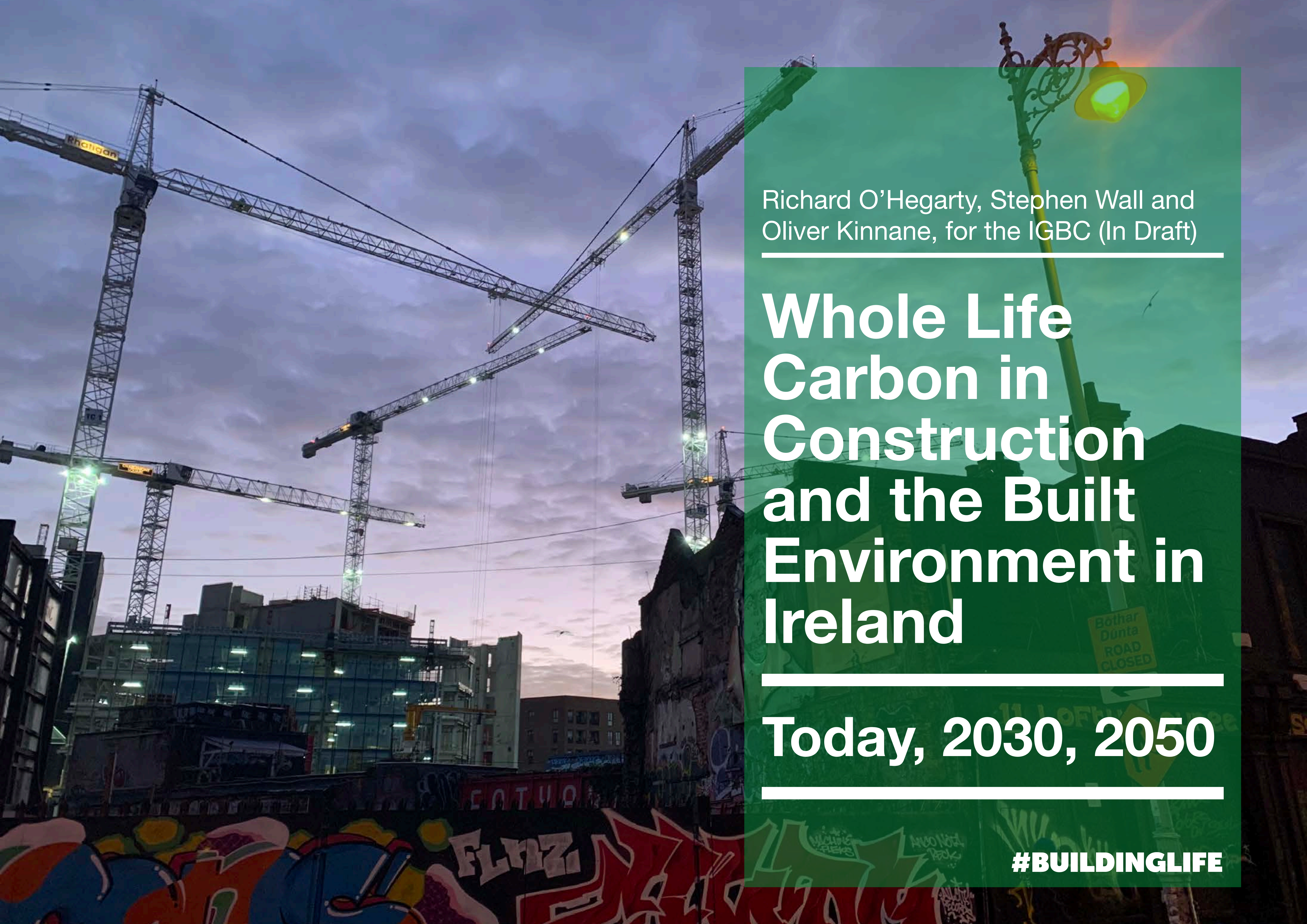

Richard O'Hegarty, Stephen Wall and
Oliver Kinnane, for the IGBC (In Draft)

Whole Life Carbon in Construction and the Built Environment in Ireland

Today, 2030, 2050

#BUILDINGLIFE

Table of Contents

Part 1: Baselining and Projections 1

Part 2: A Roadmap to Net-Zero

Introduction

The whole life carbon in construction and the built environment in Ireland is unquantified. This study aims to complete this task, make projections for the built environment to 2030, and in the next phase will model scenarios, and propose a roadmap, to get to -51% reduction by 2030 and net-zero by 2050.

This report is produced by the *Building in a Climate Emergency (BIACE)* Research Lab, UCD School of Architecture, Planning and Environmental Policy, for the Irish Green Building Council.

The project team from the *BIACE* Research Lab include:

Richard O'Hegarty, Lead Researcher

Stephen Wall, Project Researcher

Oliver Kinnane, Lead Academic

This is the third draft (v3) of a report on work in progress. The study is not yet complete and presented results remain only partially validated.

UCD School of Architecture, Planning & Environmental Policy
Scoil na hAiltireachta, na Pleanála agus an Pholasaí Chomhshaoil UCD

European Climate Foundation

Laudes Foundation

IKEA Foundation

IGBC
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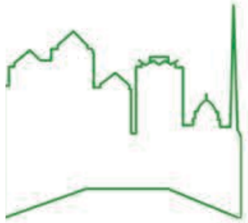


BUILT ENVIRONMENT

carbon emissions:

23 MtCO2e

in a standard year

Building Operations	Embodied Carbon
14 MtCO2e	9 MtCO2e

This accounts for

37%

of national emissions

Building Operations	Embodied Carbon
23%	14%

CEMENT

accounts for

40-50%

of materials-related emissions used in construction

RESIDENTIAL SECTOR

Residential operational carbon accounts for

45%

of built environment emissions per annum

400,000

new homes planned

NON RESIDENTIAL

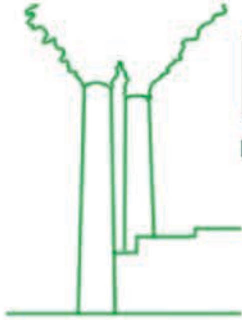
construction emits

2.7 MtCO2e

per annum,

1.4 MtCO2e

due to commercial building



PROJECTIONS TO 2030

Residential operational carbon expected to decrease by

32%

Built Environment emis-sions likely to increase by

~4 MtCO2e

if embodied carbon levels remain consistent

Housing and infrastructure plans could result in

x3

the built environment emissions target

Key Findings
Overview

Construction and operation of the Irish built environment accounts for ~23 MtCO_2e of annual emissions in a standard year

~14 MtCO_2e of emissions were due to building operation and ~9 MtCO_2e related to embodied carbon in 2018

Works outlined in national planning documents (NDP, NRP, Housing for All) will increase the annual embodied emissions considerably

Efficiency improvements in the residential sector will drive emissions downward but these will not be enough to meet targets

If all that is proposed in development plans is built, BE GHG could increase to 3 times the targeted level by 2030

Abstract

Ireland has set definite, and ambitious, targets for GHG emission reductions by 2030 and 2050. All sectors of society will be targeted but the built environment is likely to receive particular focus. However, the emissions due to the operation of the built environment, and especially its construction, are currently poorly quantified. This makes it difficult to identify the highest polluting sectors and the likely impact of any corrective actions taken.

This draft report documents a mainly top-down study of the Irish built environment, and quantifies GHG emissions associated with different sectors. Based on national targets, pledges and policies, emission projections to 2030 are made.

The construction and operation of the Irish BE is responsible for more than 36% of Irish GHG emissions (~23MtCO2), split in a 2:1 ratio between operational and embodied emissions. Emissions related to the residential sector - the one sector for which rich data exists - dominate (<50% BE GHG). The decarbonisation of electricity over the last 15 years has had significant impact on reducing BE GHG emissions and offsetting the increase in construction. There is opportunity to benefit further, by transitioning fossil fuel powered sectors to electricity, including residential space heating.

Mass retrofit of ~25% of all homes is planned by 2030, including the installation of 600,000 heat pumps. These changes bring operational emission reduction but a capital carbon cost input.

New build high efficiency residential (+400,000 units) and non-residential, retrofit and technology upgrades are included in initial projections to 2030. These are widely varying depending on the efficiencies achieved and importantly the level of construction. Efficiency improvements will drive operational carbon downward but targets will not be achieved through OC correction alone and embodied carbon needs to be focused on. There is a clear conflict between stated aims of national development and emissions reduction, however.

Construction of all that is proposed is projected to result in a built environment with over 3 times the carbon emissions of our targeted level by 2030.

The final part of this report presents more detailed and certain projections for a wide range of solutions and scenarios.

Acronyms

BE. Built Environment

BE GHG. Built Environment GreenHouse Gas emissions

BER. Building Energy Rating

CSO. Central Statistics Office

EC. Embodied Carbon

EE. Embodied Emissions

EPA. Environmental Protection Agency

GHG. GreenHouse Gas emissions

NDP. National Development Plan

NRP. National Retrofit Programme

OC. Operational Carbon

OE. Operational Emissions

SEAI. Sustainable Energy Authority of Ireland

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Study Objectives

This study aims to quantify the emissions related to the construction sector in Ireland and the built environment more generally, today and into the future.

The project has four primary objectives:

1. Baselining - To quantify the current emissions related to construction and operation of the built environment for a typical year.

2. Projections - To project future emissions related to the built environment, based on current broad policy and plans.

3. Scenarios - To predict BE emissions for a wide range of scenarios including policy implementation, technology rollouts and innovations.

4. Roadmap - To outline a road map to achieve targets of -51% by 2030, and net-zero by 2050 respectively, through a range of interventions including cement innovations, policy change, energy transitions and technology innovations.

The first of these objectives aims at estimating the current annual impact of the built environment. The second aims at estimating the future impact of the built environment, and it highlights gaps and necessary built environment related sub-sectors to target over coming years. The third sets scenarios that enable assessment of future emission pathways. Scenarios ranging from 'business as usual' to achieving 'announced pledges' will be evaluated initially for 2030 and for 2050 as we progress toward the goal of net-zero.

The study places considerable focus on correcting for trade, to ensure both territorial and non-territorial emissions are accounted for.

Background

The impact of the built environment, its operation, and to a greater extent its construction are currently poorly quantified. The high-level national climate emissions inventories do not relate data directly to the construction sector. The inventories instead report emissions related to sectors such as Agriculture, Transport, Energy Industries, Manufacturing, Residential, Public services, etc. Many of these encompass emissions related to the built environment, and are aggregated for this report.

Similarly the inventories are only concerned with territorial emissions occurring within Ireland and not the emissions due to production that occur elsewhere but are imported into Ireland (consumption based emissions). Ireland imports a high amount of building materials including processed metals and bricks as well as energy for building operation.

This report presents a preliminary evaluation of the impact of the built environment accounting for GHG emissions across a range of sectors, some of which are evaluated in greater detail than others. Similarly varying levels of data exist for different sectors.

A climate emergency has been declared by the Irish government. Ambitious and legally binding targets have been defined. This presents a new context for analysis of the GHG emissions associated with the operation and construction of the built environment. Speedy and forceful action is required to reduce its impact. A first step is to accurately quantify it.

Report Overview

This is the third draft of this working report. It continues to be published in draft form so as to openly present the work as it is ongoing, and to invite public consultation and expert review of the findings.

The first draft reports presented a preliminary evaluation of the impact of the built environment accounting for GHG emissions across a range of sectors. The results of those reports have been refined and are presented here. They will be further evaluated for the final draft due later in 2022. Additionally roadmaps to achieve net-zero by 2050, and interim targets in 2030 will be included in the final version.

Emission totals are quantified and reported on for 2009 to 2019. 2018 is given particular attention and is taken as the benchmark year, and assumed as a standard year; pre Covid related disruption to the industry and a decade after the economic crisis of 2008. It is also the year used as the baseline for which future reductions to 2030 and 2050 are compared against. Quantified totals are presented in tonnes of carbon dioxide equivalent (MtCO2e or KtCO2e) throughout.

This draft of the report is structured into two primary parts.

The first part is focused on baselining the current impact of the built environment. It includes past years and current quantification of GHG emissions.

The second looks to the future, initially projecting GHG to 2030 based on current emissions superimposed with the most definite aims, efficiencies and policies in place. Scenarios are presented, that will be further developed and interrogated in the subsequent phases of this research, and included in the reiteration of this report.

Limitations

The data used in this report is not primary data. The authors have taken the data from publicly available databases and key reports published by the EPA, SEAI, CSO and from key academic literature, listed in the Bibliography.

Since these databases use a categorisation system which is not targeted at capturing the impact of the built environment, some defined sectors are partly related to the built environment. These sectors are few and relatively less important so the uncertainty associated with this limitation is minimal.

The quality and availability of data varies considerably, across building sectors. Rich data is available for the residential sector from SEAI databases. This allows the residential sector to be focused on and evaluated in greater detail than other sectors.

An initial estimate of GHG emissions in 2030 is made, given current policy aims and projected trends. In future iterations of this report this matter will be given significantly more attention and estimates will be better linked to expected policy and reality checks on energy and technology near-term innovations.

Data availability for past years (baselining) differs considerably to that of future years (forecasting). This results in a mismatch in categorisation for future and past projections. To overcome this multiple methods are implemented. For example, the embodied carbon of the built environment for past years is estimated using both commodity-based and floor-area based categorisation. While the commodity-based estimation is more accurate and robust, the floor-area based categorisation facilitates a more seamless transition from past to future.

Part 1

Baselining

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The Built Environment and the National Context

The Irish built environment is estimated to account for > 36% of the overall annual GHG emissions in a standard year. This includes emissions resulting from the energy required for the operation (~23% of overall emissions) and the construction of the built environment (~13% of overall emissions).

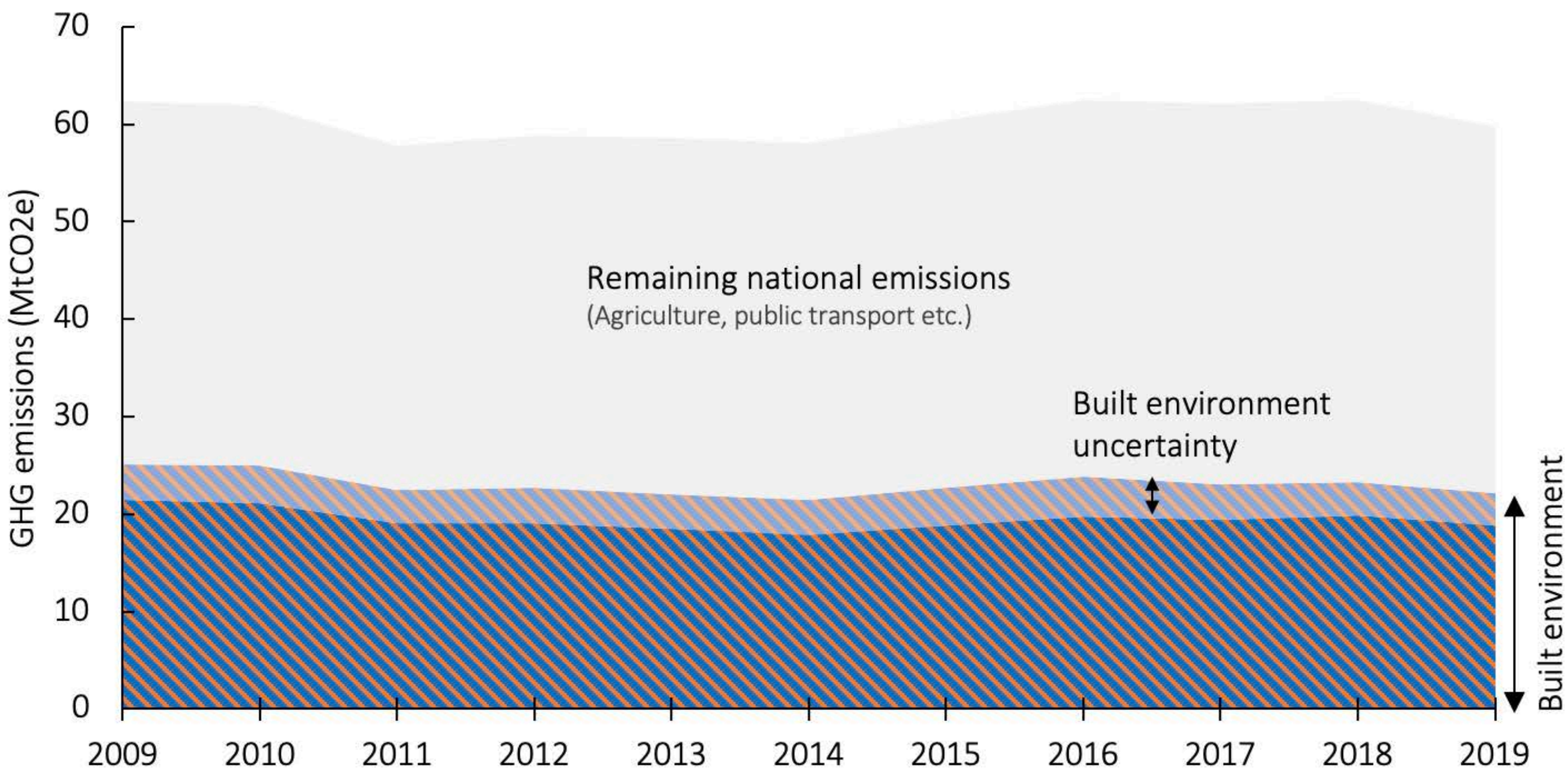
For the benchmark year of 2018 the Irish built environment was estimated to account for 23.2 ± 3.4 MtCO2e, or 37% of all national GHG emissions. This includes emissions related to the operation (14.4 MtCO2e) of the built environment and emissions related to capital construction, or those embodied in materials and products used in the construction of the built environment (8.9 MtCO2e).

Ireland's GHG consumption based emissions in 2019 were 59.8 MtCO2e, a decrease of 5% from 2018. Overall GHG related emissions have remained relatively stable in the period from 2010 through to 2019 with GHG emissions due to the built environment following a similarly stagnated trend.

These consumption emission based estimates are based on a combination of data from Ireland's national inventory of carbon (EPA) and national energy balance database (SEAI), as well as other data from the Central Statistics Office (CSO) and other reports from these three institutions.

The uncertainty in the baseline modelling of the built environment is ~15% of BE GHG and ~6% of overall GHG emissions. The uncertainty is associated to those categories which are partly-related to the built environment. For those categories it is assumed that 50% of the emissions are BE-related. A three tiered system is used and sectors are categorised as either related, not-related or partly-related to the BE.

Further tiering may enhance precision but would also increase the level of subjectivity.



National GHG emissions and those associated with the operation and construction of the built environment. Data from [6,8,18,21]

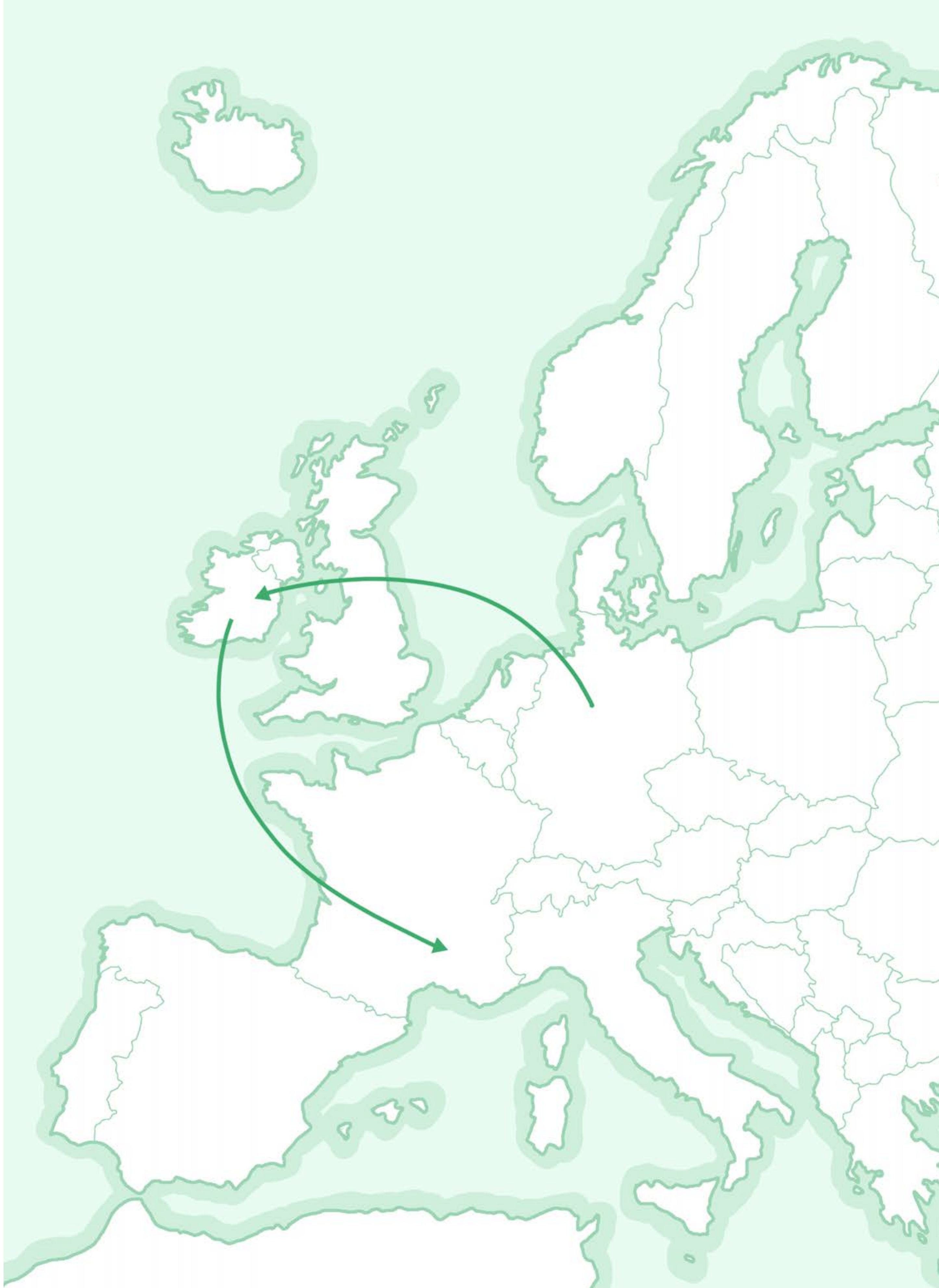
Correcting for trade

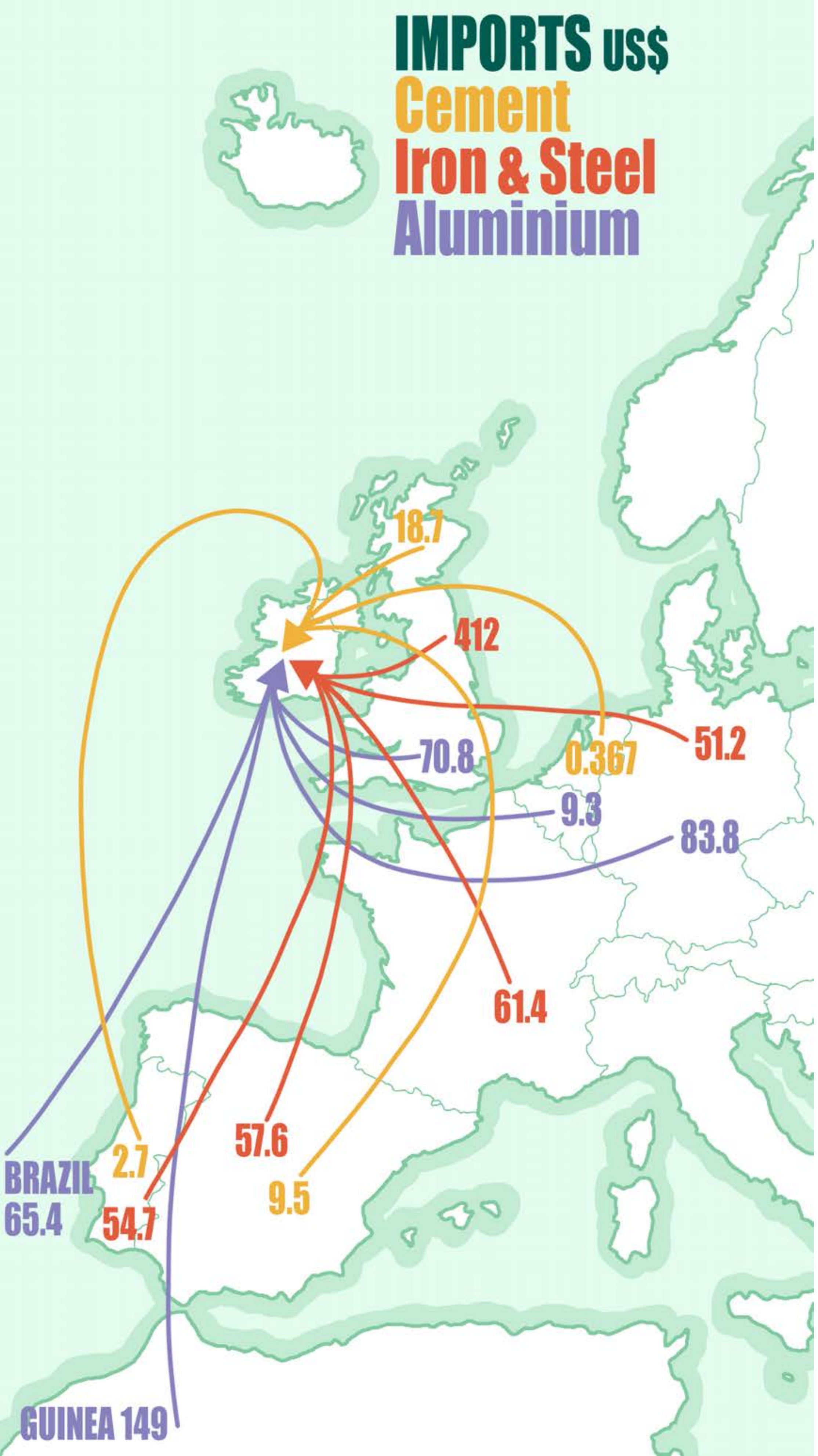
Imports & Exports

Balance of Trade

Key Points

- Ireland imports large quantities of building materials with associated high GHG emissions
- Adjustment for consumption based emissions doesn't significantly change the overall Irish BE GHG total
- Export of cement in large quantities balances the import of metals and other materials
- Cement accounts for 40-50% of emissions related to the materials used in constructing the built environment
- Steel and aluminium account for the majority of the remaining emissions from materials





Imports & Exports

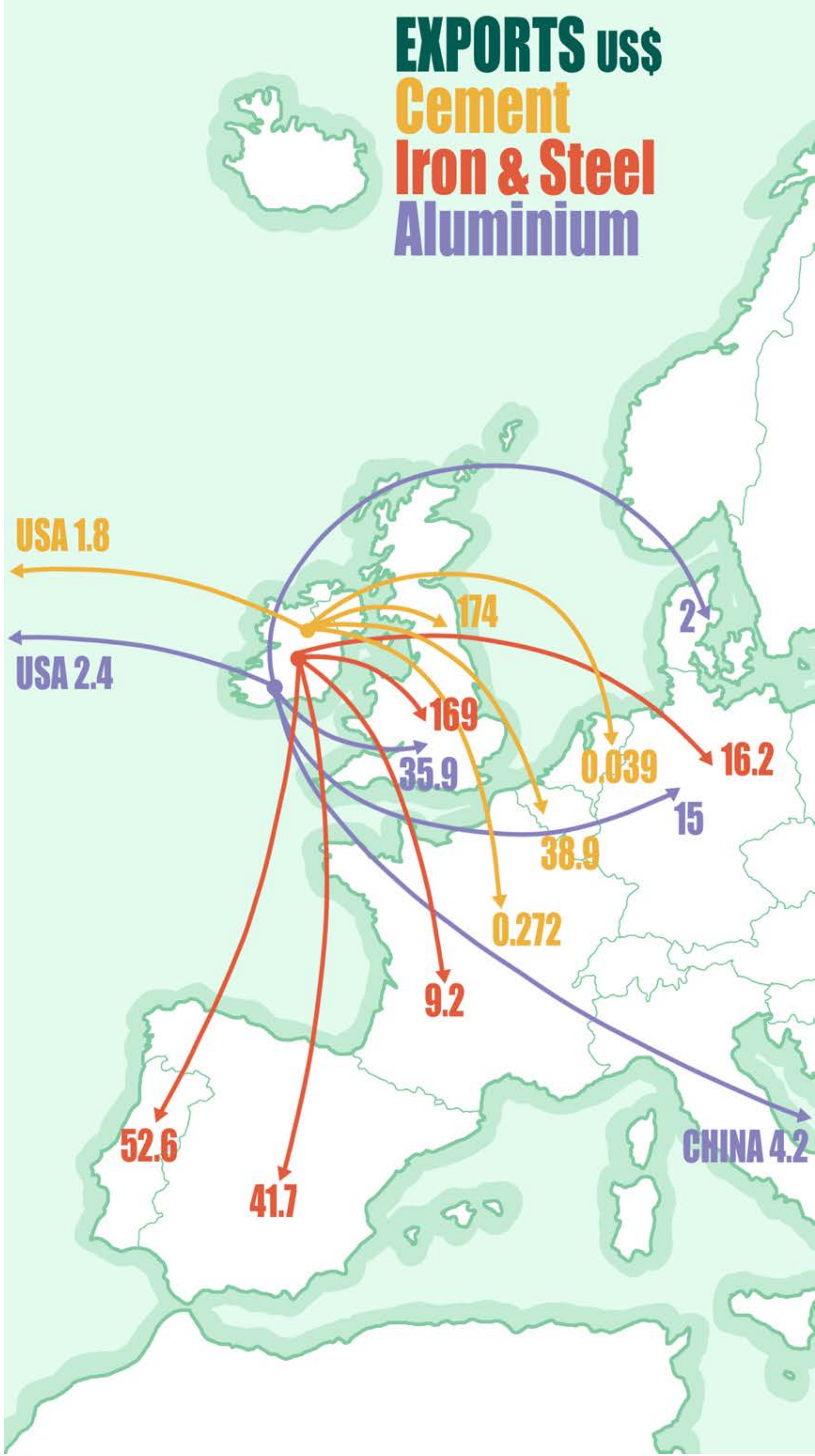
The images on either side show the key import and export destinations and sources, for the three primary categories of building materials traded.

This trade data is presented in monetary terms. However, these imports and exports are also associated with the import and export of GHG emissions.

The focus of the subsequent pages is on the quantification of any GHG accounting discrepancies caused by an imbalance in trade of materials and energy for the construction and operation of the built environment.

The vast majority of metals are imported. Cement represents the major building material exported.

This data is sourced from Resourcetrade.earth and the Comtrade database.



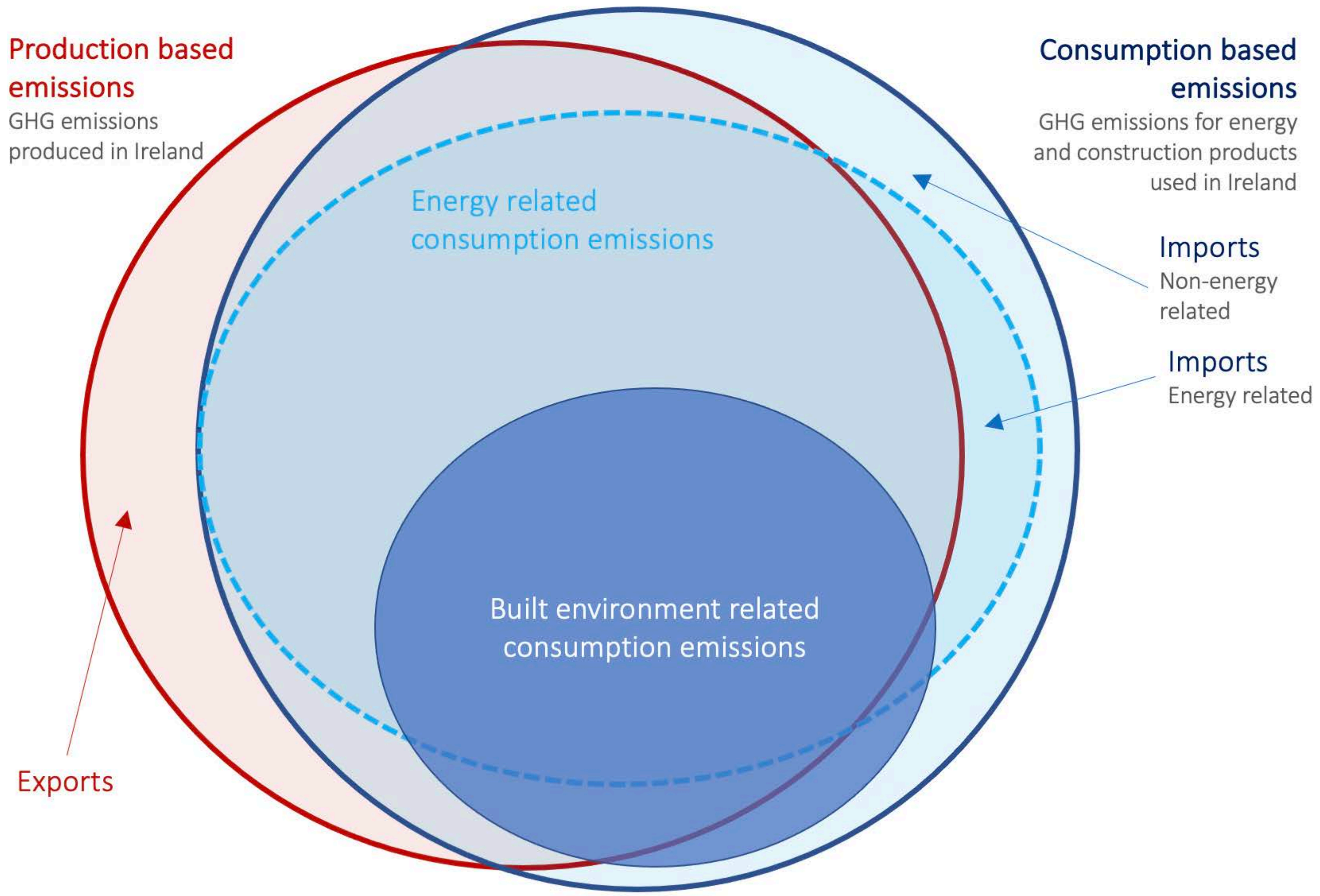
Consumption and Production based emissions

The national inventory accounts for production based emissions. CO_2 emissions measured on the basis of 'production', are the emissions related to where the emissions are produced. These are often referred to as 'territorial' emissions.

This report aims to report 'consumption based emissions', thereby adjusting emissions for trade and including emissions related to imported products for the BE in our accounting. Imported construction products for the BE thereby account for emissions from the other countries in which the materials were extracted processed and produced into building products. Exported products result in a subtraction of emissions. This adjustment is made wherever possible and always for the four years period of 2016 - 2019.

Ireland is a net importer of some materials, products and energy used in the BE. Thereby it is a net importer of GHG emissions. Hence consumption based emissions are greater than production based emissions.

Data for production based emissions is primarily sourced from reports developed by the EPA Ireland. They maintain a GHG carbon inventory database with yearly updated totals. Data is documented for 4 primary sectors (Energy, Agriculture, Waste and Industrial processes) and 46 IPCC-defined sub-sectors, some of which are fully or partly associated with the built environment.



Conceptual diagram of production and consumption related emissions

Consumption based emissions

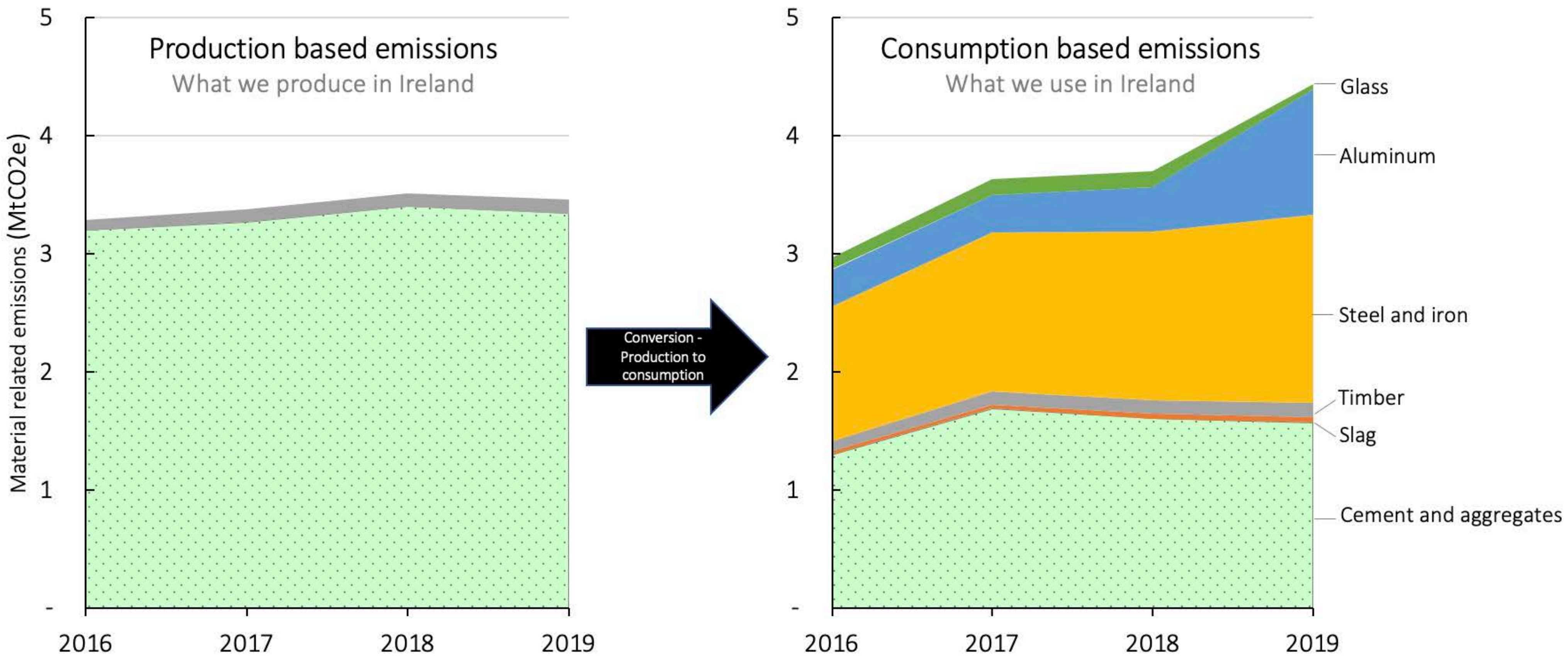
Energy ⚡ | Energy-related emissions reported in this document are based on SEAI energy balance data sheets which report final energy consumption. These relate to consumption based emission data and do not need correcting.

Materials | Material related emissions do require adjustment as the raw data used is reported on a production basis.

Taking production based emission data (sourced from the EPA GHG inventory) gives a reasonable estimate of overall GHG emissions related to the processing and manufacture of building materials. However the breakdown of the materials themselves presents a different picture, as shown in the adjacent image.

Cement and aggregates account for 43% of material related GHG emissions used in the built environment rather than the >90% indicated by the production based accounting. The balance is exported.

Ireland imports metal products, in their final processed form, in large quantities. Rock, oxides and ores are quarried in Ireland, and used in local produced building products. Some, such as alumina deriving from bauxite, are exported for processing, and later re-imported as aluminium.



Material related GHG emission comparison | Production vs Consumption

Material emissions

The embodied carbon emissions related to the built environment are divided into material type using 6 primary materials.

- Steel and iron
- Aluminium
- Cement and aggregates
- Timber
- Glass
- Slag

In their report, Cambridge Architectural Research Ltd (2021) identify 10 primary materials. In this report, a different taxonomy is required to facilitate the different input sources and hence 6 materials are defined.

Precast and brick concrete products are not included as their inclusion would result in double counting of the materials from which they are made (e.g. cement). Therefore this exercise captures the raw materials.

The trade of waste is not included as this is captured elsewhere in the model.

Aluminium | The production of aluminium encompasses several environmentally-impacting steps. Alumina is produced in Ireland from bauxite, which is then exported around Europe to produce aluminium. This is subsequently imported in the form of processed final building products. This complicates the accounting of aluminium as there are multiple phases, some requiring assumptions. A detailed study is outside the scope of this research. Instead the study considers only aluminium products. Data is accessed from the Comtrade database (Comtrade, 2021). An EU averaged embodied carbon figure for aluminium of 6.7 kgCO2e/kg (ICE Database V3.0, 2019) is used to estimate the emissions associated with aluminium imported into Ireland.

Steel | Steel is no longer produced in Ireland and hence CO2e emissions associated with steel production are reported as zero in Ireland's national carbon inventory (EPA, 2021). However, steel is used to construct the built environment and hence needs to be accounted for. Worldsteel (2020) estimate the crude steel equivalent use for Ireland per year. They estimate that in 2018, for example, Ireland used 759,000 tonne of steel. Their most recent embodied carbon estimate for crude steel is 1.89 kgCO2/kg ("worldsteel | sustainability indicators," 2020) which equates to 1.4 MtCO2e used in Ireland in 2018.

Cement | Ireland produces cement in large quantities. In fact, much of the cement (~50%) produced in Ireland is exported. GHG emissions reported for cement by the EPA are those associated with production only and hence not all related to the Irish built environment. Taking 2018 as an example year, 3.4 MtCO2e may be attributed to the production of cements and aggregates in Ireland. In the same year 2.4 Mt (by mass) of cement was exported (Chatham House, 2021), which is equivalent to 1.7 Mt of CO2e - taking an averaged embodied carbon figure of 0.7 kgCO2e/kg (Cambridge Architectural Research Ltd, 2021). This means that only ~50% of emissions related to the cement produced in Ireland are associated to the cement used in the Irish built environment.

Others | GHGs deriving from other materials including timber and glass represent a much smaller share (2.5% and 1% respectively). Slag is imported to Ireland where it is then ground and used as a cement replacement, the majority of which is used in the home market. Ireland is reported to use up to 75 million bricks per year. Bricks contain some of the raw materials that are being accounted for elsewhere including cement.

Consumption and Production of Energy

Ireland imports the majority of its fuel for energy generation, including the majority of fossil fuels beyond peat and a portion of natural gas.

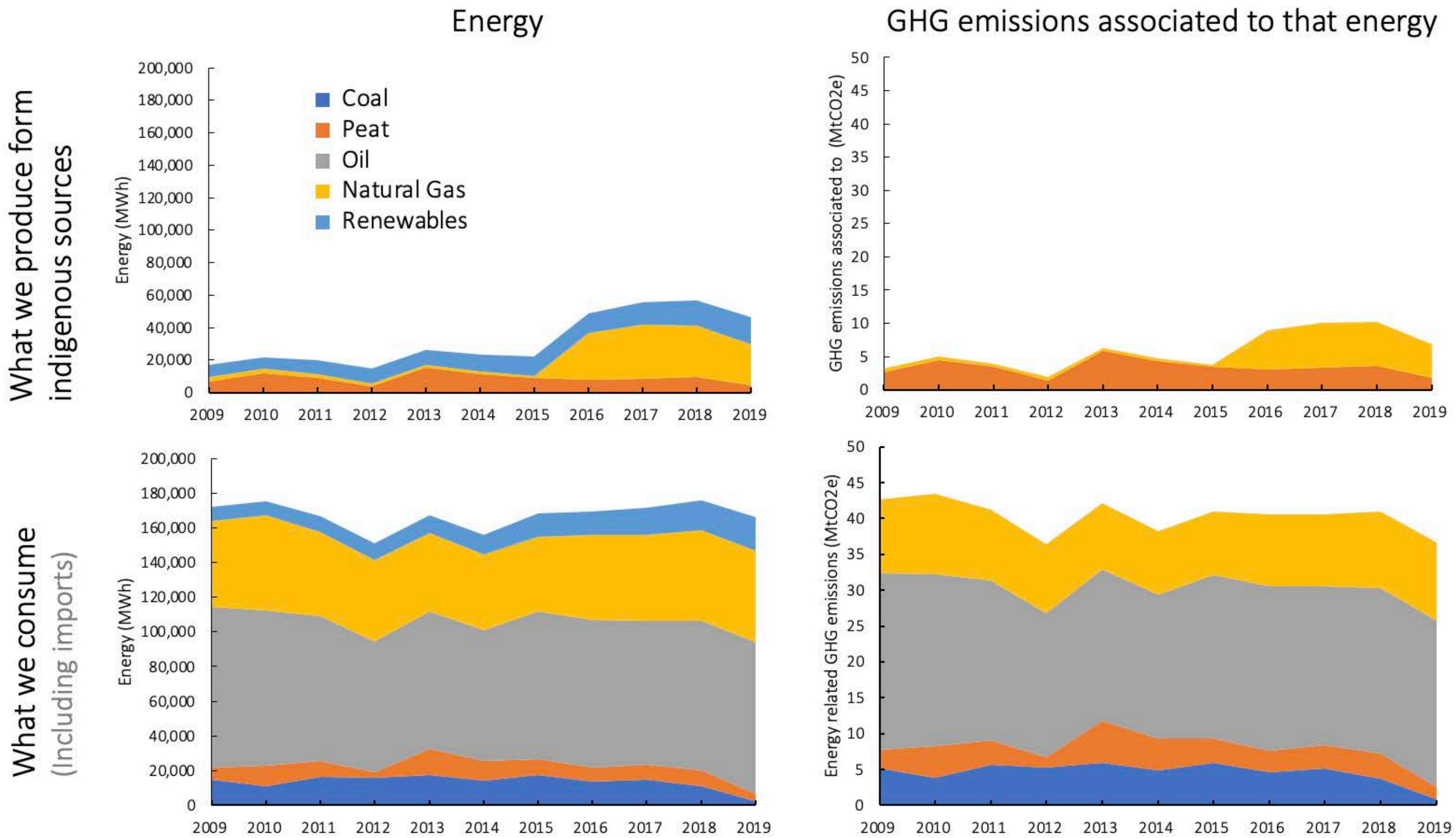
90% of Ireland's energy needs were supplied by imported sources in 2009. An increased supply of local natural gas from the Corrib gas field reduced this dependency on imported natural gas from Britain to ~70% between 2016 and 2019, but this source is again depleting.

The increasing share of renewable energy generation has reduced dependence on imported sources and has improved the carbon intensity of electricity over the last two decades. In 2009, 5% of all Irish energy consumption was from renewable sources while in 2019 this figure was 11%.

Only some of the energy presented is used for electricity generation. In 2019 approximately 28 GWh of energy was consumed while 16 GWh of energy was produced from renewable sources in Ireland - meaning approximately 58% of Irish electricity could have come from renewable sources.

In 2019, 63% of energy related GHG emissions from all sectors were from the combustion of imported oil, the majority of which (~70%) was for the transport sector. Some of which can be attributed to the built environment in the form of embodied energy of materials and buildings.

Ireland also imports and exports a small portion of electricity through the inter connector with the UK. This accounts for a very small portion of the overall energy balance and is not included in the graphs below.



Overview of energy consumption and production for all sectors in terms of both energy and associated GHG emissions

A closer look at emissions across

Ireland's Built Environment

Emissions from the Built Environment

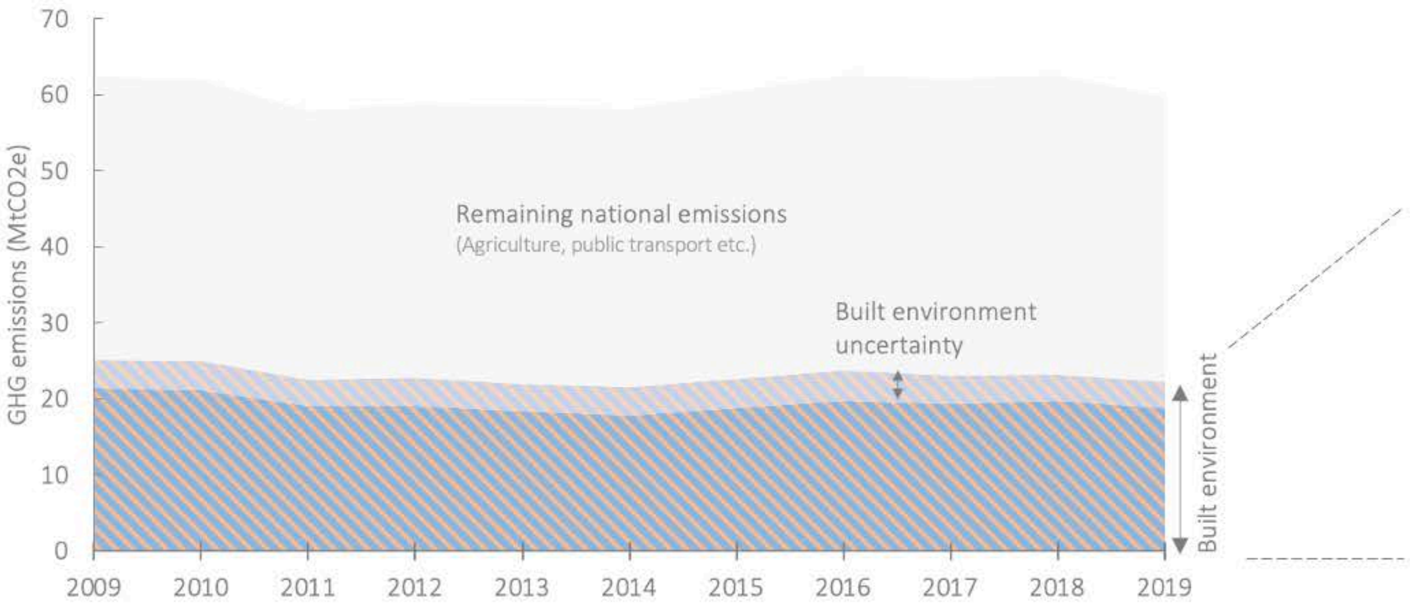
Built environment emissions are divided in the first instance into embodied (EE) and operational (OE) emissions. These are further subdivided into emissions related to different materials and construction stages, and to the operation of varied building types/sectors.

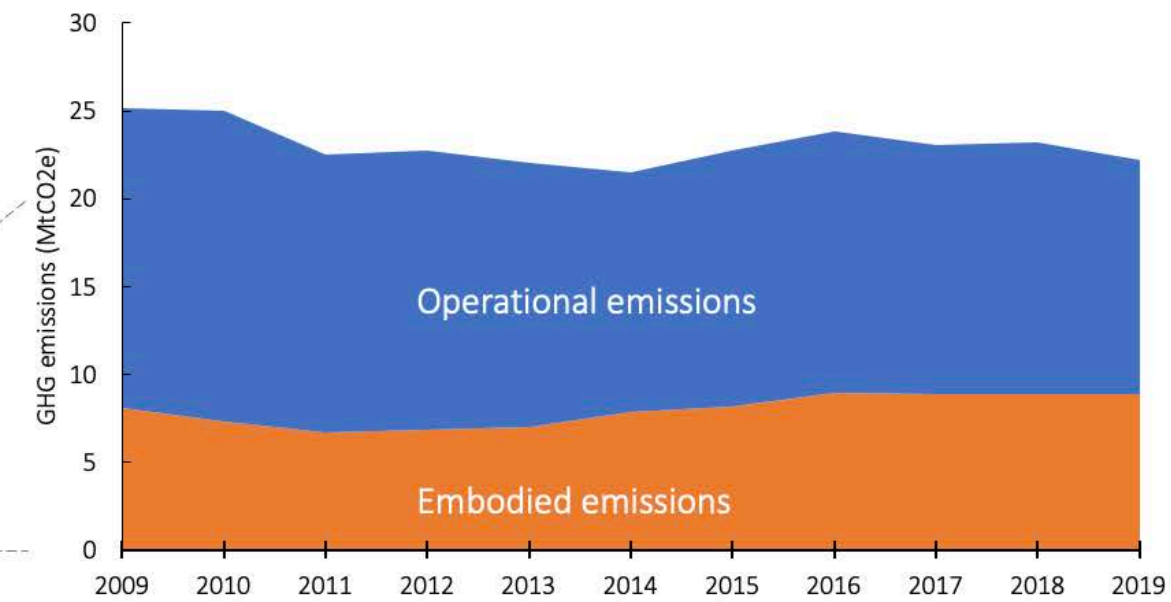
Total BE related emissions trended downward in the early part of the last decade due largely to a reduction in construction activity, during and following the economic downturn. They rebounded somewhat in the middle of the decade but have trended downwards again in more recent years due primarily to improvements in the carbon intensity of electricity.

In the baseline year of 2018 operational related emissions accounted for 62% of all BE emissions, and 23% of national emissions. In the same year capital or embodied related emissions accounted for 38% of all BE emissions, and 14% of national emissions.

In contrast, in 2011, OE and EE represented 70 and 30% of BE emissions. The proportional impact of embodied carbon is becoming increasingly significant, as building operational energy and the associated emissions reduce. In 2011 the embodied carbon total accounted for 30% of all BE related GHG emissions. In 2018, 38% and 2019 it totalled 40% of BE emissions.

Today, operational carbon from the residential sector continues to dominate BE emissions, as is later explored in more detail. It accounts for 43% of the built environment related emissions and 16% of national emissions in 2018. Hence, this is a key target area of national climate policy.





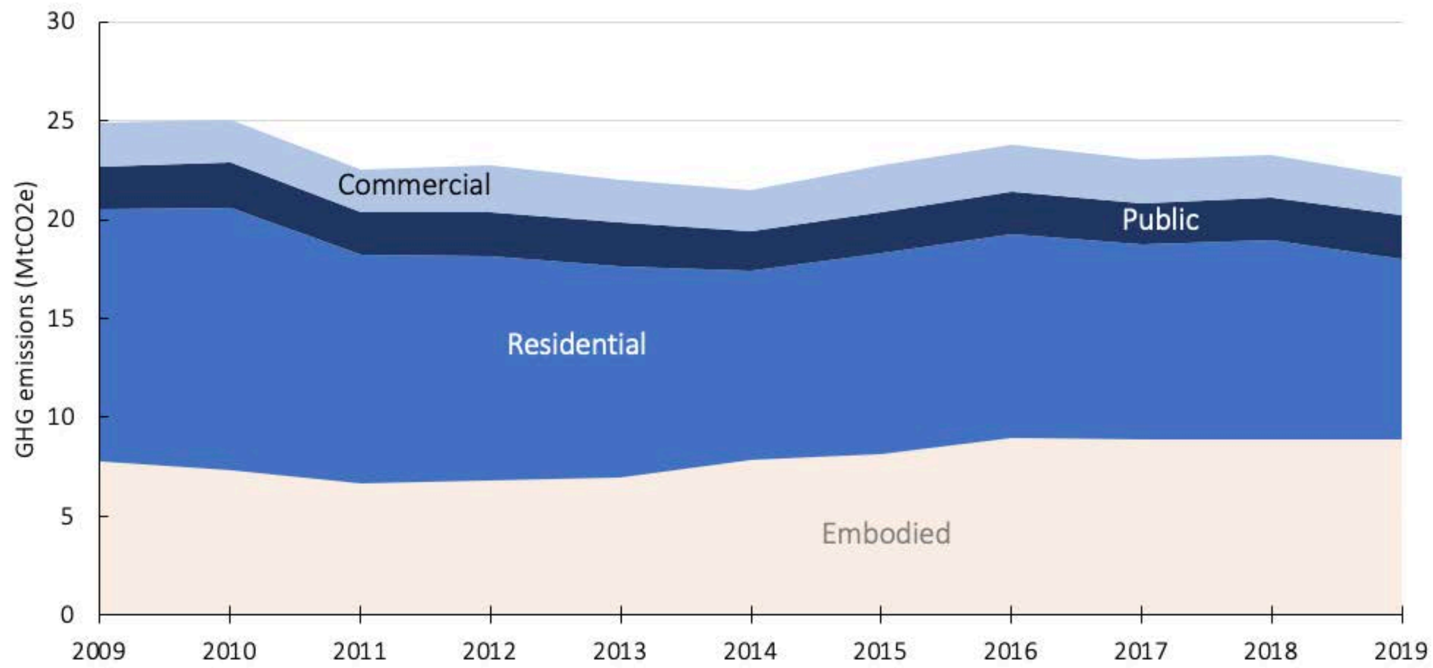
GHG Emissions for the BE divided into embodied and operational

Operational Emissions

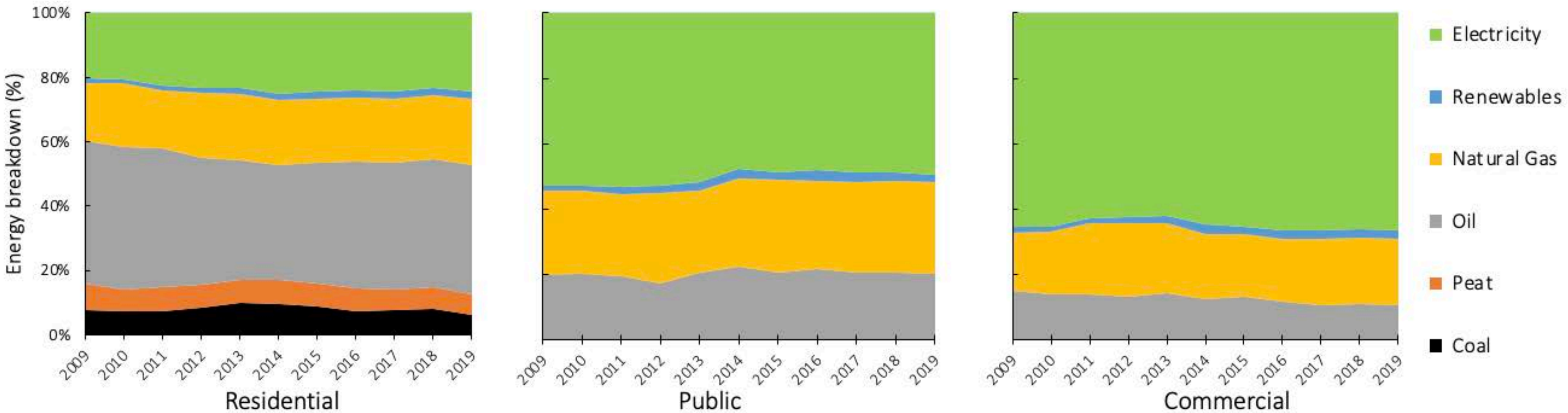
Emissions related to the operation of residential, commercial and public buildings accounts for the most significant share of BE emissions as shown adjacent.

The residential sector accounts for more than half of all building OE. This is due to the scale of the sector (>2,000,000 units), magnitude of the energy requirement of the sector (35 GWh/year), and its reliance on fossil fuels (75%) particularly for heating.

Recent reductions in residential related emissions can be attributed to a combination of better performing buildings and a slight increase in electricity usage. However (in 2018), a large proportion of the residential sector continues to rely on oil (40%), peat (7%) and coal (8%) for space heating. The commercial and public sectors are powered by a greater proportion of electricity.



Above. Operational emission breakdown by sector (also showing embodied emissions)



Above. Operational sector breakdown by fuel type

Embodied Emissions

Emissions embodied in the built environment include emissions from the processing of raw materials, manufacturing of products both on and off site as well as the emissions associated with the maintenance and end of life of the materials and products used in the built environment. Since 2011 the embodied carbon has steadily increased. Operational carbon emissions will decrease in line with a reduction in the carbon intensity of electricity resulting in a proportional increase in the embodied carbon related emissions.

Product (A1-A3) | Product stage

production boundaries account for the largest share of embodied carbon related GHG emissions. 21% of BE-GHG and 54% of embodied BE-GHG.

Construction (A4-A5) | The

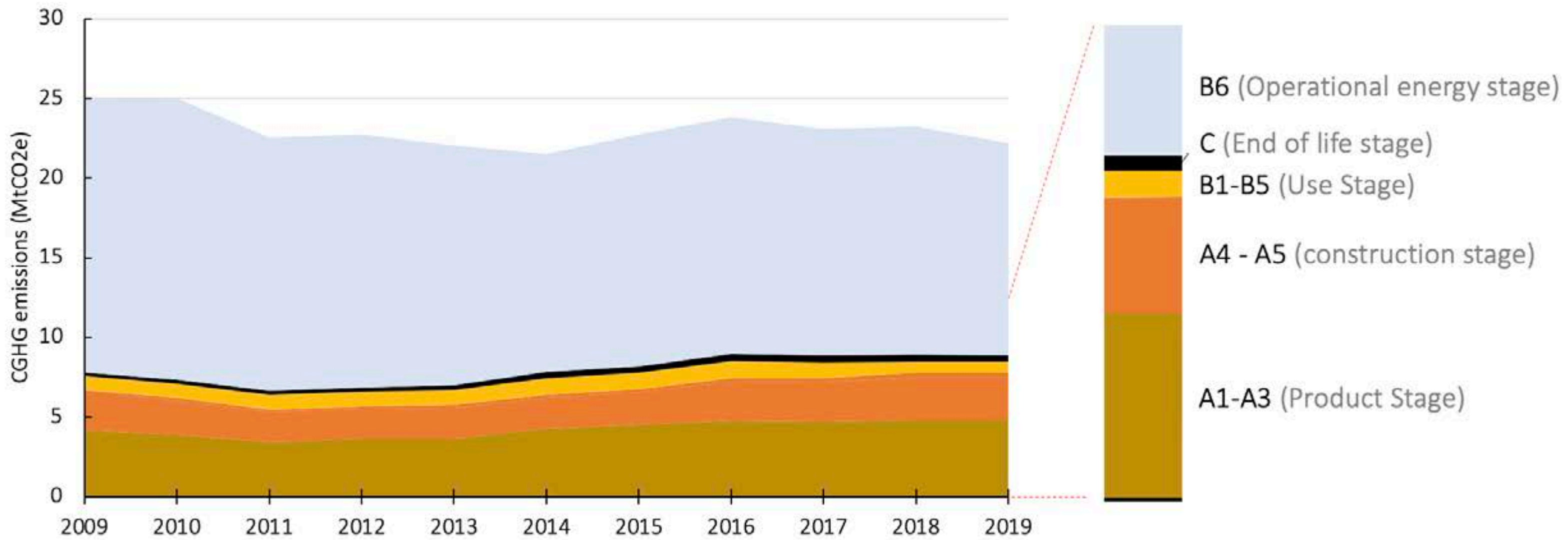
construction stage emissions derive predominantly from the transport of materials. The embodied carbon associated to transport also has the largest individual uncertainty associated to it due to the paucity of granular data related to this sub section.

Use (B1-B5) | This stage is

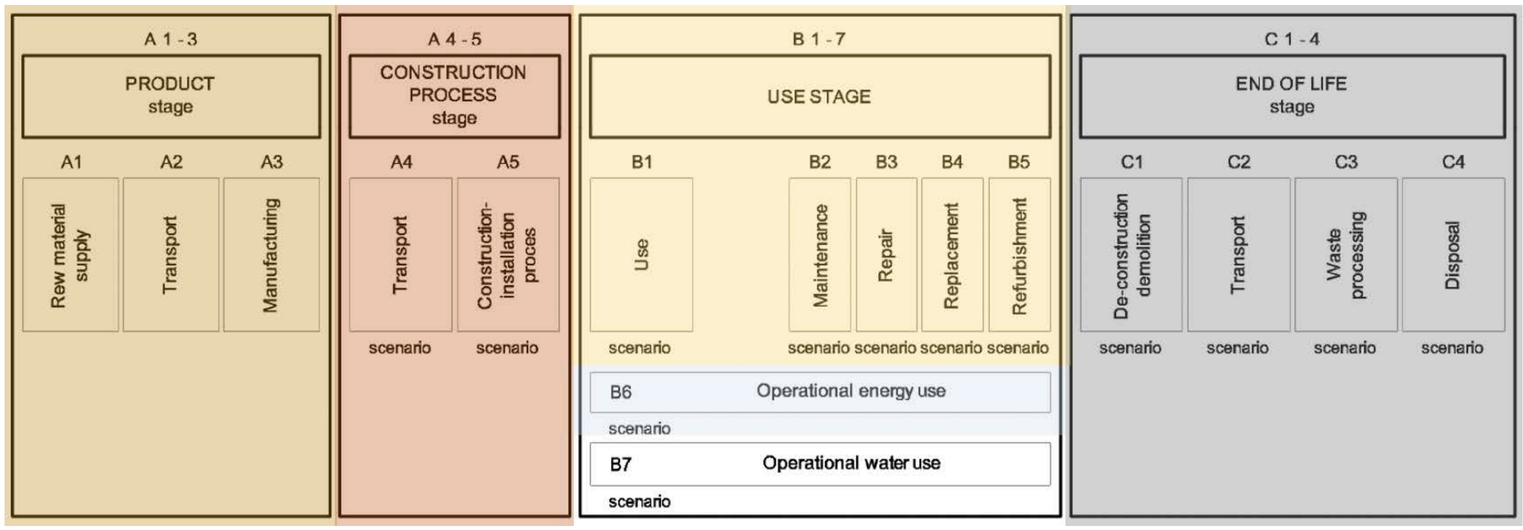
predominantly associated with refrigerant leaks a sector expected to increase in the future with the roll out of heat pump technology.

End of life (C) | These are the emissions

associated to the disposal of the materials at their end of life.



Embodied carbon of the built environment divided into life cycle analysis stages defined in EN 15978



Extract from EN 15978 “Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method”

Carbon Intensity of the Built Environment

The carbon intensity of the built environment refers to the GHG emitted for a unit of energy averaged across the mix of fuels used to heat and power our buildings.

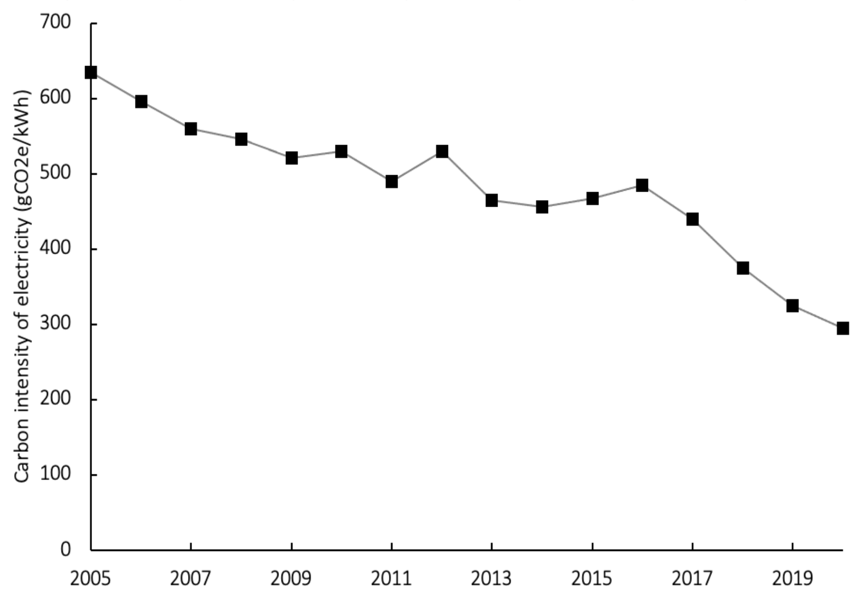
Key factors affecting the carbon intensity of the BE include the proportional usage, and carbon intensity, of electricity, as well as the mix of fossil fuels used in the different sectors of the built environment. These impact the GHG emissions of both buildings in operation and the construction of buildings and infrastructure.

The decarbonisation of grid supplied electricity has been significant between 2005 and 2018, with a 40% reduction in carbon intensity achieved primarily as a result of significant expansion of the wind power sector. The carbon intensity has fallen from 635 gCO2/kWh in 2005 to 375 gCO2/kWh in 2018. It has continued on a downward trend to 324 gCO2/kWh in 2019.

Despite this, the latest data shows that the CO_2 emissions intensity of Ireland's energy supply is 20% higher than the European average.

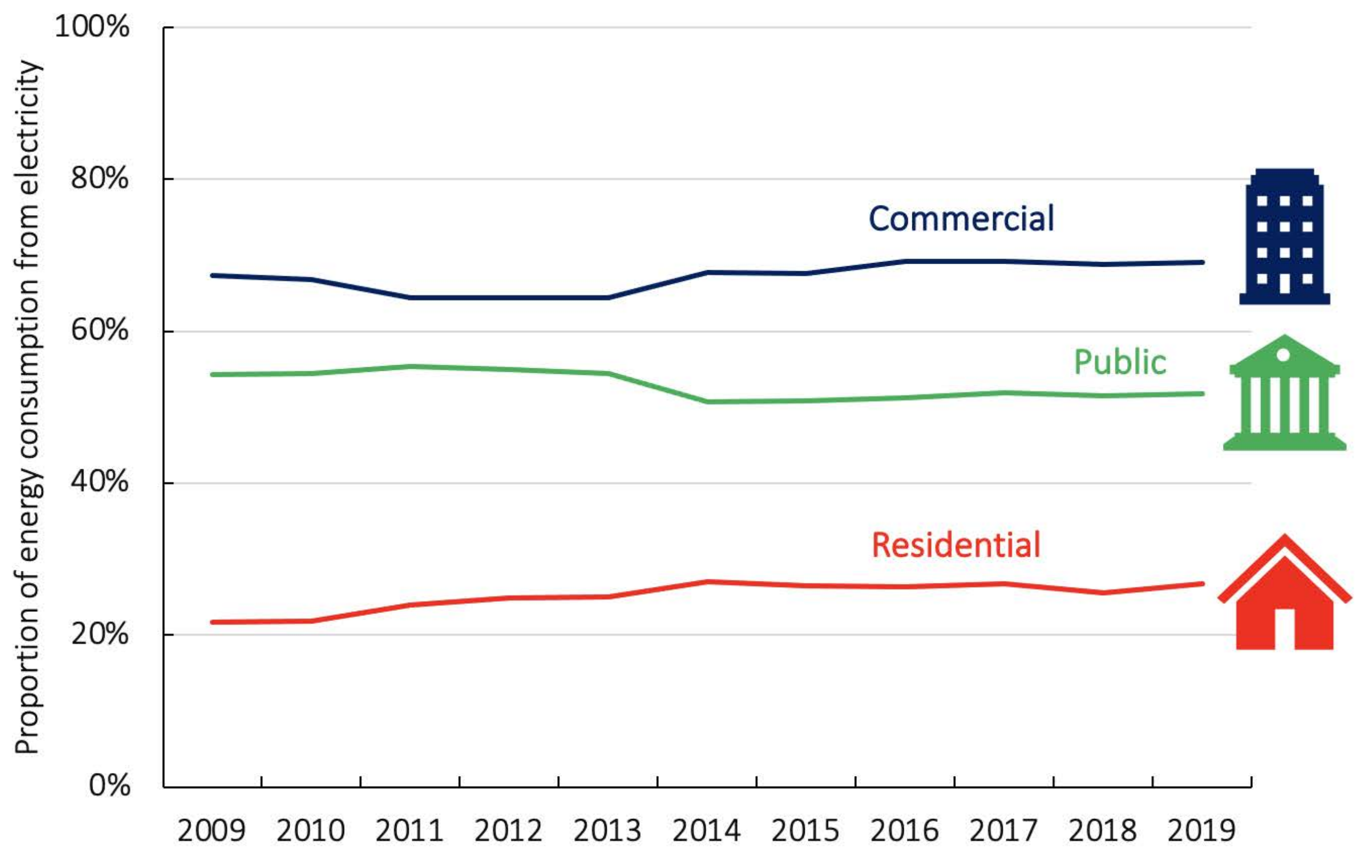
However, the impact of the improvement is pronounced on the operational related emission output.

The impact on emissions related to construction material is not as pronounced as many rely on fossil fuel sources and/or imported construction products often from countries with higher fossil fuel reliance. Additionally, process emissions, such as those from converting limestone (CaCO3) into lime (CaO) and cement, are not influenced by any change to the electricity grid.



Above. Historical carbon intensity of electricity [22]

Below. Proportion of energy from electricity by building type

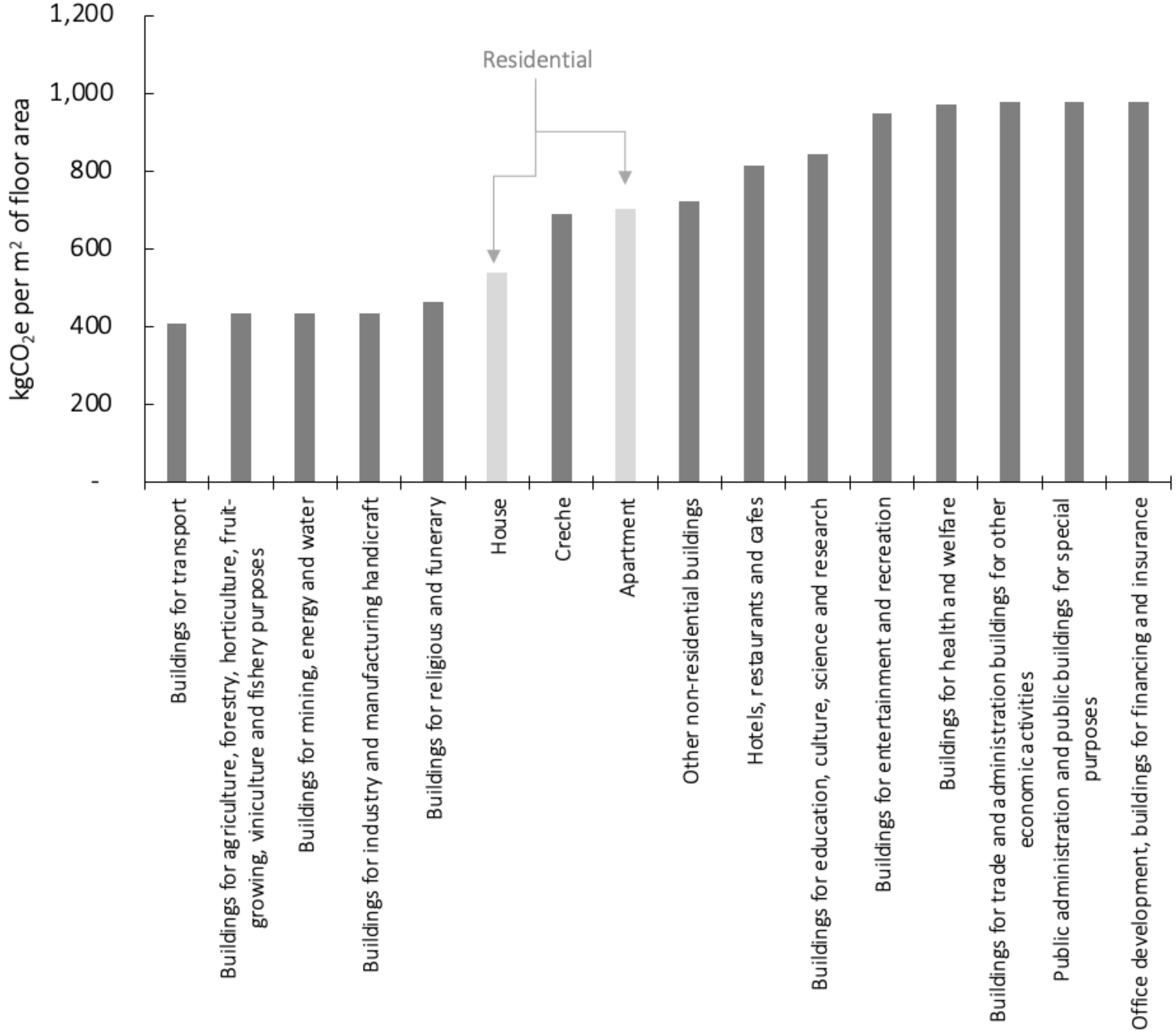


Carbon cost of construction

The embodied carbon of the built environment is also quantified based on a top down method. Where carbon intensity per m2 of floor area data (taken from the RICS "Methodology to calculate embodied carbon of materials" report) is multiplied by the m2 of floor area constructed. This is particularly useful for this exercise was it allows for a division between types of construction.

The carbon cost of building commercial offices (~1000 kgCO2) is almost 40% higher per meter squared than that of building housing (~580kgCO2). Other academic studies of the embodied emissions of housing have calculated the carbon cost of construction reporting values in a wide range (~300 kgCO2 - 1000 kgCO2)

The carbon cost of retrofit is later presented through a case study (Page 42). Although not representative of all retrofit, and likely on the high side given the ratio of technology to floor area in that case study, it shows that deep retrofit of housing comes with significant embodied carbon emissions that are often under quantified.



GHG emissions for varied building types based on a kgCO2 per m2 floor area. (RICS)

Focus on the

Current Residential Sector

This section evaluates emissions related to existing residences. It evaluates and quantifies the operational and embodied carbon of the current housing stock.

Residential

Key Points

GHG emissions related to residential operational energy accounts for 45% of all built environment related emissions

75% of the housing stock is C rated or below, with operational energy of > 50 kgCO2e/m2/yr

71% of the average home's energy demand is from fossil fuels

The average floor area of an A-rated building = 132 m^2 while the average floor areas of a G-rated building = 83 m^2

Residential Emissions

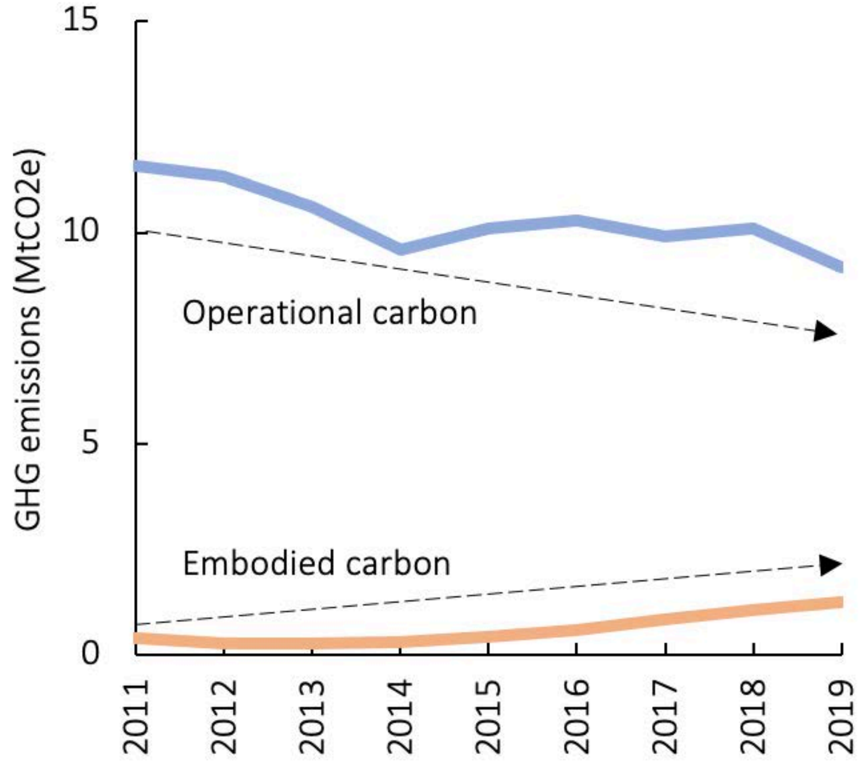
The operation of the residential sector alone accounts for just under half of all BE related emissions over the last decade. In 2018 the GHG emissions associated with the operation of the residential sector was 10 MtCO2e.

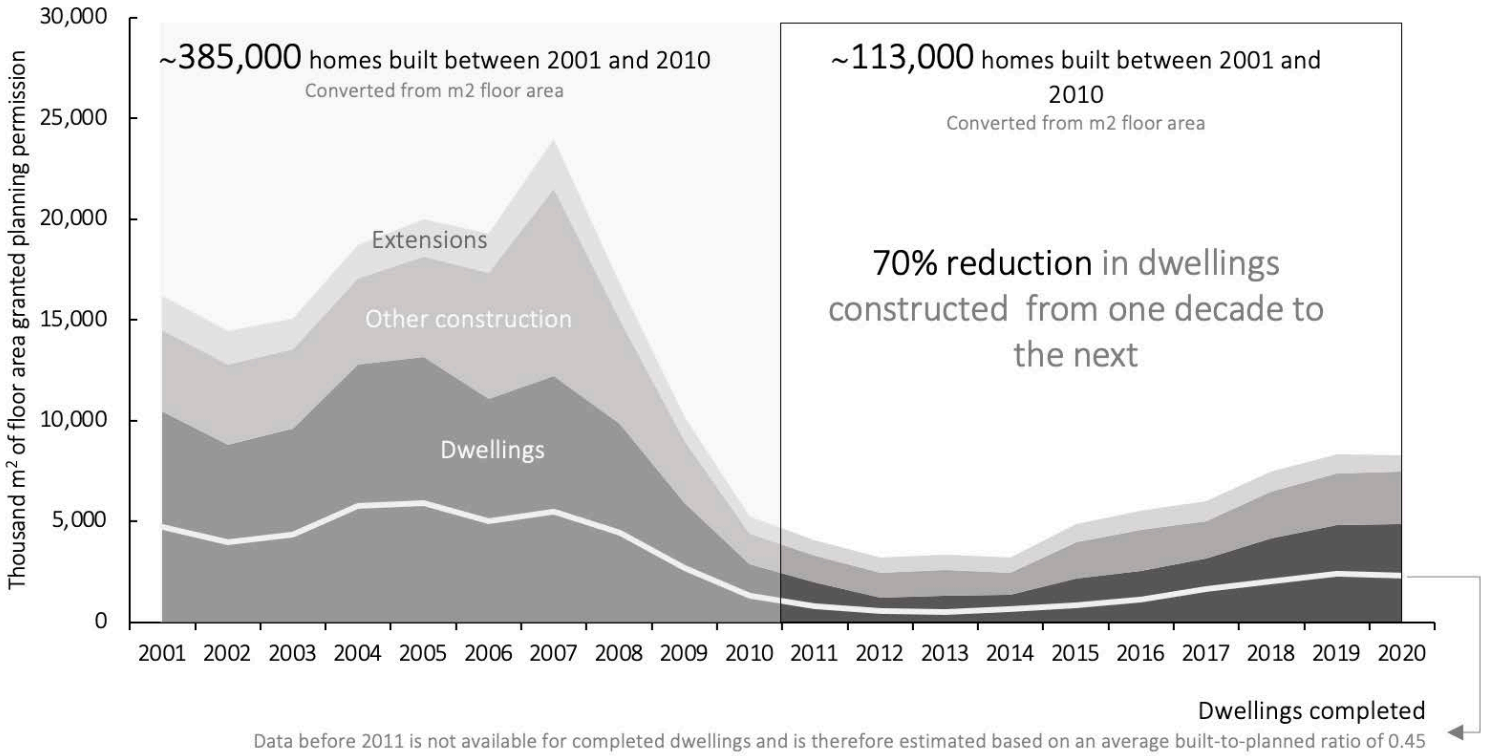
The global economic crisis of 2008 had a considerable impact on Irish construction, resulting in an overall reduction in dwellings constructed of 70% from the first to second decade of the current millennium.

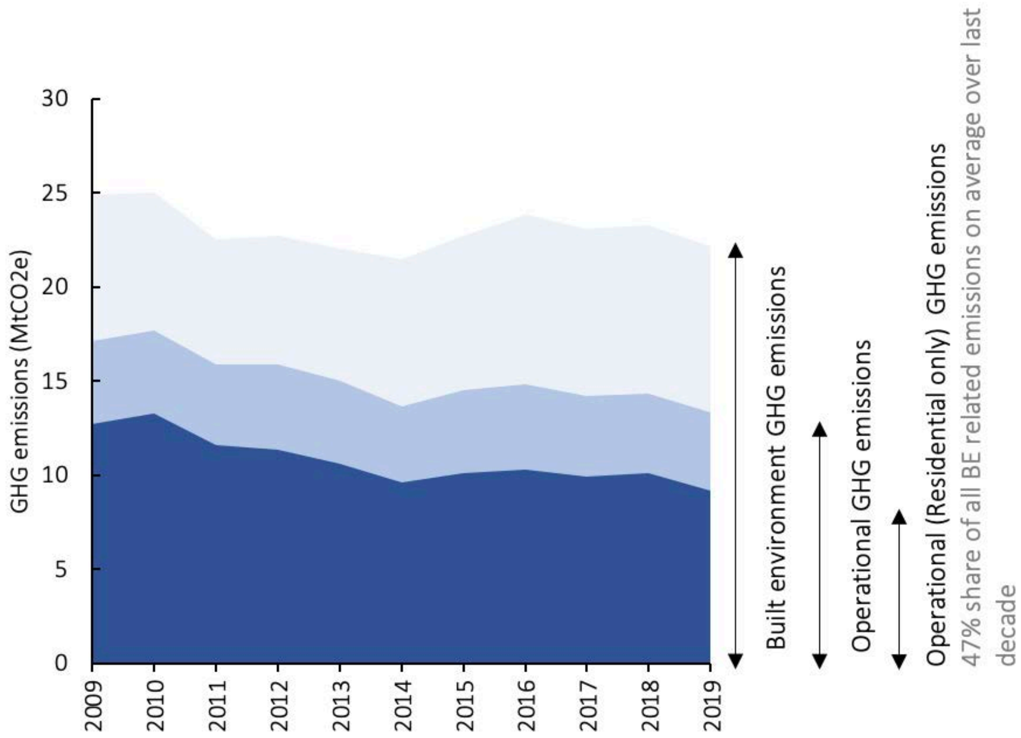
A slow increase in the construction of dwellings has been observed between 2012 and 2020 with a slow decrease in operational emissions for that same time period. This reduction in emissions can be attributed to a decrease in the carbon intensity of the electricity grid and an increased proportion of more energy efficient homes, despite the greater number of homes.

The operational carbon is reducing, despite the increase in building stock, but the embodied carbon portion is on the rise.

Data is taken from a combination of CSO databases, namely BHA03 and NDA02.



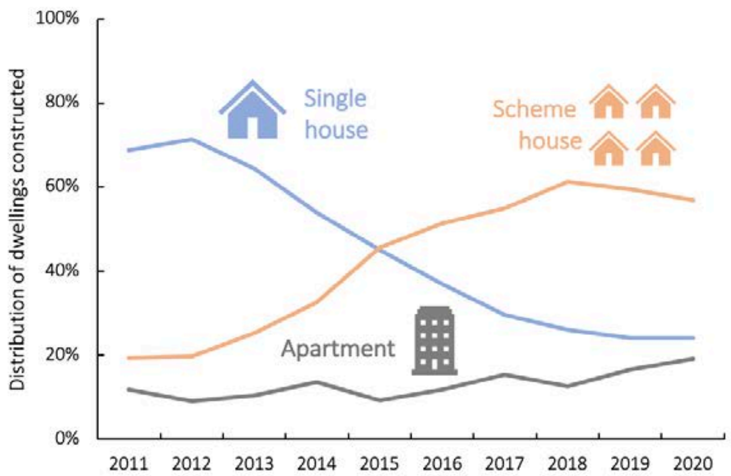




Residential building stock

In 2011 (the year with the lowest level of residential construction over the last two decades) 70% of dwellings constructed were once-off or stand-alone housing. Only in recent years has the share of development of housing schemes (estates) and apartments increased.

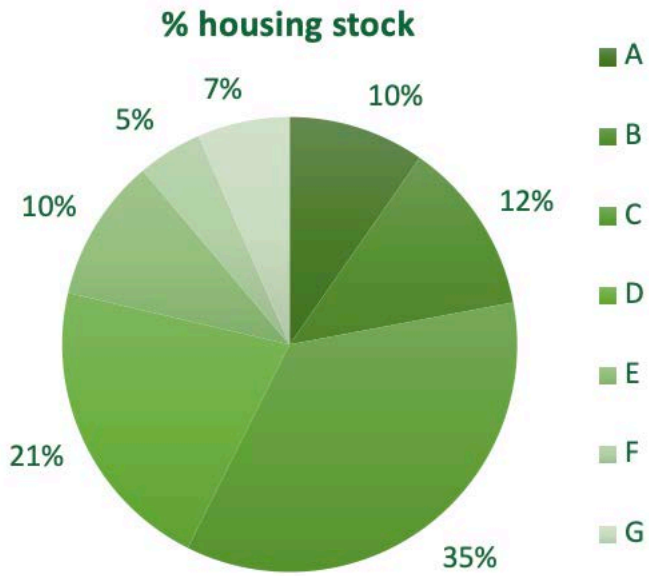
The lack of construction over the last decade has resulted in a housing crisis and a requirement for more homes.



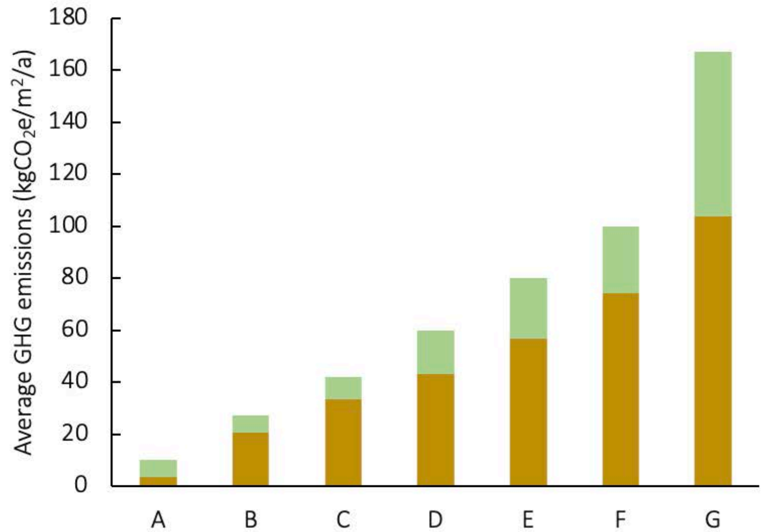
A total of 2,003,645 homes were counted from the latest census report of 2016. Of these homes 183,312 were permanently vacant. Between 2016 and 2020 an additional 83,000 homes have been built, resulting in an estimated number of occupied dwellings of 1.89 million. Of these homes ~1 million have a Building Energy Rating (BER) - 52%.

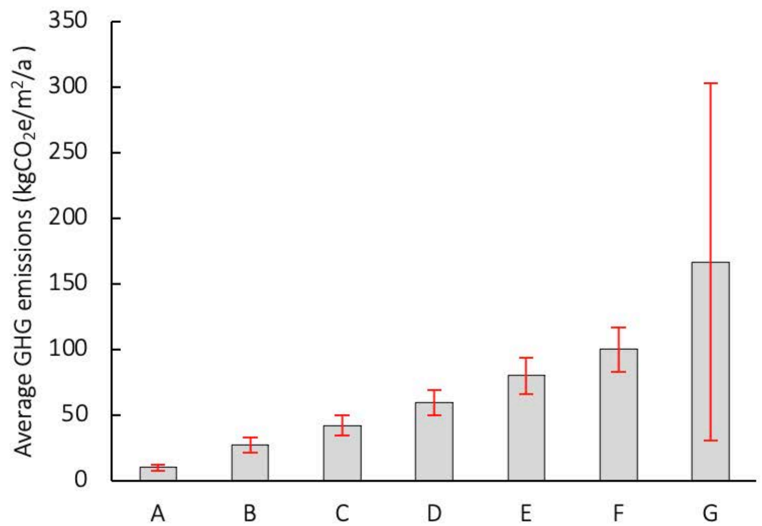
The model used in this work assumes that the SEAI's BER database provides a representative sample of all occupied buildings in Ireland. The proportional number of buildings with BERs therefore scaled up by a factor of 1.92 (1/52%).

The housing stock



- Less than 25% of the housing stock is A or B rated.
- The carbon intensity of a home in Ireland on average is 56 $kgCO_2e/m^2/a$ with a standard deviation of 17 $kgCO_2e/m^2/a$.
- 71% of buildings energy demand is from fossil fuels and 29% from electricity
- The average heated floor area of an Irish building is 113 m^2.
- As the energy rating increases from G through to A, so does the average floor area. The average floor area of an A-rated building = 132 m^2 while the average floor areas of a G-rated building = 83 m^2.





Focus on the

Current Other Sectors

This section evaluates emissions related to non-residential buildings and infrastructure.

Other sectors

Key Points

GHG emissions from non-residential construction is ~2.7 $MtCO_2e$ with ~1.4 $MtCO_2e$ due to commercial building

Emissions due to operation of the non-residential sector in 2018 was 30% of overall operation related emissions

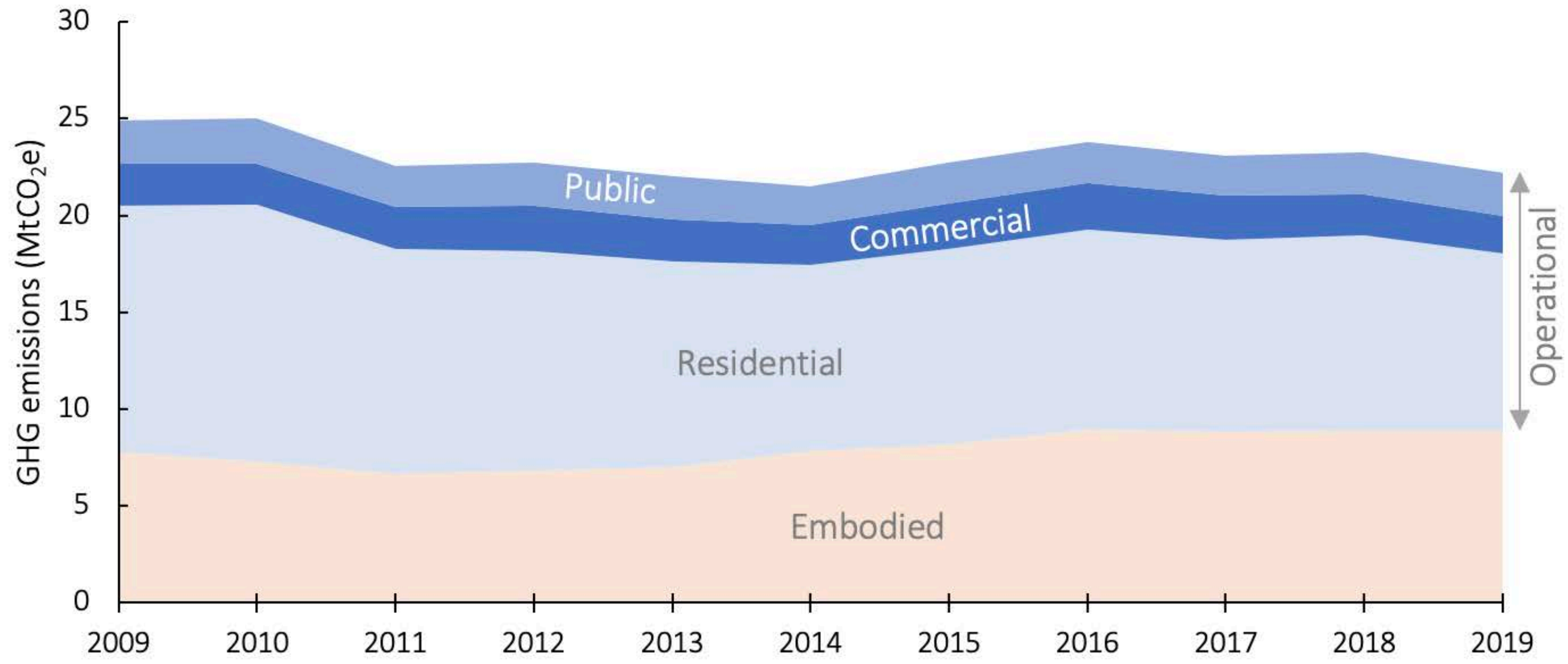
> 8% of the total non-residential constructed floor area in 2018 was for education or healthcare buildings

Varied methodologies of embodied carbon emission quantification are presented and do not show significant difference

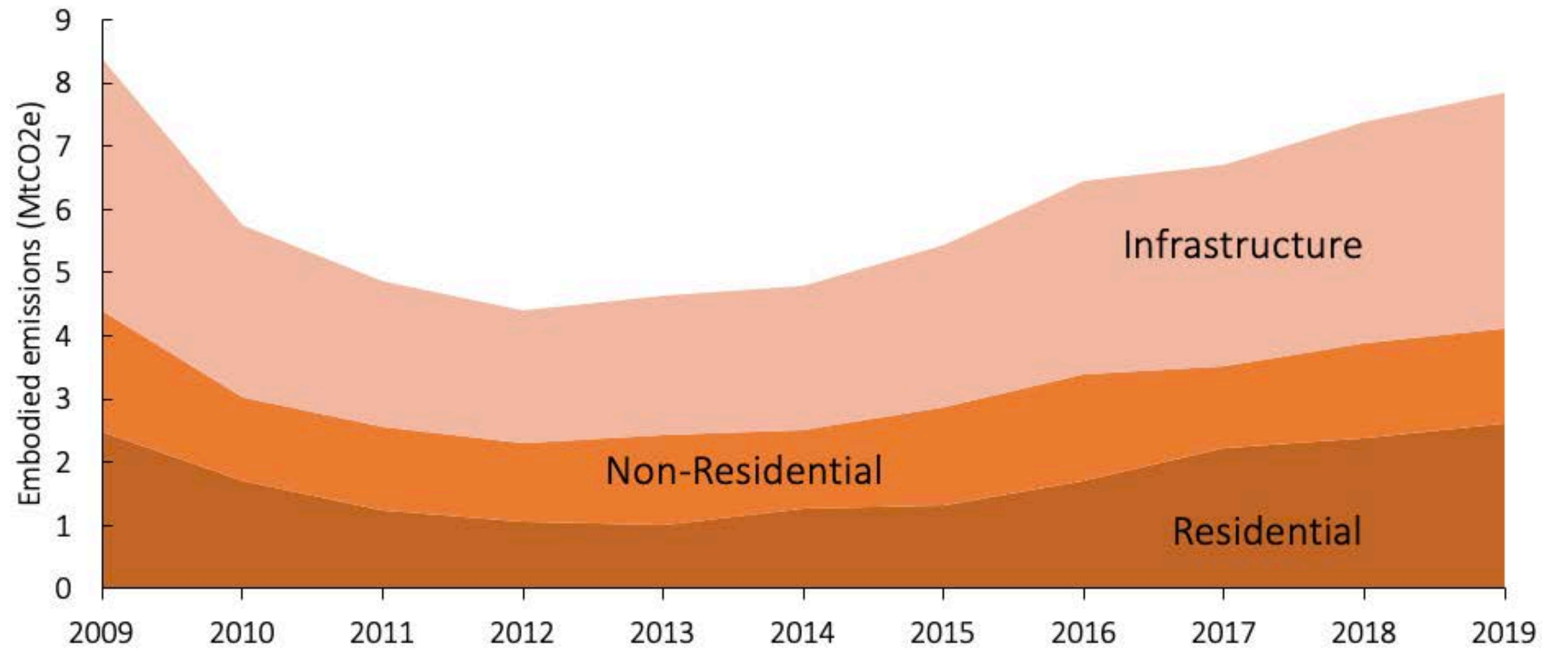
Other Sector Emissions

Operational | The share of operational carbon attributed to non-residential buildings, including commercial and public buildings, was 29% of all operational emissions in 2018 and represents approximately 20% of all built environment related GHG emissions. In 2018 operational emissions related to the commercial sector totalled 2.1 MtCO2 and those related to the public sector totalled 2.2 MtCO2.

Embodied | Construction is increasing in Ireland across all building sectors. Hence, the total and share of embodied emissions is increasing. The embodied carbon attributed to residential buildings (2.4 MtCO2) outweighed that of non-residential buildings (1.5 MtCO2) in 2018. All are proposed to increase considerably in coming years.



Above. GHG emissions for varied building types based on a kgCO2 per m2 floor area



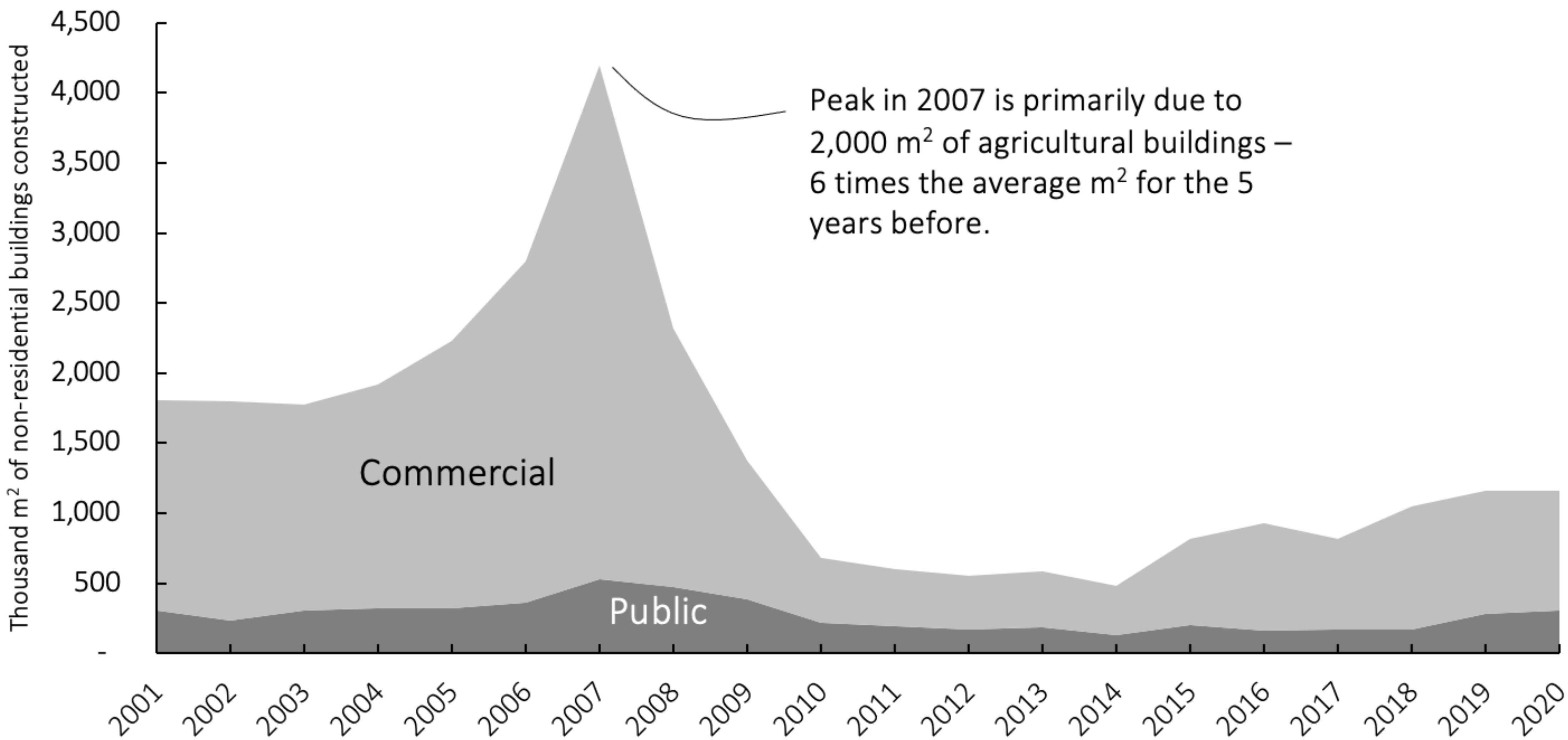
Bottom. Embodied GHG emissions for the primary building sectors of the built environment

Non-Residential historic growth

Non-residential construction is increasing in Ireland. Since 2012 the annual embodied carbon emissions associated with the non-residential sector has almost doubled.

Construction of non-residential is still lower than in the early 2000s, but is increasing. In 2018 buildings for agriculture, forestry, horticulture, fruit-growing, viniculture and fishery purposes accounted for 48% of floor area constructed according to CSO data while only 7% was for a combined sector of healthcare and education.

Non-residential operation emissions account for approximately 20% of all built environment rated GHG emissions.



Note. A strange peak in construction is seen in 2007. This is likely an aggregation or similar accounting issue that manifests in the statistical data for that period.

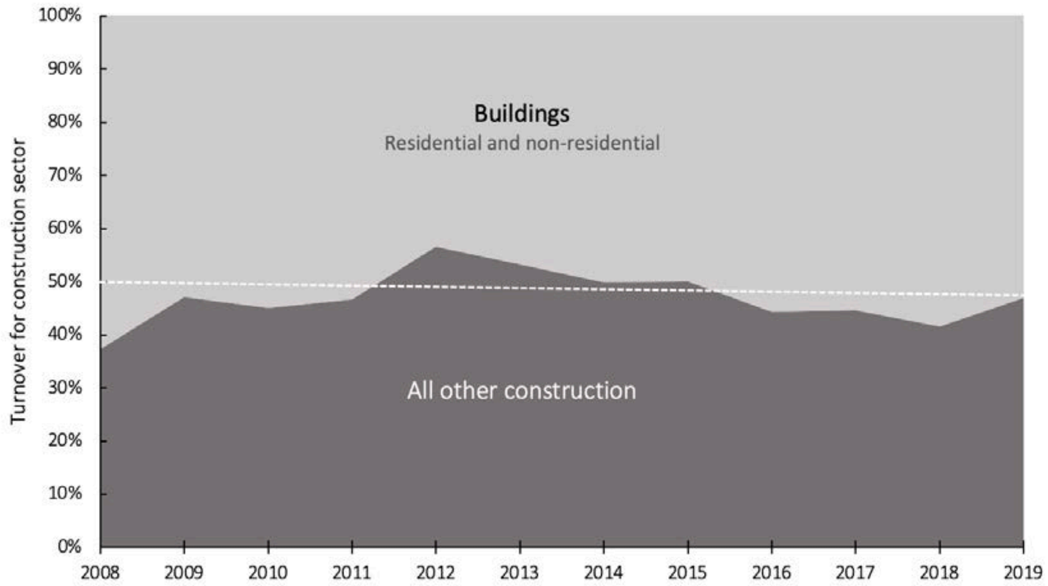
Data is taken from planning permission data and converted to m^2 constructed by applying a factor of 0.45 (the ratio between dwellings planned and constructed between 2011 and 2020)

Infrastructure

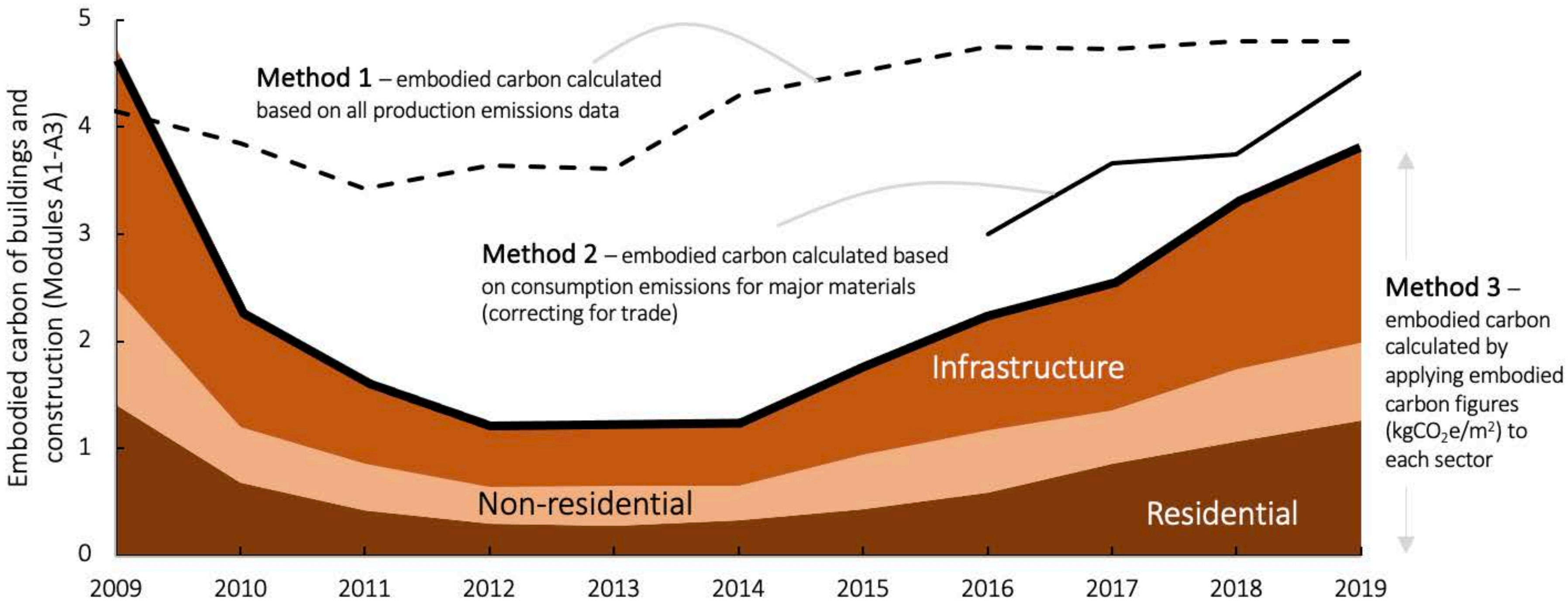
The method of quantification of the embodied emissions related to infrastructural works presents unique challenges. This is particularly due to the poorly defined and accounted for material usage in the wider urban and infrastructural context.

Two approaches are used in this project. In a broad-ranging, top-down approach, the baseline figure for embodied emissions related to infrastructure can be quantified by multiplying the emissions associated with buildings by the ratio between monetary turnover between buildings and all other construction. This data is taken from the CSOs BAA12 database. For the benchmark year of 2018 the cradle-to-gate embodied emissions associated with the construction of Irish infrastructure was 1.56 MtCO2e. Comparing the top down approach to the baseline exercise which used a bottom-up approach, it can be seen that there is better agreement after trade has been accounted for.

The National Development Plan outlines a scheme of expenditure on large scale infrastructure in Ireland over the coming 10 years. This encompasses billions of euro of investment and will necessitate high levels of embodied carbon (EC) through material extraction, manufacture, transport, and construction activities. This project aims to, as accurately as possible, quantify this embodied carbon impact and hence a bottom-up approach is applied, drawing on embodied carbon quantities documented for specific projects and extrapolating these for other proposed projects. A bottom-up approach risks underestimation of total emissions. Although it is a detailed accounting exercise, it may result in exclusion of material for ancillary works, wastage, or unaccounted for activity.



While this work remains at a nascent stage, large discrepancies currently exist between the top-down and bottom-up approaches, and with embodied emissions associated to infrastructure.



Part 2

Projections to 2030 & 2050

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Roadmap to net-zero
Projections to 2030

The second phase of this work is focused on projecting future built environment emissions. This draft document presents the first iteration of scenarios to 2030. More nuanced and detailed scenarios will be reported in subsequent iterations, with clear methodological development.

A roadmap to 2050 will be presented. This will investigate the range of solutions; from material replacement to varied retrofit intervention, different levels of sectoral construction, different levels of penetration of decarbonisation technologies, successfulness and performance gap impacts.

This draft of the report includes projections for electricity decarbonisation, retrofit new build and retrofit in line with plans outlined in the National Development Plan and other supporting and similar documents. Case studies for embodied carbon of retrofit and a bottom-up study of the carbon cost of the National Development Plan are presented, and these will form the basis for projections with more gradation in subsequent drafts.

The included projections to 2030 are made for a range of approximations and assumptions. Although a low level of confidence is associated with the absolute value of these projections, the trends are broadly reliable as they are based on recent and continuous trends and published national plans and policy for development and retrofit.

Emission projections based on current plans and policies

Projections 2030

#BUILDINGLIFE

Projections to 2030

Key Points

Different scenarios predict an increase or decrease in GHG emissions from the built environment depending on actions taken

Operational emission reductions from the residential sector will drive BE emissions downwards, but alone is not enough

Embodied emissions from proposed national development would overwhelm savings in operational emissions

Construction outlined in national development and housing plans could push BE emissions to 3 times the national target by 2030

Electricity Decarbonisation

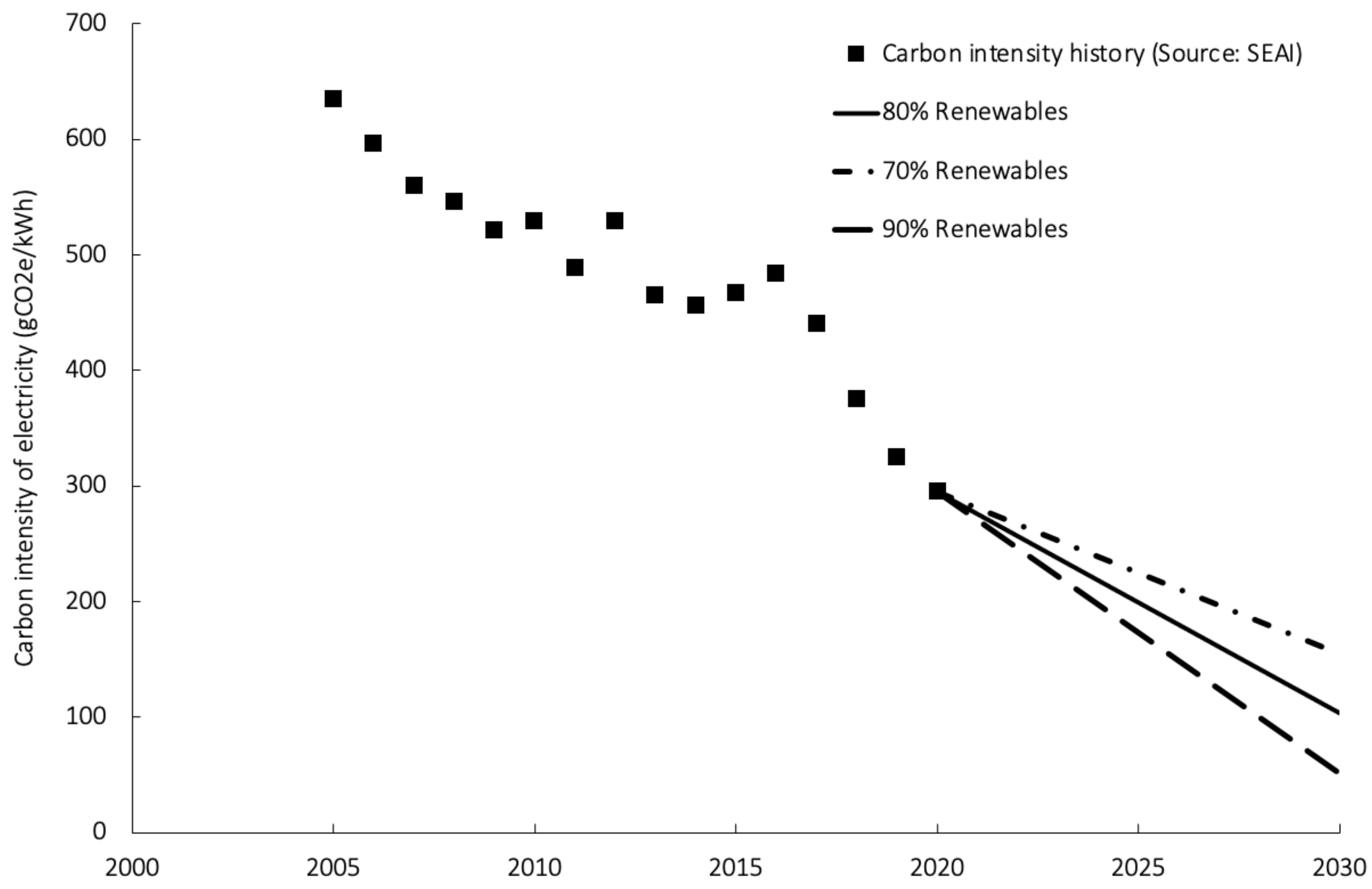
Direct and indirect actions toward decarbonisation enable reduction of built environment related emissions. The decarbonisation of electricity, more than improvements in energy efficiency of buildings, has helped reduce the operational emissions of the BE and this can be further exploited in future decades on the roadmap toward net-zero carbon emissions.

Rapid decarbonisation of the electricity grid is planned. CAP 21 calls for an increase in wind and solar of up to 80% by 2030. Targets proposed in the NDP include 4GW onshore wind, 5GW offshore, and 2.5GW solar. The transition of fossil fuel dominated loads such as residential space heating from fossil fuel to electricity power can considerably reduce BE operation emissions. In particular in the non-residential sector where electricity is the dominant energy source.

This report assumes changes to the % of renewables of the grid are linearly correlated with carbon intensity. An electricity grid which is 80% powered by renewable electricity, in line with NDP targets therefore emits 103 gCO2/kWh generated.

Latest data, available from the SEAI, reports that in 2020 the average carbon intensity was 295gCO2/kWh. This is approximately 50% higher than the carbon intensity of Natural Gas. An increase in renewable energy from 43% (2020) to 80% (2030) would reverse this comparison. A grid powered by 80% renewable energy would be 50% less carbon intense than natural gas.

Varied levels of renewable uptake are simulated in this model to investigate the effect of this critical part of the journey toward a low carbon built environment.



Forecast model

The whole life carbon of the built environment is quantified in the Part 1 baselining exercise. This model uses a bottom-up approach whereby several different data sources are processed.

Using this approach, the EC and OC can be assessed separately but any further breakdown is constrained by the taxonomy of the data sources used.

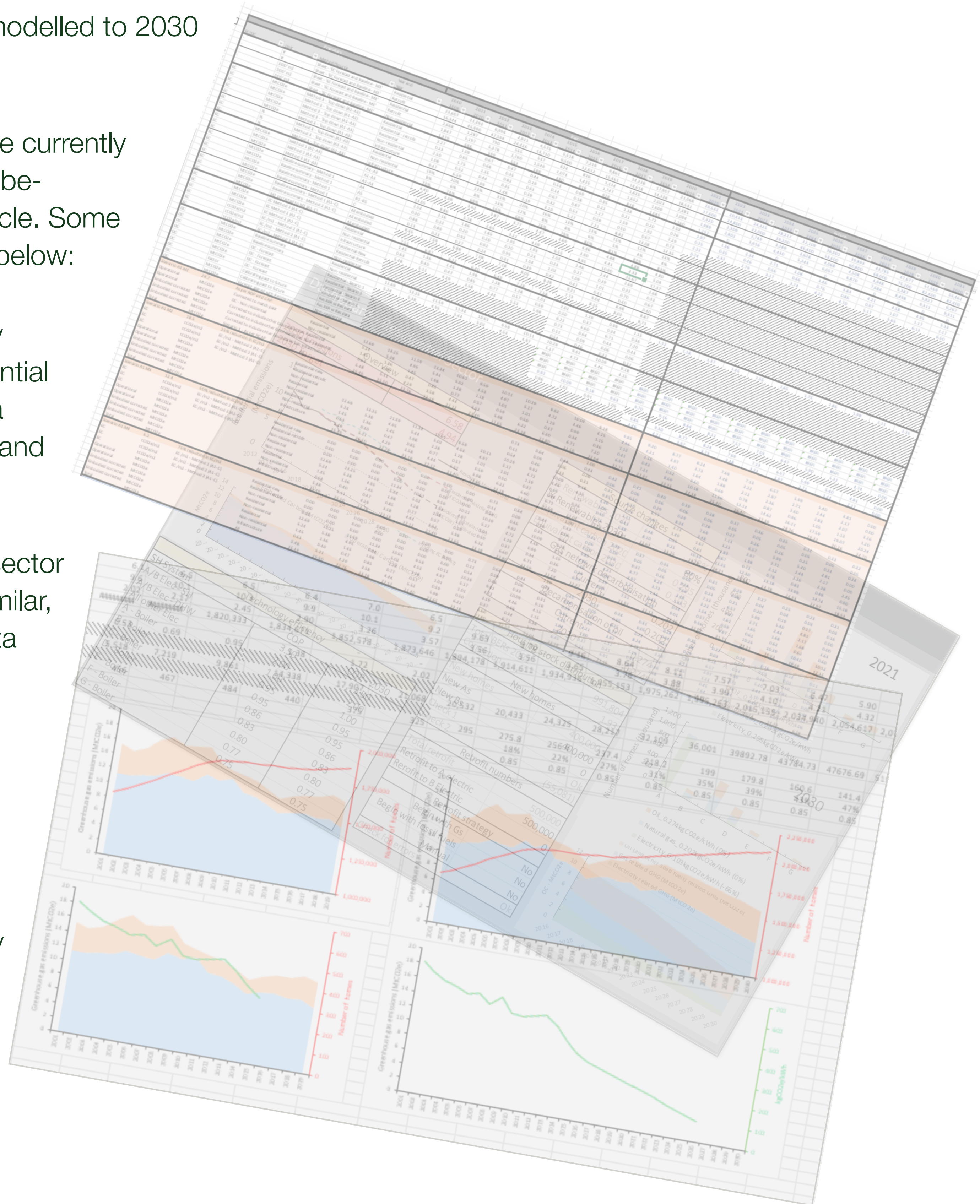
To forecast the EC and OC of the BE in terms of the 5 key sectors below, a new model is required:

- OC - Residential
- OC - Non-residential
- EC - Residential
- EC - Non-residential
- EC - Infrastructure

This model is designed specifically to allow changes listed in the NDP and long term retrofit strategy to be modelled to 2030 and 2050.

Details of this model are currently being prepared in a to-be-published scientific article. Some key features are listed below:

- The model begins by estimating the residential emissions using data from the CSO, SEAI and other.
- The non-residential sector is assessed using similar, but less granular, data sources.
- Finally the EC associated with infrastructure is assumed to be related to the EC of buildings using proxy relationships.



Operational and Embodied Emissions

2030 Residential

Residential to 2030

Key Points

400,000 new homes expected to be built, 500,000 homes to be retrofit and 600,000 heat pumps to be installed by the end of 2030.

> 50% of housing stock expected to be B rated or better by 2030.

Embodied carbon of a deep retrofit Embodied carbon is expected to increase by a factor of 5 by 2030 and account for 40% of residential emissions.

Embodied carbon of a deep retrofit estimated to be 165kgCO2e/m2

Operational

2030 Residential OC

Where we are today?

Currently less than 25% of the Irish housing stock is rated with a BER of B or better and less than 20% is heated using electricity.

The challenge to decarbonise the residential sector is threefold:

1. Our homes need to demand less energy.
2. The energy our homes demand needs to be powered by a higher percentage of electricity.
3. The fuels we use to power our homes, in particular electricity, need to be less carbon intensive.

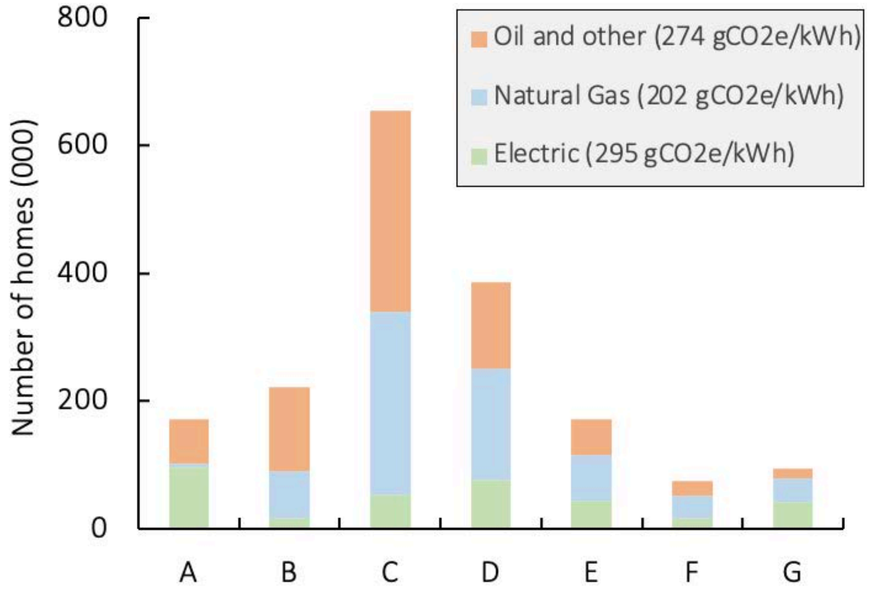
An addition of 400,000 new built homes by 2030 is proposed in the National Development Plan. This will increase operational and embodied emissions associated with the residential sector. However, the Climate Action Plan proposes all new build to be A-rated.

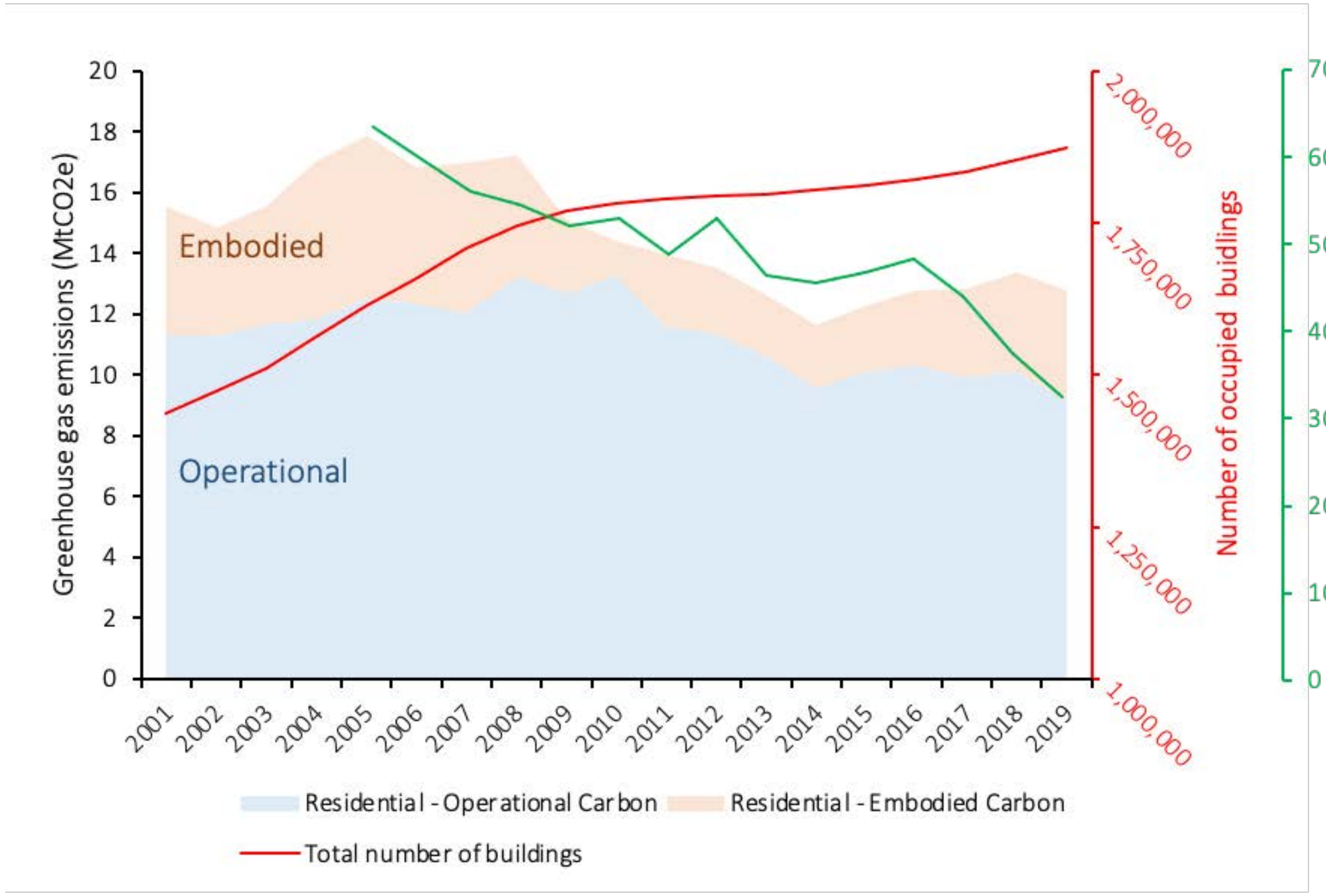
Additionally a considerable upgrade of the housing stock is planned. 500,000 homes are to be retrofit to a B-rating, or better.

Hence, 50% of Irish housing stock could be B rated or better should these targets be met.

The installation of 600,000 heat pumps and an upgrading of the electricity grid to 80% renewables is also envisaged.

The model investigates how these proposed changes will impact both our operations and embodied GHG emissions.

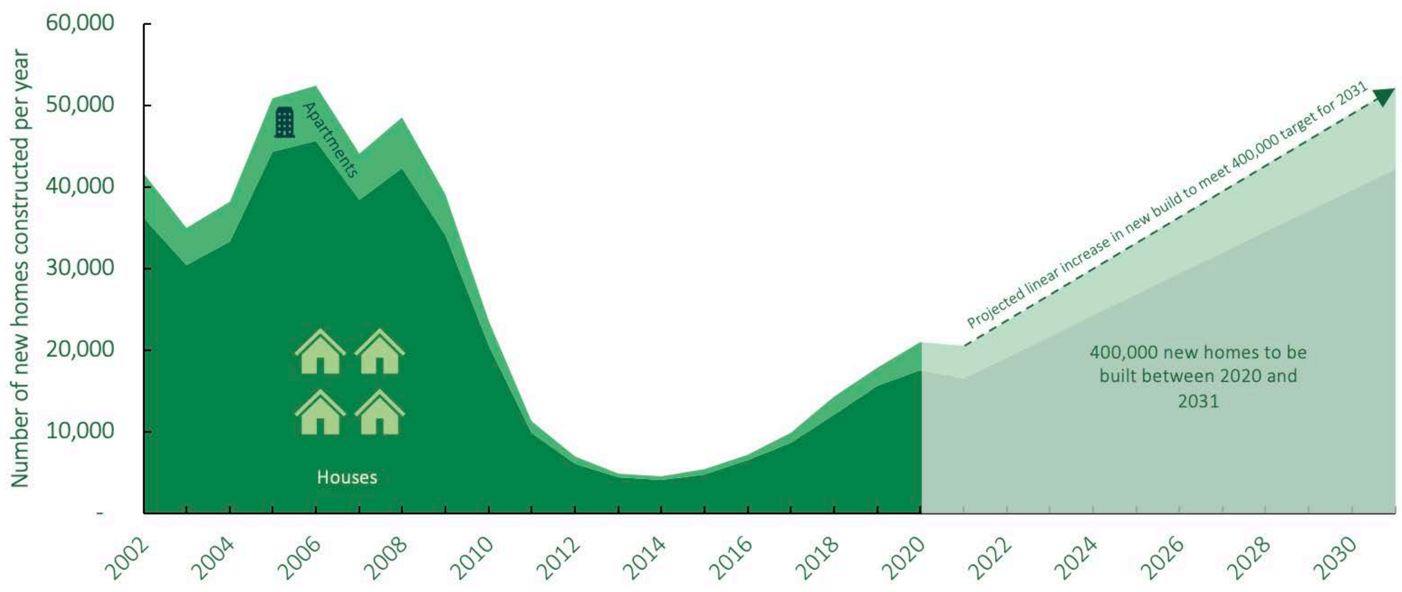


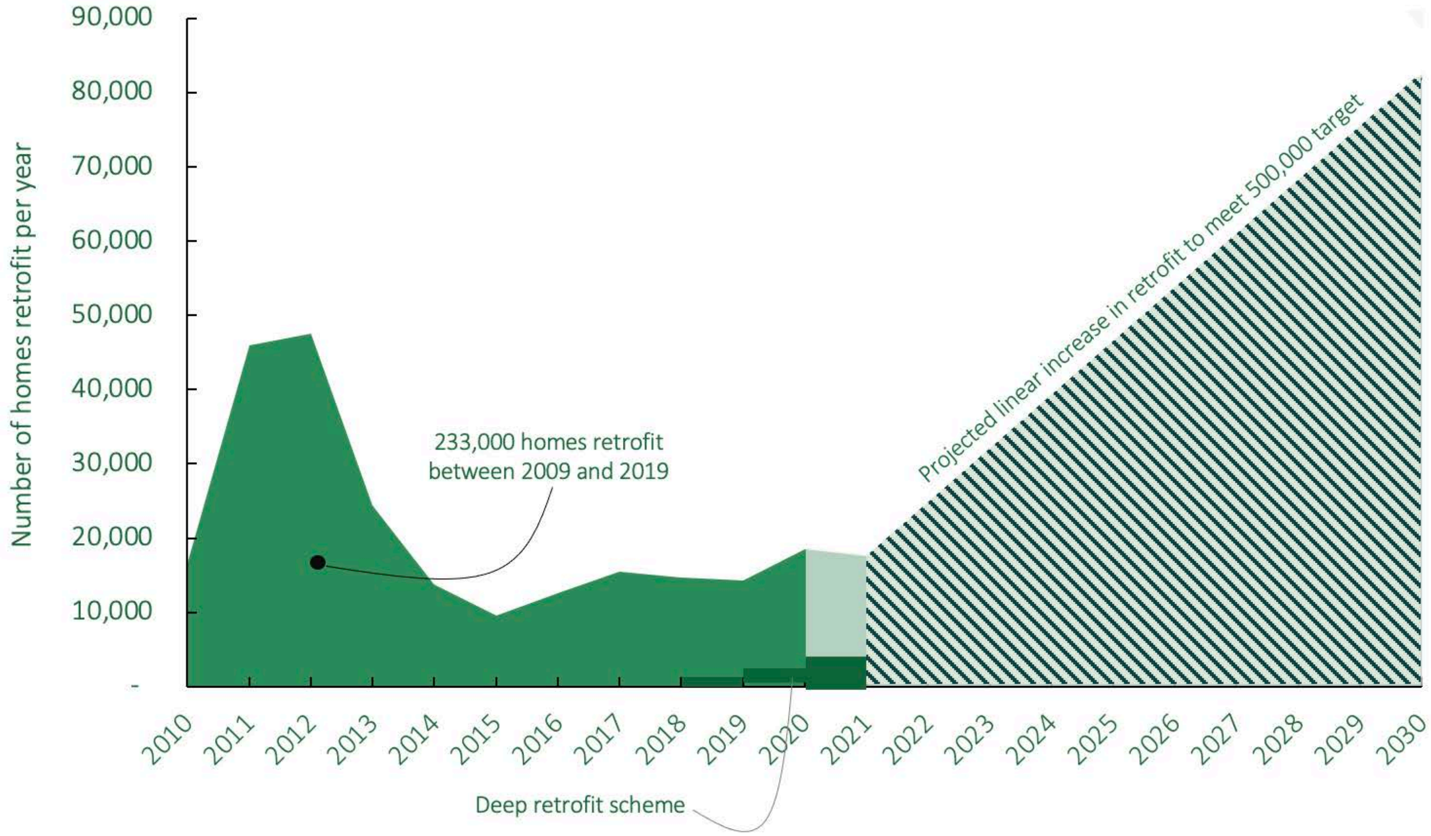


Residential sector growth | new build & retrofit

The NDP states that “a detailed assessment of structural housing demand identifies demand for almost 400,000 new homes in Ireland between 2020 and 2031, or 33,000 new homes per annum.” This model assumes the 400,000 target for 2031. This enables us to adjust the model as and when new data becomes available. For example the number of dwellings constructed in 2021 has been added, resulting in an increase in the rate of construction required until 2031.

Considerable retrofit of the residential sector is proposed over the coming years to 2030 with the aim of improving the energy efficiency of the worst of the housing stock. The National Retrofit Policy proposes a total of 500,000 homes to be retrofit by 2030. Many of these will be deep retrofit. The national press has reported budgets of 28 billion to be dedicated to retrofit [IT], or 56,000 per home. Under the Deep Retrofit SEAI Scheme, ~600 homes were retrofit in 2018, 2000 in 2019 and 4000 in 2020.



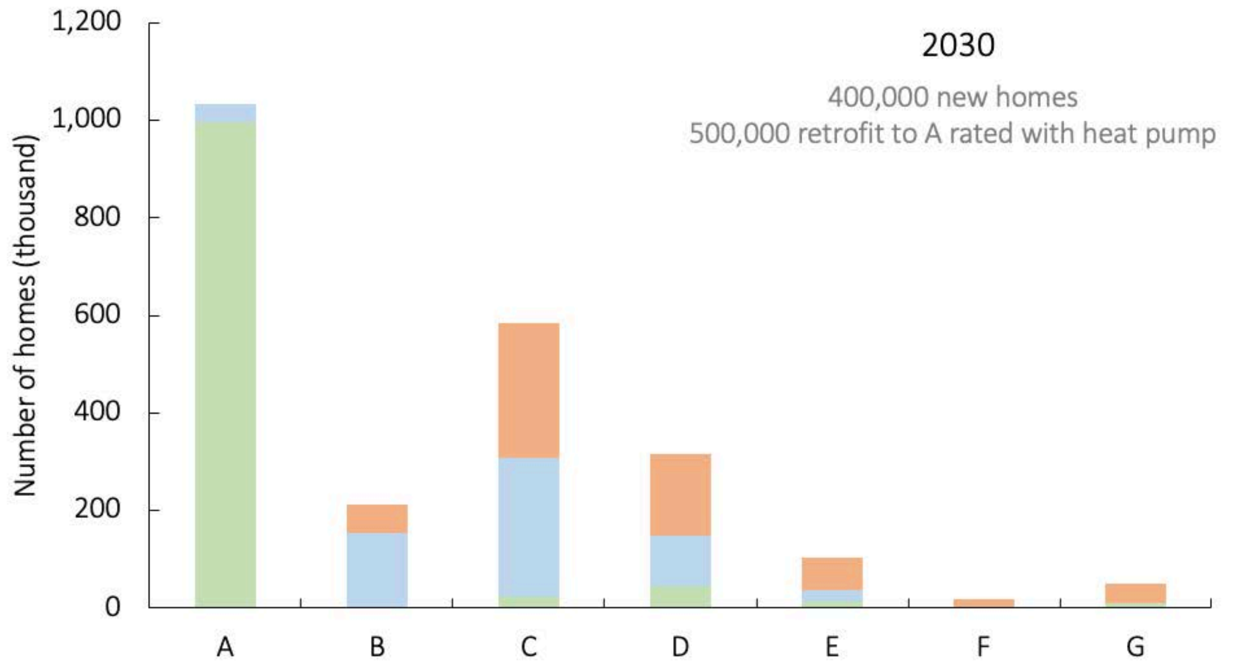


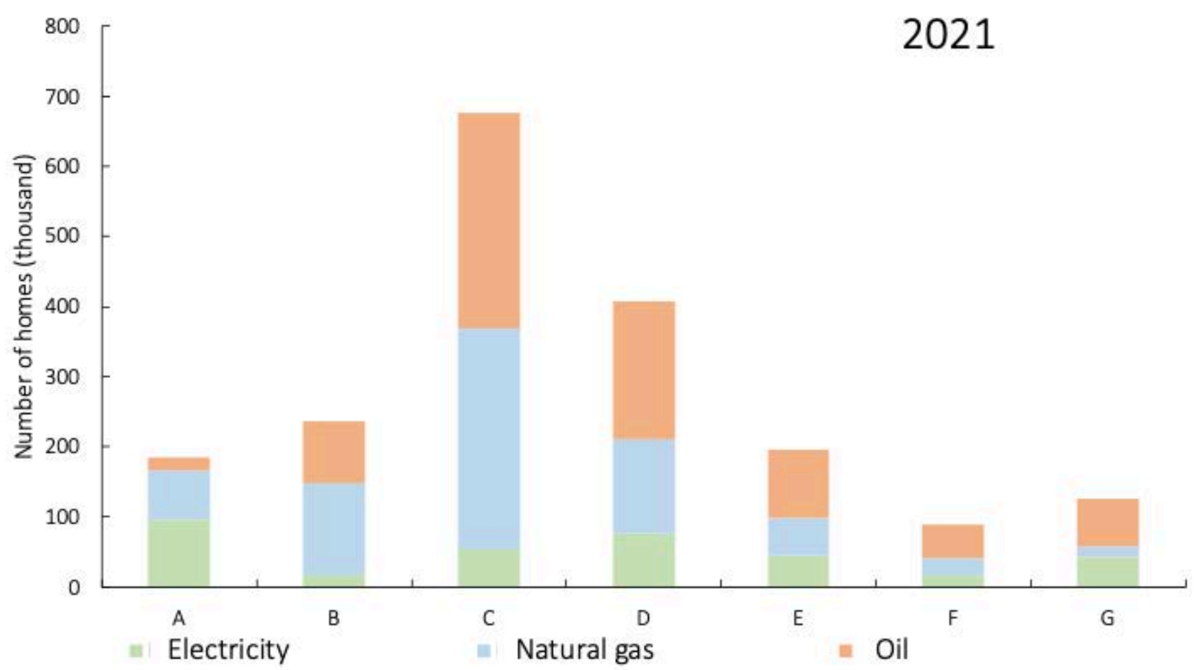
Residential Stock Projections to 2030

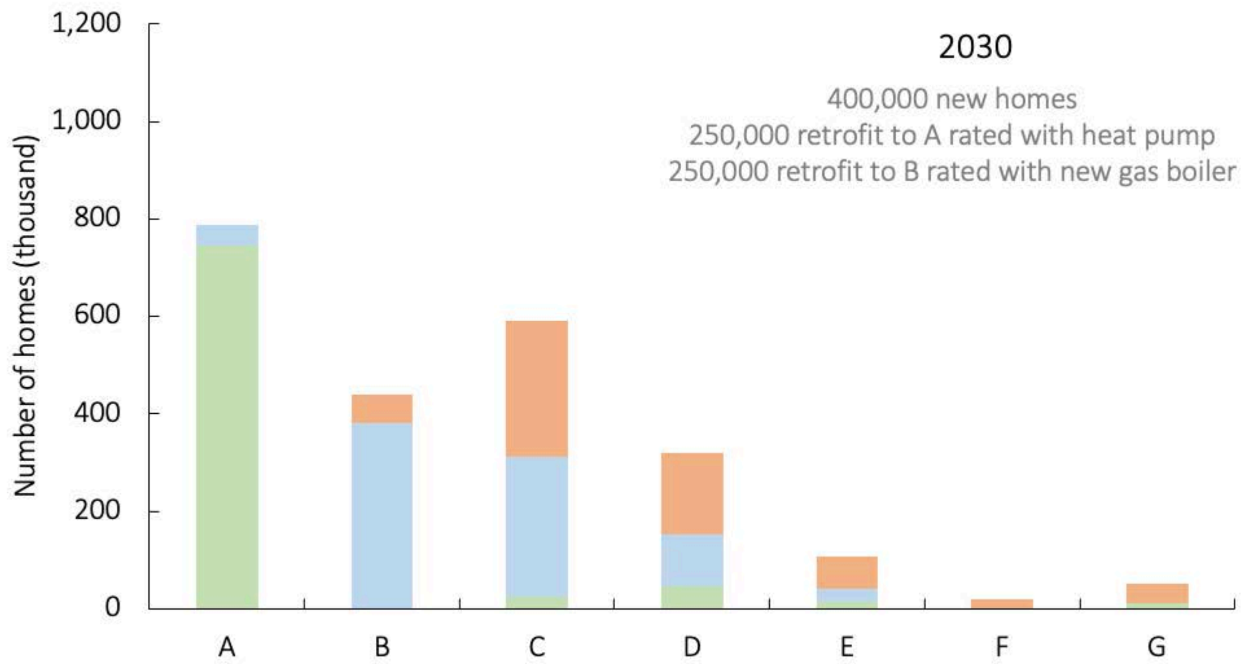
Building 400,000 new homes and retrofitting 500,000 homes will result in a change in the breakdown of our building stock.

Specific details on the precise type of retrofit is up for interpretation.

Depending on the heating system installed and level of upgrade (A or B) the distribution of the housing stock will differ. These scenarios can be investigated within the model.







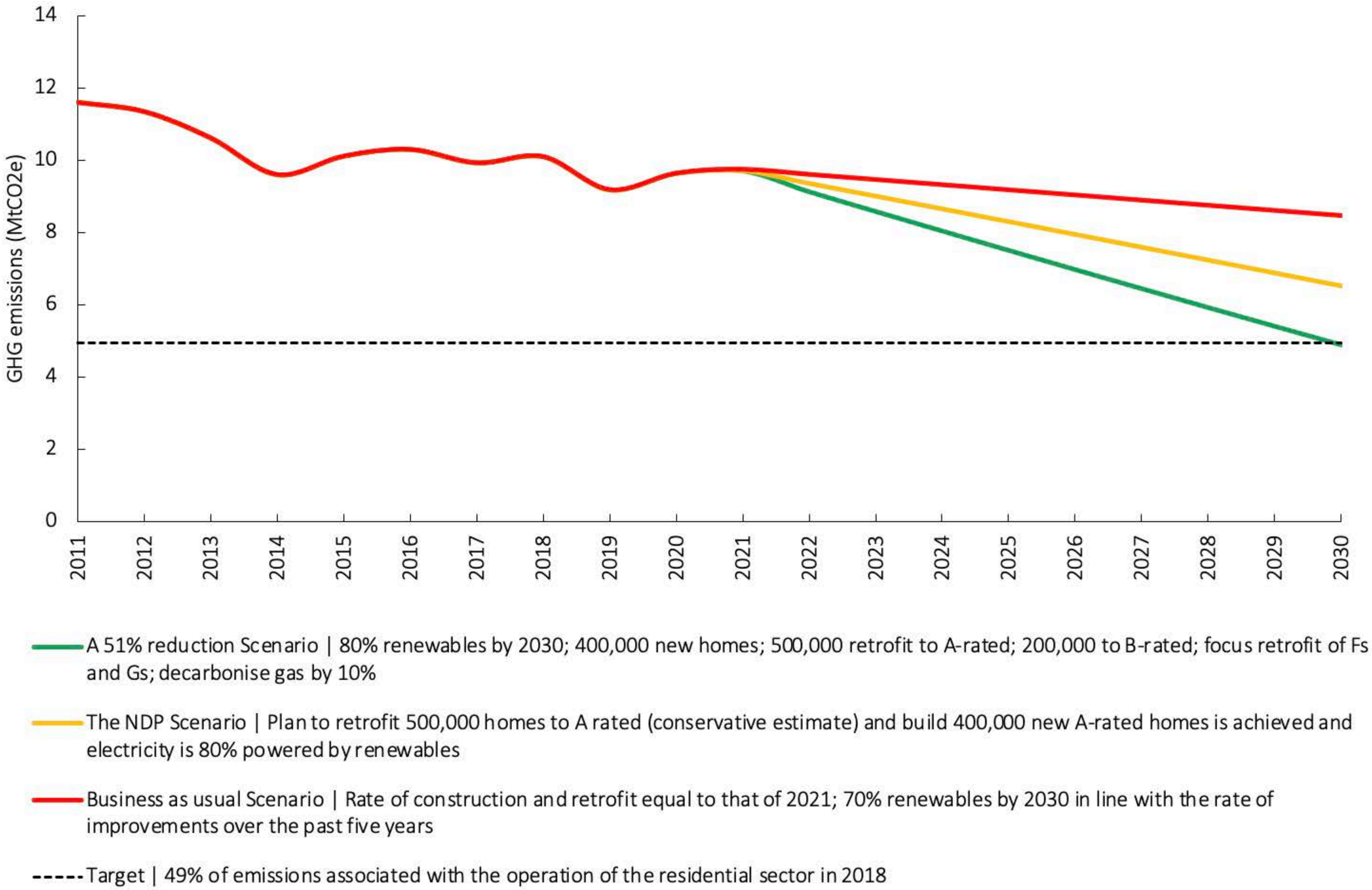
Residential Sector OC projections to 2030

If we achieve everything set out in the NDP we fall short of our target by 30%.

Notes on model: The residential sector in this model includes GHG emissions from all fuel sources including electricity. In EPA categories, electricity is assessed separately.

Three scenarios are investigated to understand what would happen:

1. If we continue at our current pace of improvement, where will we end up?
2. If we achieve what is set out in the NDP, where will we end up?
3. And, what is actually needed to achieve a 51% reduction in residential OC emissions from 2018 levels?



At our current pace of improvement (business as usual) we will fall short of our target by 70%.

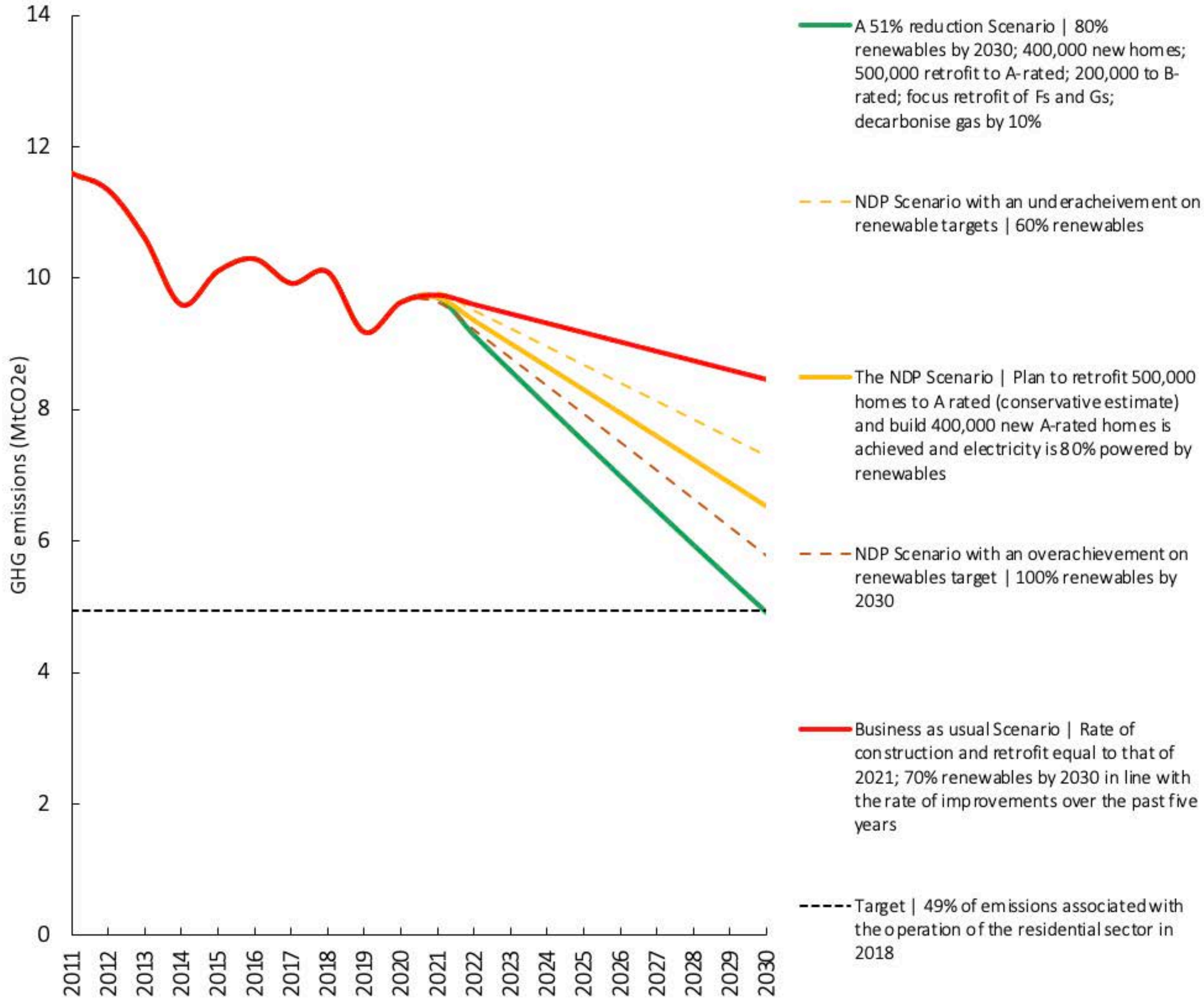
Residential Sector OC projections to 2030 | Uncertainty impacts - Retrofit

Two additional scenarios are presented here to show the impact of varying one parameter.

The rate of retrofit is adjusted above and below the target showing that:

If we retrofit 200,000 fewer homes than planned, we fall short of the target by 50%.

If we retrofit 200,000 more homes than planned, we get closer - only 17% off.



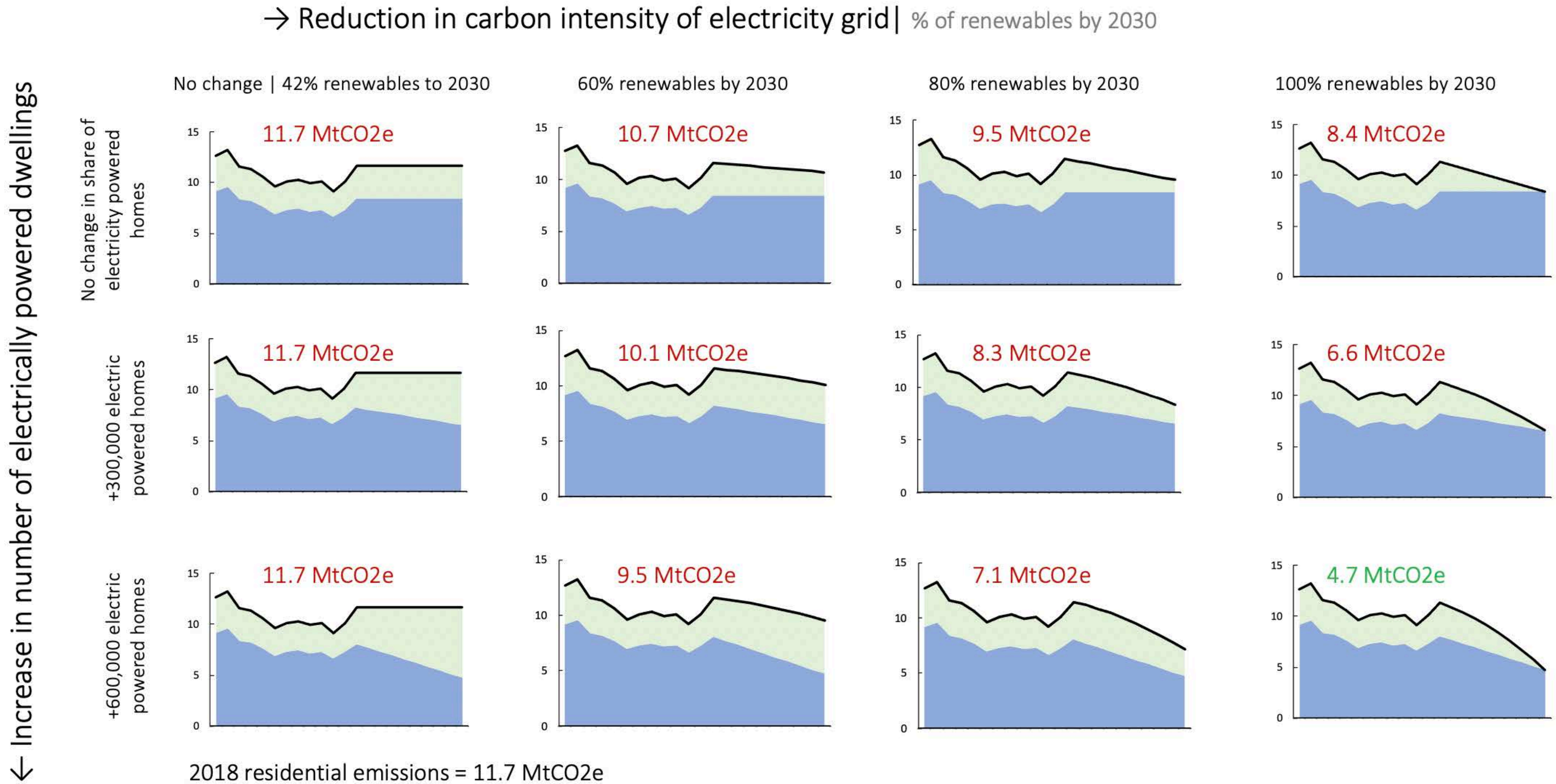
Let's just look at electricity for a moment!

A wide range of scenarios is possible with widely varying projected emissions to 2030.

The matrix of images below shows a range of scenarios for varying numbers of dwellings transitioned to electrical heating and power (y-axis), and for a varying national carbon intensity of electricity produced (x-axis).

Only adding renewables falls short because the residential sector is mainly fossil fuel powered. A combined effort of switching to electricity and making that electricity green is required.

Operation carbon scenarios | Change in share of renewables and number of homes that are powered by electricity



2018 residential emissions = 11.7 MtCO2e

51% Reduction target = 5.6 MtCO2e

Results speak to the challenge ahead, and again highlight the importance of not only focusing on one strategy (in this case source and supply electricity). Retrofit is also a crucial step.

Notes on model: This model considers OC only. It is based on an older more simplified iteration but the findings remain relevant. The green hatched area is electricity proportion. The blue is fossil based heating.

One scenario to achieve the 51% reduction was presented but…

Is there any other way?!

Yes, there are essentially infinite combinations and options to achieve a 51% reduction. Some of which are more challenging than others.

Three ways to get to 4.9 MtCO2e of OC (i.e. 49% of 2018) are presented in the table below. All of which include the construction of 400,000 homes.

In each case, the Whole Life Carbon (WLC) increases significantly but the difference in WLC between the three scenarios is small.

This is because it costs carbon to build new buildings.

	Average % of renewables used on national grid	Retrofit to A (includes HP)	Retrofit to B (no change to heating system)	Carbon intensity of natural gas (kgCO2e/kwh)	Carbon intensity of oil (kgCO2e/kwh)	Strategy	Whole life carbon residential sector (MtCO2e)
Scenario 1 – Mixed effort	80%	600,000	-	10% reduction	No change	Begin with Gs, Fs and fossil fuel homes	13.0
Scenario 2 – Focus on source	100%	400,000	100,000	20% reduction	20% reduction	None	12.7
Scenario 3 – Focus on demand	70%	725,000	-	5% reduction	No change	Begin with Gs, Fs and fossil fuel homes	13.3

Embodied

2030 Residential EC

Residential EC | New build

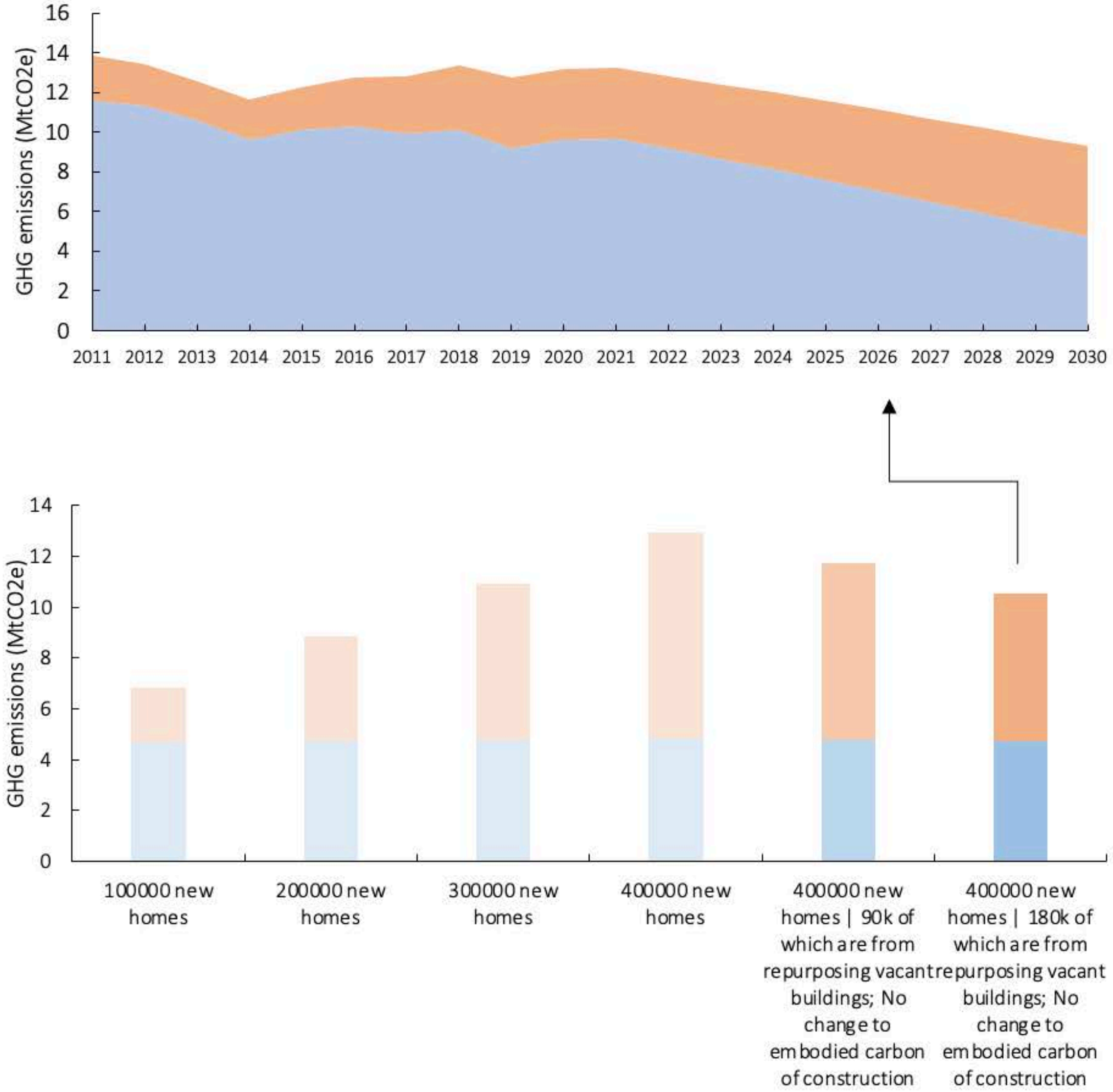
Buildings cost us carbon, but we need more homes, so what can we do to reduce the EC?

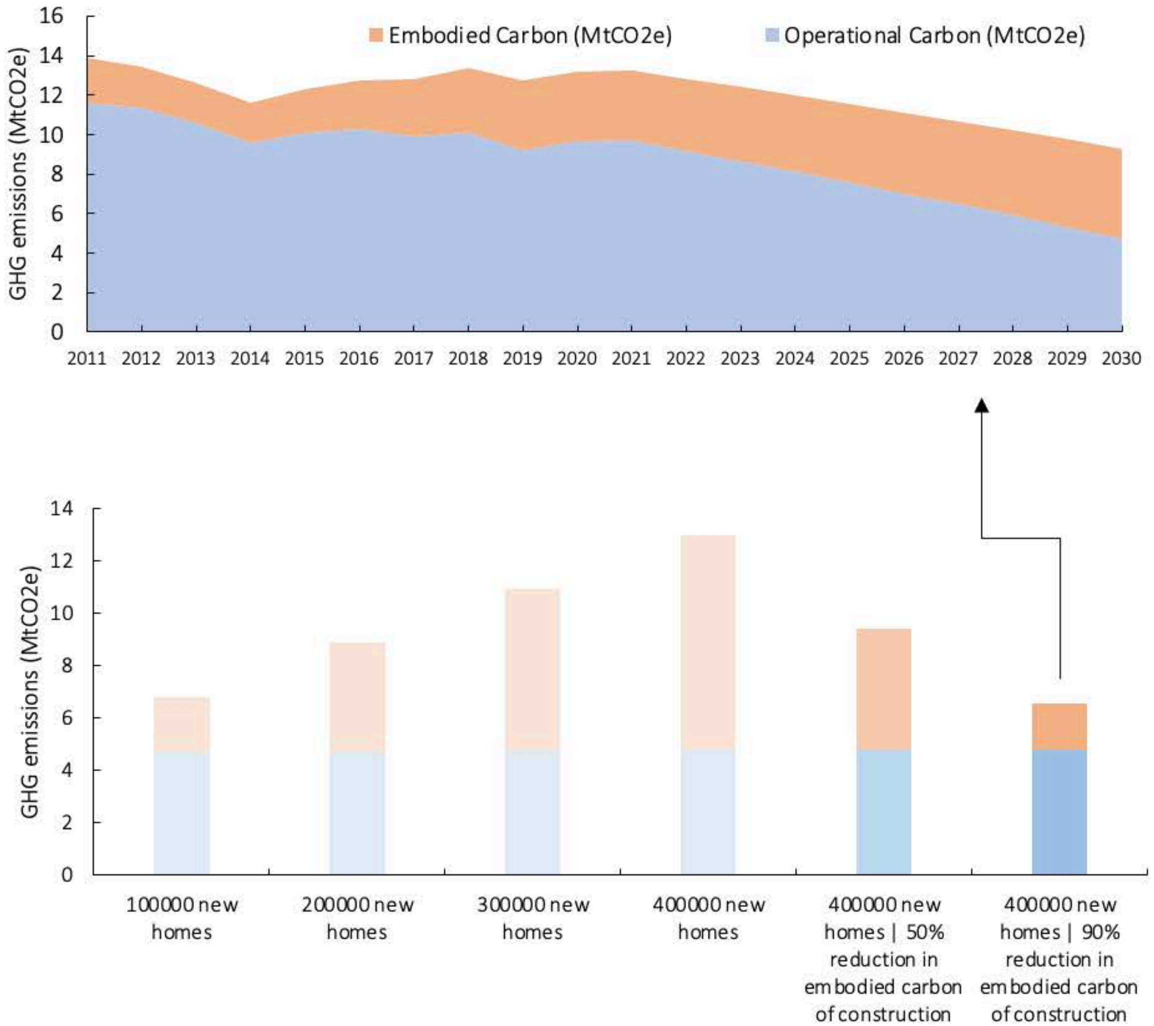
Two major routes to reducing the EC are presented here:

First, we need to try to repurpose buildings where feasible.

Second, we need to reduce the EC of the buildings we build.

Notes on model: The OC scenario shown here is for “Scenario 1 - Mixed effort”. The EC of renovation is included in the model and assumed to be 33% new build.





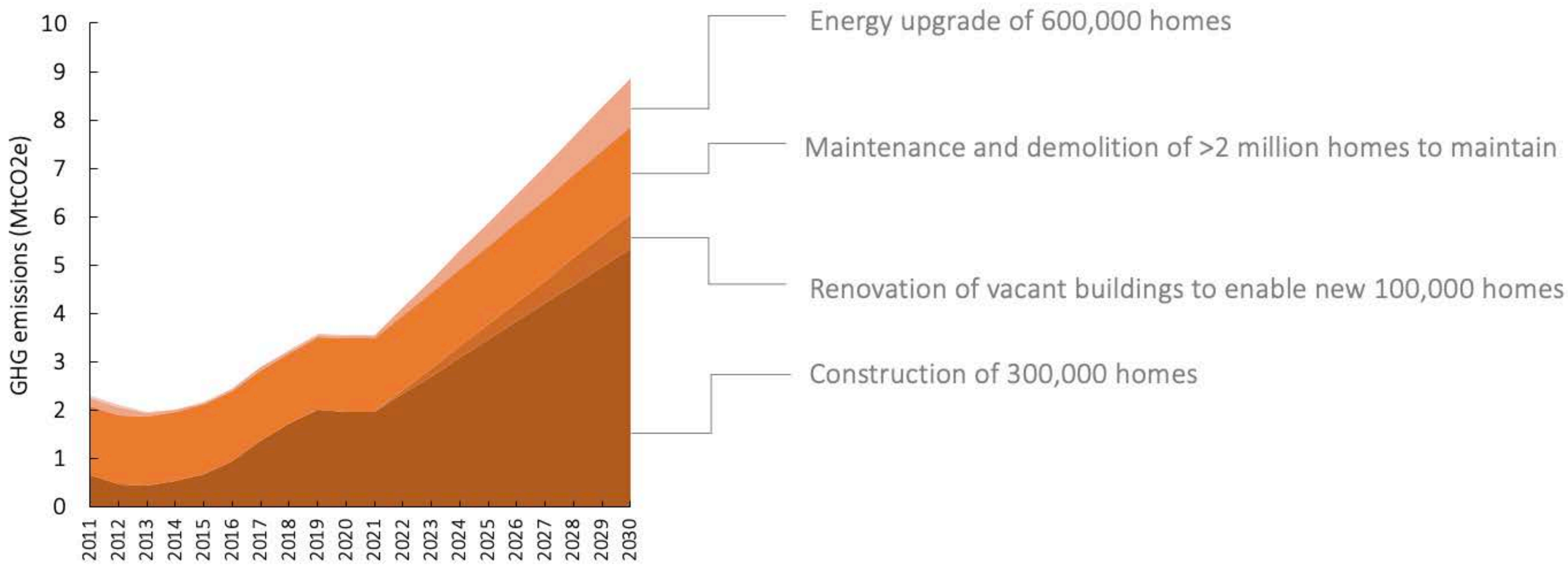
Where else does EC come from?

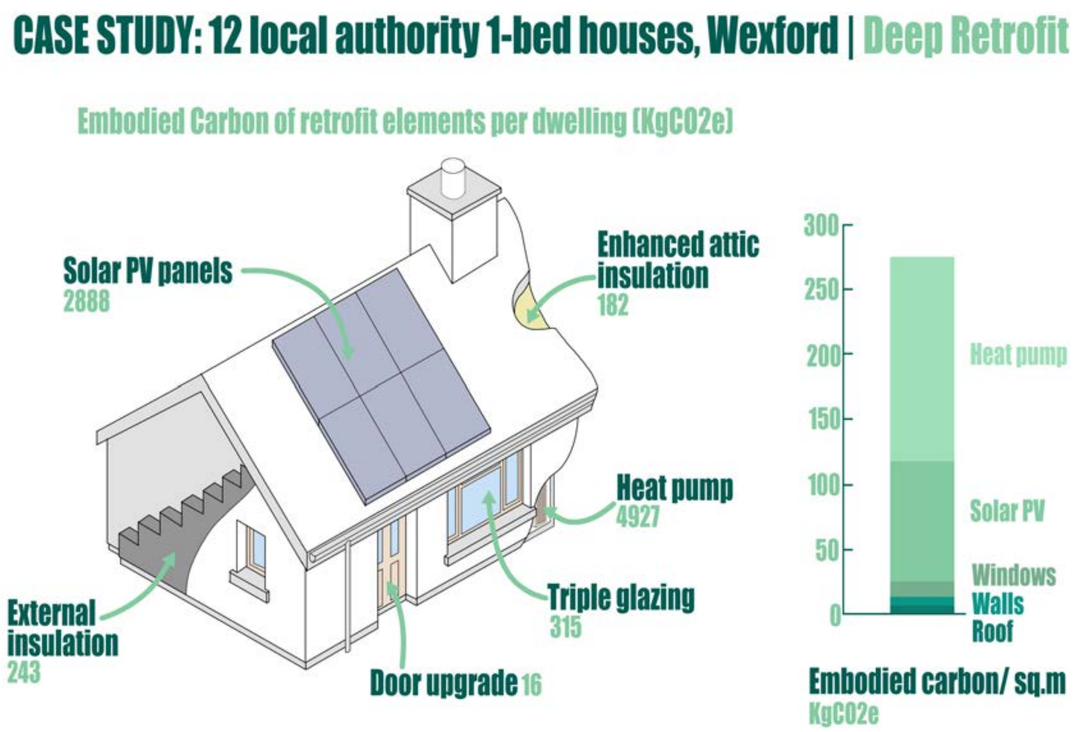
While the EC associated to the construction of new buildings is carbon intensive, accounting for more than 60% of EC emissions, other construction activity associated to the residential sector impacts the overall consumption.

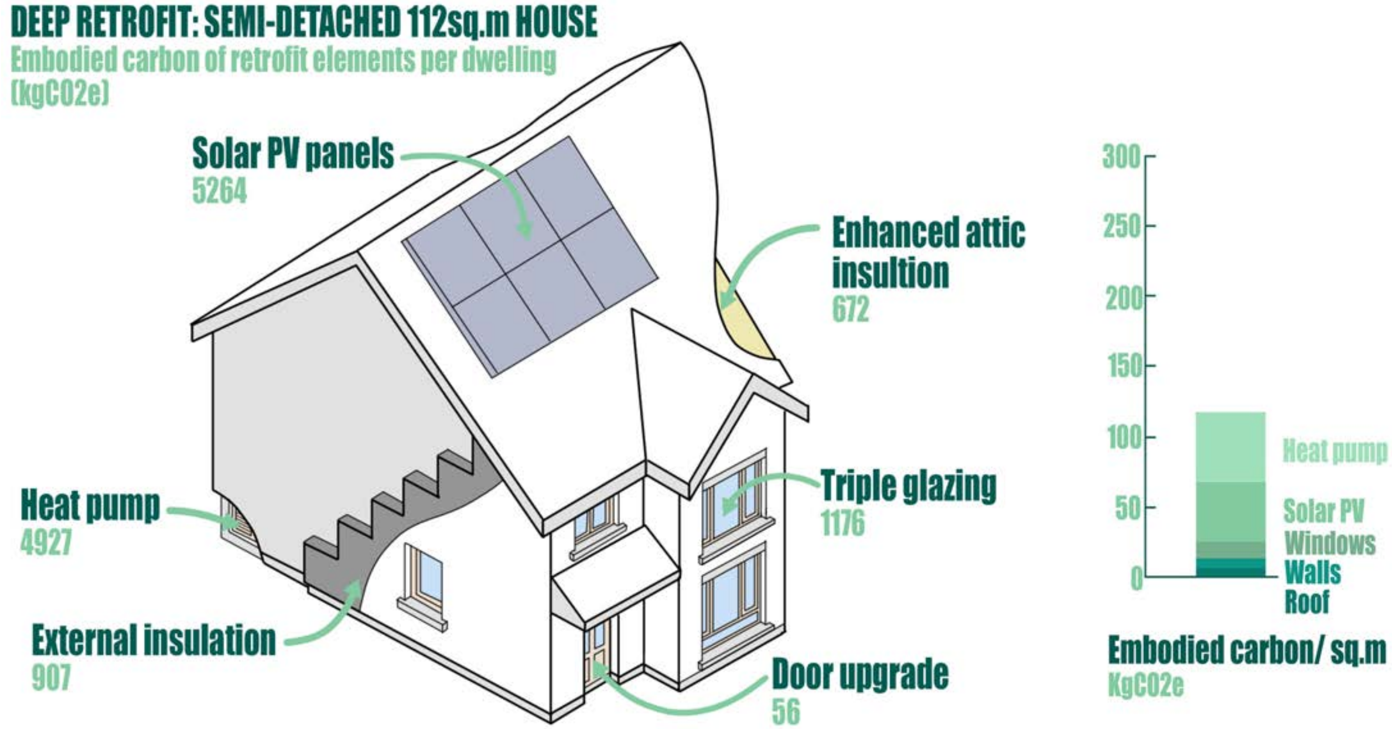
Energy upgrades add EC through the insulation, PVs and HPs added to the buildings, while the maintenance, repair and demolition parts of our growing building stock is the second largest contributor of EC in the residential sector.

Constructing buildings that last and require little maintenance is crucial too. Constructing homes that are not built to last will see an increase in the carbon emissions associated with the maintenance and demolition.

Case study calculation: the EC cost of replacing 7,500 homes effected by concrete degradation due to Mica will cost approximately 1 $MtCO_2e$.







Graphic: UCD Building in a climate emergency research group

Case Study: Deep Retrofit

Carbon Cost of Retrofit

Although retrofit reduces OC emissions, it will also add considerable embodied carbon. The carbon cost of a home deep retrofit is calculated at ~0.25 of that of new build. A case study analysis undertaken as part of the nZEB101 project involved the quantification of the embodied carbon (EC) of deep retrofit of a scheme of 1-bed, 40m2, social housing units in Wexford (O'Hegarty et al. 2020). These should not be understood as representative of all retrofit - due to the small floor area (40m2) the EC of the heat pump and solar pv, are proportionally higher than would typically be expected. When these results are extrapolated to the average size house of 112m2 (CSO), including additional envelope insulation, upsizing of PV array and the same heat pump (which is oversized for a 40m2 house), an average EC of retrofit of 165kgCO2/m2 results.

The large EC of the heat pump is primarily associated to refrigerant leaks throughout its lifecycle and is accounted for as such in the model.

Embodied Emissions

2030 Whole Life Carbon

This section evaluates and quantifies current policies to achieve reductions

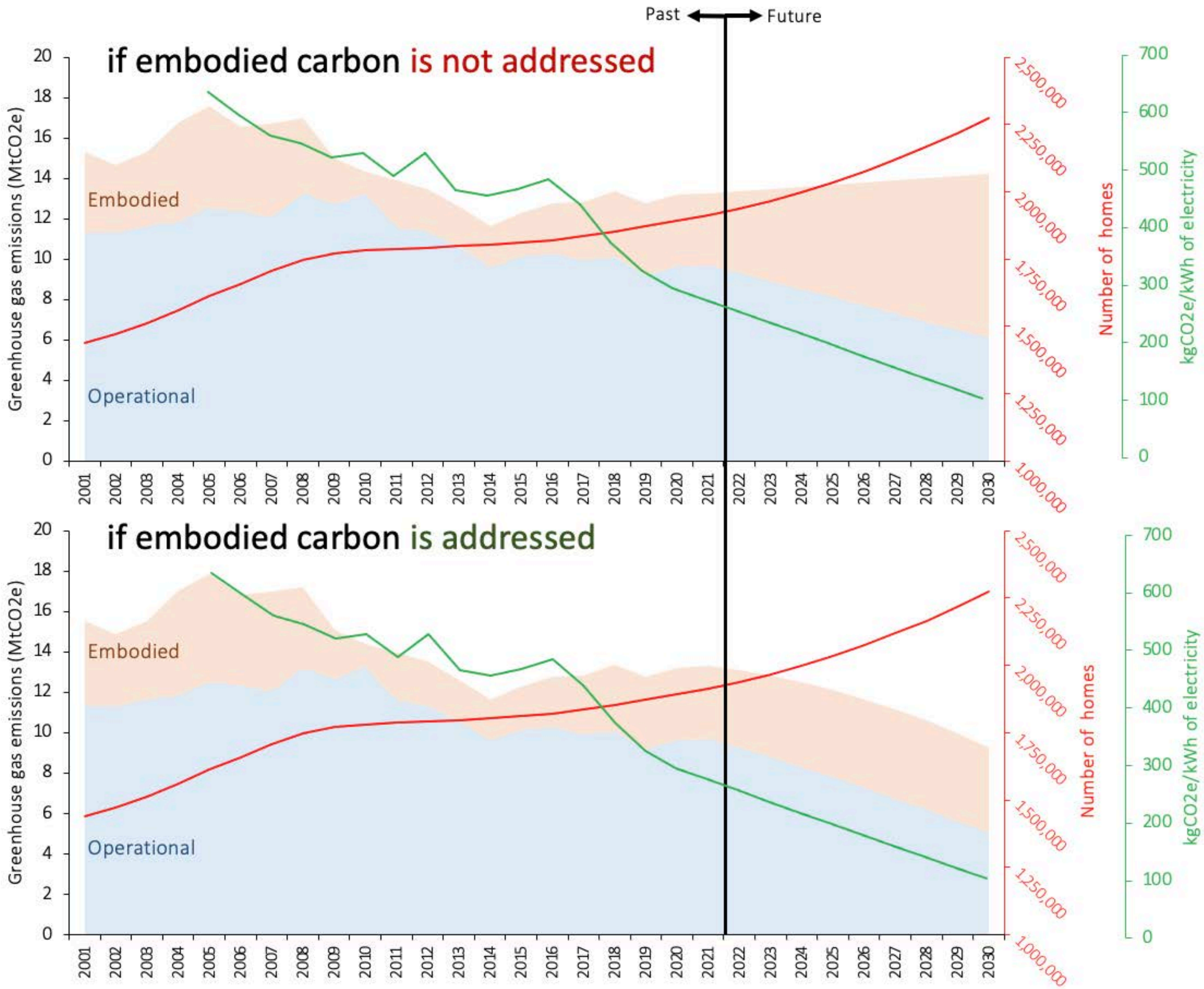
Residential Emissions Projections to 2030

Both scenarios shown on the right show 51% reduction in operational carbon emissions and include the addition of 400,000 new homes.

The top scenario however does not address embodied carbon.

This shows that the savings in carbon emissions by improving our buildings will be offset by the addition of emissions embodied in the materials used to build new ones and upgrade the current ones.

The bottom scenario shows a more promising picture where the carbon footprint of building and construction is reduced by 50% and 1/4 of new buildings are added to the current stock by repurposing vacant buildings.



Non-residential and infrastructure

2030 All Other Sectors

This section evaluates non-residential sectors, current policies to achieve reductions and planned development

All Other Sectors to 2030

Key Points

Plans for emission reduction across all other sectors of the built environment are less well defined

Considerable construction is outlined in the National Development Plan

Bottom-up evaluation of the NDP gives insight into GHG emissions associated with specific development

National emission targets will not be achieved through reduction of operational carbon emissions only

Non-residential buildings

Data on the non-residential sector is less extensive than that for the residential sector. Consequently a different approach to model this sector is adopted.

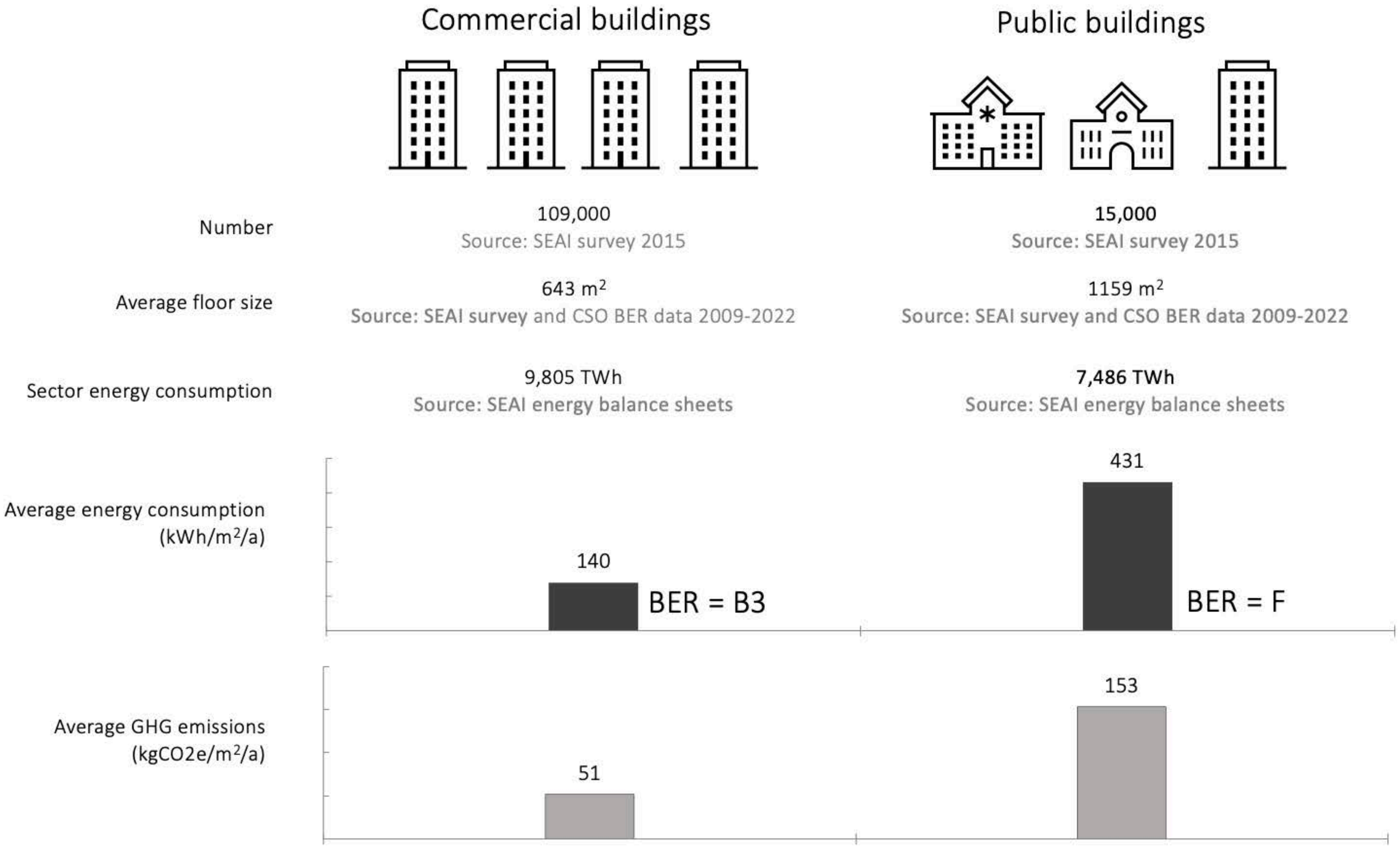
The number of commercial and public buildings in Ireland are taken from an SEAI survey conducted in 2015.

Additional buildings, up until 2022 are added to the total using data from the CSO.

Average floor areas are taken from the CSO's BER data assessment.

Total energy consumption from each sector is accounted using the SEAI energy balance sheets.

This data compilation exercise reveals greater inefficiencies in the public sector buildings compared to the private sector. This may be partly due to the difference in building function but nonetheless, highlights a need to reduce the energy consumption in public buildings.



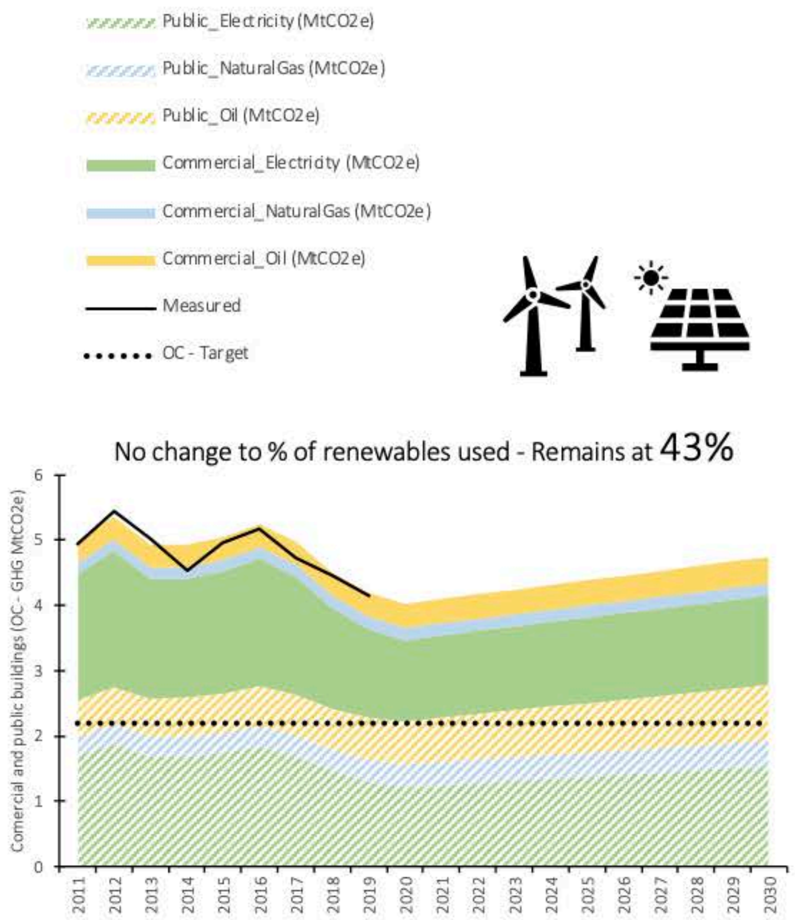
Commercial and Public Building Projections to 2030 | OC

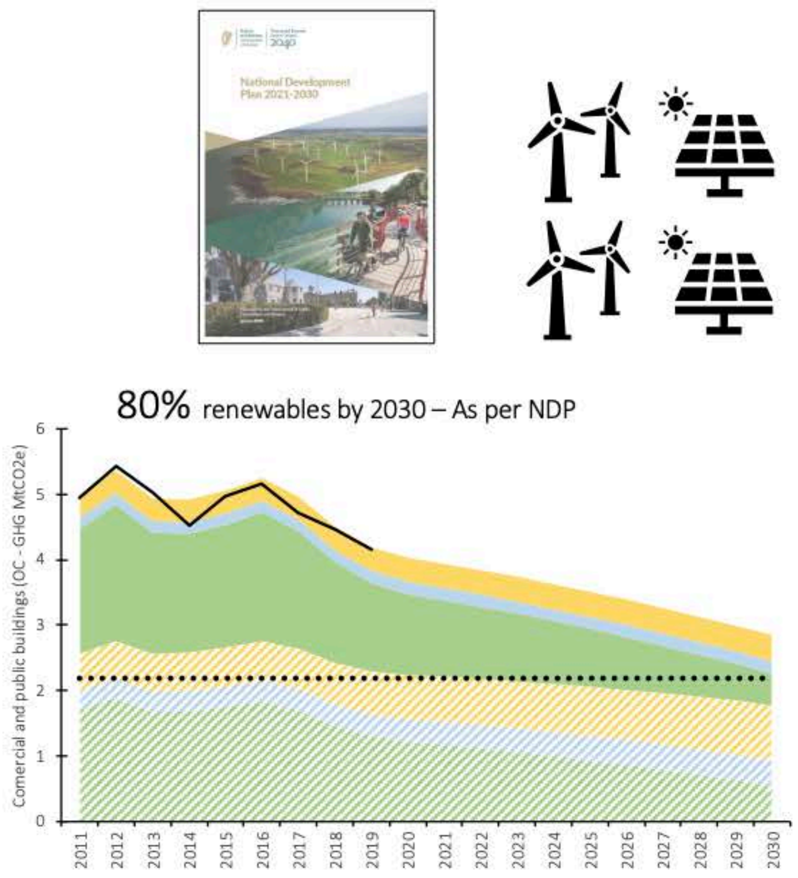
The non-residential sector differs from the residential sector primarily in that electricity supplies 67% of its energy demand. For the residential sector this figure is 25%.

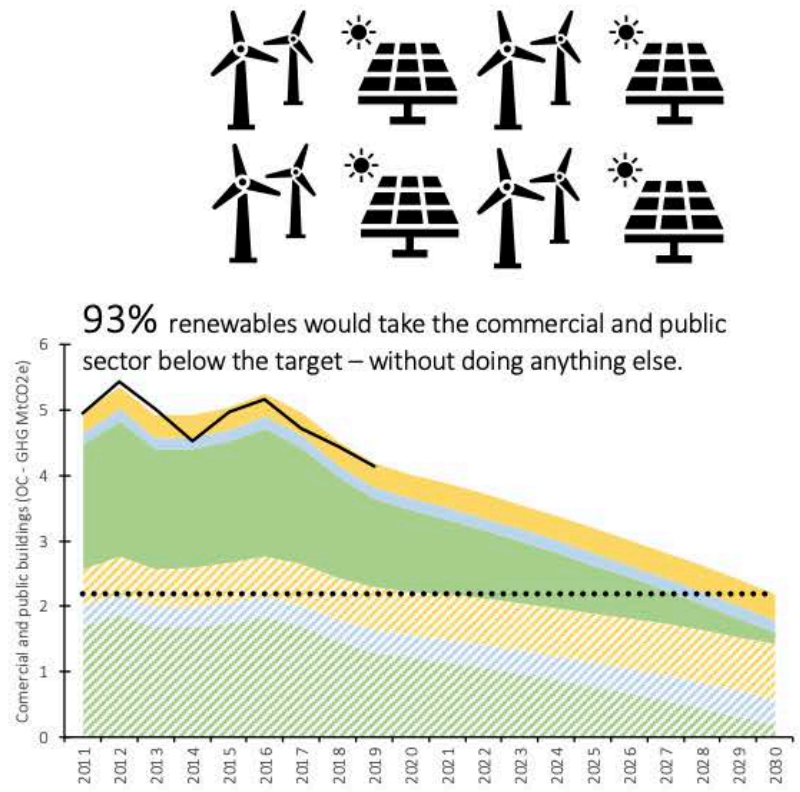
As such, a reduction in the carbon intensity alone has a considerable impact on the operational carbon associated to the non-residential sector.

In fact, if the electricity grid was powered by 93% renewable sources, the climate action plan target of 51% would be met, without needing to address the sector's efficiency.

However, this finding does not mean that the buildings should not be improved. A reduction in the energy demand for buildings in this sector would reduce the carbon intensity further. As noted on the previous page, the poorly performing buildings need particular attention.







Commercial and Public Building Projections to 2030 - WLC

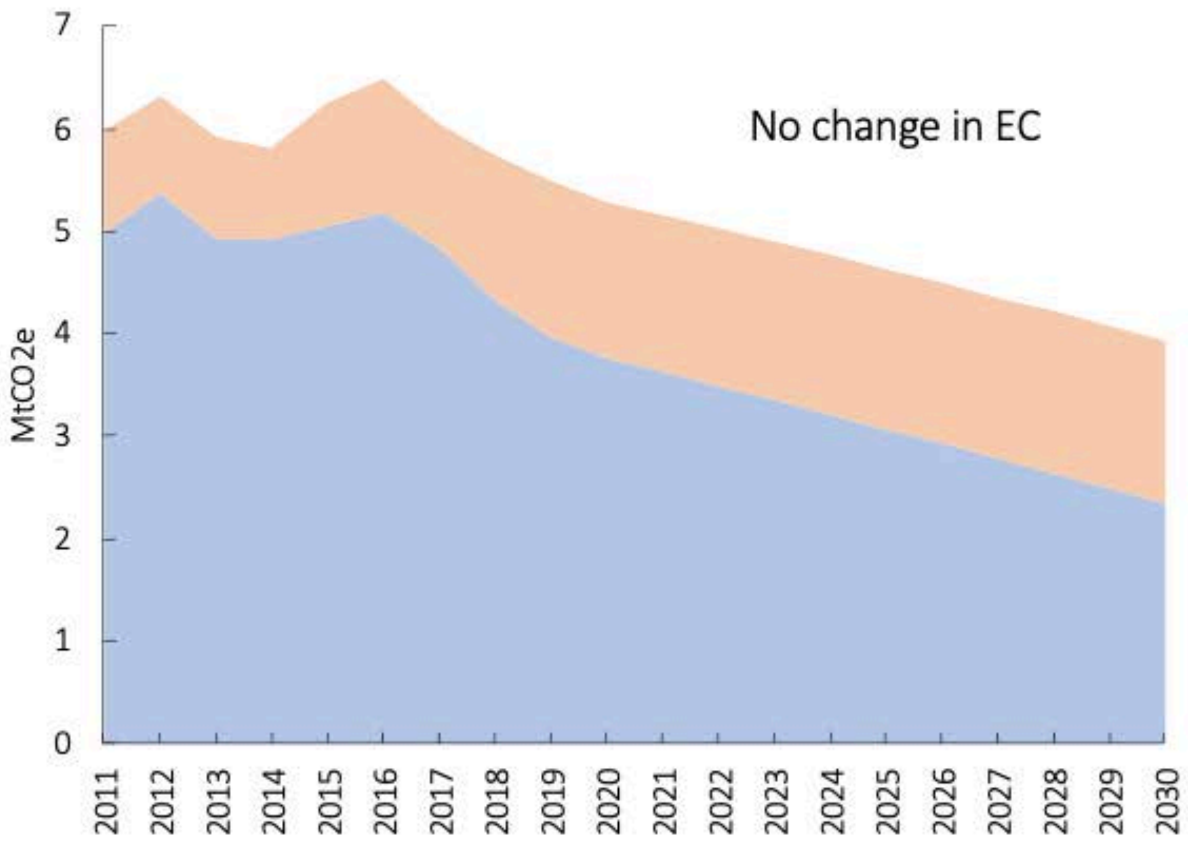
Improving the energy efficiency of the non-residential sector by 20% and improving the proportion of renewable electricity supplying the grid to 80% would achieve a 51% reduction in GHG emissions in the nonresidential sector.

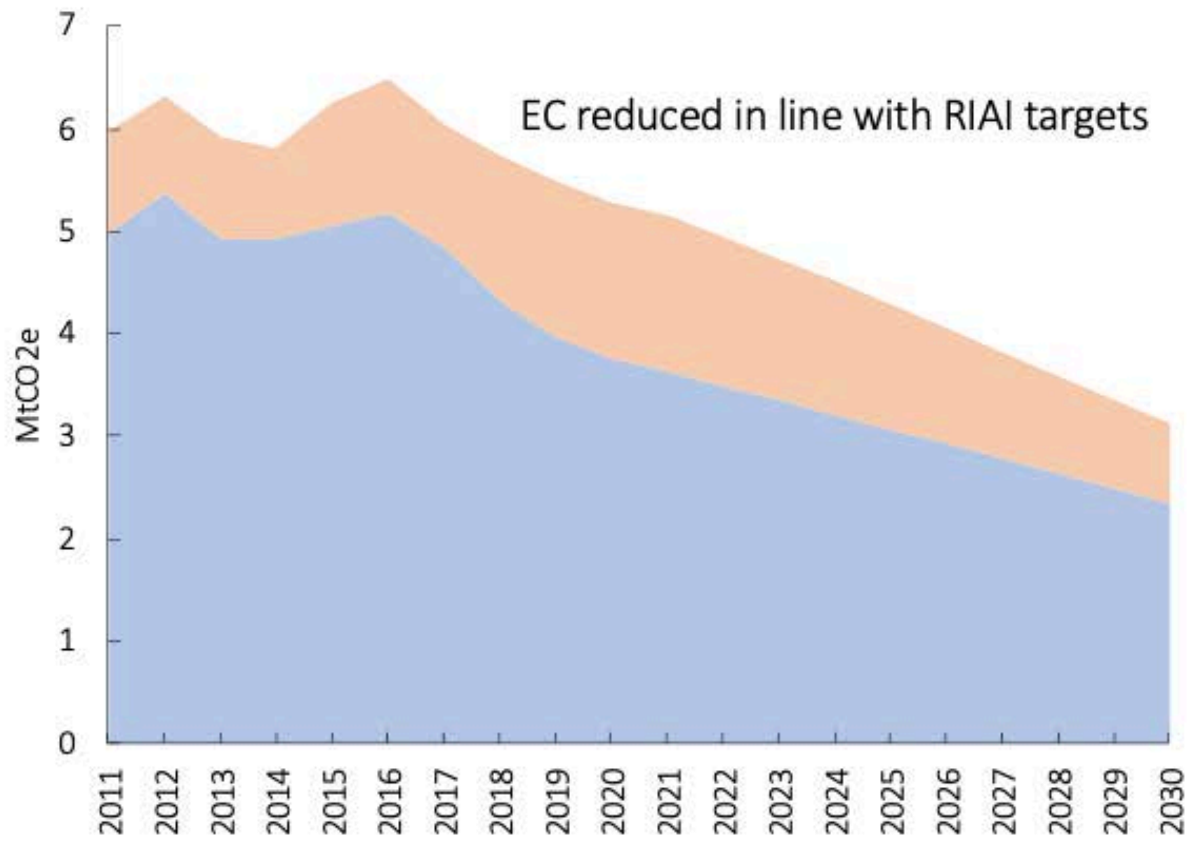
Unlike the residential sector, the number of new buildings planned is less explicit.

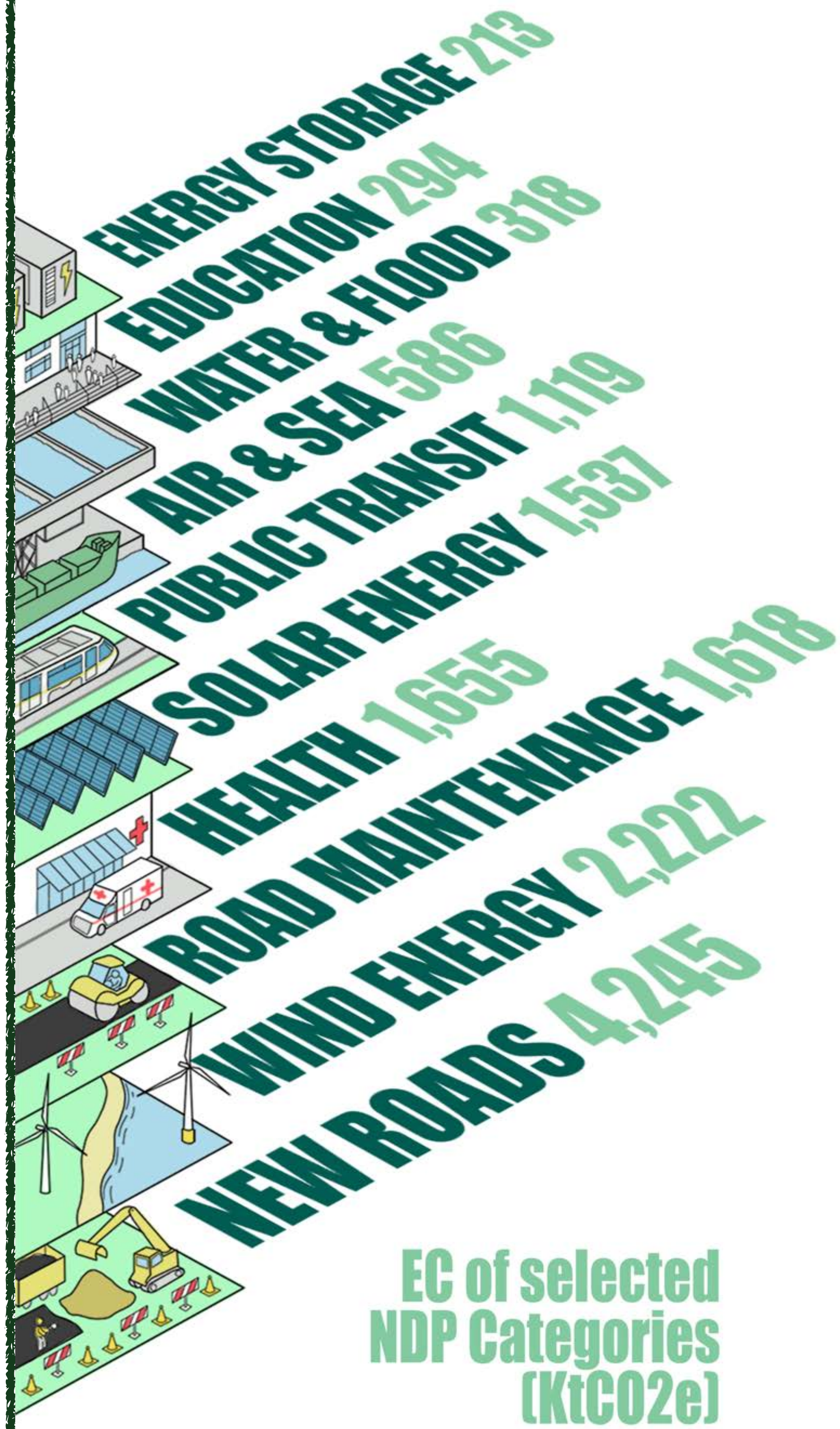
Assuming a rate of construction in line with 2020 would result in approximately 5,000 new public buildings and 15,000 new commercial buildings by 2030.

By 2030 the EC would account for 40% of all emissions associated to the non-residential sector if unaddressed.

Applying the RIAI targets a reduction in the EC of approximately 50% would be achieved which would take the WLC of the non-residential sector close to 50% of 2018 levels.







Case Study: National Development Plan

Bottom up of NDP

The infrastructure projects of the NDP represent a major construction programme involving billions of euro of investment each year over the lifetime of the plan. The NDP embodied carbon calculation, shown adjacent, is based on a mostly bottom-up approach of assigning carbon factors to projects named and referenced in the NDP. This includes projects in both the public sector (e.g. transport) and private sector (e.g. wind energy). The resulting EC figures are best estimates based on projects published in sufficient detail for an EC estimate to be formed. Some projects, such as those which will fall under the Urban Regeneration and Development Fund, are yet to be selected/ designed/ proposed to this level of detail, and so cannot be estimated for EC. For this reason, and in light of the tendency for bottom-up calculations to result in underestimation of totals, the final EC figures can be considered low estimates of the EC resulting from projects in the NDP.

Infrastructure to 2030

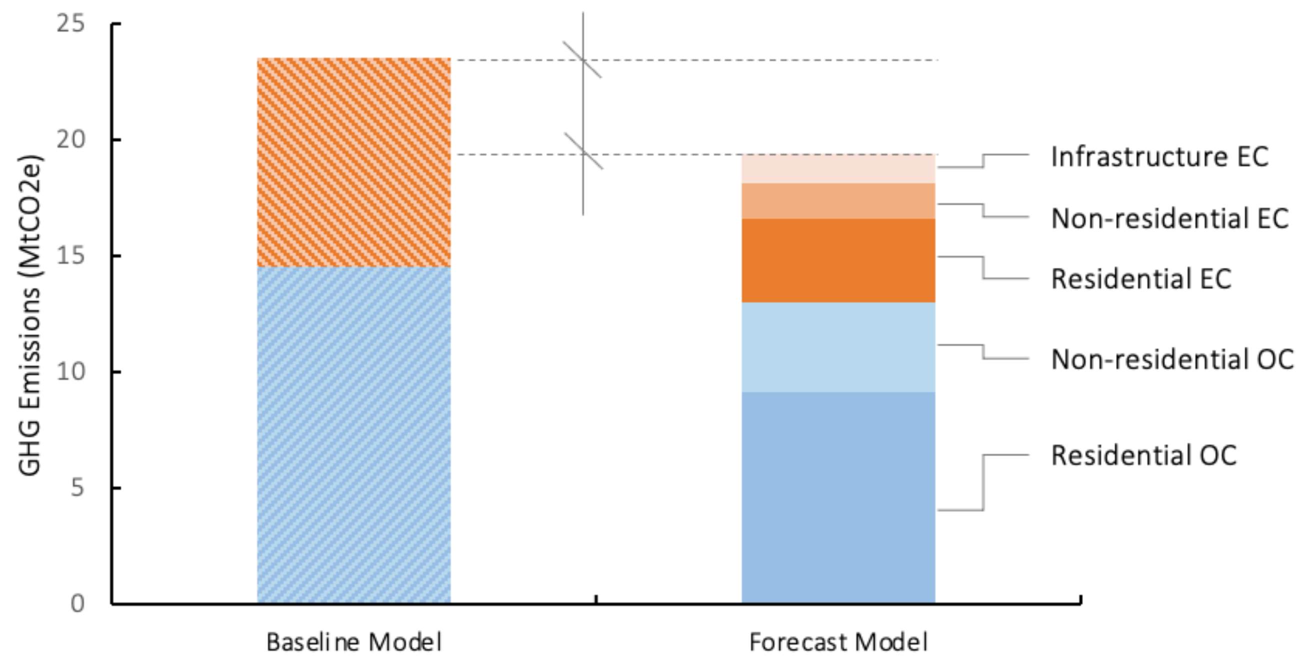
Quantifying the infrastructure poses particular challenges given the scarcity of data related to the quantity of materials used between sectors. The bottom-up analysis of the NDP highlighted a very likely underestimation of the EC of the infrastructure sector as the scope is not complete and does not include maintenance and repair.

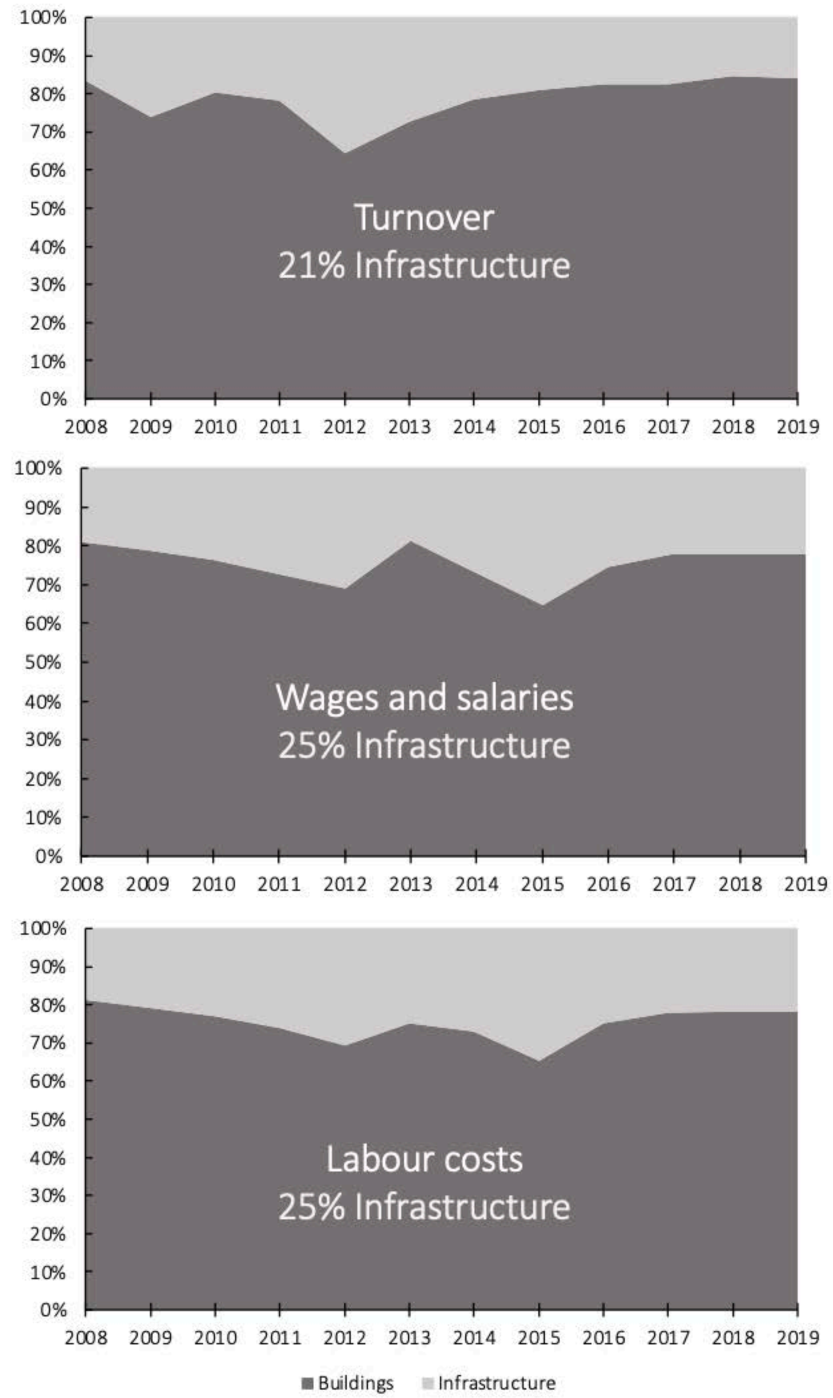
Hence another approach is required. A second approach used to quantify the EC is applied here using other reported metrics, such as turnover, wages and labour costs, as proxy relationships between buildings and infrastructure.

Four construction categories reported in the CSO database BAA12 are used and three proxy units are considered (Turnover, wages and salaries and labour costs). Considering these three metrics, a relationship of approximately 25% infrastructure and 75% buildings is observed. This relationship is assumed.

Projecting the model back to 2018 and comparing to the baseline exercise a gap is observed, due to:

- Unaccounted for EC in standard LCA approach for buildings.
- Missing infrastructure EC.





Ireland’s Built Environment

2030 BE Projections

This section presents initial projections for the entire Irish Built Environment. These are based on preliminary models with aggregated and approximate parameters. Detailed models will be included in Phase 2 of this work and later iterations of this report.

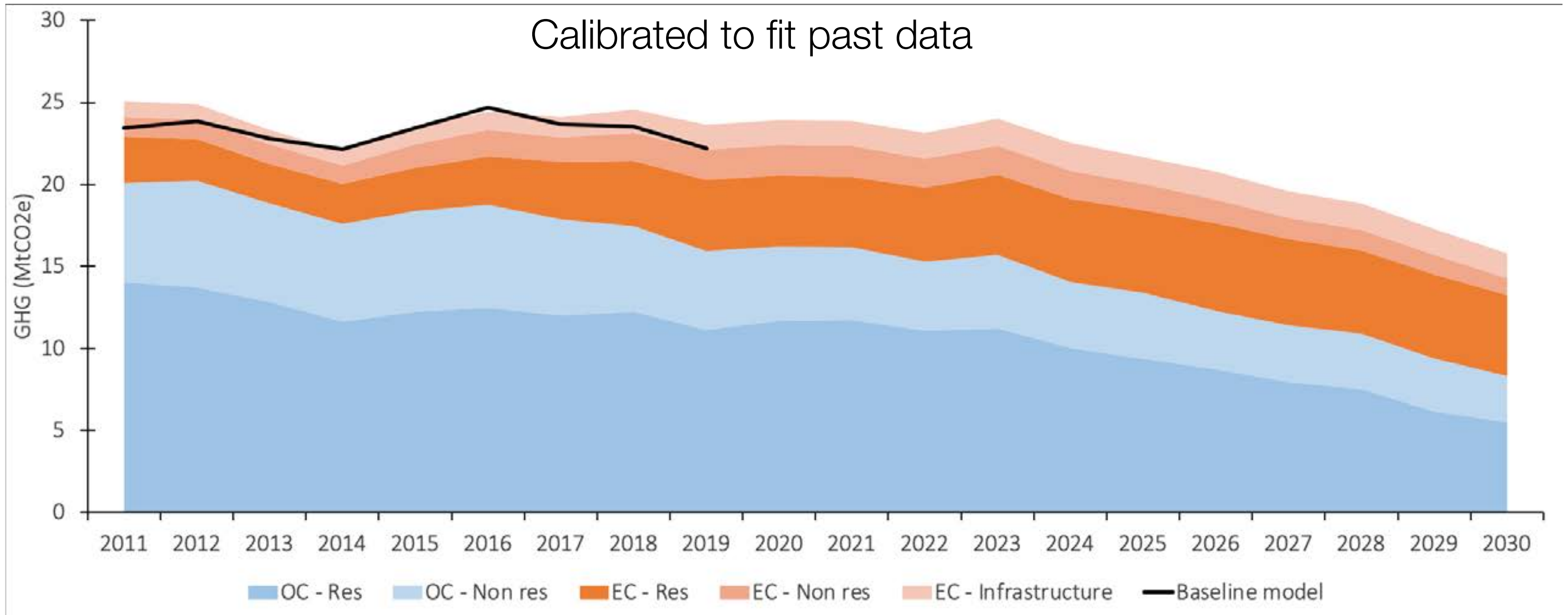
Projections to 2030 | Optimistic Scenario

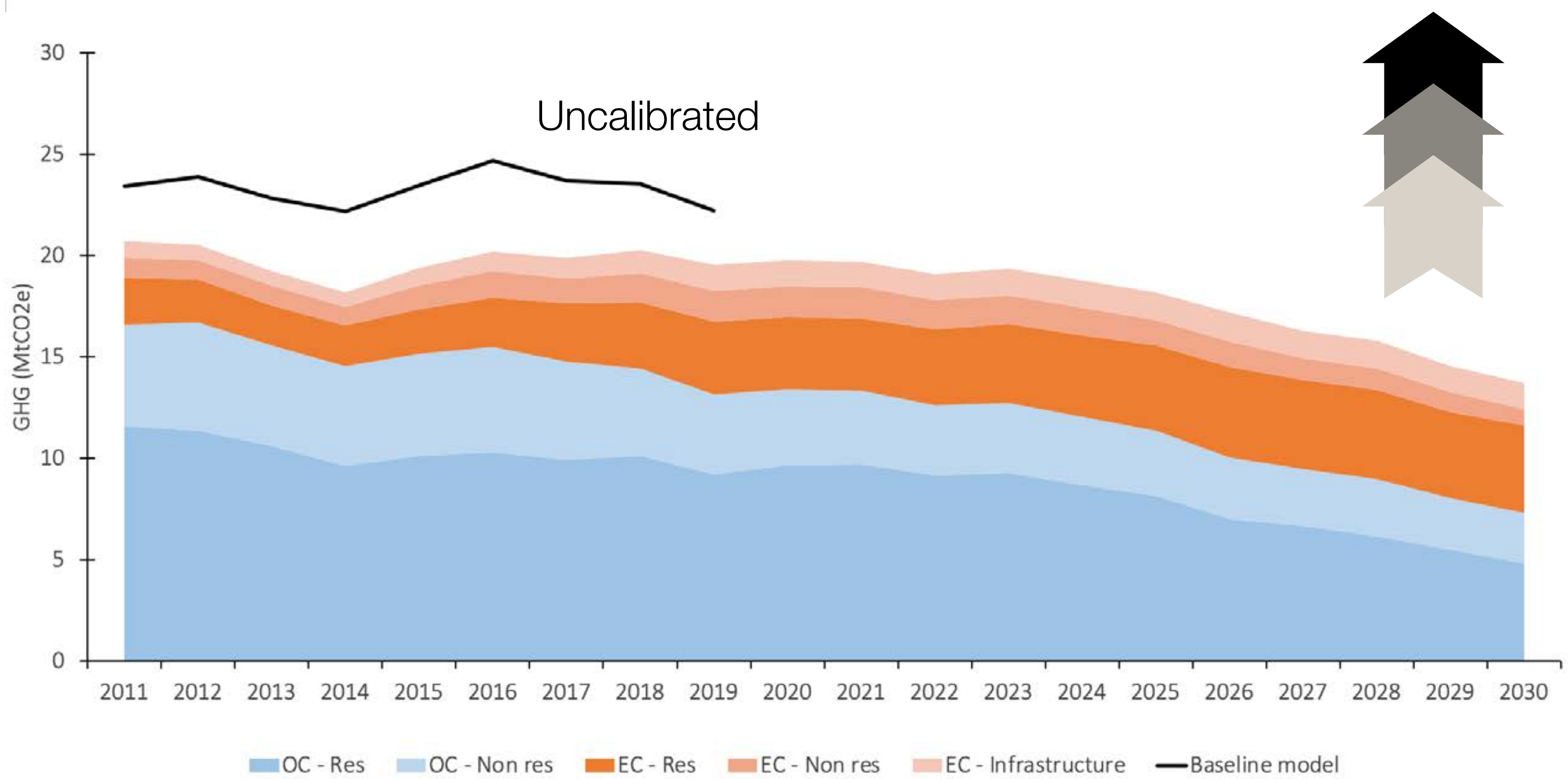
The forecast model is first scaled to match the estimates from the baseline exercise which is based on recorded data and is 15% higher.

The WLC model presented here presents a positive scenario where the OC emissions are met and where EC does not increase significantly while still achieving the NDP targets.

To achieve this scenario it is assumed that:

- The emission from the operation of all buildings is reduced by 51% using the scenarios described in earlier pages.
- The EC of constructing buildings is assumed to be 50% less intensive then today (as per RIAI targets). The EC of infrastructure is assumed to remain with the building sector taking the lead.
- 400,000 new homes are built and the non-residential sector
- Non res assumed to be 6.4% as per report
- Infrastructure assumed to grow in line with both sectors at same ratio in the past. Assuming as we build more homes we will also need same levels of infrastructure….if not more!
- EC won't be 49% less than 2018





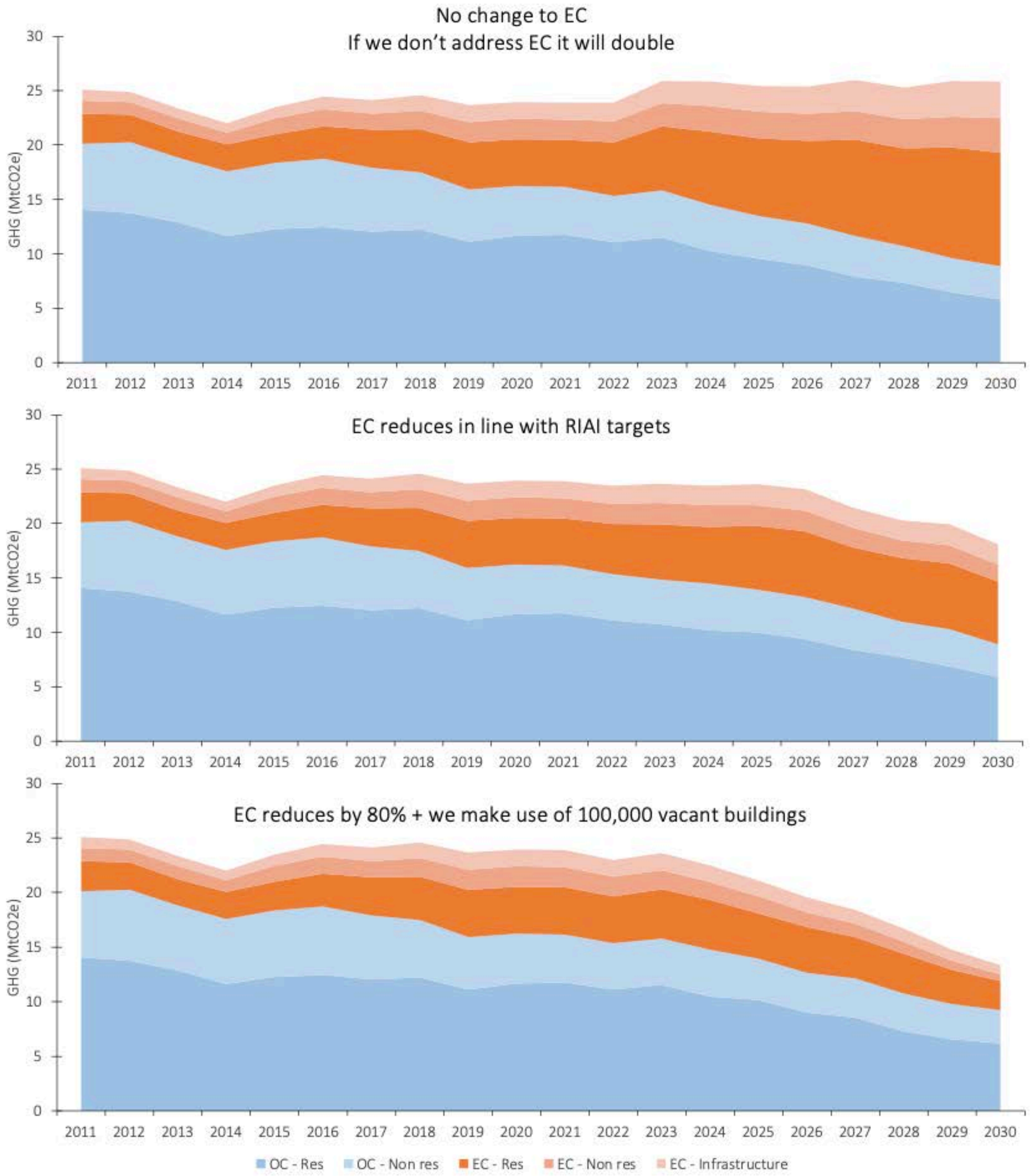
Other projections to 2030

Reduction in the carbon intensity of construction | The scenario shown adjacent assumes a broad 51% reduction in EC carbon intensity by 2030, with no change in OC. Future scenarios will look at real methods to reduce embodied carbon through innovations in concrete, increased usage of timber and other bio based materials, and lean construction methods amongst others to estimate the real impact of material and construction method innovation.

Forcing the model to meet our targets | Achieving the Climate Action Plan target of 51% less than 2018 levels will require greater reductions in emissions per unit of construction and operation to allow for the proposed construction.

One hypothetical scenario where we might meet our targets, while simultaneously building more, would require a reduction in the EC intensity by 69% on average from current levels. In this case a further 69% reduction in the operational carbon (in addition to the changes already modelled in pages 44 and 54) would also be required.

- Same OC scenario assumed i.e. mixed Scenario 1.
- Effect of not acting on EC shown and what would actually need to be done if EC was set the same 49% target.
- 80% reduction per m2 and make use of vacant buildings



Emission projections based on current plans and policies

Net Zero by 2050

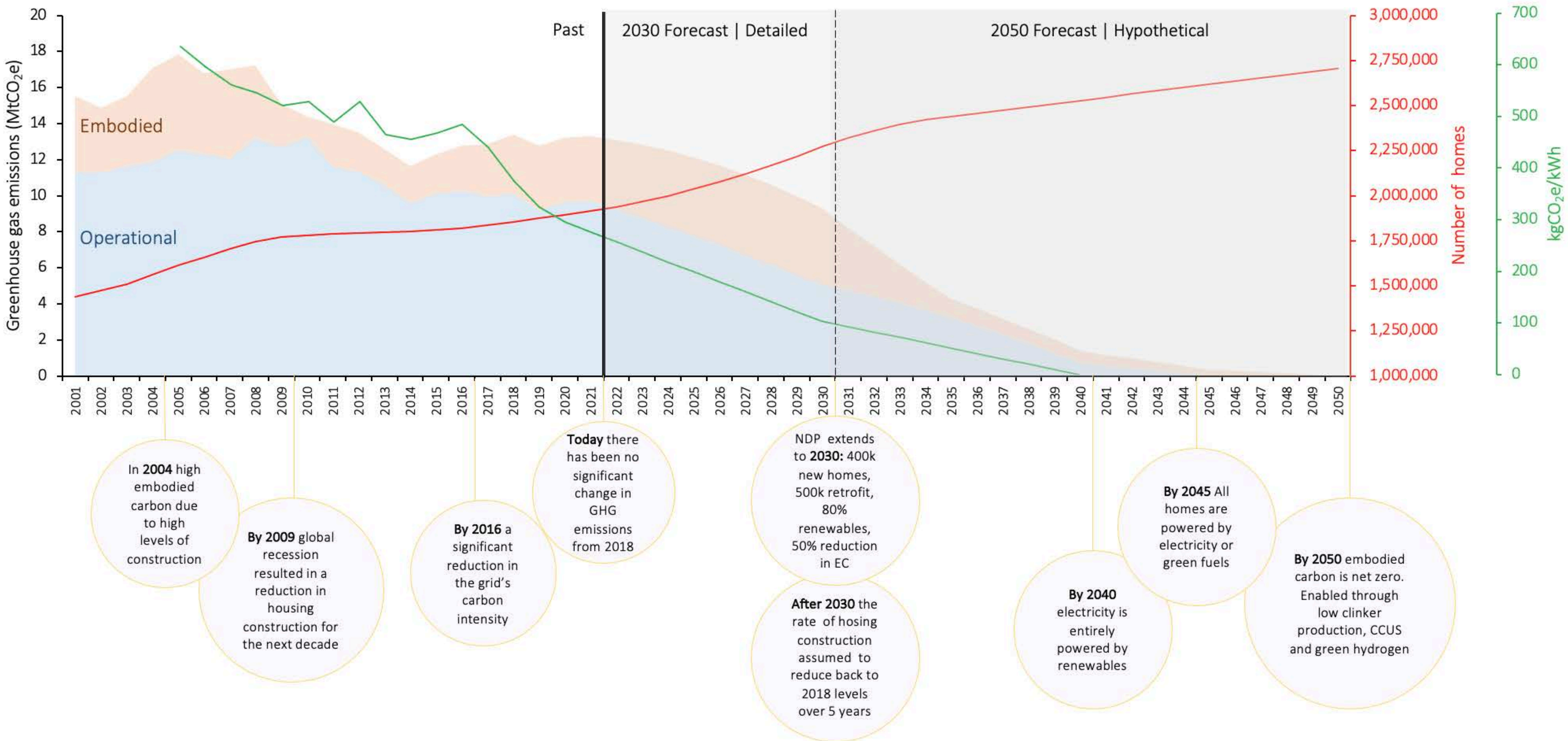
#BUILDINGLIFE

Operational Emissions

2050 Residential Operational

This section evaluates and quantifies current policies to achieve reductions

Projections to 2050 Residential



Operational Emissions

2050 Ireland Built Environment

This section evaluates and quantifies current policies to achieve reductions

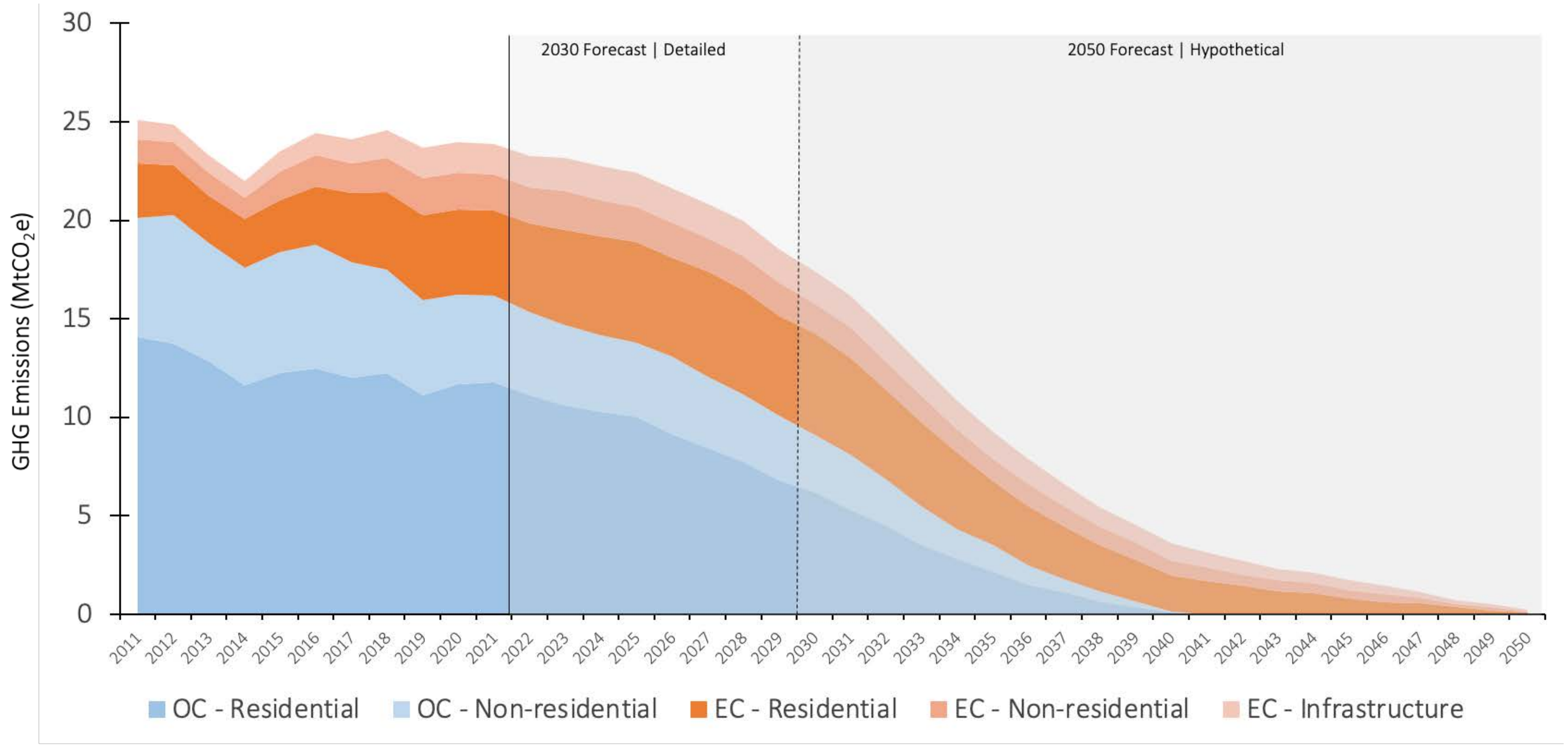
Projections for BE to 2050

Today to 2030

- OC is achievable but particularly challenging for residential sector.
- EC is very unlikely to be achievable. Even if EC reduces by 50% per m2 and 100,000 new homes comes from vacant buildings EC is still higher than 49% of 2018 level.
- While EC is not a specific target set out in the Climate Action plan…the emissions are being released and will need to be addressed at some level.

2030 to 2050

It is expected that carbon emissions associated to the operation of the built environment reach zero in advance of the embodied carbon.



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