Funded by the Horizon 2020 Framework Programme of the European Union

**CRREM – Carbon Risk Real Estate Monitor**

# FROM GLOBAL EMISSION BUDGETS TO DECARBONISATION PATHWAYS AT PROPERTY LEVEL: CRREM DOWNSCALING AND CARBON PERFORMANCE ASSESSMENT METHODOLOGY

Version 1.36 – 30.07.2020

**Prepared by:**
IIÖ Institute for Real Estate Economics, *CRREM* project coordinator

info@*CRREM*.eu
www.*CRREM*.eu
www.*CRREM*.org

July 2020

## (0) Disclaimer

*All the information in this file is shared in good faith and for general information purpose only. The CRREM Tool and the global downscaling pathways are provided free of charge and without any commitment. Beyond the intended use, all content, images and the resulting data of the use of the global pathways and/or the tool must not be transmitted to third parties, appropriated or commercially exploited without the CRREM consortium's consent. The global pathways and tool is utilised at your own risk. Neither the CRREM consortium, its members nor the European Commission are liable for any damages resulting from the use of the global downscaling pathways or the application of the CRREM tool.*

*The global pathways, tool, software, its documentation and its underlying data sets are provided "as is" and neither the European Commission, the CRREM Consortium, nor its member organisations have any obligation to provide maintenance, support or updates after the duration of the project. The Carbon Risk Real Estate Monitor (CRREM) global downscaling pathways are provided to you without any guarantee of correctness or completeness.*

*Any action you take upon the information you find in this document, is strictly at your own risk. CRREM will not be liable for any losses and/or damages in connection with the use of our website. By using this these global pathways or the CRREM Tool for your own purposes, you hereby consent to this disclaimer and agree to its terms.*

# Content



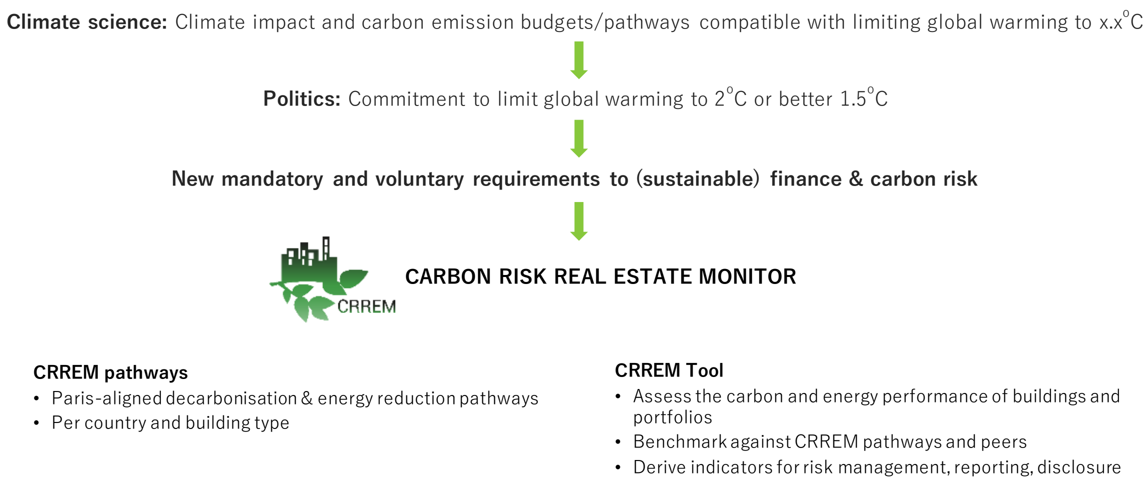
# List of Figures

# (1) *CRREM* PATHWAYS: DOWNSCALING GLOBAL MITIGATION REQUIREMENTS TO PROPERTY LEVEL

## (1.1) Overview and fundamentals regarding downscaling approach

Based on the findings of climate science on global warming and on the political decisions agreed upon in the Paris Agreement, the real estate industry faces new challenges and requires guidance in order to cope with new regulatory requirements and market expectations regarding decarbonisation (see Figure 1). The *CRREM* project has derived country-specific decarbonisation and energy-reduction pathways[1] that are aligned with the requirements of the **Paris Agreement to limit global warming to 2°C or better 1.5°C**. The *CRREM* Tool enables its potential users from the real estate sector to assess the carbon and energy performance of buildings and portfolios and benchmark assets against the *CRREM* pathways, supporting effective carbon risk management with meaningful quantitative risk indicators. For more information, please visit www.crrem.eu.

**Figure 1: From climate science to decarbonisation pathways and carbon risk indicators**

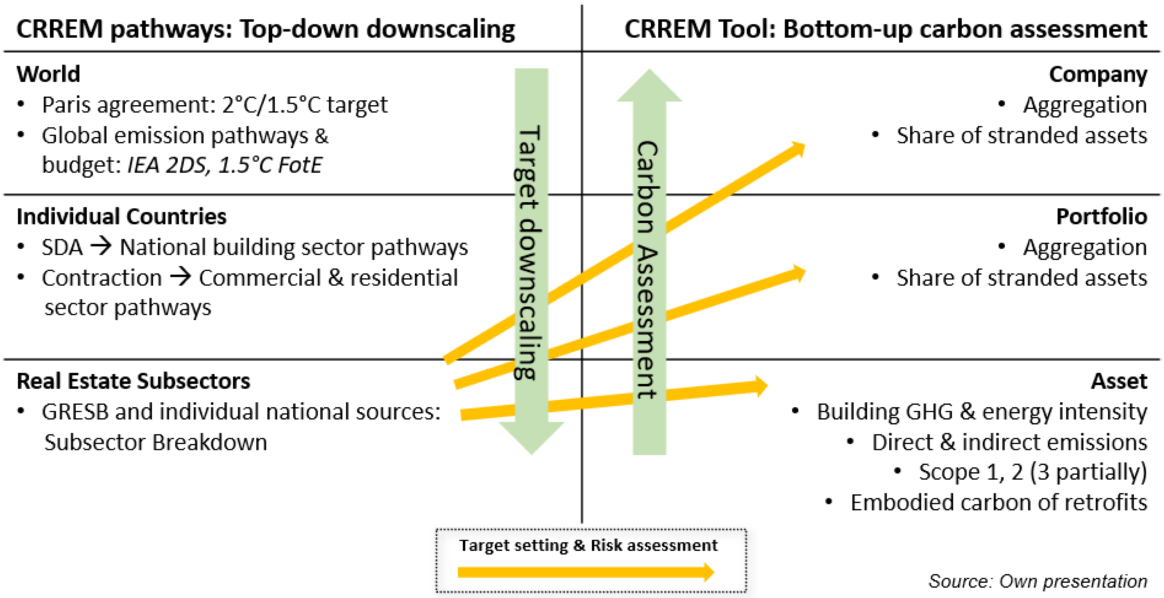



The decisive variable with regards to decarbonisation in the real estate sector is a building's so-called **carbon-intensity, measured in annual operational greenhouse gas (GHG) emissions per square metre of gross internal area** ('carbon-intensity')**. GHG emissions are expressed in in carbon dioxide equivalents (kg$CO_2$e).** This key performance indicator (KPI) includes other greenhouse gases in addition to carbon dioxide ($CO_2$), by considering their relative global warming potential compared to $CO_2$.

The next section provides an in-depth summary of the **applied downscaling-framework**, including underlying assumptions and key results.[2] Thereafter, this document provides a detailed description of each individual step of the downscaling process. Defining relevant carbon-intensity targets and pathways for the global commercial and residential real estate sector is a multi-step process requiring a variety of input data from different sources, a broad range of mathematical calculation approaches and, finally, decisions regarding specific assumptions (see Figure 2 and Figure 3 ). This process and the resulting pathways can also be used as a basis for company specific target-setting. The authors are aware that certain assumptions involve a subjective element and projections regarding future developments. However, the provided maximum amount of transparency regarding the chosen assumptions enables verifiable results and their reliable assessment.

[1] The terms 'trajectory' and 'pathway' are used interchangeably in this document expressing a chronological sequence of certain values such as floor areas or carbon-intensities.
[2] For further insights on the applied methodologies and explanatory background please read our public reports on www.crrem.eu and www.crrem.org.

**Figure 2: Overview of downscaling approach for target setting and carbon risk assessment via the CRREM Tool**

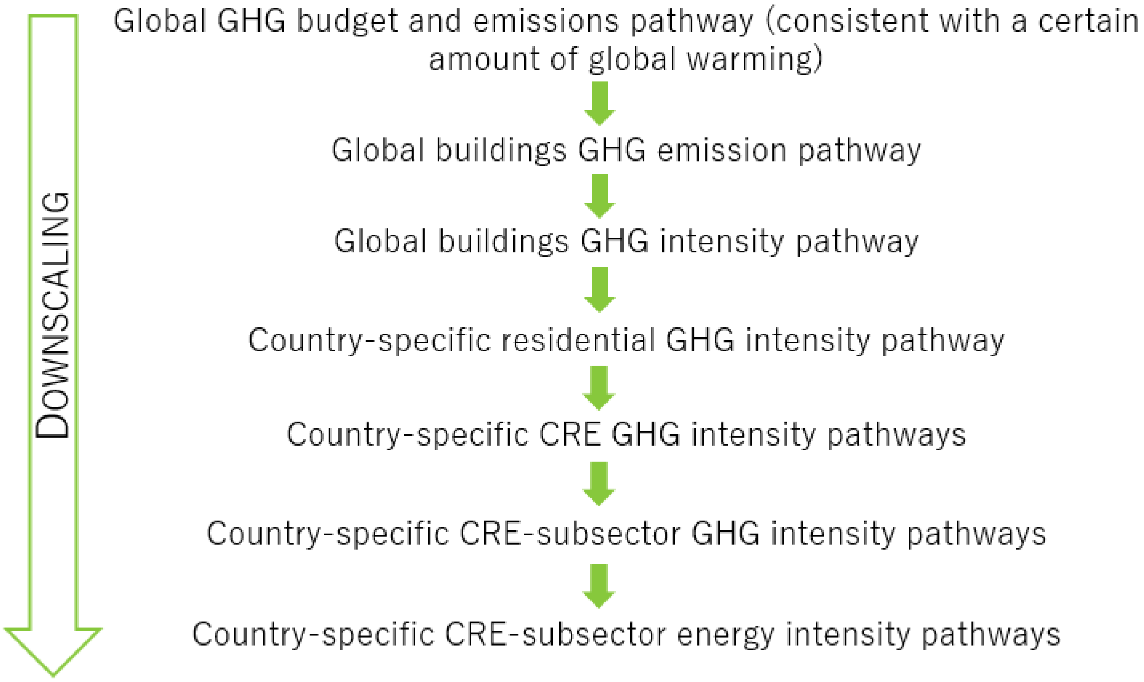



*Source: Own presentation*

In summary the model adopts **two global warming scenarios** aimed at complying with COP21-targets: 2°C and 1.5°C maximum warming by 2100. The associated anthropogenic carbon budgets and emission pathways to achieve these climate targets are calculated by the **IEA 2DS and 1.5°C FotE** . Budgets define the amount of GHG emissions that can be emitted until 2050 in order not to exceed defined warming limits. The next step is to **allocate an appropriate share of the global carbon budget to the global real estate sector** based on floor area growth rates and sector activity compared to other parts of the economy. Besides the overall amount per annum also carbon-intensities in the form of **GHG emissions per square meter ($kgCO_2e/m^2$)** are calculated. From the global emission budget, the model uses the SDA approach to derive to national building sector pathways for the residential and commercial property stock - again also taking into account different growth rates of the national building inventory. Each national pathway represents the "fair share" of carbon that each country could emit until 2050. This allocates the responsibilities and efforts required from the real estate sector to country and use-type level. Two sets of required decarbonisation pathways according to both warming scenarios are available for residential and commercial use types for 44 countries globally. All these trajectories start at the actual emission intensity of each country's building stock and converge to the same decarbonisation target. The following graphs (see Figure 4) illustrate these pathways for selected countries.

The final step uses data from *GRESB* as well as individual national sources, in order to differentiate the decarbonisation pathways for residential and commercial even further. Besides single- and multi-family residential properties also trajectories for different commercial sub-sectors like Office, Retail High Street, Retail Shopping Centre, Retail Warehouse, Hotel, Healthcare, etc. are made available. The carbon emission level and the saving capacity of each building type is intrinsically different due to the energy profiles of the activities that these buildings host. Therefore, these pathways do not converge on the same target. The calculation therefore takes into consideration the size, expected growth and differences regarding the carbon intensity and emission factors of each sub-sector per country and assumes constant relative differences between each subsector.

**Figure 3: Schematic overview of the *CRREM* downscaling methodology**



### Summary of *CRREM* Carbon Emission Downscaling

**1. Maximum amount of global warming until the end of the century, according to the targets set in the *Paris Agreement* of *COP21*:**

1.5°C and 2°C above pre-industrial levels

**2. Global $CO_2$e emission pathways and budget consistent with 1.5°C and 2°C warming. 2018-2050 Budget:**

- 1.5°C scenario: 890 $GtCO_2$e (*Friends of the Earth)*
- 2°C scenario: 1,259 $GtCO_2$e (*IEA 2DS*)

**3. Global $CO_2$e emission pathways and budget of the building sector:**

- 1.5°C scenario: 191 $GtCO_2$e
- 2°C scenario: 262 $GtCO_2$e

**4. Global $CO_2$e intensity pathway of the building sector:**

2018: 51.7 $kgCO_2e/m^2$ (starting point)

- 2050 1.5°C scenario: 1.9 $kgCO_2e/m^2$ (target)
- 2050 2°C scenario: 8.4 $kgCO_2e/m^2$ (target)

**5. Share of global real-estate related-$CO_2$e emissions under 3. covered by *CRREM*: approx. 50%**

***Note:*** *the real estate related portion of the overall carbon budget until 2050 is (cumulated) approx. 20 % and therefore well below the current ratio (of approx. 27 %). It is generally accepted that real estate has to bear a larger stake of emission reduction in comparison to other economic sectors.*

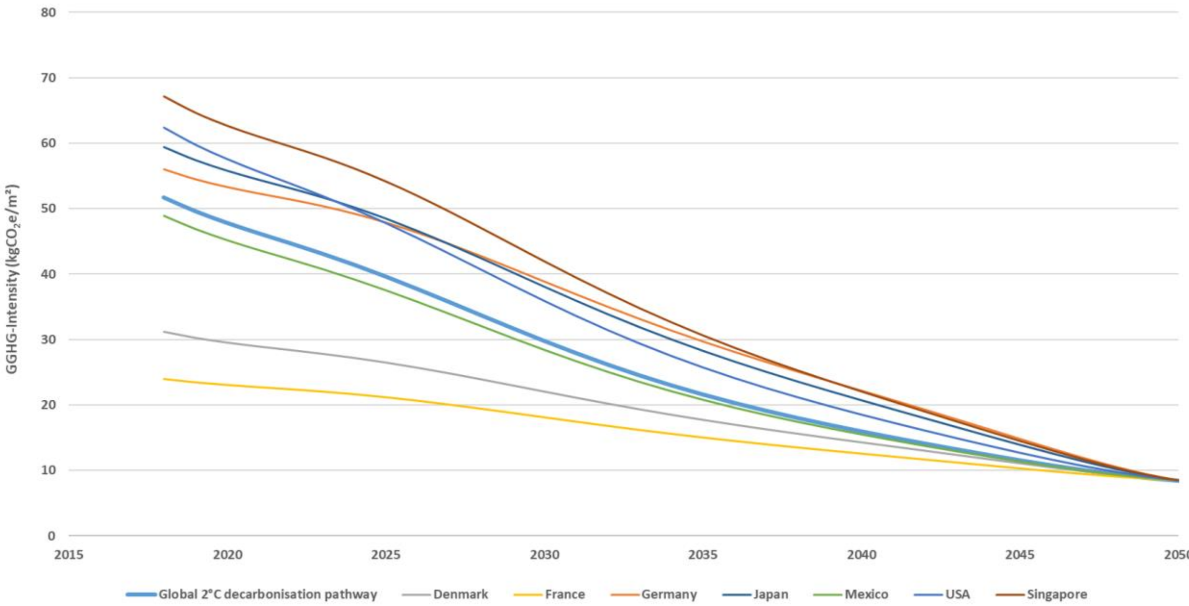
**(1.2) General remark on downscaling procedures within the *CRREM* framework**

There are a number of **different scientific approaches for downscaling a given remaining (anthropogenic) global carbon budget to single countries and industry sectors**. *CRREM* applies the so-called **convergence approach in different steps of the downscaling process** - e.g. when downscaling the global building sector carbon-intensity to national level (see Figure 4). This means that the overall-carbon-intensity of each country's building sector converges gradually towards the global average figure in the defined target year (here 2050). **Current status quo regarding the countries' individual real-estate-related energy consumption marks the starting point**. Note that energy consumption data is converted to carbon-intensities based on the respective energy mix and the emission factors of the various energy sources. Therefore, our pathways start at national sector or use-type averages and do not adopt the 'Best-in-class' approach that other initiatives propose. Therefore, some countries start above the global average and some below, followed by a gradual convergence between all countries' pathways towards one common figure in 2050. Regarding the carbon-intensities of the commercial and residential sectors within a given country, as well as of different subsectors comprising the commercial real estate industry, such as hotels or offices, *CRREM* assumes ***no*** convergence, due to certain initial differences in their specific functional requirements and related energy demands. The *CRREM* **framework was developed in accordance with a downscaling process that adheres to a given, fixed overall carbon budget, while considering different growth rates regarding a nation's real estate stock** (also referred to as different activity growth-rates). On a global scale, the population will rise from 7.8 bn to 9.7 bn in 2050[3]. This corresponds to growth in worldwide real estate floorspace from 2.5 bn m² to 4.2 bn m². Growth rates of developing countries are expected to be significantly higher than those of industrialised countries. Regarding the downscaling from a given country's overall building sector carbon-intensity to separate pathways for the residential and the commercial sector, the authors assume

[3] UN DESA (2019): World Population Prospects. A world population of 9.7 bn in 2050 corresponds to UN DESA's 'medium variant' scenario. 'Low variant': 8.8 bn; 'High variant': 10.8 bn.

a globally converging ratio of both sector's carbon performance, with significantly lower carbon-intensity figures in residential buildings.

**Figure 4: Convergence of the carbon-intensity pathway of the building sector in individual countries to the global pathway (2°C scenario)**




**(1.3) Evolution of climate change, economic activity and data availability over time**

**Note:** Carbon emission pathways are not static but subject to adjustments due to ongoing changes of the underlying data. New insights from climate science regarding climate sensitivity to greenhouse gas emissions[4] and the latest trends in global emissions are influencing results. For example, if the overall remaining global anthropogenic carbon budget is reduced, this also reduces the emission allocated to the building sector and ultimately all decarbonisation pathways must be revised accordingly. Since *CRREM* energy-intensity reduction pathways (measured in kWh/m²) are based on carbon emission pathways (measured in $kgCO_2e/m^2$), the abovementioned uncertainties affect both kinds of pathways. Energy-reduction pathways reflect how much energy can be consumed whilst adhering to the given carbon emission targets. Also, if, for instance, a country's progress in reducing the carbon-intensity of electricity generation (electric grid decarbonisation) is slower than expected, a stronger reduction in energy consumption will be required. Therefore, changes regarding the emissions factors (EF) will require adjustments to the energy-reduction pathways. Likewise, the projection of national building stock inventory growth rates might change. Furthermore, the energy mix properties use is based on projections that could be potentially be revised in the future.

All individual steps of the downscaling process, starting from global emission pathways down to individual targets for certain years and property types, are subject to uncertainty and there is an unavoidable margin of error.

[4] The specific impact of individual greenhouse gases on climate change is referred to as 'global warming potential'. See 1st CRREM report 'Stranding Risk & Carbon' for further details.

## (2) $CO_2$e EMISSION PATHWAYS FOR 1.5°C AND 2°C FOR THE PERIOD 2018-2050

The entire downscaling procedure is based on global $CO_2$e emission pathways (covering all economic sectors) which are compliant with the targets of the Paris Agreement to limit global warming to 2°C or lower 1.5°C (see Figure 5):

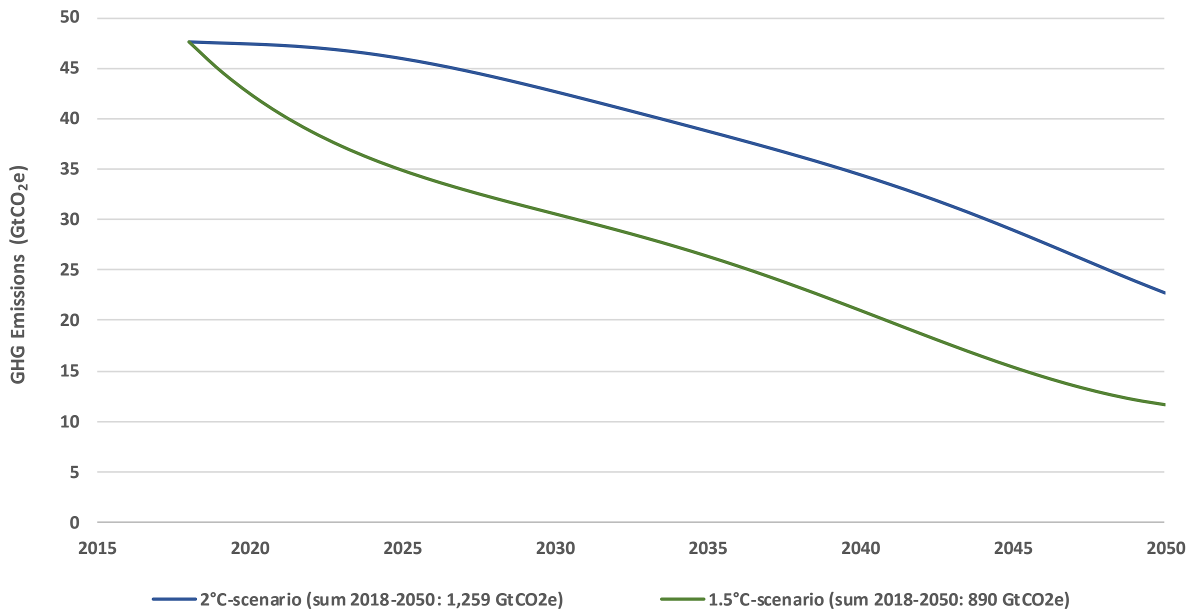
**(2.1) Global $CO_2$e emission pathways**

- 1.5°C: *Friends of the Earth FotE ('1.5FtoE')*
  *(the total anthropogenic* ***carbon emissions budget for the period 2018-2050 amounts*** *to 890 GtCO₂e)*
- 2°C: *IEA 2DS*
  *(the total anthropogenic* ***carbon emissions budget for the period 2018-2050 amounts*** *to 1,259 GtCO₂e)*

*both pathways are available on: http://tool.globalcalculator.org/*

**(2.2) Note:** *1.5FtoE* was in this updated version preferred to the scenario of *Rockström et al. (2009),* because it does not include a temporary 'overshoot' of global warming above 1.5°. The application of scenarios with 'no or limited overshoot' is a mandatory characteristic for 1.5°C-compatibility, for example according to the Technical Expert Group (TEG) on *EU climate benchmarks and Benchmark's ESG Disclosures.*

**Figure 5: Global carbon emission pathways ($CO_2$e) of 1.5°C and 2°C scenario**



## (3) GLOBAL BUILDING STOCK PROJECTIONS UNTIL 2050

Since *CRREM* decarbonisation targets are measured in terms of building carbon emissions per floor area ('carbon-intensity'), one of the first steps in the downscaling process was to derive the global trajectory of the floor area of the entire building stock including residential and commercial buildings. This trajectory was then used in a subsequent step to derive a global carbon-intensity pathway (see Figure 6).

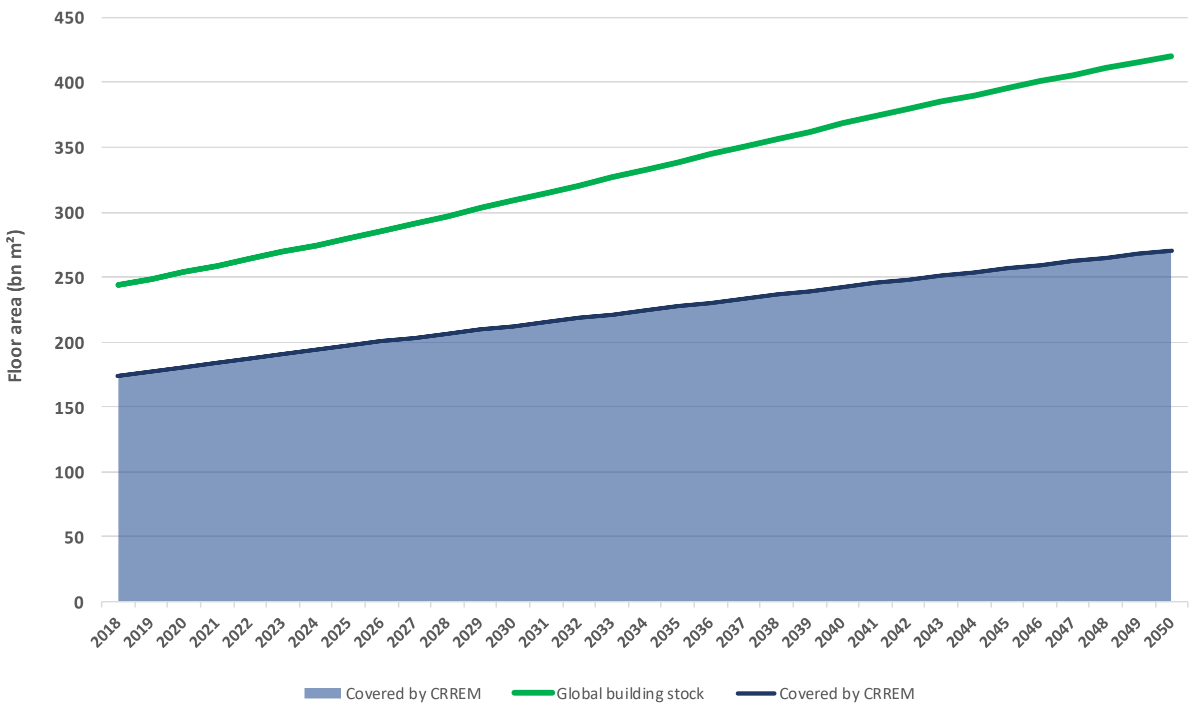
**(3.1) Estimated for *IEA 2DS* scenario, based on information in *UN Environment (2017):*** *Towards a zero-emission, efficient, and resilient buildings and construction sector. Global Status Report 2017.*

**(3.2) Assumption of similar development of global buildings' floor area in *1.5FtoE* and *IEA 2DS*.**

**(3.3) Note:** *CRREM* covers the most relevant real estate investment markets globally. In terms of floor space, approximately two thirds of the global real estate market is covered. In terms of emissions, CRREM covers around 50% of the global building sector, indicating that the carbon-intensity in the covered countries is lower than in the remaining countries.

**(3.4) Note:** The *CRREM* downscaling procedure does now refer directly to the demand-driven expansion in terms of the increasing global building stock (= new construction minus demolition). The underlying data is, of course, building upon global population growth and per capita floor space usage estimates.

**Figure 6: Evolution of global building stock (2018-2050) and part covered by *CRREM***




*Source: UN Environment and International Energy Agency (2017), own calculations.*

## (4) GLOBAL BUILDING SECTOR CARBON-INTENSITY PATHWAY

The derivation of global carbon-intensity pathways for the building sector (see Figure 7) combines the global floor area trajectory (see step (3) above) and global real estate $CO_2e$ emission pathways for 1.5°C and 2°C global warming targets (see Figure 8). These pathways are derived from two emission scenarios for the global building sector of the *International Energy Agency (2DS* and *B2DS*[5]*).* Figure 9 shows a schematic summary of the scenarios used, figures derived and assumptions applied.

**Figure 7: Global building sector GHG intensity pathway (1.5°C and 2°C global warming target)**

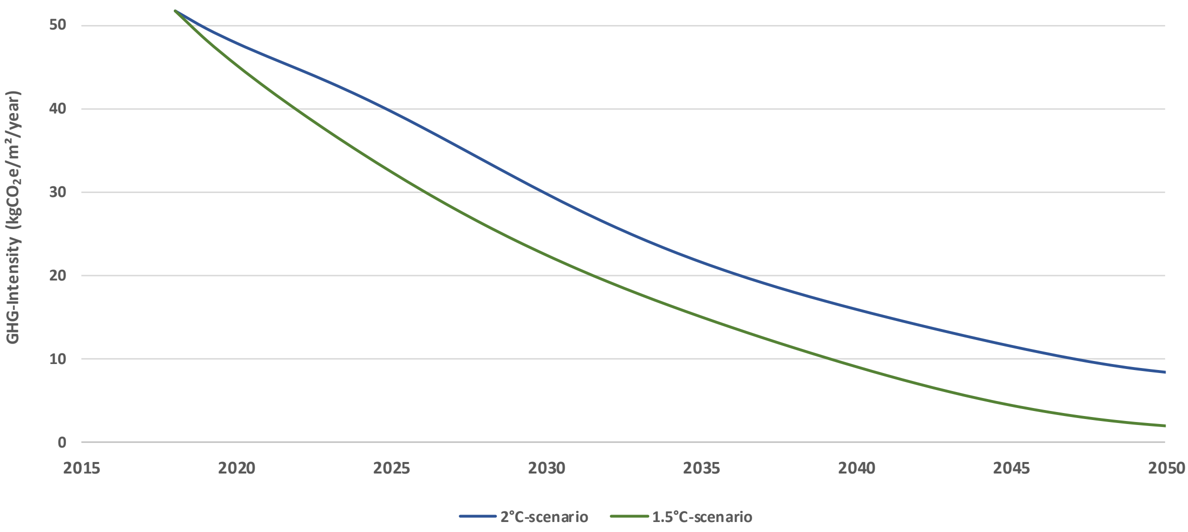
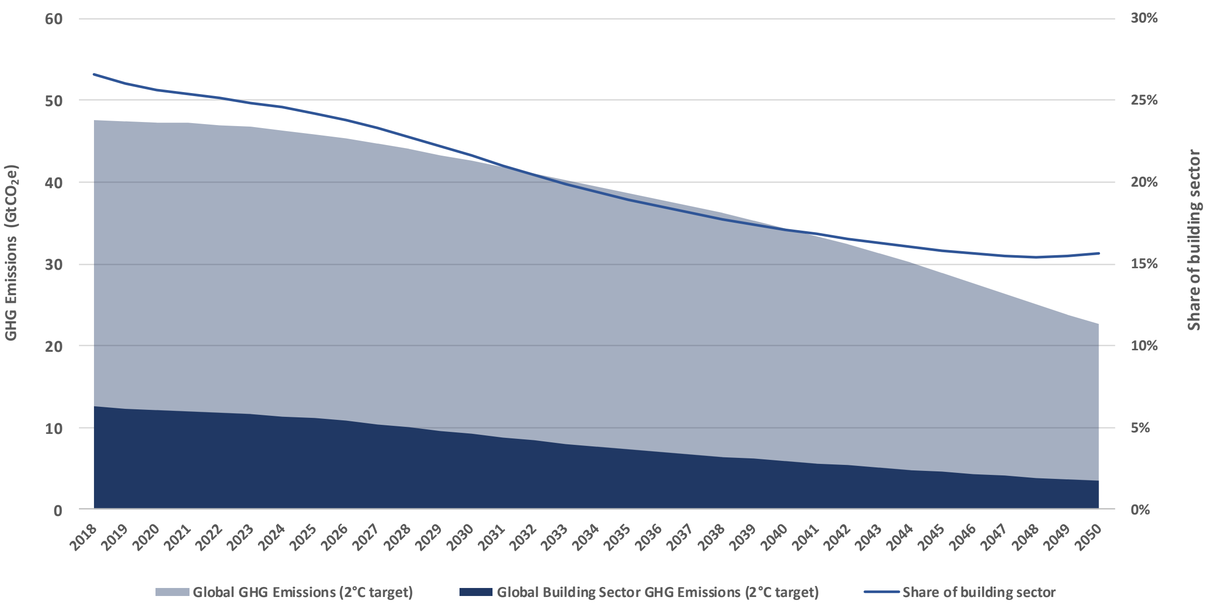
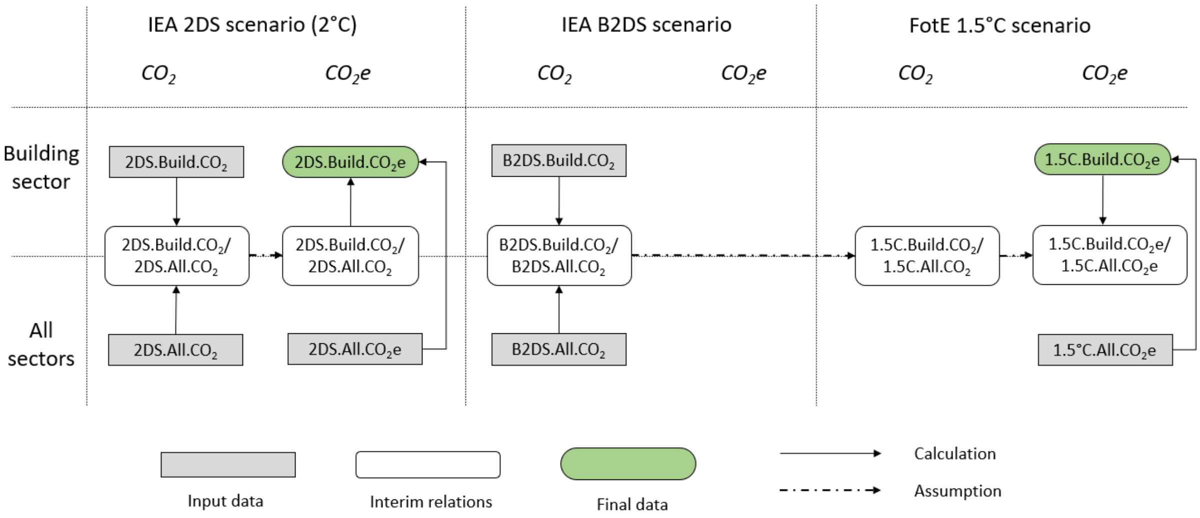



**Figure 8: Global carbon emissions (2°C scenario) of all economic sectors and the building sector**




[5] IEA B2DS = 'Beyond 2 Degree Scenario' of the *International Energy Agency* resulting in a global warming of around 1.75°C.

**Figure 9: Schematic summary of derivation of global building sectors CO2e emission pathways**




**(4.1) Underlying pathways**

- IEA 2DS: Global building sector CO2 emissions
- IEA 2DS: Global all sectors CO2 emissions
- IEA 2DS: Global all sectors CO2e emissions
- IEA BSDS: Global building sector CO2 emissions
- IEA B2DS: Global all sectors CO2 emissions

*Source: UN Environment and International Energy Agency (2017)*

**(4.2) Note:** Global CO2 emission pathways of buildings for 1.5°C and 2°C for the period 2018-2050 are based on data for the period 2017-2050 that was adapted to the latest available data on 2018 global CO2e emissions, while adhering to the total cumulative emission budget. The resulting adaptations to the original pathways have been distributed parabolically to the remaining years, with emission levels above the original pathways in early years, lower levels in later years and the same emissions in 2050. Furthermore, the IEA B2DS was used instead of the 2DS because the IEA 2BDS better reflects the ratio of the building sector emissions to all emissions.

**(4.3) Necessary assumptions made:**

- The ratio of CO2e to CO2 is the same in the building sector as for all sectors.
- The share of the global buildings sector's emissions to all sectors emissions is the same in the 1.5°C scenario (1.5FoeT) as in the IEA B2DS scenario.

## (5) Calculation of GHG intensity pathways for individual countries and use-types

In this step of the downscaling process, the decarbonisation pathway of the building sector is calculated for each of the countries covered, based on:

- The SDA *(Sectoral Decarbonisation Approach)* methodology (7),
- each country's baseline carbon-intensity using:
  - Country building stock in square meters (residential and commercial according to IPMS2),
  - country baseline for EUI (energy use intensity in kwh/m²) for use-types,
  - energy mix / sources used for property stock,
  - emission factors (EF) of energy sources.
- the assumption of converging carbon-intensities until 2050 with respect to the global figures of 1.5°C and 2°C scenarios on country level (4) (see Figure 4 above) using:
  - Projections for energy mix / sources,
  - projections for emission factors[6] for energy sources,
  - growth rate for floor space in different countries.

**(5.1) Underlying datasets**

(5.1.1) **Floor area growth projections** based on *UN Environment (2017): Global status report. Towards a zero-emission, efficient, and resilient buildings and construction sector* and further data sources at country level (see below). *EU: Eurostat* baseline data and projections according to *CTI 2050 Roadmap Tool (Shared Efforts Scenario Pathway).*

(5.1.2) Baseline 2018 buildings' **GHG intensity** figures for each country, based on **energy use intensity** (today) and the average **energy mix** for each country and property type and respective **emission factors** (each for current levels and projections until 2050). Source: See below for sources broken down by country; GRESB 2019 asset level-data.

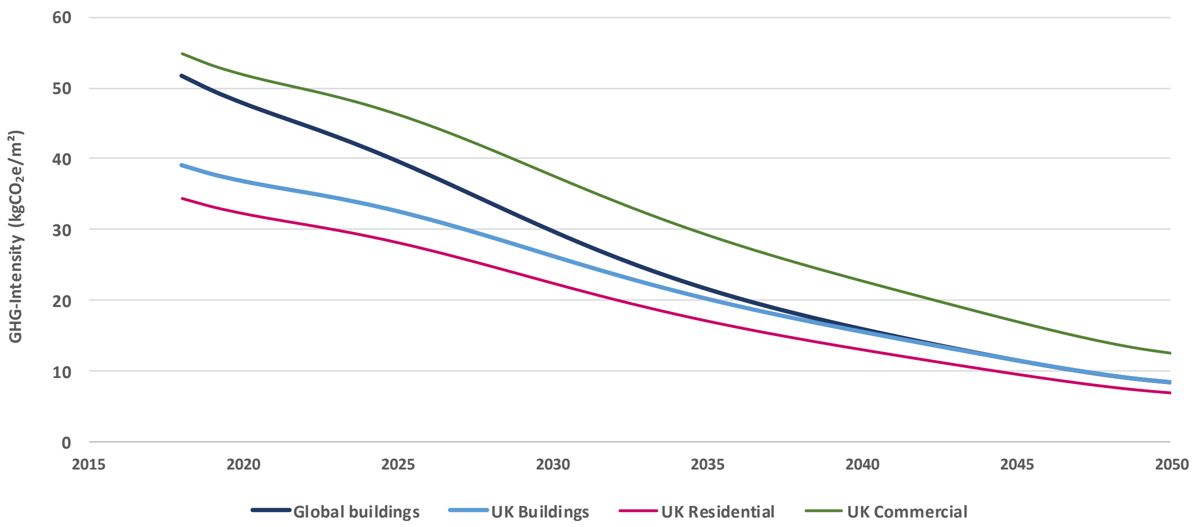
**(5.2) Calculation of country-specific GHG intensity pathways for residential and for commercial buildings (1.5°C and 2°C)**

(5.2.1) The derivation of separate decarbonisation pathways for the residential and the commercial sector within each country (see Figure 10) is based on each sector's baseline (2018) carbon-intensity and the assumption of a globally retained / constant ratio of the carbon-intensity for different residential and commercial building types.

(5.2.2) Baseline 2018 residential and commercial buildings' GHG intensity figures for each country. Note that due to limited data availability in most countries only averages were calculated (no bandwidths, percentiles etc.). *Source: See below for sources broken down by country.*

[6] Note that the EF used here for the calculation of the pathways are the same like in the CRREM-tool. E.g. EF for electricity are identical for today and their changes over time. Energy mix however for the pathways is also changing over time according to national projections for the commercial and residential sector. Within the CRREM-tool the energy source will however only change if retrofit-action occurs.

*Figure 10: Decarbonisation pathway of global buildings sector, UK buildings sector and UK residential and commercial sector*




**(5.3) Differentiation of multi-family residential and several commercial buildings sub-sectors**

(5.3.1) The derivation of distinct decarbonisation pathways for specific subsectors / use-types within the residential and the commercial real estate sector is based on the assumption of a constant global ratio of the carbon-intensity of the respective subsector (e.g. office buildings) and the commercial sector. Until 2050 the relative difference in a specific country will converge to the average difference of all countries.[7]

(5.3.2) Calibration factors based on 2019 *GRESB* asset level data and data from the *EU* research project *INSPIRE.*

(5.3.3) Calibration factors based on information on baseline ratios of different sub-sectors. *Source: See below for data sources for individual countries.*

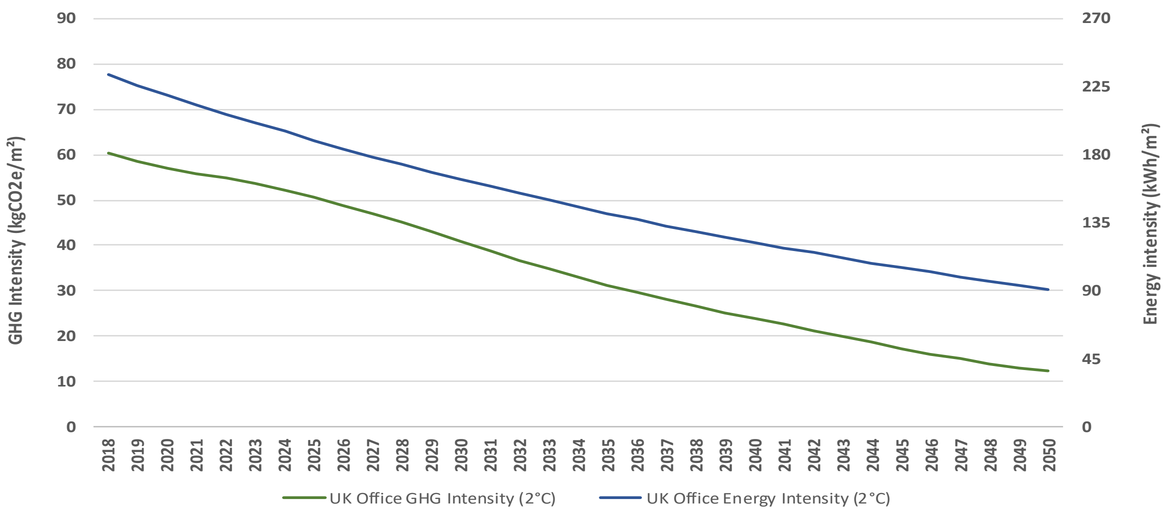
[7] E.g.: The average ratio of Hotel to all commercial properties is 1.5 in all countries. In a specific country, the baseline ratio is however 1.8. Then, this ratio will decline to 1.5 (global average ration) until 2050.

## (6) Calculation of energy-intensity pathways for individual countries and use-types

The derivation of energy-reduction pathways (EUI measured in kWh/m²) are based on the respective decarbonisation pathways (GHG emissions per square meter ($kgCO_2e/m^2$)) for each subsector within a certain country (see step (5) above) and the respective typical relationship between carbon emissions and energy consumption (emission factor, EF), based on projected figures on energy mix (share of electricity and fuels) and grid decarbonisation within each country (see Figure 11). *CRREM* energy targets are NOT kWhe but kWh! Furthermore, it is important to mention that *CRREM* is focussing on the "Net end-energy demand" (not "Primary energy demand"!).[8]

Based on projected emission factors and energy mix, typical carbon-to-energy-factors have been derived, allowing the conversion of carbon-intensity to energy-intensity figures. In some cases, grid decarbonisation might progress very fast in certain countries, resulting in no or only very small energy-reduction requirements. In such cases, *CRREM* requires (a minimum) energy-intensity reductions in line with the UN Sustainable Development Goals of at least -2.9% p.a.

**Figure 11: Decarbonisation and energy-reduction pathway for UK office buildings (2°C scenario)**




### (6.1) Underlying data and calculation procedure:

(6.1.1) Country-specific 2018 baseline end-energy-intensity (kWh/m²) data for residential and commercial buildings (and sub-sectors if available). *Source: See below for data sources for individual countries.*

(6.1.2) Calculation of 2018 country-specific and (sub-)sector-specific carbon-to-energy factors[9]

(6.1.3) Calculation of rate of change of these carbon-to-energy factors

- Evolution of share of energy sources (electricity, gas, oil, etc.) on buildings' end-energy use (separate calculation for residential and commercial buildings, if required data is available)
- Evolution of carbon-intensity of electricity generation ('grid decarbonisation')

(6.1.4) Calculation of end-energy-intensity pathways 2018-2050 based on carbon-intensity pathways (1.5° and 2°C scenario) and carbon-to-energy factors.

[8] E.g.: If 1,000 kWh were produced via renewable on site like PV and also consumed on site and another 1,000 kWh electricity is procured from the electric grid, the "Net energy demand" is still 1,000 kWh, the energy consumption of the property is however 2,000 kWh.

[9] These carbon-to-energy factors are the reversal of emission factors, describing the same relation between carbon emissions and energy consumption. Whereas emission factors denote the amount of carbon emissions related to a certain amount of energy consumption, the carbon-to-energy factors used in this step of the CRREM framework enables the calculation of the specific amount of energy consumption related to a certain amount of carbon emissions.

## (7) SDA Sectoral Decarbonisation Approach

The *SDA* **convergence methodology** offers a very flexible framework not limited only to companies willing to meet certain future sector standards or expectations. In combination with further methods, the *SDA* framework offers a useful tool that can be applied for **setting science-based, country-specific** targets. For example, *CRREM* uses the *SDA* intensity-convergence approach to derive national carbon-intensity pathways from the respective global pathway.

The use of intensity parameters enables the **consideration of different growth rates** between and within countries. Since total cumulative emissions are limited to the given remaining global budget, and carbon-intensities will converge in the target year, the future carbon-intensity pathway in a specific country will depend on the future growth of building stock in this country. If Country A grows faster than the average, *SDA* methodology allows for additional absolute emissions in this country at the expense of the other countries' budgets. At the same time, higher growth rates in Country A will result in its carbon-intensity pathway converging faster to the target intensity figures. This can be interpreted as follows: The applied methodology does not penalise activity growth per se, but links it to a higher level of responsibility and therefore expects the growth to take place at "future-proof carbon-intensity" standards. The *SDA* framework applies a so-called ***Market Share Parameter*** expressing the different growth rates and a so-called ***Sector Decarbonisation Index***, expressing the decarbonisation progress in each country:

Absolute emissions can generally be calculated for each country by multiplying sector activity (e.g. floor area) with carbon-intensity (e.g. emissions per floor area). The sum of annual absolute emissions has to remain within the defined sector budget:

$$\sum_{2018}^{2050} A_y \, SI_y \leq Budget_{2050}$$

*where:*

| | |
|---|---|
| $A_y$ | *Activity of country in year y* |
| $SI_y$ | *Intensity of country in year y* |
| $Budget_{2050}$ | *Cumulative carbon budget 2018-2050 of country compatible with a scenario below 1.5°C/2°C scenario* |

Since *SDA* applies an intensity convergence approach, it is necessary to consider **country-specific and global future activity levels** for the derivation of individual carbon-reduction pathways for a specific country:

$$m_y = \frac{CA_b/SA_b}{CA_y/SA_y} = \frac{SA_y/SA_b}{CA_y/CA_b}$$

*where:*

| | |
|---|---|
| $m_y$ | *Market share parameter of country in year y* |
| $CA_b$ | *Activity of country in base year b* |
| $SA_b$ | *Global activity in base year b* |
| $CA_y$ | *Activity of country in year y* |
| $SA_y$ | *Global activity in year y* |

The market share parameter $m_y$ presents the ratio of a country's (activity) market share in the baseline year *b* to that in year y (in the case of the real estate industry, activity is measured in square metres of floor area). In other words, $m_y$ *presents* the ratio of the global activity growth from baseline year *b* to year *y* to that of the specific country.

If a country has tripled its activity[10] within a certain period *($CA_y=3CA_b$)*[11], whereas global activity has 'only' doubled *($SA_y=2SA_b$)*, $m_y$ is 2/3, resulting in a lower country intensity target $CI_y$ as in the case of some country-specific and global growth rates:

$$m_y = \frac{SA_y/SA_b}{CA_y/CA_b} = \frac{2\,SA_b/SA_b}{3CA_b/CA_b} = \frac{2}{3}$$

*SDA* makes use of a so-called sector decarbonization index $p$ indicating the **remaining share of sectoral (/global) decarbonisation** until 2050 ($p = 1$ in the base year and $p = 0$ in 2050):

$$p_y = \frac{SI_y - SI_{2050}}{SI_b - SI_{2050}}$$

*where:*

| | |
|---|---|
| $p_y$ | *Global decarbonization index in year y* |
| $SI_{2050}$ | Global *intensity in 2050* |
| $SI_b$ | *Global intensity in base year b* |

The **target intensity of an individual country $CI_y$** according to *SDA* can be derived from the above formulas as follows:

$$CI_y = SI_{2050} + (CI_b - SI_{2050}) * p_y * m_y$$

*where:*

| | |
|---|---|
| $CI_y$ | *Intensity of country in year y* |
| $CI_b$ | *Intensity of country in base year y* |

This formula begins with the global target intensity for 2050 $SI_{2050}$ which is also the target for the respective country in 2050 $CI_{2050}$ (due to the convergence approach). The second part of the formula presents the difference between the country intensity in the baseline and target years, multiplied by the *Sector Decarbonisation Index (*presenting the global building sector's rate of decarbonisation) and the *Market Share Parameter* presenting the effect of different country growth rates. See Figure 4 for results of SDA-based convergence calculations for different countries' carbon-intensity gradually approaching the global pathway.

***Please note:*** the convergence will effectively be carried out at the level of the use-types via $CO_2$ intensities. The same national growth rates/development is applied to all use-types.

[10] Note that „activity" can be translated to „floor space growth rate" for real estate application.
[11] Figures from the Global Status Report 2016 were used for regional/country specific activity levels.

## (8) Energy and carbon assessment methodology

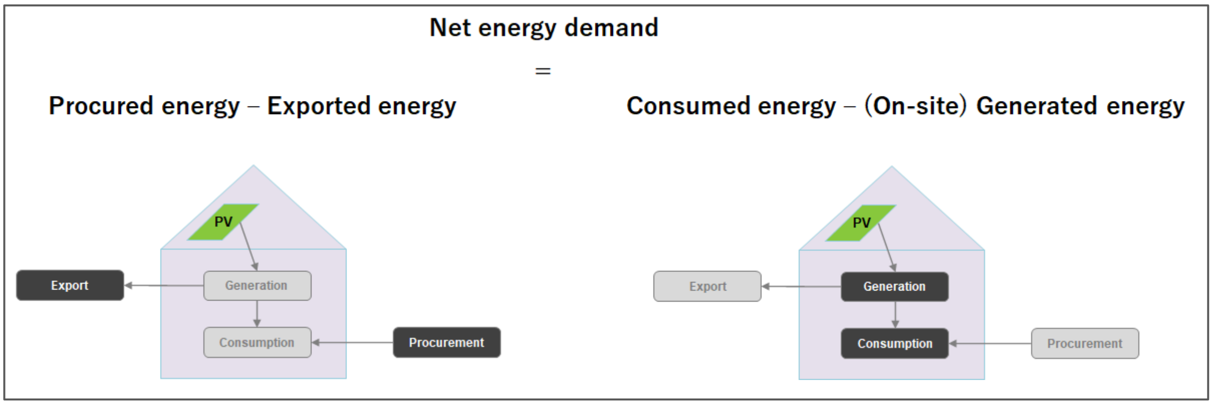
*CRREM* decarbonisation pathways and carbon risk assessment focusses on the intrinsic environmental quality of individual buildings and is intended to provide owners and potential investors with the information required to assess this quality. The impact of an individual building on climate change is determined by the amount of **greenhouse gases emitted during its operation**, comprising both **direct emissions** from burning fuels (and fugitive emissions) and **indirect emissions** related to the use of electricity and any district heating and cooling. The amount of emissions is determined by the quantity of energy consumed from different sources and its specific carbon-intensity, which is usually expressed in so-called **emission factors,** indicating the amount of carbon emissions related to a certain amount of consumed energy. Procuring certificates for renewable electricity sources does *not* reflect the intrinsic environmental quality of a building itself and does *not* increase the amount of renewable energy in a given energy grid in the short-term. Since *CRREM* decarbonisation pathways are based on national emission factors, users of the pathways have to apply national emission factors in order to yield meaningful results when benchmarking individual buildings' carbon performance by means of the **pathways. This means that emissions have to be determined according to the so-called 'location-based' approach instead of the so-called 'market-based' approach.** More information on this may be found in the *EPRA Sustainability Best Practices Recommendations Guidelines* of the *European Public Real Estate Association.* This also applies if electricity emission factors are available at a sub-national level, for example for individual federal states or other kinds of regions. The baseline carbon-intensities of *CRREM* decarbonisation pathways are based on national emission factors.[12]

*CRREM* decarbonisation and energy-reduction pathways refer to operational emissions and energy consumption figures. Taking into consideration that new developments are commonly built according to higher energy-efficiency standards, a new development should comply with the pathway for a certain number of years. With respect to typical refurbishment cycles of 15 years, this period could provide an appropriate reference point for a required minimum length of compliance.

*CRREM* energy-reduction pathways refer to the so-called end- energy, as it can be read off electricity meters and utility bills, in contrast to primary energy, which indicates how much energy has been utilised in burning fossil fuels such as oil and gas, in order to produce the final amount of consumed electric energy. The difference between end-energy and primary energy is the result of conversion, transmission and distribution losses. Generally, the relationship between these two figures is expressed in terms of so-called primary energy factors, varying between different energy sources such as electricity or gas. *CRREM* energy-reduction pathways further referring to the **net energy demand** of a certain building. This figure reflects the balance of energy imports and exports, and is *not* identical to a building's energy consumption. Figure 12 shows two different views on the net energy demand, illustrating its relationship to parameters like procurement, consumption, generation and export:

[12] Note: Users of the CRREM-tool can overwrite the default figures for the applied EF for their properties. The application of an emission factor for a certain region (or market-based approach, see above) that is lower than the national value may result in lower calculated carbon emissions for that building being lower. In that case users should also overwrite the pathways in order not to benchmark their assets to purely national levels (for EF).

**Figure 12: Schematic overview of net energy demand, energy procurement, export, consumption and generation**




The *CRREM* targets do not reflect energy consumption, but rather net energy demand. The net energy demand can be calculated by deducting the energy generated from the energy drawn/purchased from the grid, but the energy consumption would be both generated and consumed from the grid. An example of "low net energy" would be heat-pumps as they consume small amounts of energy from the grid, but generate a larger amount of energy through heat from the earth on site.

## (9) Data sources

**Globally and EU -** *Building Stock and floor space growth rates*

GABC (2016): Global Status Report 2016. Online: https://www.worldgbc.org/news-media/global-status-report-2016.

GABC (2017): Global Status Report 2017. Online: https://www.worldgbc.org/news-media/global-status-report-2017.

European Commission: EU Buildings Stock Observatory.

**European Union**

*Energy Mix and Development Over Time*

ECF European Climate Foundation, ClimateWorks Foundation: CTI 2050 Roadmap Tool. https://stakeholder.netzero2050.eu/

*Emission Factors and EF Development*

European Commission (2016): EU Reference Scenario 2016. Energy, transport and GHG emissions Trends to 2050. Online: https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf.

Moro A., Lonza L., (2018): Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. (Used for electricity emission factors).

*European District Heating Prices*

Energiforsk (2016): European Price Series.

*Other sources*

Eurostat (2019): Early estimates of CO2 emissions from energy use. https://ec.europa.eu/eurostat/documents/2995521/9779945/8-08052019-AP-EN.pdf/9594d125-9163-446c-b650-b2b00c531d2b.

INSPIRE project: Deliverable 2.1a – Survey on the energy needs and architectural features.

UK Department for Business, Energy & Industrial Strategy (2016): Building Energy Efficiency Survey (BEES). https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees.

***Please note:*** Country specific sources have been used to derive to individual starting values for all countries.

**Japan**

*Building Stock*

Statistics Bureau of Japan (2016): Japan Statistical Yearbook 2016.

*Building Stock Development*

World Green Building Council (2016): Global Status Report 2016. Online: https://www.worldgbc.org/news-media/global-status-report-2016.

*Energy Consumption & Emissions*

GIO Greenhouse gas Inventory Office of Japan (2019): National GHG Inventory Report of JAPAN.

*Emission Factor Development (Scenario 2 “Made-In-Japan” used)*

IGES Institue for Global Environmental Strategies (n.y.): Japan 2050 Low Carbon Navigator. http://www.en-2050-low-carbon-navi.jp.

*Energy Intensities*

Otsuka, A. (2018): Regional Determinants of Energy Efficiency: Residential Energy Demand in Japan. In: Energies, 11(6):1557.

Japan Sustainable Building Consortium (n.y.): DECC (Data-base for Energy Consumption of Commercial Buildings). Online: http://www.jsbc.or.jp/decc.

*Indirect Emissions*

TEPCO (2017): TEPCO CO2 Emissions Factor FY 2016. Online: https://www.tepco.co.jp/en/press/corp-com/release/2017/1447967_10469.html.

*Energy and Carbon Intensities*

The current starting point intensities of Japan (2018): DECC Data Set.

*Other Sources*

Berraho, D. (2012): Options for the Japanese electricity mix by 2050.

CarbonBrief (2019): The Carbon Brief Profile: Japan.

Kikp Network (2014): Japan Climate Vision 2050: An energy future independent of nuclear power and fossil fuels.

Tokyo Metropolitan Government (2019): Dataset on carbon intensity of commercial properties.

**Australia**

*Building Stock*

de Jong, P., van Oss, S. C. F., Wamelink, H. (2007): High Rise Ability. In: Earthquake Resistant Engineering Structures VI, p. 1-11.

BHG (2019): Average house size Australia: How many square metres is standard? https://www.bhg.com.au/average-house-size-australia-how-many-square-metres-is-standard

*Building Stock Development*

The Global Status Report (2017): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC).

*Emission Factor Development*

ClimateWorks (2016): Gas-Electricity substitution projections to 2050. https://www.energynetworks.com.au/resources/reports/gas-electricity-substitution-projects-to-2050/

*GHG Emissions*

COAG Council of Australian Governments - Energy Council (2018): Trajectory for low energy buildings.

COAG Council of Australian Governments (2012): National Strategy on Energy Efficiency. Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia. Part 1 – Report.

*Energy Consumption*

Department of the Environment and Energy (2019): Australian Energy Statistics, September 2019.

Department of the Environment and Energy (2019): Australian Energy Update 2019.

Department of the Environment and Energy (2019): Australian Energy Flows 2017-18. https://www.energy.gov.au/sites/default/files/australian_energy_statistics_2019_energy_flows_2017-18.pdf

*Other Sources*

Australian Bureau of Statistics (2019): Energy Account, Australia, 2017-18. https://www.abs.gov.au/ausstats/abs@.nsf/0/5E025753112D1A80CA2578800019C952?Opendocument

Carr, C., McGuirk, P., Dowling, R. (2019): Geographies of energy transition: the case of high-performing commercial office space in the central business districts of Sydney and Melbourne, Australia. Australian Geographer, 50(1), p. 29-48.

Department of the Environment and Energy (2019): National Inventory by Economic Sector 2017.

EY: Mid-tier commercial office buildings in Australia. https://www.gbca.org.au/uploads/97/36449/Mid-tier%20Commercial%20Office%20Buildings%20Sector%20Report_FINAL.pdf

Foliente, G. C., Seo, S. (2012): Modelling Building Stock Energy Use and Carbon Emission Scenarios. In: Smart and Sustainable Built Environment, 1(2), p. 118-138.

JLL (2019): Australian Cities for a Metropolitan Age.

Oldfield, P., Swinbourne, R., Symons, K. (2019): Decarbonising Commercial Buildings. In Decarbonising the Built Environment (pp. 163-191). Palgrave Macmillan, Singapore.

**Brazil**

*Building Stock*

IFC International Finance Corporation – World Bank Group (n.y.): Green Buildings Market Intelligence – Brazil Country Profile.

UN United Nations (2017): Household Size and Composition Around the World 2017.

*GHG Emissions*

USAID (2019): Greenhouse Gas Emissions in Brazil.

Greenpeace (2016): Energy [R]evolution. For a Brazil with 100% clean renewable energy.

*Energy Consumption*

Lamberts, R. / LabEEE-UFSC (n.y.): Brazil's non-domestic energy and buildings context.

Borgstein, E. (2018): Towards policy for efficient buildings in Brazil.

EIA U.S. Energy Information Administration (2019): Global energy consumption driven by more electricity in residential, commercial buildings.

EPE Empresa de Pesquisa Energética (2019): Balanco Energético Nacional 2019 ano base 2018.

EPE Empresa de Pesquisa Energética, Ministério de Minas e Energia, Brasil Governo Federal (2017): Anuário Estatístico de Energia Elétrica 2017 ano base 2016.

**Canada**

*Building Stock*

Point2 Homes (2017): Canadians enjoy second-most living space per person: Global survey.

Statistics Canada (2017): Census in Brief - Dwellings in Canada.

Survey of Commercial and Institutional Energy Use (SCIEU) (2014): Buildings 2014 – Data Tables, Table 19.

*Building Stock Development*

The Global Status Report (2017): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC).

*Carbon Emissions*

Government of Canada (2013): Step 2: Compare with other Facilities. https://www.nrcan.gc.ca/maps-tools-publications/publications/energy-publications/energy-efficiency-publications/energy-efficiency-buildings/step-2-compare-other-facilities/6563

Government of Canada (2019): Energy and Greenhouse Gas Emissions (GHGs). https://www.nrcan.gc.ca/science-data/data-analysis/energy-data-analysis/energy-facts/energy-and-greenhouse-gas-emissions-ghgs/20063.

CERI Canadian Energy Research Institute (2017): Greenhouse Gas Emissions Reductions in Canada Through Electrification of Energy Services.

ICSC International Council of Shopping Centers (2016): Results Report. Shopping Center Energy Intensity Benchmarking Study.

*Energy Consumption*

Government of Canada (2015): Survey of Commercial and Institutional Energy Use (SCIEU) – Buildings 2014.

CEA Canadian Electricity Association (2018): Electricity 101.

Tardy, F., Lee, B. (2019): Building related energy poverty in developed countries – Past, present, and future from a Canadian perspective. In: Energy and Buildings, 194(1), p. 46-61.

**China**

EDGAR Emissions Database for Global Atmospheric Research (2019): Fossil CO2 and GHG emissions of all world countries, 2019 dataset.

Fridley, D. G., Zheng, N., Zhou, N. (2008): Estimating total energy consumption and emissions of China’s commercial and office buildings.

GBPN Global Buildings Performance Network (2019): China: the world’s largest single market in new construction.

IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data.

IGES Institute for Global Environmental Strategies (2019). IGES List of Grid Emission Factors.

Jiang, Y., Yan, D., Hu, S., Guo, S., Cui, Y., Peng, C. (2016): China Building Energy Survey 2016.

**Norway**

Cheng, V. S., Tong, J. C. (2017): Building Sustainability in East Asia: Policy, Design and People.

**Hong Kong**

Cheng, V. S., Tong, J. C. (2017): Building Sustainability in East Asia: Policy, Design and People.

Chung, I. C. / BEAM (2015): Energy USE (EU) for New Buildings.

EDGAR Emissions Database for Global Atmospheric Research (2019): Fossil CO2 and GHG emissions of all world countries, 2019 dataset.

HKSAR Planning Department (2016): Hong Kong 2030+: Towards a Planning Vision and Strategy Transcending 2030. Baseline Review: Population, Housing, Economy and Spatial Development Pattern.

Hong Kong Business Environment Council (2018): Investing in Buildings Energy Efficiency. How to enhance Hong Kong's Policy Framework.

Hong Kong Census and Statistics Department (2018): Hong Kong Energy Statistics. 2018 Annual Report.

Hong Kong Council for Sustainable Development (2011): Combating Climate Change: Energy Saving and Carbon Emission Reduction in Buildings.

Hong Kong Electrical and Mechanical Services Department (2019): Hong Kong Energy End-use Data 2019.

Hong Kong Environment Bureau (2015): Climate Change Report 2015.

Hong Kong Rating and Valuation Department (2019): Hong Kong Property Review 2019.

Hong Kong Transport and Housing Bureau (2018): Hong Kong: The Facts (Housing).

Hong Kong Transport and Housing Bureau (2019): Housing in Figures 2019.

Lam, J. C., Chang, A. L. S. (2007): Characteristics of electricity consumption in commercial buildings. Survey of electricity consumption in fully air-conditioned office buildings and hotels in Hong Kong, implications for energy conservation in buildings. In: Building Research & Information, 22(6).

Lam, J. C., Li, D. H. W. (2003): Electricity consumption characteristics in shopping malls in subtropical climates. In: Energy Conversion and Management.

**India**

AEEE Alliance for an Energy Efficient Economy (2019): Building Stock Modelling. Key enabler for driving energy efficiency at national level.

CarbonBrief (2019): The Carbon Brief Profile: India.

Deshmukh, A. A. (2015): Building Energy Performance in India. Thoughtful Cooling ToT: Cooling Interiors Efficiently and Sustainably.

EIA U.S. Energy Information Administration (2017): Buildings energy consumption in India is expected to increase faster than in other regions. https://www.eia.gov/todayinenergy/detail.php?id=33252

GBPN Global Buildings Performance Network (2014): Residential Buildings in India: Energy use projections and savings potentials.

IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data.

Indian Bureau of Energy Efficiency (n.y.): Energy benchmarks for commercial buildings.

Indian Ministry of Power / Central Electricity Authority (2018): CO2 Baseline Database for the Indian Power Sector.

Kachhawa, S., Kumar, S., Singh, M. (2019): Decoding India's residential building stock characteristics to enable effective energy efficiency policies and programs.

Kumar, S., Yadav, N., Singh, M., Kachhawa, S. (2018): Estimating India's commercial building stock to address the energy data challenge.

World Resources Institute / Ross Center (2018): A first step down the road to zero-carbon buildings in India.

**Korea**

Chung, S. Y., Cheon, D. K., Chang, H., Kwak, H. (2013): The case of Korea: the quantification of GHG reduction effects achieved by ICTs.

Climate Transparency (2018): Brown to Green 2018.

IEA International Energy Agency (2019): Data and statistics. https://www.iea.org/data-and-statistics

Lee, I. H., Ahn, Y. H., Park, J., Kim, S. (2014): District Energy Use Patterns and Potential Savings in the Built Environment: Case Study of Two Districts in Seoul, South Korea. In: Asian Journal of Atmospheric Environment, 8(1).

**Malaysia**

EdgeProp (2019): Five things you probably did not know about the size of Malaysian homes (referring to: Valuation and Property Services Department / UNCHS and The World Bank).

Hassan, J., Zin, R. M., Majid, M. Z. A., Balubaid, S., Hainin, M. R. (2014): Building Energy Consumption in Malaysia: An Overview. In: Jurnal Teknologi, 707(7), p. 2180-3722.

Huda, M., Okajima, K., Suzuki, K. (2017): CO2 Emission from Electricity Generation in Malaysia: A Decomposition Analysis. In: Journal of Energy and Power Engineering, 2017(11), p. 779-788.

IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data.

Ministry of Natural Resources and Environment Malaysia (2015): Malaysia. Biennial Update Report to the UNFCCC.

Moghimi, S., Azizpour, F., Sohif, M., Lim, C. H., Salleh, E., Bin Sopian, K. (2014): Building energy index and end-use energy analysis in large-scale hospitals—case study in Malaysia.

Ponniran, A., Mamat, N. A., Joret, A. (2012): Electricity Profile Study for Domestic and Commercial Sectors. In: International Journal of Integrated Engineering, 4(3), p. 8-12.

UNDP United Nations Development Programme (2016): UNDP Strategic Plan Environment and Sustainable Development.

**Mexico**

Climate Transparency (2017): Brown to Green 2017.

Global Alliance for Buildings and Construction (2018): 2018 Global Status Report.

INEGI Instituto Nacional de Estadística y Geografía (2015): Households and housing units. https://en.www.inegi.org.mx/temas/vivienda/

NAMA apoyada para la Vivienda Nueva en México. Acciones de Mitigación y Paquetes Financieros (2017): Vivienda sustentable en México. Vivienda nueva.

SENER Secretaría de Energía (2018): Balance Nacional de Energía: Consumo final de energía por sector. http://sie.energia.gob.mx/bdiController.do?action=cuadro&cvecua=IE7C02

UNEP SBCI Sustainable Buildings & Climate Initiative (2009): Greenhouse Gas Emission Baselines and Reduction Potentials from Buildings in Mexico.

### New Zealand

Amitrano, L. (2014): BEES Building Energy End-use study.

EECA Energy Efficiency and Conservation Authority (2017): Programme Review Commercial Buildings.

McDonagh, J. (2010): Electricity Use Trends in New Zealand Office Buildings, 1990-2008.

Ministry for the Environment (2018): New Zealand's Greenhouse Gas Inventory 1990-2017.

Ministry of Business, Innovation & Employment (2019): Energy in New Zealand 2019.

Ministry of Business, Innovation & Employment (2019): New Zealand energy sector greenhouse gas emissions. https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/new-zealand-energy-sector-greenhouse-gas-emissions/

The Royal Society of New Zealand (2016): Transition to a low-carbon economy for New Zealand.

### Norway

Enova (2018): Enovas byggstatistikk 2017. Rapporten presenterer analyser og statistikk om energibruk fordelt etter bygningstyper, samt variasjoner avhengig av alder, størrelse og oppvarmingssytem.

Statistics Norway (2019): Emissions to air. https://www.ssb.no/en/klimagassn

### Philippines

Arcadis (2018): Arcadis Insider Environmental Sustainability 10-Year Anniversary Special Edition.

IFC International Finance Corporation (n.y.): Green Buildings Market Intelligence. Philippines Profile.

IGES Institute for Global Environmental Strategies (2019): IGES List of Grid Emission Factors.

Philippine Statistics Authority (2019): Construction Statistics from Approved Building Permits: Second Quarter 2019 (Preliminary Results).

### Singapore

Department of Statistics Singapore (2019): Households. Statistics on resident households compiled by the Singapore Department of Statistics. https://www.singstat.gov.sg/find-data/search-by-theme/households/households/latest-data

National Climate Change Secretariat (2016): Singapore's Climate Action Plan: Take Action Today, For a Carbon-Efficient Singapore.

National Climate Change Secretariat (n.y.): Singapore's Emissions Profile. https://www.nccs.gov.sg/climate-change-and-singapore/national-circumstances/singapore's-emissions-profile

Singapore Building and Construction Authority (2018): BCA Building Energy Benchmarking Report.

Singapore Building and Construction Authority (2018): Super low energy building. Technology roadmap.

Singapore Urban Redevelopment Authority (2019): Release of 3rd Quarter 2019 real estate statistics.

van der Heijde, J. (2017): Innovations in Urban Climate Governance Voluntary Programs for Low-Carbon Buildings and Cities.

**Switzerland**

BAFU Bundesamt für Umwelt (2018): Data on CO2 emissions of households. htto://www.bafu.admin.ch

**USA**

*Building Stock*

U.S. Energy Information Administration (EIA) (2015): Residential Energy Consumption Survey (RECS), Table HC10.1 Total square footage of U.S. homes, 2015.

U.S. Energy Information Administration (EIA) (2015): Commercial Buildings Energy Consumption Survey (CBECS) Table B7. Building size, floorspace, 2012

U.S. Energy Information Administration (EIA) (2017): Residential Building Survey, 2015.

U.S. Census Bureau (2019): Quarterly Starts and Completions by Purpose and Design.

Center for sustainable systems / University of Michigan (2019): Residential Buildings Factsheet.

Center for sustainable systems / University of Michigan (2019): Commercial Buildings Factsheet.

*Building Stock Development*

Moura MCP, Smith SJ, Belzer DB (2015): 120 Years of U.S. Residential Housing Stock and Floor Space. PLOS ONE 10(8): e0134135. https://doi.org/10.1371/journal.pone.0134135.

Global Status Report (2017): Building Stock development for North America.

*Energy Consumption*

Obrinsky, M., Walter, C. (2016): Energy Efficiency in Multifamily Rental Homes: An Analysis of Residential Energy Consumption Data. In: Journal of Sustainable Real Estate, 8(1).

U.S. Energy Information Administration (2014): 2012 Commercial Buildings Energy Consumption Survey. https://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c4.php

U.S. Energy Information Administration (EIA) (2017): Residential Building Survey, 2015. Table CE1.1 Summary annual household site consumption and expenditures in the U.S.—totals and intensities, 2015.

Obrinsky, M., Walter, C. (2016): Energy Efficiency in Multifamily Rental Homes: An Analysis of Residential Energy Consumption Data. In: Journal of Sustainable Real Estate, 8(1).

Energy Information Administration (2009): How Much Energy is Consumed in Residential and Commercial Buildings in the United States? Retrieved from: http://www.eia.gov/tools/ faqs/faq.cfm?id586&t51. 2014a.

*Emission Factors*

EPA United States Environmental Protection Agency (2018): Emission Factors for Greenhouse Gas Inventories.

EIA U.S. Energy Information Administration (2019): Annual Energy Outlook 2019 with projections to 2050.

IEA U.S. Energy Technology Perspective (2017): Reference Technology Scenario (Building).

*Direct & Indirect emissions for residential and commercial*

Leung, J. (2018): Decarbonising U.S. Buildings. Online: https://www.c2es.org/document/decarbonizing-u-s-buildings.

*Other Sources*

Balaras, C., Micha, M., Dascalaki, El, Kontoyiannidis, S. (2017): Energy use intensities for non-residential buildings.

Bawden, K., Williams, E. (2015): Hybrid Life Cycle Assessment of Low, Mid and High-Rise Multi-Family Dwellings. In: Challenges, 2015(6), p. 98.116.

EIA U.S. Energy Information Administration (2019): Electricity intensity of U.S. homes and commercial buildings decreases in coming decades.

EPA United States Environmental Protection Agency (2018): Emission Factors for Greenhouse Gas Inventories.

Global Alliance for Buildings and Construction (2018): 2018 Global Status Report.

ICSC International Council of Shopping Centers (2016): Results Report. Shopping Center Energy Intensity Benchmarking Study.

IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data.