessed 3 November 2023].

ANAH. (2023a). Bilan 2022 MaPrimeRénov'. [Online]. Last Updated: 01/03/2023. Available at: https://www.anah.gouv.fr/anatheque/bilan-2022-maprimerenov [Accessed 1 November 2023].

ANAH. (2023b). Soutenir les copropriétés. [Online]. Last Updated: 30/07/2023. Available at: https://www.anah.gouv.fr/action/missions/coproprietes [Accessed 1 November 2023].

BDEW. (2023). Beheizungsstruktur des Wohnungsbestandes in Deutschland. [Online]. Last Updated: 10.10.2023. Available at: https://www.bdew.de/service/daten-und-grafiken/beheizungsstruktur-wohnungsbestand/ [Accessed 1 November 2023].

BMWK. (2022). 177.5 billion Euros for climate action, energy security and help with energy costs. [Online]. Last Updated: 27/07/2022. Available at: https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2022/07/20220727-177.5-billion-Euros-for-climate-action-energy-security-and-help-with-energy-costs.html [Accessed 1 November 2023].

Boletín Oficial de la República Argentina. (2023). Resolución 517/2023. [Online]. Available at: https://www.boletinoficial.gob.ar/detalleAviso/primera/289826/20230707 [Accessed 1 November 2023].

BPIE. (2013). A GUIDE TO DEVELOPING STRATEGIES FOR BUILDING ENERGY RENOVATION. [Online]. Last Updated: February 2013. Available at: https://bpie.eu/wp-content/uploads/2015/10/Developing-Building-Renovation-Strategies.pdf [Accessed 1 November 2023].

BPIE. (2020). A Review of EU Member States' 2020 Long-term Renovation Strategies. [Online]. Last Updated: September 2020. Available at: https://www.bpie.eu/wp-content/uploads/2020/10/LTRS-Assessment_Final.pdf [Accessed 1 November 2023].

BPIE. (n.d.). Germany. [Online]. Available at: https://www.bpie.eu/germany/ [Accessed 1 November 2023].

Brown, D. (2018). Business models for residential retrofit in the UK: a critical assessment of five key archetypes. [Online]. ResearchGate. Last Updated: August 2018. Available at: https://www.researchgate.net/publication/323758891_Business_models_for_residential_retrofit_in_the_U [Accessed 1 November 2023].

Bureau of Energy Efficiency. (2022). The Energy Conservation (Amendment) Act, 2022 No. 19 of 2022 [Online]. Last Updated: 19th December, 2022. Available at: https://beeindia.gov.in/en/the-energy-conservation-amendment-act-2022-no-19-of-2022 [Accessed 1 November 2023].

CAGBC. (2020). Accelerating to Zero: Upskilling for Engineers, Architects, and Renewable Energy Specialists. [Online]. Available at: https://portal.cagbc.org/cagbcdocs/advocacy/CAGBC_Accelerating_To_Zero_Carbon_Skills_Gap_Report.pdf [Accessed 1 November 2023].

Canary Wharf Group. (2021a). Canary Wharf Group Successfully Issues Multi-Tranche Debut Green Bonds. [Online]. Last Updated: 12.04.21. Available at: https://group.canarywharf.com/press-release/canary-wharf-group-successfully-issues-multi-tranche-debut-green-bonds-120421/ [Accessed 1 November 2023].

Canary Wharf Group. (2021b). Green Bond Framework. [Online]. Last Updated: March 2021. Available at: https://group.canarywharf.com/wp-content/uploads/2021/04/canary-wharf-group-green-bond-framework-march-2021.pdf [Accessed 1 November 2023].

CCC. (2020a). Sixth Carbon Budget. [Online]. Last Updated: 9 December 2020. Available at: https://www.theccc.org.uk/publication/sixth-carbon-budget/ [Accessed 1 November 2023].

CCC. (2020b). The Sixth Carbon Budget: Buildings. [Online]. Available at: https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Buildings.pdf [Accessed 1 November 2023].

CCC. (2022). Progress in reducing emissions: 2022 Report to Parliament. [Online]. Last Updated: 29 June 2022. Available at: https://www.theccc.org.uk/wp-content/uploads/2022/06/Progress-in-reducing-emissions-2022-Report-to-Parliament.pdf [Accessed 1 November 2023].

CCC. (2023). Climate policy that cuts costs International policy comparison. [Online]. Last Updated: June 2023. Available at: https://www.theccc.org.uk/wp-content/uploads/2023/06/Climate-policy-that-cuts-costs-International-policy-comparisons-Energy-Saving-Trust-and-Green-Alliance.pdf [Accessed 1 November 2023].

CE Delft. (2022). The natural gas phase-out in the Netherlands. [Online]. Last Updated: February 2022. Available at: https://ce.nl/wp-content/uploads/2022/04/CE_Delft_210381_The_natural_gas_phase-out_in_the_Netherlands_DEF.pdf [Accessed 1 November 2023].

Centraal Bureau voor de Statistiek. (2021). 92 procent woningen op aardgas begin 2019. [Online]. Available at: https://www.cbs.nl/nl-nl/nieuws/2021/07/92-procent-woningen-op-aardgas-begin-2019 [Accessed 1 November 2023].

Centraal Bureau voor de Statistiek. (2023). Greenhouse gas emissions 9 percent lower in 2022. [Online]. Last Updated: 15 March 2023. Available at: https://www.cbs.nl/en-gb/news/2023/11/greenhouse-gas-emissions-9-percent-lower-in-2022 [Accessed 1 November 2023].

Cheslak, K. (2020). Implementing Building Performance Standards: Consistency is key. [Online]. Last Updated: September 29, 2020. Available at: https://newbuildings.org/implementing-building-performance-standards-consistency-is-key/ [Accessed 1 November 2023].

CITEPA. (2023). Secten – le rapport de référence sur les émissions de gaz à effet de serre et de polluants atmosphériques en Fran. [Online]. Last Updated: 29 June 2023. Available at: https://www.citepa.org/fr/secten/ [Accessed 1 November 2023].

City of London. (2023). 'Creating a Skilled Workforce for Central London's Sustainable Skyline'. [Online]. Available at: https://www.cityoflondon.gov.uk/assets/Business/skyline-skills-recommendations-report-pdf-9mb.pdf [Accessed 1 November 2023].

Climate Transparency. (2022). Germany. [Online]. Available at: https://www.climate-transparency.org/wp-content/uploads/2022/10/CT2022-Germany-Web.pdf [Accessed 1 November 2023].

de Wilde, M. (2019). The sustainable housing question: On the role of interpersonal, impersonal and professional trust in low-carbon retrofit decisions by homeowners. [Online]. ScienceDirect. Available at: https://www.sciencedirect.com/science/article/pii/S2214629618307928 [Accessed 1 November 2023].

Department for Levelling Up, Housing & Communities. (2023). Energy Performance of Buildings Data: England and Wales. [Online]. Last Updated: 26 Oct 2023. Available at: https://epc.opendatacommunities.org/ [Accessed 1 November 2023]

Department of the Environment, Climate and Communications. (2022). National Retrofit Plan. [Online]. Last Updated: 8 February 2022. Available at: https://www.gov.ie/en/publication/5052a-national-retrofit-plan/ [Accessed 1 November 2023].

E3G. (2021). Renovate2Recover: How Transformational Are The National Recovery Plans For Buildings Renovation?. [Online]. Available at: https://www.renovate-europe.eu/wp-content/uploads/2018/09/Renovate2Recover_Full-Study-1.pdf [Accessed 1 November 2023].

Economidou, M., Todeschi, V., and Bertoldi, P. (2019). Accelerating energy renovation investments in buildings. [Online]. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC117816 [Accessed 1 November 2023].

EEA. (2022). Cooling buildings sustainably in Europe: exploring the links between climate change mitigation and adaptation, and their. [Online]. Last Updated: 26 Apr 2023. Available at: https://www.eea.europa.eu/publications/cooling-buildings-sustainably-in-europe/cooling-buildings-sustainably-in-europe [Accessed 1 November 2023].

Energy saving trust. (n.d.). Scotland EPC data. [Online]. Available at: https://www.scottishepcregister.org.uk/ [Accessed 1 November 2023].

Environmental Audit Committee. (2021). Energy Efficiency of Existing Homes Fourth Report of Session 2019–21. [Online]. Last Updated: 22 March 2021. Available at: https://committees.parliament.uk/publications/5171/documents/52521/default/ [Accessed 1 November 2023].

EU BIM SPEED. (n.d.-a). Demonstration Cases. [Online]. Available at: https://www.bim-speed.eu/en/demonstration-cases#13 [Accessed 1 November 2023].

EU BIM SPEED. (n.d.-b). Harmonized Building Information Speedway for Energy-Efficient Renovation. [Online]. Available at: https://www.bim-speed.eu/en/Project%20Results%20%20Documents/Dissemination%20Materials/BIMfographics/BIMfographic1%20Project%20Overview%20Print%20pdf.pdf [Accessed 1 November 2023].

European Parliament. (2023). Energy Performance of Buildings Directive. [Online]. Available at: https://www.europarl.europa.eu/RegData/etudes/ATAG/2023/739377/EPRS_ATA(2023)739377_EN.pdf [Accessed 1 November 2023].

European Commission. (n.d.-a). Long-term renovation strategies. [Online]. Available at: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en [Accessed 1 November 2023].

European Commission. (n.d.-b). Working Groups. [Online]. Available at: https://eefig.ec.europa.eu/working-groups_en [Accessed 1 November 2023].

Feldstein, S. (n.d.). Age Of U.S. Commercial Buildings. [Online]. Available at: https://www.commbuildings.com/ResearchComm.html#:~:text=Age%20of%20U.S.%20Commercial%20Buildings,years%20old%20. [Accessed 1 November 2023].

Galvin, R. (2023). Policy pressure to retrofit Germany's residential buildings to higher energy efficiency standards. [Online]. ScienceDirect. Last Updated: 1 June 2023. Available at: https://www.sciencedirect.com/science/article/pii/S0360132323003438 [Accessed 1 November 2023].

Gazzetta Ufficiale. (2023). Decree-Law 16 February 2023, n. 11. [Online]. Last Updated: 16 February 2023. Available at: https://www.gazzettaufficiale.it/eli/id/2023/02/16/23G00020/sg [Accessed 1 November 2023].

German Federal Ministry of Justice. (2019). Federal Climate Change Act (Bundes-Klimaschutzgesetz). [Online]. Last Updated: 18 August 2021. Available at: https://www.gesetze-im-internet.de/englisch_ksg/englisch_ksg.html [Accessed 1 November 2023].

Green Finance Institute. (2020). Financing energy efficient buildings: the path to retrofit at scale. [Online]. Available at: https://www.greenfinanceinstitute.com/wp-content/uploads/2020/06/Financing-energy-efficient-buildings-the-path-to-retrofit-at-scale.pdf [Accessed 1 November 2023].

HCC. (2019). First Annual Report of the High Council on Climate of France. [Online]. Last Updated: June 2019. Available at: https://www.hautconseilclimat.fr/wp-content/uploads/2019/06/hcc_rapport_annuel_2019-english-1.pdf [Accessed 1 November 2023].

HCC. (2020). Renovating Better: Lessons from Europe. [Online]. Last Updated: November 2020. Available at: https://www.hautconseilclimat.fr/wp-content/uploads/2023/09/hcc_rapport_renover_mieux-english.pdf [Accessed 1 November 2023].

HCC. (2023). Acter L'Urgence: Engager Les Moyens. [Online]. Last Updated: June 2023. Available at: https://www.hautconseilclimat.fr/wp-content/uploads/2023/06/HCC_RANC_2023-VF.pdf [Accessed 1 November 2023].

House Sustainable Energy and Environment Coalition. (2023). Inflation Reduction Act. [Online]. Available at: https://seec.house.gov/ira. [Accessed 1 November 2023].

IEA. (2021). Net Zero by 2050. [Online]. Last Updated: May 2021. Available at: https://www.iea.org/reports/net-zero-by-2050 [Accessed 1 November 2023].

IEA. (2022). All countries targeted for zero-carbon-ready codes for new buildings by 2030. [Online]. Last Updated: September 2022. Available at: https://www.iea.org/reports/all-countries-targeted-for-zero-carbon-ready-codes-for-new-buildings-by-2030-2 [Accessed 1 November 2023].

IEA. (2023). Buildings: CO2 Emissions. [Online]. Available at: https://www.iea.org/energy-system/buildings#tracking [Accessed 1 November 2023].

Irish Central Statistics Office. (2023). Domestic Building Energy Ratings Quarter 4 2022. [Online]. Last Updated: 19 January 2023. Available at: https://www.cso.ie/en/releasesandpublications/ep/p-dber/domesticbuildingenergyratingsquarter42022/ [Accessed 1 November 2023].

JLL. (2022). Retrofitting buildings essential to reduce energy costs and combat the global energy crisis. [Online]. Last Updated: November 10, 2022. Available at: https://www.jll.co.uk/en/newsroom/retrofitting-buildings-essential-to-reduce-energy-costs-and-combat-the-global-energy-crisis [Accessed 1 November 2023].

Kurmayer, N. (2022). Germany's €177bn climate budget to focus on renovations. [Online]. Last Updated: 28 July 2022. Available at: https://www.euractiv.com/section/energy-environment/news/germanys-e177bn-climate-budget-to-focus-on-renovations/ [Accessed 1 November 2023].

Larsen, J et al. (2022). A Turning Point for US Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act. [Online]. Rhodium Group. Last Updated: August 12, 2022. Available at: https://rhg.com/research/climate-clean-energy-inflation-reduction-act/ [Accessed 1 November 2023].

Leung, J. (2018). Decarbonising U.S. Buildings. [Online]. Last Updated: July 2018. Available at: https://www.c2es.org/wp-content/uploads/2018/06/innovation-buildings-background-brief-07-18.pdf [Accessed 1 November 2023].

LGA. (2022). Retrofit Skills Discussion Paper. [Online]. Available at: https://lga.moderngov.co.uk/documents/s40473/5%20FINAL%20PPB%20Retrofit%20Skills%20Paper.pdf [Accessed 1 November 2023].

Ministères Écologie Énergie Territoires. (2022). PLAN DE SOBRIÉTÉ ÉNERGÉTIQUE. [Online]. Available at: https://www.ecologie.gouv.fr/sites/default/files/dp-plan-sobriete.pdf [Accessed 1 November 2023].

NAHB. (2021). Median Age of Housing Stock by State Varies by More Than 35 Years. [Online]. Last Updated: Apr 05, 2021. Available at: https://www.nahb.org/blog/2021/04/median-age-of-housing-stock-by-state-varies-by-more-than-35-years/ [Accessed 1 November 2023].

O'Hegarty, R., Kinnane, O. (2022). Whole life carbon quantification of the built environment: Case study Ireland. Building and Environment 226, 109730. https://doi.org/10.1016/j.buildenv.2022.109730

O'Hegarty, R., Kinnane, O. (2023). A whole life carbon analysis of the Irish residential sector - past, present and future. Energy and Climate Change 4, 100101. https://doi.org/10.1016/j.egycc.2023.100101

PBL. (2021). Netherlands Climate and Energy Outlook 2021. [Online]. Available at: https://www.pbl.nl/sites/default/files/downloads/pbl-2021-netherlands-climate-and-energy-outlook_2021-summary-4709.pdf [Accessed 1 November 2023].

PBL. (2022). Climate and Energy Outlook of the Netherlands 2022. [Online]. Last Updated: December 2022. Available at: https://www.pbl.nl/sites/default/files/downloads/pbl-2022-climate-and-energy-outlook-of-the-netherlands-2022-4839.pdf [Accessed 1 November 2023].

Quinn, B. (2023). Plan to replace gas boilers with heat pumps should be reviewed, says Gove. [Online]. The Guardian. Last Updated: 25 Jul 2023. Available at: hhttps://www.theguardian.com/environment/2023/jul/25/gas-boilers-heath-pumps-gove-government-green-policies-ban-new-petrol-diesel-cars [Accessed 1 November 2023].

Retrofit Academy. (n.d.). Retrofit Academy. [Online]. Available at: https://retrofitacademy.org/ [Accessed 1 November 2023].

SEAI. (2018). Energy in the Residential Sector 2018 Report. [Online]. Last Updated: April 2018. Available at: https://www.rte.ie/documents/news/2018/04/energy-in-the-residential-sector-2018-final.pdf [Accessed 1 November 2023].

SEAI. (2020). Energy In Ireland 2020 Report. [Online]. Last Updated: December 2020. Available at: https://www.seai.ie/publications/Energy-in-Ireland-2020.pdf [Accessed 1 November 2023].

SEAI. (2023a). National Retrofit Plan Quarterly Progress Report Full Year 2022. [Online]. Last Updated: March 2023. Available at: https://www.seai.ie/publications/SEAI-Retrofit-Annual-Report-2022.pdf [Accessed 1 November 2023].

SEAI. (2023b). Promoting retrofitting among homeowners in Ireland through a behavioural lens. [Online]. Last Updated: March 2023. Available at: https://www.seai.ie/publications/Promoting-retrofitting-among-homeowners-in-Ireland-through-a-behavioural-lens.pdf [Accessed 1 November 2023].

Service-Public.fr. (2023). MaPrimeRénov' evolves: new products in 2023. [Online]. Last Updated: 6 February, 2023. Available at: https://www.service-public.fr/particuliers/actualites/A16350?lang=en [Accessed 1 November 2023].

Sheeran, R. (2022). Turf sales: Ban in Republic of Ireland renews peatlands debate. [Online]. BBC. Last Updated: 13 November 2022. Available at: https://www.bbc.co.uk/news/uk-northern-ireland-63588575 [Accessed 1 November 2023].

Smeeton, G. (2022). Poorly insulated homes to cost £1,000 more to heat this year than if they had been upgraded to meet Government's target. [Online]. Last Updated: 6th October, 2022. Available at: https://eciu.net/media/press-releases/2022/poorly-insulated-homes-to-cost-1000-more-to-heat-this-year [Accessed 1 November 2023].

TIMEPAC. (n.d.). The new EPC for Europe. [Online]. Available at: https://timepac.eu/ [Accessed 1 November 2023].

UKGBC. (n.d.). Domestic Retrofit. [Online]. Available at: https://ukgbc.org/policy-advocacy/domestic-retrofit/. [Accessed 1 November 2023].

Umweltbundesmat. (2021). Umweltbundesmat. [Online]. Available at: https://www.umweltbundesamt.de/sites/default/files/medien/361/dokumente/2021-01-12_em_entwicklung_in_d_thg_sektoren_v1.0_0.xlsx [Accessed 1 November 2023].

US EPA. (2023). Inventory of U.S. Greenhouse Gas Emissions and Sinks. [Online]. Available at: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks [Accessed 1 November 2023].

Vivier, L. and Giraudet, L-G. (2022). A retrofitting obligation for French dwellings - A modelling assessment. [Online]. Last Updated: June 2022. Available at: https://hal.science/hal-04012427v1/document [Accessed 1 November 2023].

Wells, I. (2023). Rishi Sunak scraps home energy efficiency taskforce. [Online]. BBC. Last Updated: 23 September 2023. Available at: https://www.bbc.co.uk/news/uk-politics-66900999 [Accessed 1 November 2023].

WGBC. (2015). Quality Assurance Guide For Green Building Rating Tools. [Online]. Last Updated: September 2015. Available at: https://worldgbc.org/wp-content/uploads/2022/03/WorldGBC_QA_Guide_for_Green_Building_Rating_Tools.pdf [Accessed 1 November 2023].

WGBC. (2023a). Advancing Net Zero Status Report 2023. [Online]. Available at: https://worldgbc.org/wp-content/uploads/2023/07/WorldGBC-ANZ-Status-Report-2023_FINAL-compressed_1.pdf [Accessed 1 November 2023].

WGBC. (2023b). Global Policy Principles for a Sustainable Built Environment. [Online]. Last Updated: 12 April, 2023. Available at: https://worldgbc.org/wp-content/uploads/2023/04/WorldGBC-Global-Policy-Principles_FINAL.pdf [Accessed 1 November 2023].

WGBC. (n.d.). Sustainable Building Certifications. [Online]. Available at: https://worldgbc.org/sustainable-building-certifications/ [Accessed 1 November 2023].

Which?. (2023). Worryingly few households planning insulation improvements to their homes, despite concern about high energy prices, Which? reveals. [Online]. Last Updated: 19 September 2023. Available at: https://www.which.co.uk/policy-and-insight/article/worryingly-few-households-planning-insulation-improvements-to-their-homes-despite-concern-about-high-energy-prices-which-reveals-aMcgb3IteDqC [Accessed 1 November 2023].

White House. (2022a). Building A Clean Energy Economy. [Online]. Available at: https://www.whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf [Accessed 1 November 2023].

White House. (2022b). Fact Sheet: Biden-Harris Administration Announces First-Ever Federal Building Performance Standard, Catalyzes American Innovation to Lower Energy Costs, Save Taxpayer Dollars, and Cut Emissions. [Online]. Last Updated: DECEMBER 07, 2022. Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2022/12/07/fact-sheet-biden-harris-administration-announces-first-ever-federal-building-performance-standard-catalyzes-american-innovation-to-lower-energy-costs-save-taxpayer-dollars-and-cut-emissions/ [Accessed 1 November 2023].

White House. (2022c). Fact Sheet: White House Takes Action on Climate by Accelerating Energy Efficiency Projects Across Federal Government. [Online]. Last Updated: AUGUST 03, 2022. Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/03/fact-sheet-white-house-takes-action-on-climate-by-accelerating-energy-efficiency-projects-across-federal-government/?utm_medium=email&utm_source=govDelivery [Accessed 1 November 2023].

White House. (2023a). Readout of White House Convening on Advancing Clean Buildings. [Online]. Last Updated: MAY 05, 2023. Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2023/05/05/readout-of-white-house-convening-on-advancing-clean-buildings/ [Accessed 1 November 2023].

White House. (2023b). Fact Sheet: Biden-Harris Administration Announces New Actions and Investments to Lower Energy Costs, and Make Affordable Homes More Energy Efficient and Climate Resilient for Hard-Working Families. [Online]. Last Updated: MAY 11, 2023. Available at: https://www.whitehouse.gov/briefing-room/statements-releases/2023/05/11/fact-sheet-biden-harris-administration-announces-new-actions-and-investments-to-lower-energy-costs-and-make-affordable-homes-more-energy-efficient-and-climate-resilient-for-hard-working-families/ [Accessed 1 November 2023].

3Keel. (2022). Global Retrofit Index. [Online]. Last Updated: 24/10/2022. Available at: https://www.3keel.com/wp-content/uploads/2022/10/Global_Retrofix_Index.pdf [Accessed 1 November 2023].

Appendix

Table A1

League table showing scores of all G20 members assessed in the 2022 Global Retrofit Index

Rank	Country	Existing stock (/25)	Retrofit performance (/25)	Retrofit policy (/50)	Total score (/100)
1	Germany	6.0	18.8	36.8	61.5
2	Netherlands*	8.0	20.0	28.3	56.3
3	France	9.0	16.3	30.3	55.5
4	UK	8.0	16.3	28.5	52.8
5	Croatia*	6.0	20.0	26.0	52.0
6	Italy	8.0	12.5	31.3	51.8
7	Australia	11.5	7.5	13.5	32.5
8	Mexico	8.5	8.8	5.0	32.3
=9	Brazil	14.0	11.3	3.8	29.0
=9	Canada	6.0	5.0	18.0	29.0
=9	Republic of Korea	7.0	5.0	17.0	29.0
=12	Japan	8.0	7.5	13.3	28.8
=12	United States	7.0	7.5	14.3	28.8
14	Turkey	9.0	0.0	17.0	26.0
15	Saudi Arabia	6.5	12.5	4.0	23.0
16	China	9.0	0.0	12.5	21.5
	South Africa	Insufficient data			
	Argentina	Insufficient data			
	Indonesia	Insufficient data			
	India	Insufficient data			
	Russia	Insufficient data			

**Croatia and the Netherlands are not G20 countries, but have been included as case studies representing EU performance (It was not possible to assess the EU, a G20 member, as a whole)*

Table 4.2

League table showing scores of all G7 members assessed in this index

1	Germany	6.0	18.8	36.8	61.5
3	France	9.0	16.3	30.3	55.5
4	UK	8.0	16.3	28.5	52.8
6	Italy	8.0	12.5	31.3	51.8
=9	Canada	6.0	5.0	18.0	29.0
=12	Japan	8.0	7.5	13.3	28.8
=12	United States	7.0	7.5	14.3	28.8

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