CRREM

Carbon Risk Real Estate Monitor

# FROM GLOBAL EMISSION BUDGETS TO DECARBONIZATION PATHWAYS AT PROPERTY LEVEL


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CRREM


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## ALLIGNMENT WITH THE SCIENCE BASED TARGETS INITIATIVE

*The Science Based Targets initiative (SBTi) is a global body enabling businesses to set ambitious emissions reduction targets in line with the latest climate science. It is a collaboration between CDP, the United Nations Global Compact, World Resources Institute (WRI) and the World Wide Fund for Nature (WWF). The SBTi is focused on accelerating companies across the world to halve emissions before 2030 and achieve net-zero emissions before 2050.*

*As part of its target-setting methods, the SBTi provides emissions reduction pathways for a number of sectors, which companies must use in calculating their science-based targets. For buildings, the SBTi has provided global commercial and residential pathways for in-use emissions for several years. With the SBTi's ambition update to 1.5ºC, and the need to offer the buildings sector more granular pathways reflecting building typology and location, in January 2022 the SBTi embarked on a partnership with CRREM to provide the sector with one single set of 1.5°C-aligned in-use emissions pathways.*

*The SBTi's and CRREM's technical teams have worked together over January-August 2022 to ensure the underlying assumptions, carbon budgets and methodological foundation of the pathways are fully aligned. The partnership combines the previous work of both organisations and guarantees one major global standard for operational decarbonization of real estate holdings which investors and other market participants can rely on. The technical work, carried out by CRREM, underwent a thorough review process by the SBTi over August-September 2022, where the methodology was assessed by comparison to relevant literature, methodological choices were subjected to sensitivity analyses, and limitations to the method were identified (and are discussed further in this methodology document).*

*After integrating potential changes resulting from this public consultation, the SBTi will operationalise the new set of pathways by integrating them in its target-setting tools.*

*This work forms part of the SBTi's larger Buildings Project, which is developing new methodologies, tools and target-setting guidance to set a global pathway for all buildings' emissions to align with 1.5°C — including both embodied and in-use emissions. Detailed target-setting guidance to be published in 2023 will provide companies in this sector the clarity they need to set targets using the new pathways.*

SCIENCE BASED TARGETS
DRIVING AMBITIOUS CORPORATE CLIMATE ACTION

**Science Based Targets**
Karl Downey

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# Acronyms and Abbreviations

| ABBREVIATION | MEANING | ABBREVIATION | MEANING |
|---|---|---|---|
| **bn** | Billion | **IIGCC** | Institutional Investors Group on Climate Change |
| **°C** | Degrees Celsius | **IPCC** | Intergovernmental Panel on Climate Change |
| **$CH_4$** | Methane | **IEA** | International Energy Agency |
| **$CO_2$** | Carbon dioxide | **kg** | Kilogram |
| **$CO_2e(q)$** | Carbon dioxide equivalent | **KPI** | Key performance indicator |
| **CRREM** | Carbon Risk Real Estate Monitor | **kWh** | Kilowatt hour |
| **CRE** | Commercial | **$m^2$ or sqm** | Square metres |
| **DH** | District Heating | **$N_2O$** | Nitrous oxide |
| **ESG** | Environmental, social and governance | **NDC** | Nationally Determined Contribution |
| **EF** | Emission Factor | **NED** | Net energy demand |
| **EU** | European Union | **PFC** | Perfluorocarbons |
| **EUI** | Energy Use Intensity | **RMF** | Residential Multi Family |
| **EUR** | Euro | **RSF** | Residential Single Family |
| **F-Gas** | Fluorinated gas | **SBTi** | Science Based Targets initiative |
| **GHG** | Greenhouse gas | **SDA** | Sectoral decarbonization approach |
| **GIA** | Gross Internal Area | **$SF_6$** | Sulphur hexafluoride |
| **GR** | Growth rate | **TCFD** | Task Force on Climate-related Financial Disclosures |
| **GRESB** | Global Real Estate Sustainability Benchmark | **TWh** | Terawatt hours |
| **Gt** | Gigaton | **T&D** | Transmission & Distribution (losses) |
| **HDD/CDD** | Heating degree days/Cooling degree days | **vs** | versus |
| **HH** | Household | **RE** | Real Estate |
| **HFC** | Hydrofluorocarbons | **Yr** | Year |

## (1) WHY DECARBONIZATION PATHWAYS MUST CHANGE OVER TIME

The baseline year of the *Carbon Risk Real Estate Monitor* (CRREM) operational ('in use') decarbonization pathways was updated from 2018 to 2020. The ambition level clearly needs to change in the light of new scientific data available (e.g., IEA and IPCC overall remaining anthropogenic carbon budgets moving forward).

What are the most relevant driving forces leading to changes?

- Remaining global anthropogenic budget slightly reduced: On a global scale, we do not see significant changes regarding the remaining carbon budget for all sectors compared to our first version (468 vs. 519 Gt $CO_2$-only). This 10% decrease regarding the remaining budget from 2020 onwards until 2050 causes the decarbonization curves to be steeper. Leaving all other aspects unchanged this will of course imply lower intensities per m² floorspace in the future.

- Real estate sector overshoot: Due to the fact that the thresholds defined in the past as 1.5 degree aligned were surpassed (just about all sectors globally are lagging behind defined targets, see before) remaining budgets going forward must be revised accordingly. The pathways have become stricter (steeper) because the real estate sector as a whole has shown more consumption than projected from the baseline year (since 2018). The overall remaining budget from 2020 onwards is reduced due to this aspect. Often energy/carbon intensities are currently/at present still on average higher on a like-for-like basis[1] than projected based on the first CRREM pathway release (some countries and/or use-types may perform better, whilst others are still lagging behind).

- Building stock growth rate with largely unchanged projection: Also, global floorspace projections did not change significantly. New figures show just an overall increase of 1.6% compared to the previous data for the period from 2020 to 2050. This implies again slightly lower intensity per m² floorspace (assuming ceteris paribus the same given budgets).

- More ambitious grid decarbonization: Besides aspects that lead to increased consumption and carbon intensities in the past few years, we note that the decarbonization of the electric grid did on average gain traction and emission factors (here: EF) for electricity were going down significantly. This, ceteris paribus, reduces carbon intensities given the same energy consumption level. At the same time this implies lower carbon intensities per m² floorspace going forward since also future projections for the energy sector show on average more ambitious grid decarbonization until 2050. Vice versa a given Carbon intensity combined with reduced grid EF will lead to a higher energy allowance all other aspect being equal.

- Changing energy-mix / electrification: Besides a move towards more renewables, we note that generally the electrification of the real estate sector is also gaining momentum. In countries with a *lower* EF for electricity compared to the remaining energy mix, this is decreasing the weighted EF already today; whereas in some countries, a currently relatively *higher* EF of the electric grid compared to the residual energy mix is – at least in the near future (short-term) -, leading to *increased* carbon intensities of the sector. Regarding projections, we note that electrification combined with the decarbonization of the energy sector (here electric grid) plays a major (indirect) role for the real estate sector in order to achieve climate targets.

- Alterations of the applied methodology: For carbon counting and benchmarking, it is important to clearly state the assumptions and methods used. Due to the alignment with the SBTi, CRREM now applied the EF (for electricity) *without* (*excluding*) transmission & distribution losses. In the first version

[1] Note: like-for-like is in this case referring mainly to the inclusion of T&D-losses.

of the CRREM pathways, we applied the EF *including* T&D-losses. The lower EF are now reducing carbon intensities accordingly (within pathways, but also when applying the tool with updated and lower EF).

The evolution of climate change, economic activity and data availability over time will also lead to further updates of the CRREM pathways in the future. 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 (GHG) emissions[2], and the latest trends in global emissions, are influencing results. For example, if the overall remaining global anthropogenic carbon budget is shrinking faster than expected, this also implies reduced emission budgets allocated to the building sector, and ultimately all decarbonization pathways must be revised accordingly. Since CRREM energy-intensity reduction pathways (measured in $kWh/m^2$) are based on carbon emission pathways (measured in $kgCO_2/m^2$ or GHG emission pathways referred to as $kgCO_{2e}/m^2$), the abovementioned uncertainties affect both kinds of pathway. Energy-reduction pathways reflect how much energy can be consumed, whilst still 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 decarbonization) is slower than expected, a stronger reduction in energy consumption will be required. Likewise, the projection of national building stock inventory growth rates might face more changes in the future. Furthermore, the applied energy mix is based on projections that could also potentially be revised again in the future.

Note: 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.

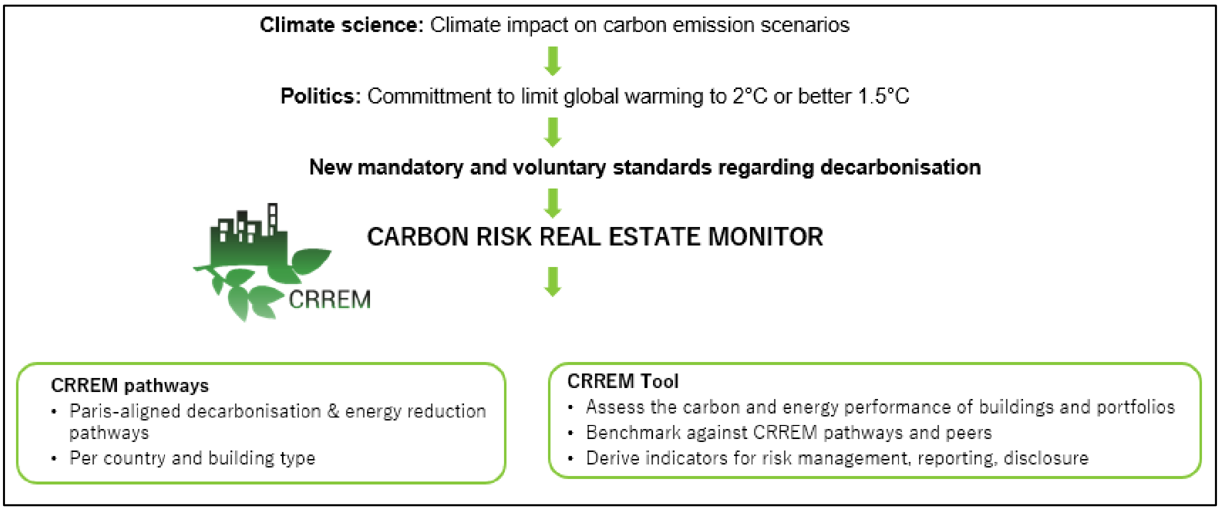
[2] The specific impact of individual greenhouse gases on climate change is referred to as 'global warming potential'. See 1st CRREM report 'Stranding Risk & Carbon' for further details.

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

### (2.1) Overview and fundamentals regarding the downscaling approach

Based on the findings of climate science on global warming and on the political decisions agreed upon in the Paris Agreement[3], the real estate industry requires guidance in order to **align the sector's decarbonization ambition regarding the respective 'fair share' of the real estate industry** (see Figure 1). To enable Net-Zero-commitments and ensure a decarbonized economy in 2050, the *Carbon Risk Real Estate Monitor initiative* (CRREM initiative) has derived country-specific carbon- and energy-reduction pathways[4] that are aligned with the requirements of the Paris Agreement to limit global warming to a maximum of 1.5°C, **thus ensuring that defined sector thresholds are not exceeded**. These pathways can be applied for target setting, transition-risk analysis and ongoing performance optimization. They are addressing the 'in-use' operational emissions and exclude embodied carbon. 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. The Science-Based Targets initiative (SBTi) and the CRREM initiative have entered into a partnership to jointly provide fully aligned **1.5°C decarbonization pathways for the real estate sector**. The partnership is intended to ensure globally consistent standards to support real estate market participants to formulate, set, and **implement science-based targets for reducing operational carbon emissions of buildings towards a 1.5°C future**

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




The decisive variable with regard to decarbonization in the real estate sector use-phase is a building's so-called **carbon-intensity, measured in terms of annual operational greenhouse gas (GHG) emissions per square metre of gross internal area** ('carbon-intensity')**.** GHG emissions are expressed in carbon dioxide equivalents ($CO_{2e}$). This key performance indicator (KPI) includes other greenhouse gases[5] in addition to carbon dioxide ($CO_2$), by considering their relative global warming potential compared to $CO_2$. For real estate, F-gases are particularly relevant, as, according to CRREM's research, buildings are responsible for approx. 550 Mt $CO_{2e}$ per year, almost a third of all global F-gases. This also aligns with previously stated numbers by the IPCC, an eighth to a third of all

[3] United Nations Framework Convention on Climate Change (UNFCCC) (2015). Paris Agreement. Online: https://unfccc.int/sites/default/files/resource/parisagreement_publication.pdf

[4] 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.

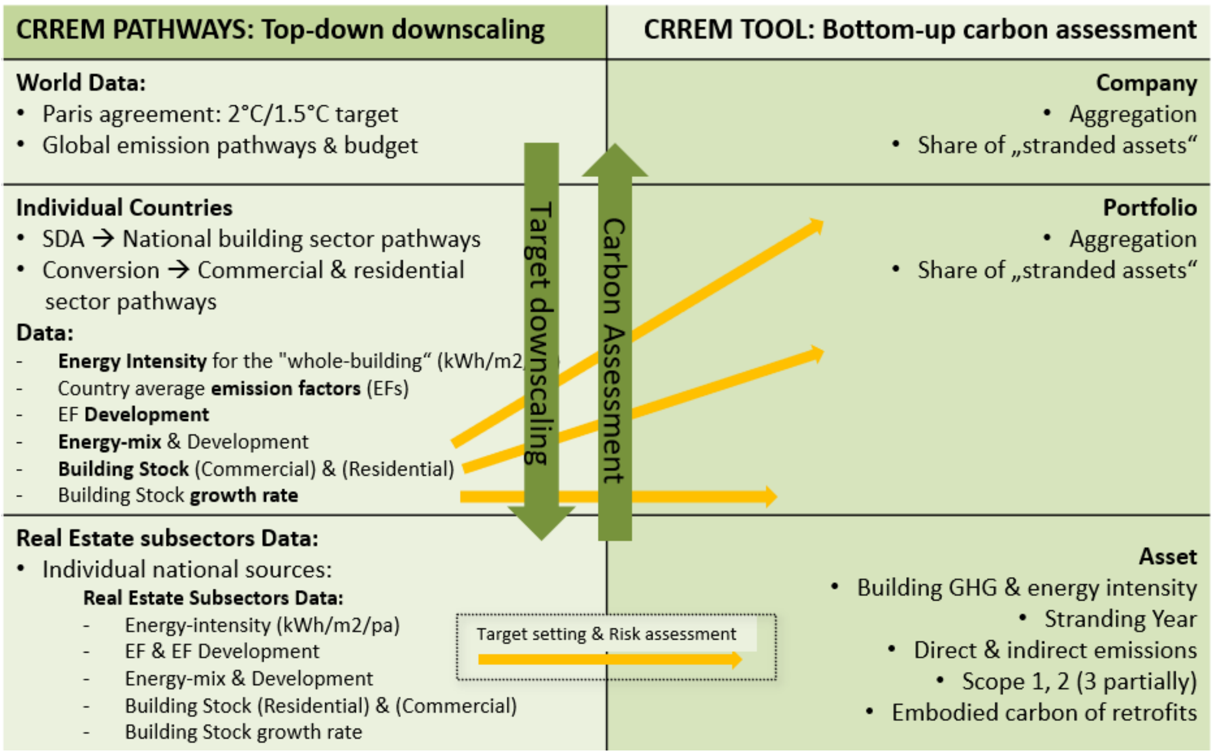
[5] Including $CH_4$, $N_2O$, HFCs, PFCs & $SF_6$ according to Kyoto.

F-gases globally (IPCC, 2014)[6]. For this update of the **CRREM 1.5°C-pathways, a separation has been made between the $CO_2$-only-pathways (expressed in $kgCO_2/m^2$), the pathways for other-GHGs and the combined GHG-pathway (expressed in $kgCO_{2e}/m^2$).**

The next section provides an in-depth summary of the **applied downscaling-framework**, including underlying assumptions and key results.[7] 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 and target validation of The SBTi.

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 enable verifiable results and reliable assessment (see also section (11) for all applied sources).

**Figure 2: Overview of downscaling approach for target setting and carbon risk assessment via the CRREM Tool[8]**




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. For the current as well as future updates and in-line with the approaches of other leading initiatives, the pathways based on **1.5°C scenarios** will in the centre of attention. The associated

[6] Also accounting and reporting $CO_{2e}$-emissions according to the GHG protocol and GRI requires proper tracking of F-gases (World Resource Institute, WBCSD, 2018). Likewise accurate assessment of transitions risk in line with TCFD recommendations would require appropriate assessment of refrigerants. So not just regarding the assessment of transition risk, but also for corporate sustainability reporting this information must be gathered as all GHG-emissions including CO2 'equivalents' must be reported and disclosed (GHG Protocol, 2004/2011/2013/2015/2021 // GRI, 2016).
[7] For further insights on the applied methodologies and explanatory background please read our public reports on www.crrem.eu and www.crrem.org.
[8] NOTE: CRREM initiatives refers to the term 'Stranded asset' or 'Stranding year' with regard to the non-compliance of assets related to the respective decarbonization pathway. 'Stranding' does not mean a property gets worthless. For more details see www.crrem.eu/tool.

anthropogenic carbon budgets are derived from IPCC and emission pathways to achieve these climate targets, calculated also in alignment with IEA 1.5°C Net-zero by 2050.[9] Budgets define the amount of GHG emissions that can be emitted until 2050, in order not to exceed defined warming thresholds.

The next step is to **allocate an appropriate share of the entire anthropogenic 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 absolute amount per annum **carbon-intensities** in the form of **GHG or $CO_2$-only-emissions per square meter ($kgCO_{2e}/m^2$)** are also calculated. **It is important in all steps of the downscaling process to ensure that defined thresholds are not exceeded.** Double counting must be avoided and cross-sector alignment must be ensured.

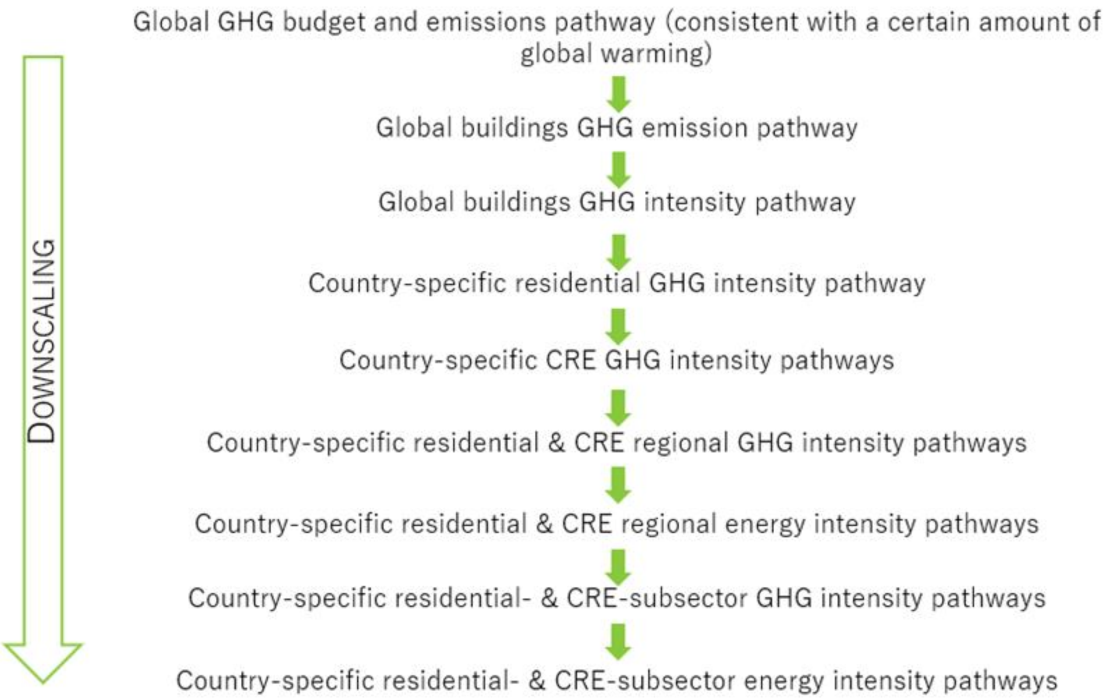
Based on this global operational real estate-related emission budget, the model applies the Sectoral Decarbonization Approach (referred to below as the **SDA convergence approach)**[10] **to derive to national building sector pathways**, which are broken down further, differentiating between the **residential and commercial property stock** - again also taking into account different growth rates of the national building inventory. Each resulting national pathway represents therefore the 'SDA-based share' of carbon that each country could emit until 2050. This allocates the responsibilities and efforts required from the real estate sector to the country and building-use-type levels – enabling market participants to benchmark their portfolios and define short, mid-term and long-term targets that also could be validated by The SBTi. Two sets of required decarbonization pathways, according to both warming scenarios, are available for residential and commercial use types for 44 countries globally. The largest and globally most important real estate markets were selected, covering altogether 90% of the institutional real estate stock worldwide. Data availability as well as the demand for scientifically sound decarbonization pathways was high in these countries. In the future, the coverage of countries with detailed pathways available can be expanded further, likewise a default pathway for residential and commercial properties in countries to date not covered, will be available. **Sub-national or regional pathways** are available for the USA and Australia (due to the size of the countries and different climate zones) – such additional more regional breakdowns, for example for China, will only be added once local data is robust, accessible and reliable enough. All these **trajectories start at the actual current emission intensity of each country's building stock and converge to the same decarbonization target**. The graph below (seeFigure 4) illustrates these pathways for selected countries.

The final step applies aggregated stats as well as individual national sources, in order to **differentiate between the decarbonization pathways for residential and commercial even further, according to various real estate use-types**. Besides single- and multi-family residential properties, **trajectories for different commercial sub-sectors** like Office, Retail High Street, Retail Shopping Centre, Retail Warehouse, Hotel, Healthcare, etc. are also made available. The current carbon emission level and the saving capacity of each building type is intrinsically different due to the energy profiles of the activities performed in these buildings. The calculation therefore takes into consideration the size, expected growth, and differences regarding the carbon intensity, energy mix and emission factors of each sub-sector per country, and assumes constant relative differences between each subsector.

[9] Please note: an overview of all original sources can be found in the appendix.

[10] SBTi Quelle SDA Convergence: SBTi (2015) : Sectoral Decarbonization Approach. Online: https://sciencebasedtargets.org

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




In the IEA- and the SBTi-aligned pathways, the building sector is not required to fully reach Zero-emissions by 2050. A small residual may remain – and the gap will be closed by carbon sinks and other offsetting measures.[11]

CRREM is applying the so-called **whole building approach for the in-use-phase**. The analysis therefore includes tenant and landlord-controlled space. Scope delineation between the Scopes 1, 2, 3 is therefore irrelevant in this case, since **all operational emissions of the property are taken into account**. Only a holistic view of the property can ensure a proper implementation of decarbonization strategies. As the CRREM methodology is based on the 'whole-building' approach, F-gases should also be included if relevant. Some property-types, especially retail buildings, record up to 20% or more of the overall global warming potential resulting from F-gases (due to refrigerant losses ).[12] Therefore, including those gases, tracking and optimizing their use is equally important for achieving climate targets within the real estate sector (see also above for the overall share of the real estate industry regarding F-gases globally). For this update, a more in-depth analysis of the **$CO_2$-equivalents ($CO_{2e}$)** was possible, based on new available data regarding the emissions of the real estate sector related to other GHG besides $CO_2$. Therefore, the previous approach of using a lump sum percentage according to the overall relationship of $CO_2$ vs. other GHG for all sectors was optimized.

[11] IEA (2021), World Energy Model, IEA, Paris

[12] Accounting and reporting $CO_{2e}$ emissions according to the GHG Protocol and the Global Reporting Initiative requires proper tracking of F-gases (World Resource Institute, WBCSD 2018). Likewise, an accurate assessment of transition risk in line with TCFD recommendations would require an appropriate assessment of refrigerants. This information must be gathered for corporate sustainability reporting as well as transition risk analysis, as all GHG emissions, including $CO_2$ equivalents, must be reported and disclosed (GHG Protocol 2004; GRI 2016).

**<u>SUMMARY OF *CRREM* CARBON EMISSION DOWNSCALING:</u>**

**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 overall $CO_2$-only and $CO_{2e}$ emission budget 2020-2050 all sectors consistent with 1.5°C global warming:**

- 1.5°C scenario: 759 Gt $CO_{2e}$ (*IPCC + PBL, 50% likelihood as well was IEA)*
- 1.5°C scenario: 468 Gt $CO_2$ only (*IPCC, 50% likelihood as well was IEA)*

**3. (Thereof) global $CO_2$-only and $CO_{2e}$ emission budget of the building sector 2020-2050:**

- 1.5°C scenario: 102 Gt $CO_{2e}$
- 1.5°C scenario: 91 Gt $CO_2$ only

**4. Global $CO_2$-only and $CO_{2e}$ intensity pathways of the building sector:**

- 2020: 37.4 $kgCO_{2e}/m^2$/pa (starting point)
- 2020: 34.9 $kgCO_2$ only/$m^2$/pa (starting point)
  - 2050 1.5°C scenario: 0.63 $kgCO_{2e}/m^2$/pa (target)
  - 2050 1.5°C scenario: 0.38 $kgCO_2$ only/$m^2$/pa (target)

**5. *Real estate related portion of the overall $CO_2$-only budget until 2050*:** *(cumulated) approx. 19.49%*

*Note: Also, in 2050 there will be a remaining residual emission level for properties.*

(A detailed table including all data sources and changes caused by new inputs can be found in section (11).)[13]

The CRREM pathways/trajectories are not tied to any national laws/legislation and only focus on the Paris-targets and therefore staying within the limits of maximum 1.5°C global warming. However, national-projections are considered for the calculations applied to derive the CRREM pathways, for example, of the energy-mix development or other input parameters (such as Emission factors (EF) etc.). CRREM does therefore not rely on any political statement of the ruling party or anything similar, but on scientific projections (such as the 'EU reference scenario'), because it should be a projection of what is likely to happen and not merely wishful thinking. Hence the EF of the grid are reflecting the actual 'status quo' and projections for the future based on a 1.5-degree alignment of the energy sector. Whereas global projections are directly aligned with IEA NZE 2050, country specific projections are based on 1,5-degree aligned national forecasts according to sources disclosed in the appendix. The same applies to the energy-mix, which is also differentiated for the sector (real estate) and is further differentiated between the residential vs. commercial energy mix and the respective development over time.

**(2.2) 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.[14] CRREM applies the so-called **SDA 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). By

[13] For step 3 & 4: excluding T&D losses for electricity.

[14] Hirsch et. al. (2019): Stranding Risk & Carbon. Science-based decarbonising of the EU commercial real estate sector. CRREM report No.1, 2019, Wörgl, Austria.

applying this approach, it is possible - amongst other advantages - to ensure that the **overall defined threshold is not exceeded** and the defined carbon budget is not surpassed.

The **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 (according to the energy mix). Therefore, the pathways start with national sector and sub-use-type averages and **do not adopt a 'Best-in-class' approach** that some 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 target-figure in 2050** (converging all-building carbon-intensities). 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 does however not assume a full convergence. This is 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 also 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 according to projections from 7.8 bn at present to more than 10.2 bn by 2050.[15] This corresponds to **growth in worldwide real estate floorspace from 2.44 bn m² in 2020 to 4.27 bn m² in 2050**.[16] The growth rates of developing countries are expected to be significantly higher than those of industrialised countries (for more details how this impacts the decarbonization curves please see section (4)).

Regarding the downscaling from a given country's overall building sector carbon-intensity, in order to separate pathways for the residential and the commercial sector, the authors assume a globally converging ratio of both sector's carbon performance, with significantly lower carbon-intensity figures within residential buildings. This means that the ratio between residential and commercial real estate will converge to the same ratio in all countries (until 2050).

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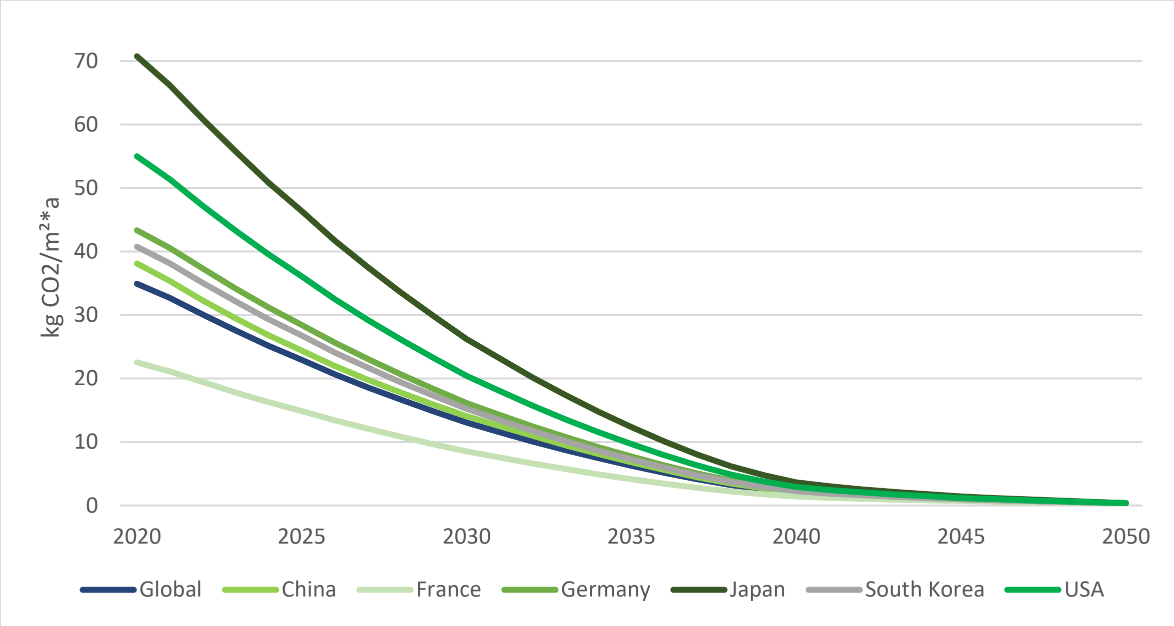
[15] UN DESA (2022): World Population Division. A world population of 10.2 bn in 2050 corresponds to UN DESA's 'median scenario'
[16] IEA (2021), Tracking Buildings 2021, Paris // see also: United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector. Nairobi.

**Figure 4: Convergence of the carbon-intensity pathway of the building sector in individual countries to the global pathway (1.5°C scenario)**




The calculation prescribes emissions-reduction pathways for all countries according to their starting emissions intensity and anticipated growth in floor space. The process does not follow any particular equity postulate or policy prescriptions regarding historic emissions or wealth distribution. Nevertheless, the **application of the SDA-convergence approach is particularly useful in the context of trade-offs between developing and developed economies**:

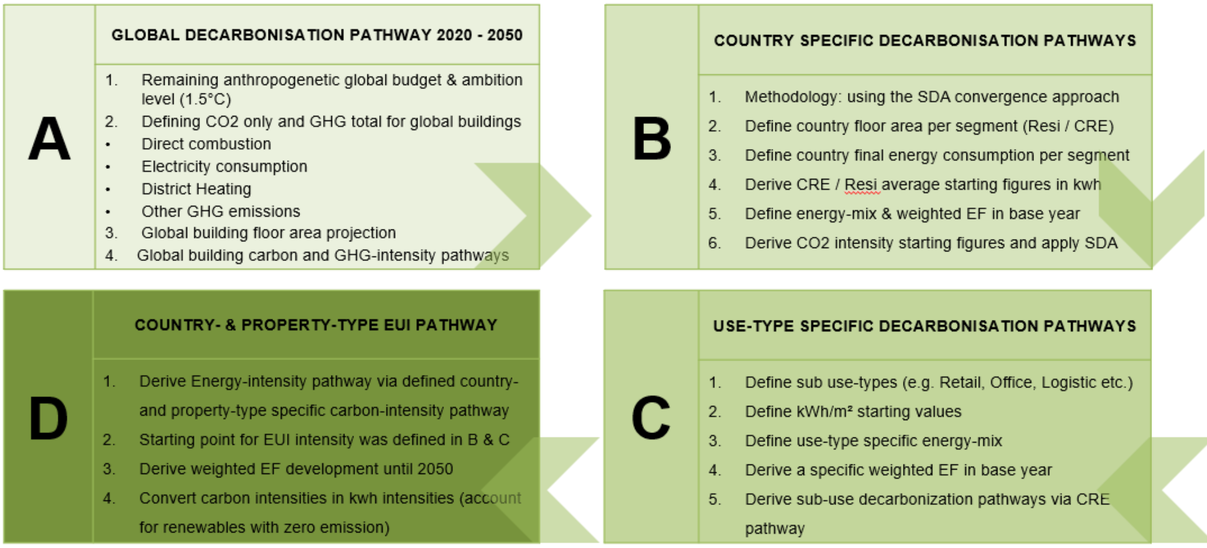
- Countries with higher floor space growth rates but the same starting figures regarding carbon intensities will have HIGHER reduction requirements per m²-floorspace.
- (Nonetheless) countries with higher floor space growth rates, but the same starting figures regarding carbon intensities, will have HIGHER absolute emission compared to non-growth countries with all other aspects remaining the same.

This will **allow developing countries to grow (higher absolute allowance)**, but at the same time, the new stock added should be relatively energy efficient compared to the standing investments and not emit any carbon emissions. In addition to this the m-Parameter-cap (see section (4)) will also be beneficial for developing countries compared to advanced economies.

## (3) FOCUS ON CRREM DOWNSCALING STEPS IN DETAIL

In the following sections, the steps for country and use-type-specific decarbonization pathways will be discussed in more detail, following the steps illustrated in the graph below.

**Figure 5: Steps of the CRREM downscaling-methodology**




## A. GLOBAL DECARBONIZATION PATHWAY 2020 - 2050

The major changes regarding the CRREM $CO_{2e}$ and $CO_2$ emission pathways for 1.5°C for the period 2020-2050 resulting from changes of the overall global budget can be summarized as follows:

- **Compared to data used in previous CRREM pathways, no major change regarding the budgets is evident. Budgets, however, decreased slightly due to overshoot in previous years.**
- **New IPCC and IEA data shows most projected reductions in the years 2030 until 2040 (incl. complete grid decarbonization until 2040), whereas older sources projected most absolute reductions at the very beginning, and lower ones at the end.**
- **The IEA NZE scenario pathway for the electricity sector that we aligned to, requires a decarbonized (net zero) grid sector by 2040. This is reflected accordingly in the budget for the building sector, using the whole-building-approach.**

### (A.1) Remaining anthropogenic global budget & ambition level

The entire downscaling procedure is based on global $CO_{2e}$ emission pathways (covering all economic sectors) which are compliant with the targets of the Paris Agreement to limit global warming to 1.5°C.

- 1.5°C: *IPCC & PBL[17] (50% likelihood)*
  *(The total anthropogenic* ***GHG emissions budget for the period 2020-2050 amounts to 759 $GtCO_{2e}$ and 500 $GtCO_2$-only****)*
- 2°C: *IPCC & PBL (83% likelihood)*
  *(The total anthropogenic carbon emissions budget for the period 2020-2050 amounts to 1,191 $GtCO_2e$)*

[17] PBL was used for the effective $CO_2$-'equivalent' emissions in 2018 & 2019. // IEA NZE uses 468 Gt $CO_2$ to account for other GHG emissions related to the use of energy.

A higher likelihood for the 2°C was chosen, as the 2°C is the absolute minimum target to be reached. Therefore, the probability of effectively achieving this, must be even higher.

This update takes into account the emissions that resulted in the years 2018-2019.The overshoot compared to a 1.5°C-compliant world in these two years is leading to even higher target levels in the remaining years until 2050 (all other aspects being equal).

**Figure 6: Global Budget all sectors**

| 1,5° Scenario | Starting Year | Data Source | CO2 Budget [Gt CO2] | Probability | Budget Other GHG [Gt CO2e] | Effective Emissions 2018 & 2019 CO2 [Gt CO2] | Effective Emissions Other GHG 2018 + 2019 [Gt CO2e] | Global Budget All GHG [CO2e] | Effective Emissions 2018 + 2019 [Gt CO2e] | 2018 + 2019 Goal [Gt CO2e] | Budget Starting 2020 (Prediction from 2018) [Gt CO2e] | Change in Ambition Level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CRREM first version** | 01.01.2018 | Friends of the Earth | | | 320 | | | 890 | 104 | 92 | 798 | |
| **CRREM Update** | 01.01.2020 | IPCC/IEA | 468 | 50% | 291 | 76 | 29 | 759 | | | 759 | -4,80% |
| **2° Scenario** | | | | | | | | | | | | |
| **CRREM first version** | 01.01.2018 | IEA 2DS | | | 320 | | | 1.259 | 104 | 95 | 1.164 | |
| **CRREM Update** | 01.01.2020 | IPCC | 900 | 83% | 291 | 76 | 29 | 1.191 | | | 1.191 | 2,35% |

| Effective Emissions [Gt $CO_{2e}$] | 2018 | 2019 |
|---|---|---|
| **$CO_2$** | 37.67 | 38.02 |
| **$CH_4$** | 9.70 | 9.83 |
| **$N_2O$** | 2.81 | 2.84 |
| **F-Gases** | 1.68 | 1.74 |
| **Total** | **51.86** | **52.43** |

*Source: International Energy Agency (2021), Net Zero by 2050, IEA, Paris*

**(A.2) Deriving the real estate share and defining $CO_2$-only and GHG total budgets for global buildings**

The CRREM $CO_{2e}$ and $CO_2$ real estate budget for 1.5°C for the period 2020-2050 changes mainly due to different allocation of the overall global budget to the sectors. Additionally, a more precise pathway for the other GHG was derived. Major changes can be summarized as follows:

- **First CRREM version budgets:** 191 Gt $CO_{2e}$ was the total GHG budget for the building sector (in use phase) from 2018 to 2050 (first CRREM version). The 2018 to 2050 $CO_2$-only budget in the first CRREM version was 130 Gt $CO_2$ (excluding other GHG). The value for 2020 to 2050, based on these figures, was 167 Gt (all GHG), or 111 Gt ($CO_2$-only) - i.e., two years must be deducted for a like-for-like comparison.
- **Current updated budgets:** If the T&D-losses were again included the $CO_2$-only for 2020 until 2050 would amount to 107 Gt for the building sector (in use). The delta of 111 to 107 (minus 3 % first-version vs. update) is mainly resulting from the overshoot during the last years.
- **T&D-losses effect:** Without T&D-losses the updated budget amounts to 91 Gt ($CO_2$-only). The delta of approx. 15 % for the entire period are the effect resulting from losses (107 vs. 91 Gt $CO_2$-only).
- **Other GHG / increased granularity:** The remining delta between first and updated version regarding the overall real estate in-use GHG budgets is resulting from the increased granularity regarding the other GHG. Whereas in the first version a lump sum aligned with the add-on-factor for all sectors was applied we could now extract more precise data from new data sources available to isolate the other-GHGs (mainly F-gases) resulting from the use-phase of properties only.

- **Whereas the first CRREM version was derived from data that included transmission and distribution losses (T&D-losses), as well as trade effects in the EF, this version aligns with The SBTi cross-sector-requirements and excludes all distribution losses and trade effects. Only for a like-for-like comparison at the global level, do we show the figures that correspond to the first version. Excluding distribution losses results in approx. 20% lower $CO_2$-only intensities in the first year and an overall (2020-2050) 15% lower emissions budget.**

- **Compared to data used in previous CRREM pathways, the real estate sectors share of $CO_2$-only of all global emissions from 2020 to 2050 is 22.95% (compared to 21.42% on a like-for-like basis – both including T&D losses), resulting in no major changes. The share of the overall $CO_2$-budget is 19.49%, excluding T&D losses.**

- **Regarding other GHG-emissions, the First Version of CRREM applied a general approach and especially highlighted as a first Real Estate tool, the importance of F-Gases in the buildings sector. Compared to data used in previous CRREM pathways, more granular data on the use of F-Gases in the buildings sector is now available. This data - which was not available in 2018 - now enables a more in-depth calculation in line with the Kigali Amendment to the Montreal Protocol. This leads to an overall budget of 10.35 Gt $CO_{2e}$ (2020-2050). If the Montreal Protocol will be revised, real estate ambitions regarding the F-Gases need to be changed accordingly. This data basis shows that the overall $CO_{2e}$ budget is approx. 39% lower than in the first version (102 vs. 167 Gt) -mainly driven besides a more granular analysis of other GHG by the exclusion of T&D-losses and the overshoot in previous years.**

- **New data shows a complete decarbonization (faster) of the electric grid in a 1.5 scenario until 2040, compared to older projections. This will impact on Scope 2 / emissions from electricity consumptions.**

To derive the total real estate budget in the whole building approach, the following research steps were completed (A.2.1 to A.2.4). The main sources used are:

- IEA Net-Zero NZE: Global building sector $CO_2$ emissions

- UNFCCC GHG Inventory, US United States Environmental Protection Agency & Kigali Amendment to the Montreal Protocol: Global building sector $CO_{2e}$ emissions

**(A.2.1) Direct combustion**

**Direct combustion** of the sector adds up to **41.14 Gt $CO_2$ from 2020 to 2050.** The underlying depreciation starts relatively low at 2% year on year (2020 to 2021). It rises to levels of up to 29% year on year by 2050. However, the absolute yearly reduction stays between 0.06 and 0.14 Gt $CO_2$ at maximum.

**(A.2.2) Electricity consumption**

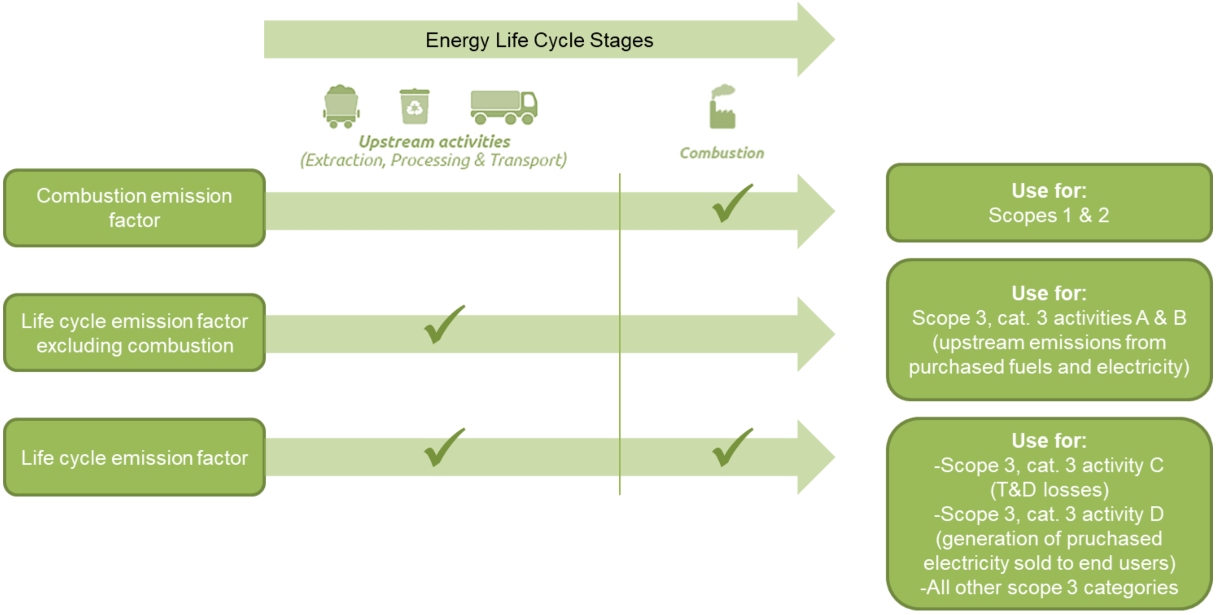
**The electricity consumption** within the real estate sector accounts for **43.31 Gt $CO_2$ from 2020 to 2050**. Electricity consumption rises steadily within the next three decades. In 2050 the **energy demand from the buildings sector will be 34% higher than in 2020**. With a year-on-year perspective, the growth rates range between 0.4 to 1.4%. In total, the energy demand is projected by the IEA with 15,800 terawatt hours (TWh) per year, resulting in a higher electrification of the building sector. Despite a significant growth regarding the absolute consumption of electricity the resulting GHG-emissions are expected to constantly decrease due to a faster decarbonization of the electric grid.

**(A.2.3) Excluding transmission and distribution (T&D) losses**

The consumption of electricity in buildings is the reason for $CO_2$-emissions elsewhere. The grid emission factor (EF) can account for (1.) the upstream losses (extraction, production and transportation of fuels consumed in the generation of electricity), (2.) electricity generation (and related combustion) and (3.) own use of energy within the generation, pumping, transmission and distribution systems. The respective EF can therefore be applied with or without T&D-losses, which result from the generation of electricity, steam, heating and cooling that is consumed (i.e., lost) in a T&D system, but reported by the end user. This is part of the Scope-3-emissions for landlords, as the energy associated with these emissions was neither consumed nor generated on site, but a result of downstream losses which are Scope 2 emissions for the energy sector (see Figure 7 regarding the treatment of T&D according to GHG protocol[18]). From a whole-building perspective (focussing on the complete energy consumption), we included those emissions in the first pathway version. In order to align and being consistent with The SBTi, we exclude these losses from now on.[19] The most relevant argument for not including T&D losses in this context is therefore the scope delineation and attribution.

[18] Category 3: Fuel- and Energy-related activities not included in Scope 1 or Scope 2 – Technical Guidance for calculating Scope 3 emissions p. 38 ff // GHG Protocol (2013) Technical Guidance for Calculating Scope 3 Emissions.
[19] Also, other standards like the WRI protocols and the ENERGY STAR portfolio manager do not include T&D losses.

**Figure 7: Treatment of T&D-losses according to GHG protocol**




*Source: GHG Protocol (2013) Technical Guidance for Calculating Scope 3 Emissions.*

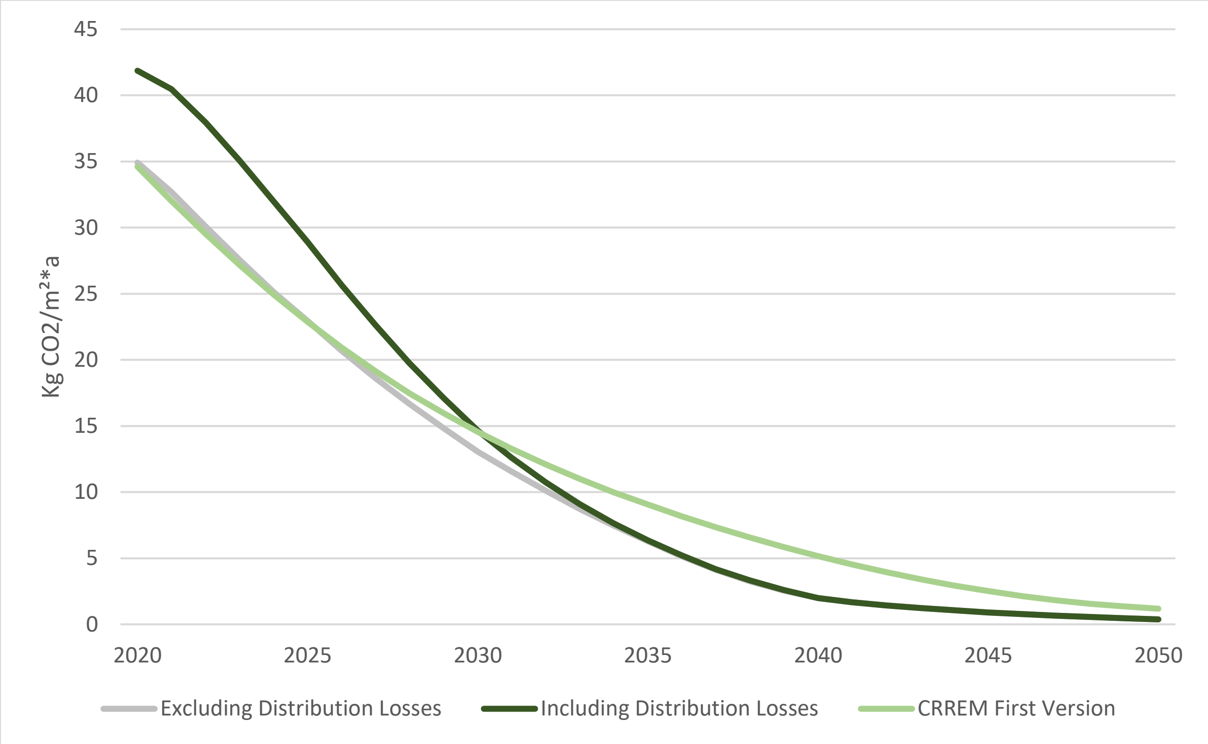
The effects from the T&D losses are significant, which is why a precise differentiation seems essential. For example, the distribution losses in the EU, according to Moro Lonzo[20], already amount to 13.8% (still EU-28) and up to 20% for individual countries.[21]

Since the effect is applied to both the target paths and the use of the same EF in the asset analysis in the CRREM tool, ceteris paribus (assuming an energy mix of the building in line with the market average), this does *not* result in any changes regarding the stranding point of assets.

[20] See Section 1(11), Table 2

[21] A World Bank database provides T&D loss rates by country (http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS?order=wbapi_data_value_2009+wbapi_data_value+wbapi_data_value-last&sort=desc) – here: On average between 8 to 10% T&DL.

**Figure 8: Global building sector $CO_2$-only intensity pathways (excluding vs. including T&D-losses)** [22]




The effect of excluding distribution losses results in approx. 20% lower $CO_2$-only intensities in the first year, and overall (2020-2050), 18% lower emissions budget.

This effect reduces carbon intensities at the beginning (since the EF are lower) and also results in a steeper depreciation rate at the beginning.

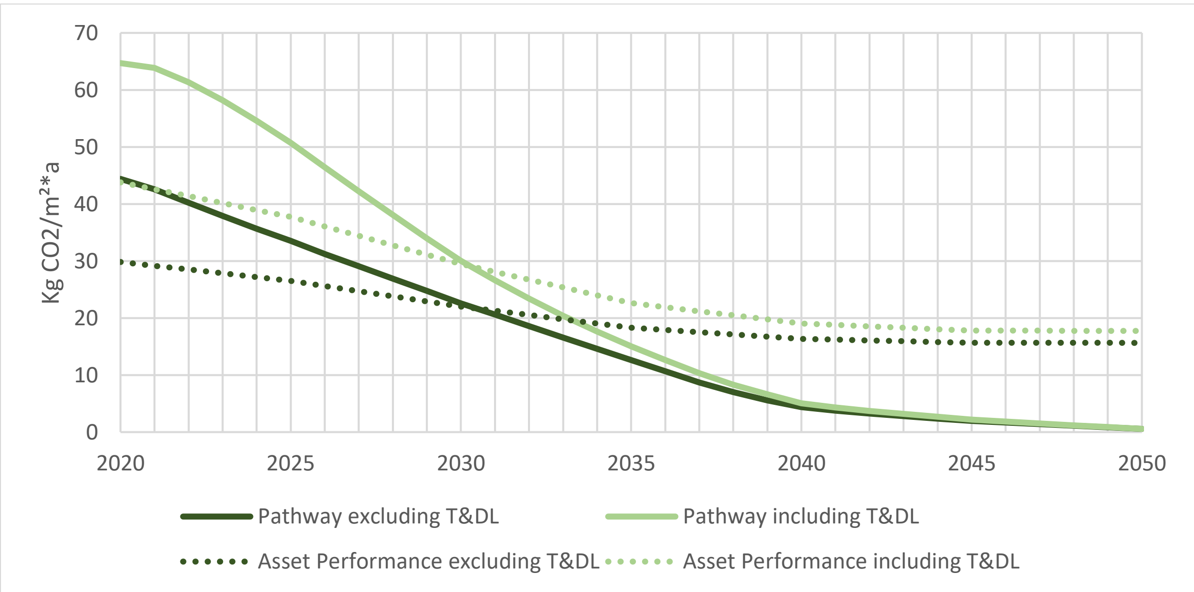
[22] Coincidence, that both lines (First Version and excluding D&T Losses) have the same starting point

**Figure 9: Depreciation rates of grid emission factors with vs without distribution losses**


*Source: own calculations based on the IEA NZE*

It is important to mention, that the effect of excluding T&D Losses in the EF is also reflected in the asset performance. In the figure below an example is given. In case, that the average energy mix applies also to the asset, the stranding point does not change. For consistency, users of the CRREM tool must also, from now on, apply the emission factor where T&D losses have not been taken into account.

**Figure 10: Asset Performance comparison including and excluding T&DL**




*Source: CRREM, 2022.*

### (A.2.4) District heating (DH)

**District Heating (DH) accounts for roughly 6% of the global emissions from the building sector** and is therefore an important source of carbon emissions within the real estate sector. Approx. 0.48 Gt $CO_2$ resulted in 2020 from district heating[23].

As increasing the share of units connected to the DH system is often quoted as a high priority in fighting climate change, it is therefore important to also ensure that the DH is provided from renewable sources. As an initial step, research was undertaken to establish the district heat production per region globally and consider the respective building share. Subsequently - also referring to IEA research - the total worldwide district heating production is interpolated between the numbers given by IEA until 2050 (considering the share of coal, gas oil, electricity and renewables to derive a worldwide pathway)[24]. Next, via the respective fuel emissions factor, the overall district heating emissions are calculated. Step 4 derives the depreciation rate until 2050, which was calculated via an approximation of the emission factors of the individual energy sources. Nevertheless, the global source of the emission factor is considered more valid and therefore, only the rate of change was taken. This then allows the calculation of the global district heating pathway, using the global emission factors and total worldwide district heating production. Taking a carbon intensity index for the various global regions, an emission factor per region was derived as the index is multiplied with the global emission factor for district heating (please note: The carbon intensity Level of the District Heating on a county level is assumed to be constant overtime, in relation to the global average EF of the global DH). To take efficiency gains and newly to the DH connected units into account, an index was created (the total number of units was taken from the IEA NZE figure 3.29). Further, to reflect buildings' positive kWh savings with respect to the newly connected units and energetic retrofits, an index is created and used on the total demand from the building sector. Global average kWh/m²*a is calculated via IEA NZE Annex A. Lastly, all researched and calculated values are taken into account for a global Buildings District Heating Pathway.

The emissions from district heating are Scope 2 emissions according to the GHG protocol and have therefore been added to the calculation of the base year emissions of each country. Double accounting does not occur, due to the given EF for the grid and DH. In cases of combined generation, the energy providers distribute the emissions either to Grid or to DH. CRREM uses the given EFs as noted in the source section. With this method, double accounting is ruled out.

We currently still observe in some countries relatively high EF for DH systems and often only a low ambition to decarbonize these systems over the next years. Asset owners are therefore encouraged to contact their local DH providers and encourage them to decarbonize these systems faster. Aligned with net-zero targets they should also be fully decarbonized at latest by 2050.[25]

### (A.2.5) Share of other GHG emissions related to Real Estate Sector

**The global F-Gas allowance for the building sector is 10.35 Gt for the period 2020 until 2050**. The first pathways version applied the same ratio of $CO_{2e}$ to $CO_2$ in the building sector, as for all sectors. Due to the **improved data availability, a detailed analysis of other GHG emissions was possible**. Against this background, the **previously (conservatively) relatively high add-on factor could be reduced considerably**.

Research on the amount of other GHG was based on the UNFCCC GHG-inventory Data of the Annex I countries and data provided by the United States Environmental Protection Agency. The reduction path was given by the *Kigali Amendment* to the *Montreal Protocol* and specific legislation on country level.

[23] Own calculations based on the IEA District Heating Report, IEA NZE.
[24] Shares based on the IEA NZE.
[25] In the CRREM-tool - which will be updated accordingly to the new pathways - we will include (as before) the update average EF on a country level. Especially for DH we advise users to apply the specific regional EF provided by their utility company. These projections should be entered in the individual settings sheet of the CRREM-tool to account for the most accurate regional input data (as the default figures used integrated in the backend only account for the country average).

**The share of all other GHG to $CO_2$-only is from 2020-2050 11.6% on average**. With a lower add-on of approx. 6% in 2020 and higher shares at the end (since some other GHG cannot be as easily removed as $CO_2$). Compared to the first CRREM version, this more in-depth possibility to research the GHG-emissions related to the property sector enabled us to reduce the add-on factor that was previously related to the overall shar of other GHG in all sector.

$CO_2$-only pathways were specifically requested by The SBTi, but are much needed anyway, as there are many asset-owners not measuring and indeed also not reporting on F-gases. However, as a minimum requirement then, appliance of the $CO_2$ pathway. Also, there are units not emitting any F-gases in contrast to others, which emit a lot. The deviation among the individual assets is huge. So, for this case, a mix of the two emission types would not be favourable.

### (A.2.6) Global carbon-intensity pathways (absolute emissions)

Looking at the differences between the first and updated CRREM $CO_2$-only global pathways, it can be clearly seen that the starting point in 2018 was (extending the light green curve) basically the same as in 2020 for the updated version. The sector (unfortunately like society as a whole) overshot the required reduction in 2018 and 2019. The 'higher' starting point in 2020 is (in order to catch up with the budget) leads to more ambition in later years.

**Figure 11: Global building sector $CO_2$-only pathway (absolute emissions, update including T&D-losses)**

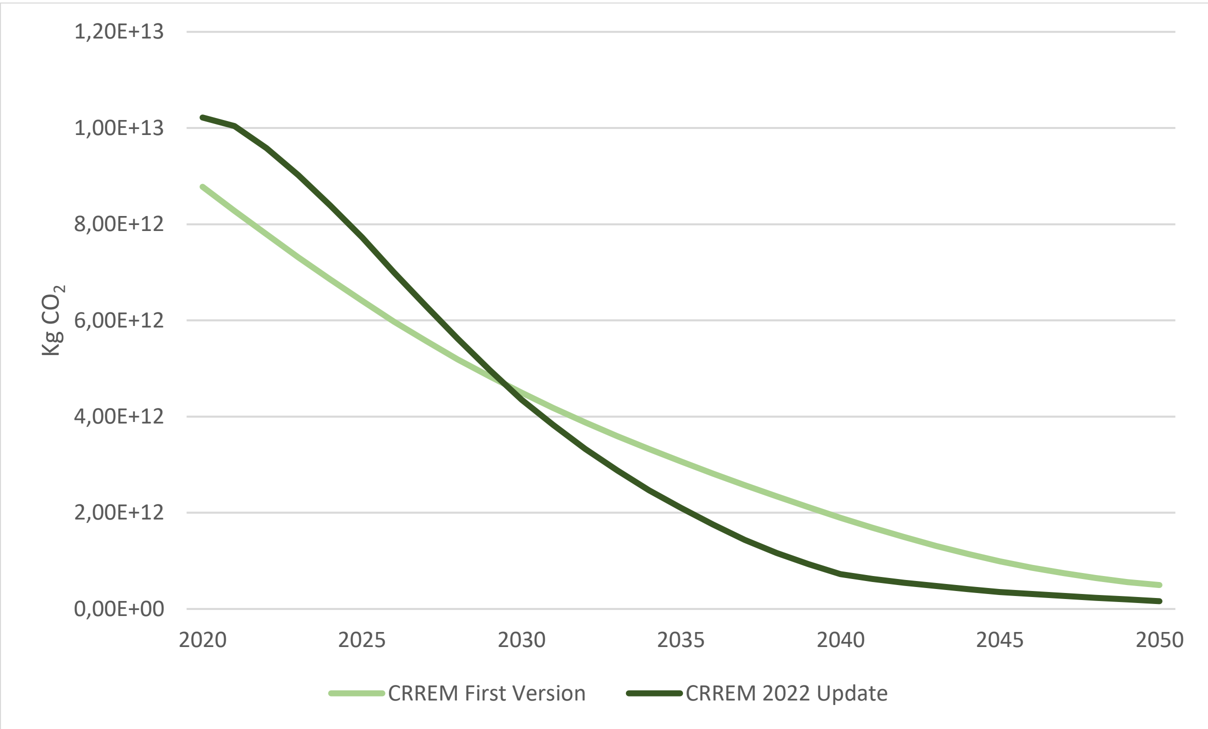


**Figure 12: Global building sector $CO_2$-only pathway (absolute emissions, update excluding T&D-losses)**

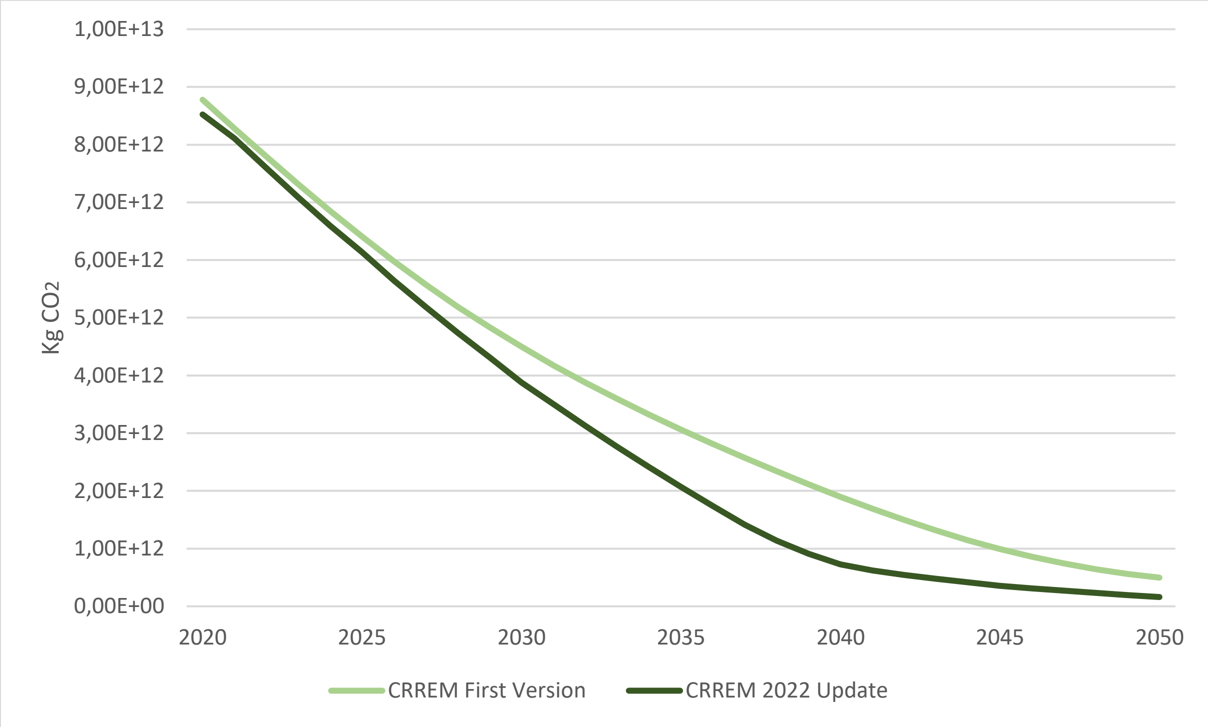
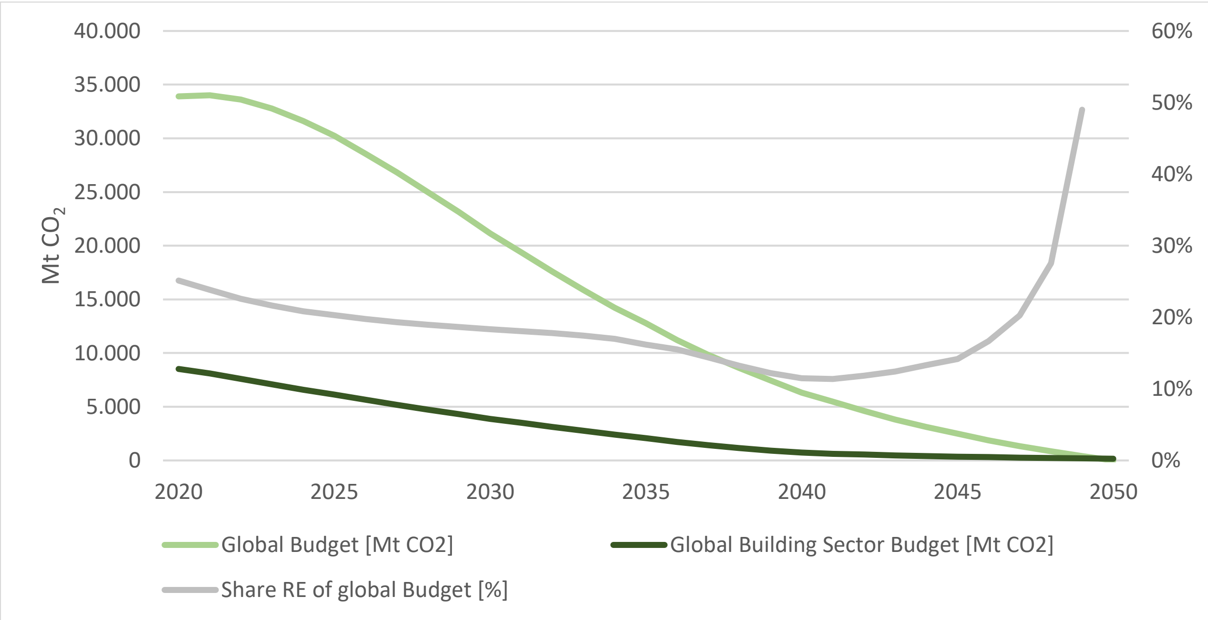



**Figure 13: Global carbon emissions (1.5°C scenario) of all economic sectors and the building sector**



**(A.3) Global building stock projections until 2050**

- **Compared to data used in previous CRREM pathways only, a slight deviation can be noted compared to the new projections.**
- **In 2020, the total global square meter figure is 4% lower than in the first version.**
- **For 2050 a 2% higher outcome regarding the global building stock is now projected.**

Since CRREM decarbonization 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 gross internal area (GIA) 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 (A.1) ).

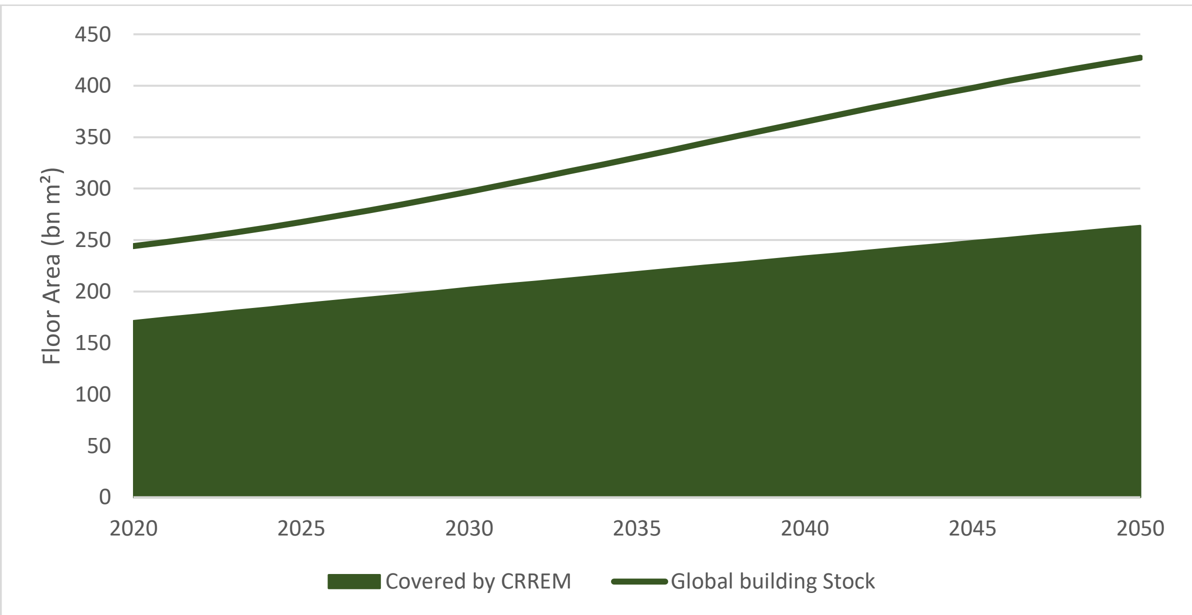
Estimated total building stock is based on Tracking Buildings 2021: IEA (2021). The projection for 2050 is founded on the *IEA NZE* report and other data sources for quality assurance. The sources project an increase of 75% of the total global building stock in the period from 2020 to 2050. Earlier sources in the *Global Status Report for Buildings and Construction* state a comparable increase.

To derive country-specific energy-targets (see section (D)), a breakdown between the commercial and residential building stock is required. This is here accomplished on the basis of the forecasts provided at country level. We consider our sample including approx. 70% of the global property stock in 2050 to be large enough, in order to draw conclusions related to the composition of the entire building stock. The IEA total kWh for the building stock is, however, the basis to derive the kWh-energy targets per m².

CRREM covers in considerable detail, the most relevant real estate investment markets globally. In terms of floor space and emissions, approximately 70% (approx. 171 billion m²) of the global real estate market is covered in detail. For the remaining countries, regional pathways will be published.

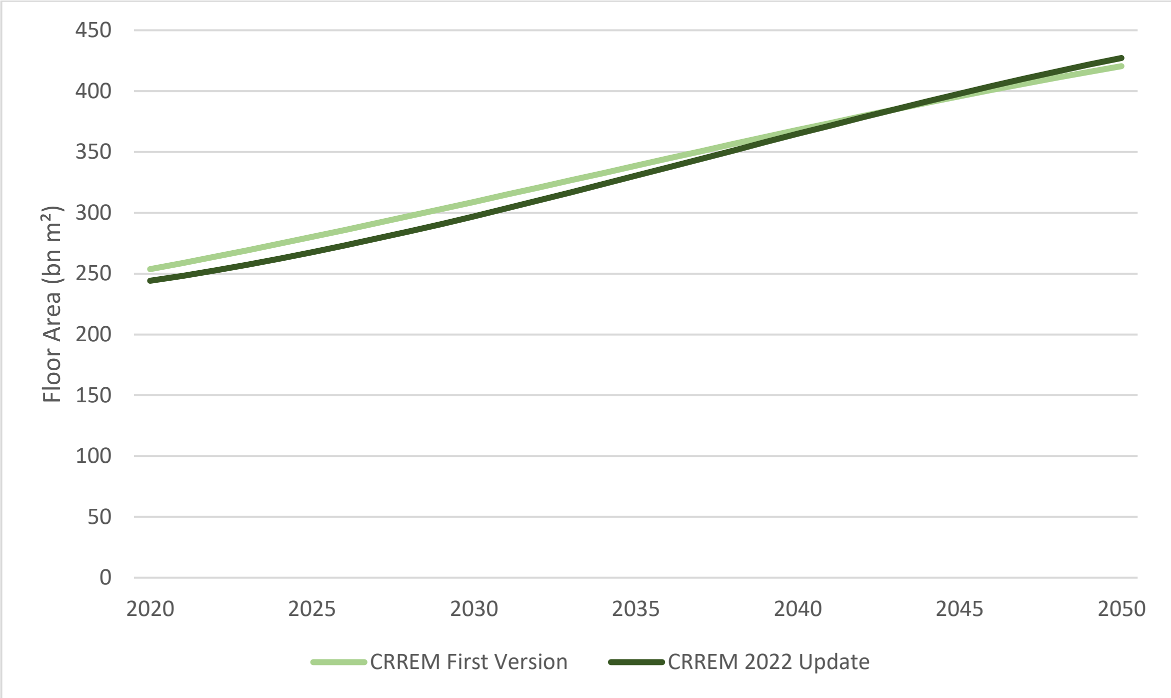
The CRREM downscaling procedure refers directly to the demand-driven expansion in terms of the increasing global building stock (= new construction minus demolition). The underlying data, of course, builds upon global population growth and per capita floor space usage estimates.

**Figure 14: Evolution of global building stock (2020-2050) and part covered in detail by CRREM**




*Source: IEA NZE & IEA Tracking Buildings (2021); own calculations.*

**Figure 15: Evolution of global building stock (in m²) old vs. new**




*Source: IEA NZE & IEA Tracking Buildings (2021), CRREM 2022.*

**(A.4) Global building sector carbon- and GHG-intensity pathways**

- ***From this version onwards, pathways can be applied as $CO_2$-only, other-GHG-emissions or combined all GHG-emissions.***
- ***The global average in 2020 for building related in-use emissions amounts to around 35 Kg$CO_2$-only per square meter. This is a reduction from the baseline figure in 2018, which is mainly caused by the methodology change regarding TDL.***
- ***On a like-for-like basis - including TDL - the starting point for CO2-only was in 2018 at 40,16 KgCO2-only per square meter and it is in 2020 at 41,86 KgCO2-only per square meter – illustrating again the overshoot and on global average no significant progress regarding the decarbonization of the build environment.***

The derivation of global carbon-intensity pathways for the building sector (see Figure 8) combines the global floor area trajectory (see step (A.3) Global building stock projections until 2050 above) and global real estate absolute $CO_2$ emission pathways for 1.5°C (see step (A.2) Deriving the real estate share and defining $CO_2$-only and GHG total budgets for global buildingsabove). These pathways are derived from the emission scenario for the global building sector in-use-phase aligned with the IEA and IPCC. The other GHG-emissions related to the real estate sector were derived from an in-depth analysis of the UNFCCC GHG inventory data (see above (6)). Whereas the first CRREM pathways had only a GHG-pathways covering all emissions in one figure, from this update onwards the overall GHG-intensity-pathway is further broken down. It can be applied as $CO_2$-only, other GHG or combined (see Figure 16 and Figure 17) trajectory.

**Figure 16: Global carbon emission pathways on square meter basis ($CO_2$-only) of 1.5°C scenario**

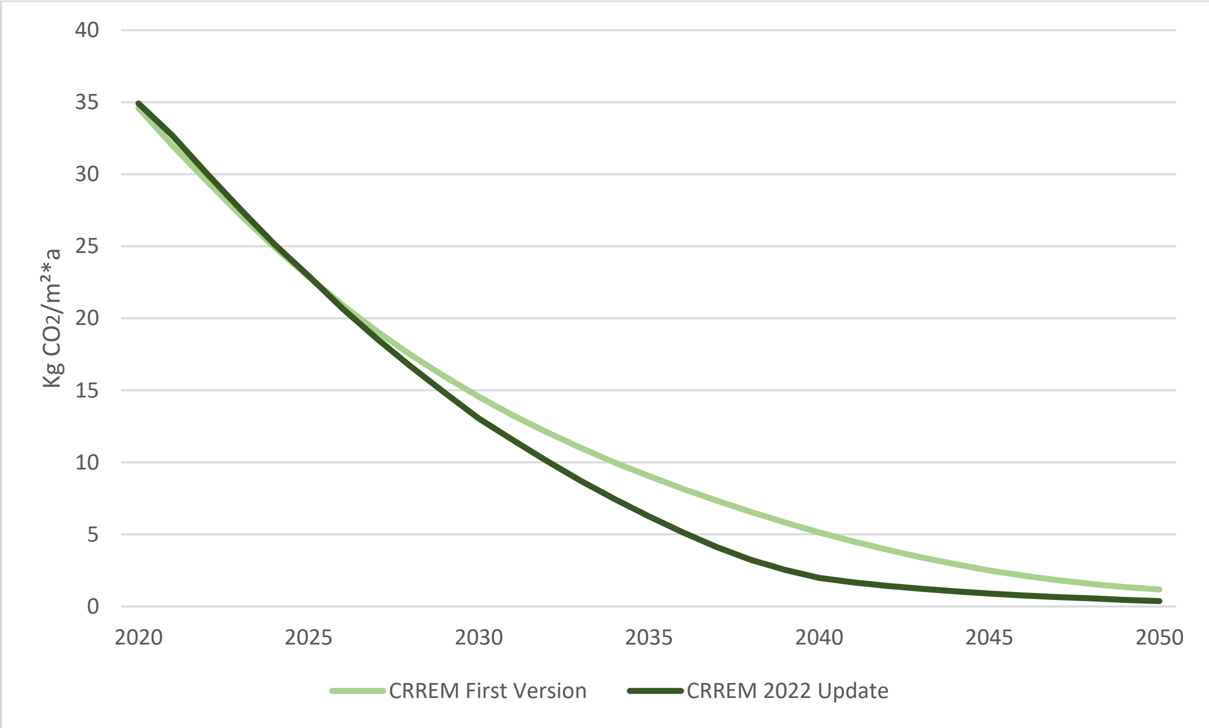
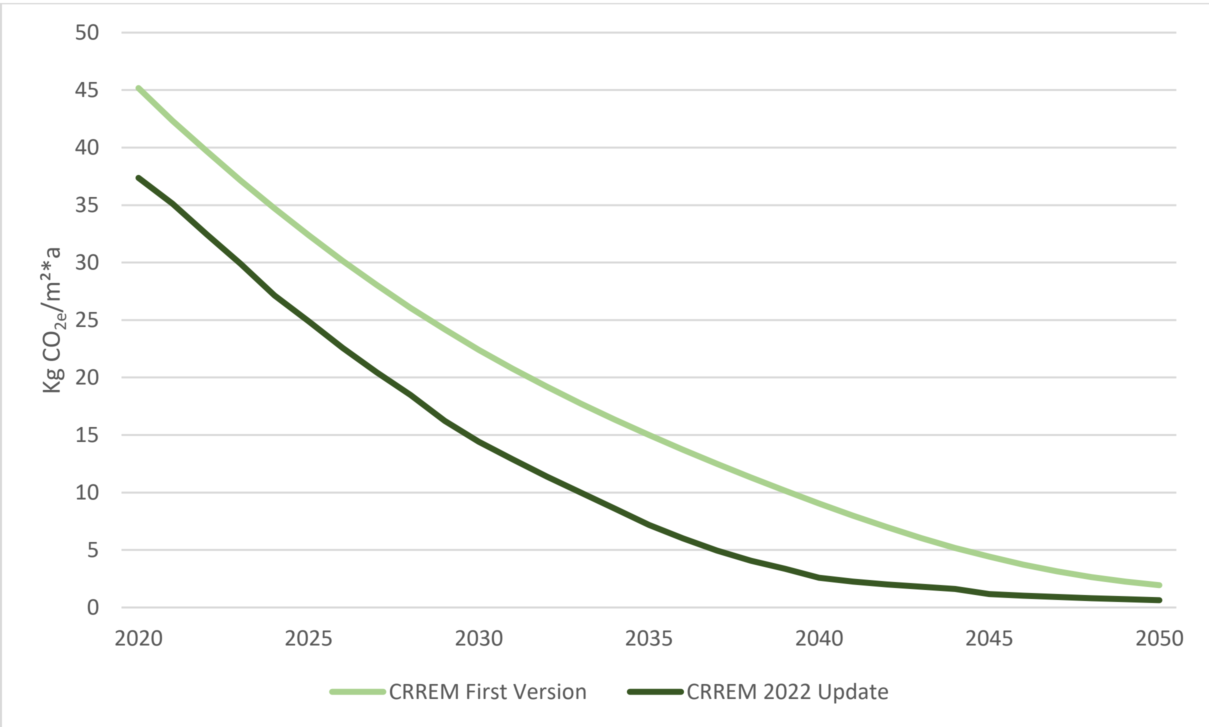



**Figure 17: Global building sector $CO_{2e}$ intensity pathways**



## B. Country Specific Decarbonization Pathways

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

- The SDA *(Sectoral Decarbonization Approach)* methodology (for more details see section (4)),
- each country's baseline carbon-intensity using:
  - Country building stock in square meters (residential and commercial Gross Internal Area (GIA) according to IPMS2),
  - country baseline for EUI (energy use intensity in kWh/m²) for different 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 scenario on country level (see above (4)) using:
  - projections for energy mix / sources,
  - projections for emission factors[26] for energy sources,
  - growth rate for floor space in different countries.

**(B.1) Underlying datasets for the calculation of GHG intensity pathways for individual countries:**

(B.1.1) **Global floor area and growth projections** aligned to IEA (2021, plausibility check via Global Status Report) and individual country data sets (**Floor area and growth rates within countries for residential and commercial real estate**) when available.

(B.1.2) Baseline 2020 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).[27]

Note that application of the SDA approach implies that (floor space) **growth rates lead to higher reduction requirements**:

- A country with more growth has a higher (reduction) change per m² (must reduce relatively more emissions per m²) compared to a nation with the same starting figures but lower growth going forward.
- A country with more growth nevertheless always has more absolute emissions available under the same conditions than a country with the same conditions and no growth - therefore developing countries can grow more.

The 'm' parameter in the SDA approach is (see section (4)) capped to '1', which implies that advanced economies which might even have a shrinking overall building stock, will at least face the same relative reduction per m² regarding the $CO_2$-intensities like the global pathway.

[26] Note that the EF used here for the calculation of the pathways are the same as in the CRREM-tool. E.g. EF for electricity are identical for today and for their changes over time. Energy mix for the pathways, however, 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.

[27] Sources B.1.1. and B.1.2.: See below for sources broken down by country.

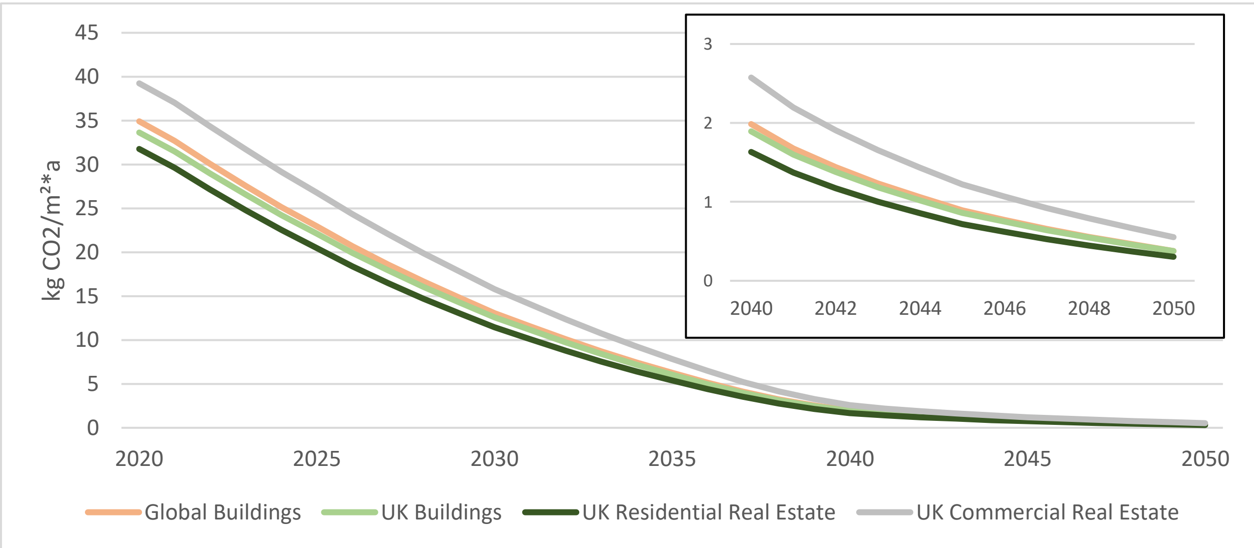
(B.2) Calculation of country-specific GHG intensity pathways for residential and for commercial buildings (1.5°C)

(B.2.1) The derivation of separate decarbonization pathways for the residential and the commercial sector within each country is based on each sector's baseline (2020) carbon-intensity and the assumption of a globally retained / constant ratio of the carbon-intensity for different residential and commercial building types. **It is expected that commercial buildings will still have a higher energy consumption in 2050 than residential buildings**. Also, within the commercial real estate sector, a differentiation is assumed for the target year 2050. These different target figures are also reflected in the $CO_2$-pathway, which leads to a slightly higher allowance for the commercial compared to the residential real estate sector in each country. Since the countries' absolute budgets and pathways are derived from downscaling the global budget, it is ensured that the **overall remaining global budget is not exceeded.**

(B.2.2) Baseline 2020 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.*

(B.2.3) Derivation of sub-regional pathways for the residential and the commercial sector with country-specific sources and alignment through data partners.

**Figure 18: Decarbonization pathway of global buildings sector, UK buildings sector and UK residential and commercial sector**



## C. USE-TYPE SPECIFIC DECARBONIZATION PATHWAYS

### (C.1) Overview of the approach

The CRREM calculation of $CO_2$-only and GHG intensity **pathways covers the following property-types**: Office, Retail High Street, Retail Shopping Center, Retail Warehouse, Hotel, Industrial Distribution Warehouse, Healthcare, Lodges/Leisure & Recreation, Medical Office, Residential Multi-family (RMF), Residential Single-family (RSF). Additionally, for the 2020 update, the industrial distribution warehouse pathway has been split into cold and warm storage.

Please note: a new category 'Data centres' could not be included, as the values are very variable and no reliable benchmarks could be provided. According to *Bitkom*, the average energy consumption of data centers in Germany adds up to 7,805 kWh/m²*a or 2,970 kg $CO_2$/m²*a. A data center also faces the paradoxical situation that higher energy intensity per m² makes the data center more efficient. Higher efficiency through state-of-the-art IT-equipment results in lower land consumption. The saved embodied carbon emissions and other reduced environmental impacts due to the construction of less efficient data centers leads us to the conclusion that an evaluation according to general CRREM standards is not appropriate.

The calculation of the $CO_2$ starting values of sub-types is based on individual collections of average kWh/m²*a-figures in the respective countries for the corresponding property-sub-use. If this figure is not available, or the benchmark is not sufficiently reliable, an average adjustment factor (Commercial or Residential real estate to sub-use) is applied for the region. This is derived and validated on the basis of aggregated data from CRREM data partners.

For the **conversion of the derived kWh-start value of the sub-use into $CO_2$, a weighted EF is necessary**. This is not identical to the weighted EF of the areas Residential or Commercial real estate per country. Rather, an even more detailed specification of the **respective energy mix of the sub-use type per country is made**. In order to derive the respective weighted EF for CRE, the sub-uses were differentiated in terms of their electricity and DH share, using the average factors based on real data from our data partners by country and type of use on the basis of more than 30,000 properties. For the EU, an adjustment was also made to the average electricity shares based on the 'EU-Energy Balance'. For Residential Real Estate, the same electricity share of the energy mix was applied for both RSF and RMF.

### (C.2) Differentiation of multi-family residential and several commercial buildings sub-sectors

(C.2.1) The derivation of distinct decarbonization pathways for specific subsectors/use-types within the residential and the commercial real estate sector is based on the on the assumption of a constant global ratio of the carbon-intensity of the respective subsector (e.g., office buildings) and the commercial sector. From a socioeconomic perspective, this is a valid assumption, as no major changes in the composition of the building sector are anticipated. By 2050, the relative difference in a specific country will converge to the average difference of all countries.[28]

(C.2.2) Sub-use type starting figures are based on local research and statistics from data partners. If no national statistics were available, we used calibration factors based on aggregated stats from data partners covering more than 30,000 observations. Also, the respective weighted EF in terms of their electricity and DH share was calculated. *Source: See below for data sources for individual countries.*

[28] 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.

## D. COUNTRY & PROPERTY-TYPE EUI PATHWAYS

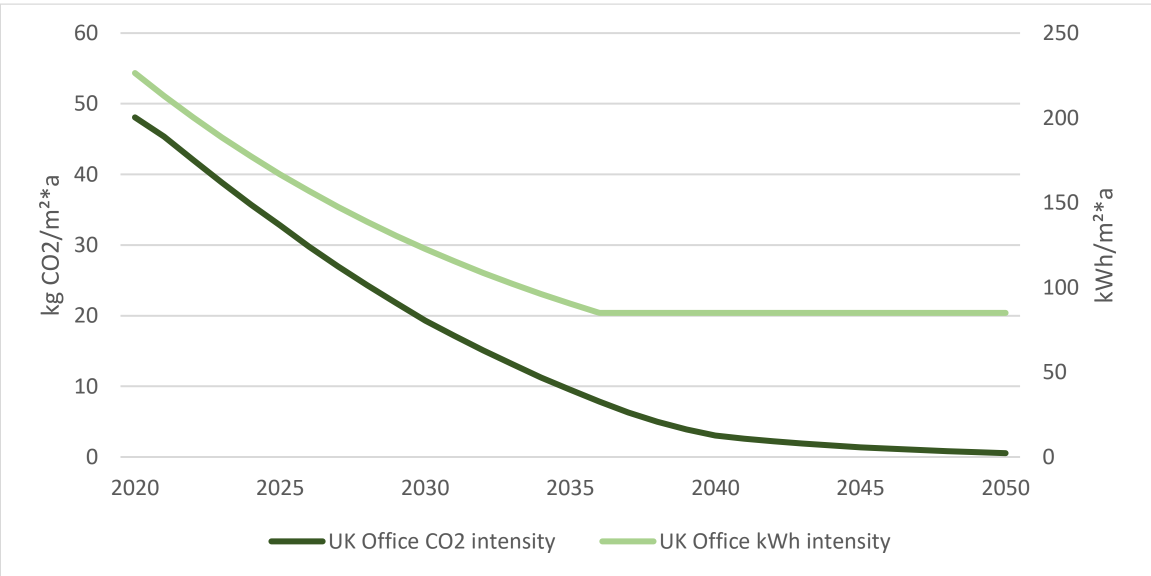
**(D.1) Overview regarding the approach**

The CRREM EUI pathways now refer to the **energy consumption** of a building and not anymore to the **net energy demand**. For further explanation of the methodology change please see Section (5). [29]

The **derivation of energy-intensity pathways for individual countries and use-types** (EUI measured in kWh/m²*a) are based on the respective decarbonization pathways (carbon emissions per square meter ($kgCO_2$/m²*a)) 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 for energy mix (share of electricity and fuels) and grid decarbonization within each country (see (B.1) Underlying datasets for the calculation of GHG intensity pathways for individual countries:). CRREM energy targets are NOT kWhe but kWh!

**Based on projected emission factors and energy mix, typical carbon-to-energy-factors have been derived, enabling the conversion of carbon-intensity to energy-intensity figures**. In some countries, grid decarbonization might progress very rapidly, 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% per year.

**Figure 19: Decarbonization and energy-reduction pathway for UK office buildings (1.5°C scenario)**




**(D.2) Underlying data and calculation procedure**

(D.2.1) Country-specific 2020 baseline end-energy-intensity (kWh/m²*a) data for residential and commercial buildings (and sub-sectors if available). *Source: See below for data sources for individual countries.*

(D.2.2) Calculation of 2020 country-specific and (sub-)sector-specific carbon-to-energy factors.[30]

[29] 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.

[30] 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.

(D.2.3) 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 decarbonization').

(D.2.4) Calculation of end-energy-intensity pathways 2020-2050 based on carbon-intensity pathways (1.5°C scenario) and carbon-to-energy factors.

**(D.3) Energy target figures**

Due to the fact that now - in contrast to the first CRREM version - some energy sources are actually completely decarbonized by 2050 according to forecasts, the existing method of deriving the energy paths was expanded. For this purpose, the concept of energy target values was introduced. With these target values, it should be noted that target achievement is *only* achieved if **(1.)** the **EUI corresponds to the stated energy-intensity figure**, AND **(2.) the asset also meets the $CO_2$-target for the respective year** (which means in 2050 it must be completely decarbonized, renewable energy). The energy target values are derived from the renewable energy budget available for the real estate industry in 2050 (according to the IEA and other sources) and are determined separately for commercial and residential real estate. A global breakdown takes into account the respective possibilities and limits of energy efficiency in various climate zones and allocates the overall budget based on bioclimatic zones and the respective HDD/CDD (Heating and cooling degree days). The building stock of the country is also considered, based on population projections in order to ensure that the available budget is not exceeded. All targets are rounded up to 5 digits.

Heating degree days have a greater impact than cooling degree days on the overall kWh target for 2050. This is according to the energy use in 2050 projected by the IEA for heating and cooling spaces. Space heating is projected to account for 17% of the overall energy use ('whole building approach') whereas space cooling just accounts for 11%.[31]

The example stated below for Canada and the US illustrates the effect of the number of HDD and CDD. As Canada has more heating degree days compared to the US, but less cooling degree days, the overall energy target exceeds the allowance of the US by about 30%. This procedure was applied to the sub-regions for USA and Australia.

**Figure 20: Effect of heating and cooling degree days based on the example of USA and Canada**

| | | | Energy Targets [kWh/m²*a] | |
|---|---|---|---|---|
| | Cooling Degree Days | Heating Degree Days | Commercial RE | Residential RE |
| USA | 76.7 | 142.4 | 70 | 50 |
| Canada | 16.0 | 311.1 | 100 | 70 |

[31] IEA (2021): District Heating Report.

**(D.4.) Relative rate of required improvements in asset-level energy performance 2021-50**

Figure 21 illustrates the relative change in EUI from 2021 until 2050. Countries in green show a lower relative change (in kWh/$m^2$) compared to other nations which will face higher reductions (red show higher relative change). The reasons are as follows:

1. **Higher starting point in kWh** (here, the country average is higher than those of others), of course requiring higher ambition if the end point should be the same (which is, for other reasons, *not* always the same). So here, the Top 4 green have 226 kWh/$m^2$*a average vs. worst four 254 kWh (12% more). The best performing countries have around 60% reduction whereas the red countries tend towards 80%. For countries which do have a relatively higher energy-intensity at the beginning, it is rather more ambitious to achieve the 2050 targets.

2. **Grid decarbonization:** A further driver is a slightly lower grid decarbonization in the red marked countries. A faster grid decarbonization would ceteris paribus lead to a higher allowance for energy consumption (low grid EF results in higher energy intensity). For example, 300 kWh with 0.5 EF results in 150 kg $CO_{2e}$/$m^2$*a in 2021. Without any grid decarbonization, the example asset with targeted emissions of 12.5 kg/$m^2$ in 2040 would therefore need an energy intensity of maximum 25 kWh (so 92%) to reach the given target.

**Figure 21: Relative rate of required improvements in asset-level energy performance 2021-50**

| | OFFICE | R HS | R SM | Hotel | Health | Leisure |
|---|---|---|---|---|---|---|
| BG | 0,6 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 |
| LV | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 | 0,5 |
| SE | 0,6 | 0,6 | 0,7 | 0,6 | 0,6 | 0,6 |
| NL | 0,6 | 0,6 | 0,6 | 0,7 | 0,5 | 0,5 |
| UK | 0,6 | 0,6 | 0,6 | 0,6 | 0,7 | 0,6 |
| CH | 0,6 | 0,6 | 0,6 | 0,6 | 0,5 | 0,6 |
| NOR | 0,6 | 0,6 | 0,4 | 0,5 | 0,5 | 0,6 |
| HK | 0,6 | 0,6 | 0,6 | 0,6 | 0,6 | 0,6 |
| DE | 0,6 | 0,6 | 0,6 | 0,6 | 0,5 | 0,6 |
| GR | 0,7 | 0,6 | 0,7 | 0,6 | 0,6 | 0,6 |
| HU | 0,6 | 0,6 | 0,6 | 0,6 | 0,6 | 0,6 |
| HR | 0,7 | 0,6 | 0,7 | 0,7 | 0,7 | 0,7 |
| CHI | 0,6 | 0,6 | 0,6 | 0,6 | 0,5 | 0,6 |
| JAP | 0,6 | 0,6 | 0,7 | 0,7 | 0,7 | 0,7 |
| MAL | 0,7 | 0,7 | 0,7 | 0,7 | 0,8 | 0,7 |
| MEX | 0,8 | 0,7 | 0,7 | 0,7 | 0,8 | 0,7 |
| PHI | 0,7 | 0,7 | 0,7 | 0,7 | 0,8 | 0,7 |
| SGP | 0,8 | 0,8 | 0,7 | 0,8 | 0,7 | 0,8 |

*Source: CRREM, 2022.*

Despite the new baseline year 2020, the actual data showed no impact in terms of specific reduced energy consumption with regard to Covid-19. If deviations in the data or an impact was identified, then we have adjusted for this aspect accordingly.

## (4) SDA Sectoral Decarbonization Approach

The *SDA* **convergence methodology** offers a very flexible framework which is 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 more rapidly 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 in conformity with 'future-proof carbon-intensity' standards. The *SDA* framework applies a so-called ***Market Share Parameter*** (**m-parameter**) expressing the different growth rates and a so-called ***Sector Decarbonization Index***, expressing the decarbonization progress in each country: Countries growing less than the average will not be rewarded in terms of lower decarbonization responsibilities. In order to take this into account, the m-parameter is capped at 1.

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

$$\sum_{2020}^{2050} A_y \, SI_y \leq Budget_{2050}$$

*where:*

| | |
|---|---|
| $A_y$ | *Activity of country in year y* |
| $SI_y$ | *Intensity of country in year y* |
| $Budget_{2050}$ | *Cumulative carbon budget 2020-2050 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 m-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[32] within a certain period *($CA_y$=$3CA_b$)*[33], 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) decarbonization** 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 Decarbonization Index (*presenting the global building sector's rate of decarbonization) and the *Market Share Parameter* presenting the effect of different country growth rates. SeeFigure 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 within the commercial real estate sector. On a socioeconomic basis, this is a valid assumption.

**Use of the SDA Approach**

The SDA was originally not designed for the purposes of deriving country-level pathways. However, the application is feasible. Country pathways calculated using the SDA do not include 'sufficiency' in terms of reducing or optimising floor area per capita as a mitigation method. Differentiated heating and cooling demands are not part of the budget calculation for 2050 in terms of $CO_{2e}/m^2$. However, they are considered in the energy targets. Also, access to renewable energy is not included in the calculation on a country level.

- There is a lack of literature sources to which to compare the SDA pathways. But in general, where a like-for-like comparison can be made, the SDA yields similar but slightly steeper reductions.

[32] Note that 'activity' can be translated to 'floor space growth rate' for real estate application.
[33] Country specific research was done to derive growth or depreciation rates for the building stock

- The effect of the m-parameter is generally small, and therefore does not create a large equity issue (by allocating less carbon budget to developing countries). The base year emissions intensity is by far the most influential factor in the cumulative budget allocated. But it is nonetheless important to take the base year emissions into account to keep the pathways feasible and the targets possible to achieve. In order to ensure that the carbon budget is not exceeded, the m parameter is used. This parameter may not exceed 1, so as not to reward decreasing building stocks in specific countries.
- A modification to m, or a new parameter, could in theory be used to take equity considerations into account (to deliberately allocate more budget to developing countries). For a short discussion of this, see Section 7. In conclusion, no modification has been made.
- Access to renewable energy is not explicitly included in the calculation at country level. The global pathway does depend on access to renewables.
- In conclusion, the use of the SDA to derive country pathway does not lead to better or worse results than other potential methods, and it conserves the overall budget. All potential methods would be influenced substantially by base year emissions intensity.

## (5) ENERGY AND CARBON ASSESSMENT METHODOLOGY

CRREM decarbonization pathways and carbon risk assessment focusses on the **intrinsic environmental quality of individual buildings** and is intended to provide owners and other interested parties 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 (in-use)**, 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. Embodied carbon emissions are of course also an important component of emissions over the entire life cycle of real estate. CRREM focuses on the operational phase and therefore does not include embodied carbons. The level 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 (EF),** indicating the amount of carbon emissions related to a certain amount of energy consumed. 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 within a given energy grid in the short-term. Since CRREM decarbonization pathways are based on national emission factors, users of the pathways should also 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 should be determined according to the so-called 'location-based' approach instead of the so-called 'market-based' approach for a like-for-like comparison.**[34] 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 decarbonization pathways are based on national emission factors.[35]

CRREM **energy-reduction pathways refer to the so-called end-energy consumption**, as it can be read off electricity meters and utility bills, plus renewable energy produced and consumed on-site (sometimes also referred to as 'site-energy').[36] This is in contrast to the primary energy concept, 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 upstream activities, 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 now refer to the **energy consumption** of a building. By contrast, in the first version of CRREM, we referred to the **net energy demand** of a certain property. Numerous stakeholders claimed that the net energy demand targets were 'not achievable'; this perception was mainly resulting from the misinterpretation of the EUIs, often viewed as energy-consumption figure. Switching now to a purely consumption-based number makes it for market participants easier to directly refer to their energy bills (and adding energy produced and consumed on-site on top of that). Also, problems regarding the creditability of energy generation in the immediate vicinity of the site (but not 'on-site') was related to the net-energy-concept, which is also why the CRREM initiative decided to change the methodology regarding the energy targets.

Another reason for changing the methodology is to **promote efficiency-first-strategies**. With the previous methodology a bad performing asset (with high energy consumption of e.g. 500 kwh/m²*a) could score very

[34] The SBTi accepts both approaches for company target validation. CRREM pathways are location-based.

[35] Note: If possible, the location-based factors should be used, which will allow the best 'like-for-like' comparison and optimization on the asset. We recommend to use the location-based factors. However, in the tool we will keep the option for all users to switch to the market-based approach if they wish. 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. In that case users should also overwrite the Grid EF-pathways in order not to benchmark their assets to purely national levels.

[36] See definition of energy star in the US for details:
https://www.energystar.gov/buildings/benchmark/understand_metrics/source_site_difference

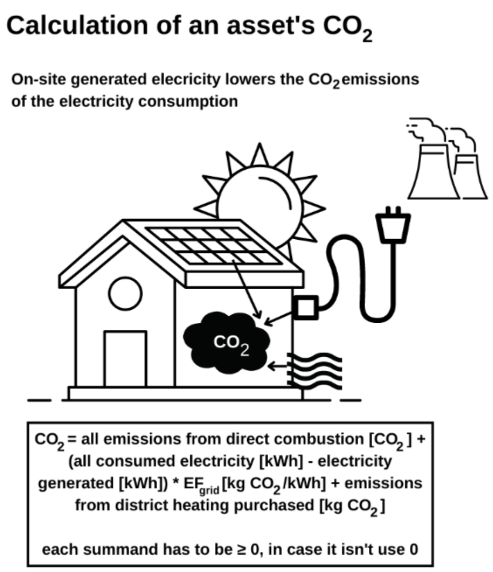
good in the CRREM asset performance, as long as enough renewable energy was provided on-site (to cover the relatively high demand, e.g. covering the entire demand with renewables produced on-site would result in a net-energy-demand of zero). In contrast a fairly energy efficient building with a very competitive (low) consumption level (e.g. with an energy demand of just 50 kwh/m²/*a) would still have a higher net-energy-demand compared to the first example. Energy efficient buildings are therefore not just net-energy-efficient but rather low-energy-consumptions properties – which in turn can contribute to an overall cleaner grid by producing more renewable energy on-site than they need to cover their own demand.

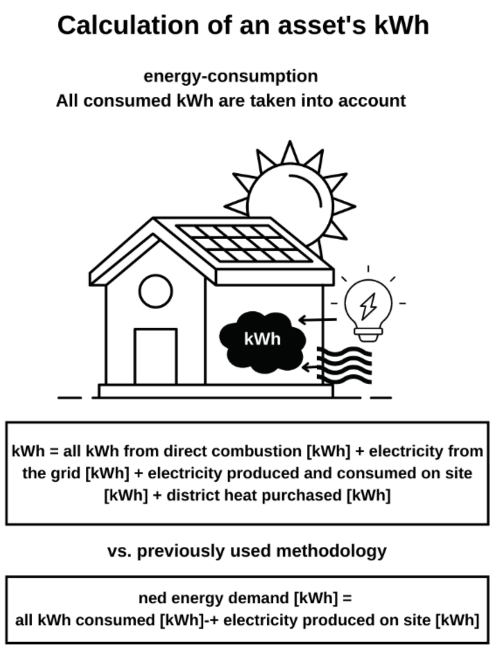
The consumption based EUI view is stipulating energetic-refurbishment investments - like putting insulation to the façade etc. - since lower EUI´s will support the alignment with the CRREM energy-intensity-pathway. At the same time this method is ALSO fostering renewable energy production on-site, since the net-zero/renewable energy generated and consumed on site is of course still taken into account with regard to the $CO_2$ intensity of the asset. The renewables produced and consumed on site have an emission factor of zero. Therefore, they add to the overall building’s energy consumption, but NOT to its carbon footprint – in turn the overall carbon intensity is relatively lower (compared to assets purely relying on the grid). Note that also renewable energy produced on site and sold back to the grid is equally reducing the carbon intensity of the property. The direct combustion emissions of an asset are not affected by a possible oversupply of energy within an asset.

The energy targets take into account the heating and cooling degree days of each country (see D.3). This ensures that an incentive is provided for both the expansion of renewable energies and the reduction of energy requirements. A 1.5°C aligned building does not strand in **both pathways** – $CO_2$ and kWh intensity.

It is necessary to differentiate between the GHG and the EUI perspective. Please note that the changes regarding the CRREM energy consumption-based EUIs and the carbon-intensities are aligned (and not conflicting) with the EPBD recast in 2021/2022 (EU EPBD-4). The new template for EPCs includes the requirement to clearly showcase renewable energy production on-site and how much it represents compared to the building's overall energy consumption; as well as how much it improves the overall building's GHG emissions. The CRREM tool calculates already the energy consumption of the building separately and shows in a transparent way how much of that energy was provided by renewable energy production on site. Therefore, a differentiation between overall consumption and consumptions share procured from the grid is guaranteed. Finally, the revision of the EPBD improves the recognition of renewable energy sources in the calculation of the overall performance of the building – supported by the CRREM approach already. If only the balance is shown (net-energy-demand) this will not enable market participants to comply with the revised regulation (since the amount the on-site renewables contributed can in this figure not be revealed. In the proposal for the revision of the EPBD it is stated, that the new EPCs should also state how much of the building's needs are covered by the on-site generated renewable energy. So additional data is not needed. Also, the EPCs should take into account how much the $CO_2$ performance of a building is improved by this. This is in line with the CRREM approach (see below). In this context it makes much sense to take into account produced energy on-site, which also reflects the formerly used methodology by CRREM.

Figure 22: Schematic overview of Carbon- and Energy-footprint of an asset




Example for illustration (here a completely electrified property):

**A. Energy footprint:**

1. Total renewable energy produced on site: 100 kWh (EF = 0) (= 2. + 3.)
2. Renewable energy exported to the grid: 40 kWh
3. Renewable energy produced & used on site: 60 kWh
4. Energy imported from the grid: 70 kWh (EF = 0.3)

- Total energy-consumption of the property: 130 kWh (= 4. + 3.)
- Net-energy-consumption of the property: 30 kWh (= 4. - 2. or = Total Cons. -1.)

**B. Carbon footprint:**

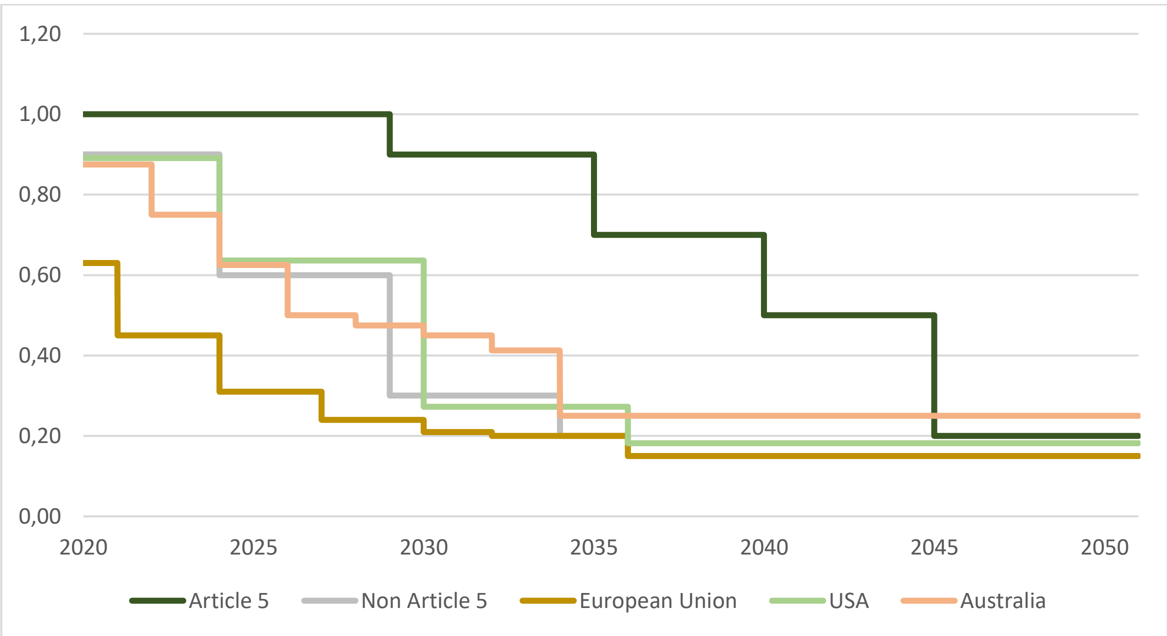
- 30 kWh * 0.3 kg$CO_2$/kWh (EF) = 9 kg $CO_2$
- Note: for reporting purposes according to GHG protocol the gross electricity procured would need to be reported, in contrast to taking into the effect of surplus renewable energy for transition risk analysis. So, in this case 70 kWh * 0.3 kg$CO_2$/kWh (EF) = 21 kg $CO_2$ (no deduction of the electricity produced and sold back to the grid).

## (6) INTEGRATION OF F-GASES & OTHER GHG'S IN THE BUILDING SECTOR

**F-Gases (HFCs and PFCs) are an important source of GHG within the build environment**. In Europe they amount to approx. 18% of all GHG combusted/emitted on site. In some of the southern European countries (e.g. Portugal or Malta) F-Gases amount to approx. 30%. For some asset classes, this proportion is significantly higher than the average, since at least in Central Europe, residential units are rarely cooled. Global emissions from F-Gases amount to 1.7 Gt $CO_{2e}$. The *IPCC* estimates building-related emissions from F-Gases at 1/3 to 1/8 of all global F-Gas emissions back in 2014. Other sources expect these numbers a bit higher, up to more than 50% (600 Mt $CO_{2e}$) of a total of 1.1 Gt $CO_{2e}$ (just F-Gases) back in 2010. In 2020, the *United States Environmental Protection Agency* reported 811 Mt $CO_{2e}$ of 'Air Conditioning and Refrigeration' (global). Emissions from mobile air conditioning (cars) and industrial refrigeration are to be deducted. Using the data from all ANNEX I countries, the share of these two is 1/3 of the stated 811 Mt $CO_{2e}$. So overall, we are talking about approx. 576 Mt $CO_{2e}$ emissions per year, a share of around 16% from all direct emissions in the building sector.[37] Not taking these emissions into account would be a major methodological mistake.

The **Phase-Down-Pathway for F-Gas emissions was agreed on in the *Kigali Amendment* to the *Montreal Protocol*** in 2016. All countries are divided into two sections: Article 5 and Non-Article 5 nations. Article 5 countries have been granted a less ambitious phase down, whereas the non-article-5 countries have to undergo a much faster phase down. (National) Legislators are of course allowed to take a faster track. Australia, for example, chose a phase down which rapidly reduces the emissions during the next years.[38] The European Union has also decided to reduce emissions more than required by the Kigali Amendment within the next ten years (brown line in the figure below).

**Figure 23: Global Phase Down for F-Gases**




*Source: UNIDO: Way to go with UNIDO Mapping the HFC phase-down, 2017.*

[37] All F-Gas conversion factors from HFCs/PFCs to $CO_{2e}$ are based on the GWP100. For the derivation of the paths, the GWP100 from the AR4 were decisive, since the states continue to report according to the standard under decision 24/CP.19. Ar4 is decisive here. In the previous version of the CRREM tool, the GWPs from AR5 were used. This will be changed accordingly to the GWP100 from AR4 so that there is consistency between the data. It is important to note that this no longer corresponds to the latest state of science.

[38] Australian Government: HFC Phase Down, 2021. Online available: https://www.awe.gov.au/environment/protection/ozone/hfc-phase-down/hfc-phase-down-faqs#quota-allocations-and-limits

To integrate the F-Gases, an additional component will be added to the existing $CO_2$-allowance of each building. The reported F-Gases of commercial refrigeration are assigned to the Commercial Real Estate Sector. As data availability on the distribution of air conditioning in residential and commercial housing is very poor, these were assigned to all buildings equally, even though their use might differ in the various property types now and in the future. F-Gases at a country level are then assigned to the Commercial and Residential Sector and given an extra allowance. It is of fundamental importance that this allowance is only granted as long as the use of F-Gases is also reported for the building. If this is not the case, only the $CO_2$ pathway must be used.

The phase down on a country level is based on the steps defined in the Kigali amendment. If countries (for example the EU or Australia) establish a stricter phase down, the pathway of the stricter regulation was applied accordingly. Further adjustments are to be made if more countries integrate a more rigid Phase-Down-Pathway or if another binding global agreement will be established in the future. To reflect the wide spread throughout the asset classes - especially commercial buildings have a higher consumption of F-Gases - more research is needed on this topic and additional adjustments/ calibrations might be needed going forward.

The graphs below show the add-on for the respective European and non-EU countries in regards to the other GHGs in $KgCO_{2e}$ per square meter in 2020. The average for both Europe and the non-EU pathways is around 6 $KgCO_{2e}$ per square meter. Some deviations to the average can be noticed, including Luxembourg and Germany on the lower end versus Portugal and Croatia on the higher end. For the non-EU countries - especially in Australia - a high rate of fugitive emissions can be noticed. Of course, higher amounts of fugitive emissions can be expected in warmer regions due to the higher need for cooling.

**Figure 24: F-Gases for commercial buildings Europe**

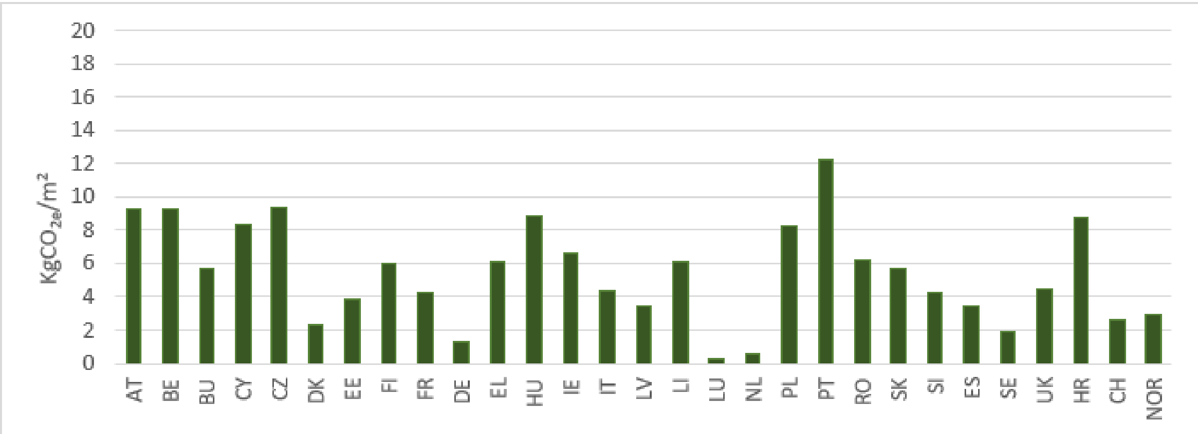
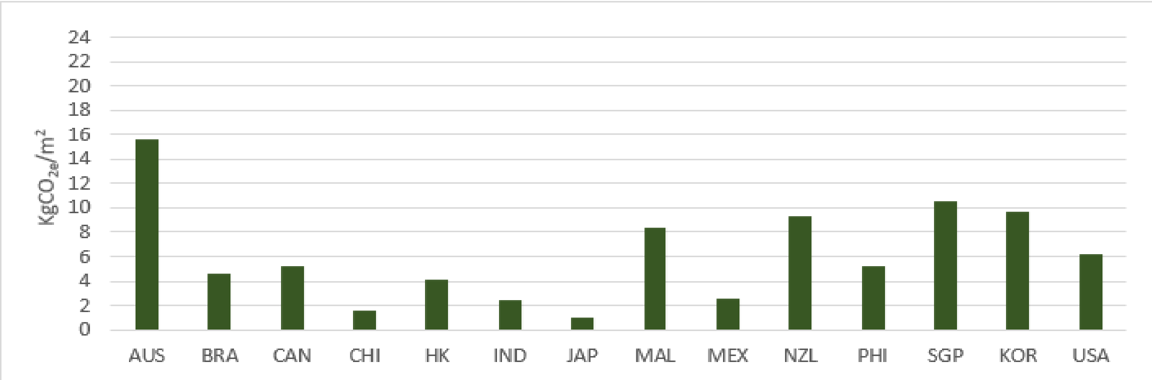


**Figure 25: F-Gases for commercial buildings globally**




The tracking and reduction of F-gases is also relevant since they are integrated in heat-pumps – which in turn are always viewed as the solution for decarbonization and provision of renewable energy.[39]

[39] IEA (Nov. 2022): The Future of Heat Pumps, IEA, 2022. https://iea.blob.core.windows.net/assets/01324438-d634-4d49-95d8-3d08aaab00d5/TheFutureofHeatPumps.pdf

## (7) HOW TO INTEGRATE AN EQUITY COMPONENT?

It is necessary to highlight that distributing the allowance of future emissions in terms of equity is a political question and not a scientific one. The Paris Agreement and the related NDCs of each country are based on voluntary self-commitments of the ratifying states. CRREM uses mathematical input and applies the SDA approach, aligned with The SBTi and the IEA Net Zero by 2050 Pathways for the buildings and energy sector. The IEA evaluated what is within the technical possibilities in each sector, and then distributed potential budgets and created the Net Zero Pathways. CRREM then downscales the budgets to each country and within the country to the different asset classes. The downscaling process takes into account different growth rates of the national building inventory in both residential and commercial subsectors. Each national pathway represents the 'SDA based share' of carbon that each country's building sector is allowed to emit until 2050. This allocates the responsibilities and efforts required by the real estate sector to the country and use-type level. Thus, there is a global equity component, but again, the decarbonization of the building sector has to be in line with technical limitations as IEA recommends.

The global budget for the buildings sector is unequally distributed, based on the current emissions. This in turn is based on the unique characteristics of the asset class 'Real Estate'. Real estate is inherently long-term, investment cycles are long and modernisation requires a high level of budget, know-how and craftsmanship. This all means that the countries with a higher share of emissions in the building sector have to decarbonize other sectors faster, in order to align with derived national $CO_2$ budgets on a per capita basis (e.g.), which are also used by the German Advisory Council on the Environment (Sachverständigenrat Umweltfragen).[40] The approach of distributing emissions on a per capita basis would not be suitable for the building sector, because buildings in warmer climatic zones already require significantly less $CO_2$ today than in middle or northern Europe. The base year emissions must, however, be taken into account for logical reasons. The share of emissions (in relation to all emissions of a country) rises with more heating-degree days.

In conclusion an equity adjustment, or distribution, should only be built in when all NDCs (of all global countries) combined result in a 1.5°C pathway and the global distribution is solved at a political level. Then, it would be necessary to apply each country's decarbonization pathway to the building sector.

Note: see also the equity related wording above related to the m-parameter-cap.

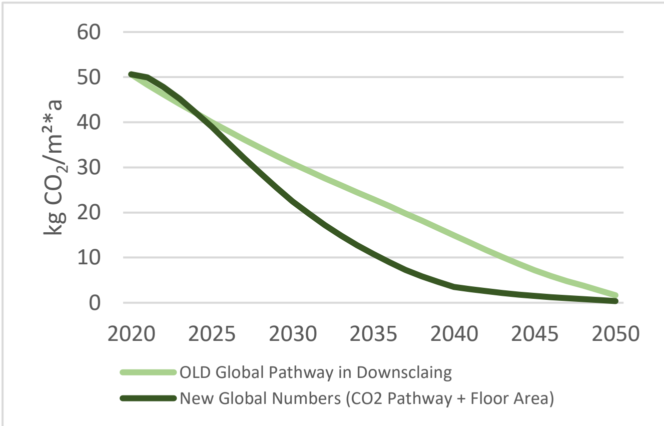
[40] B. Knopf and O. Geden: Ist Deutschland auf dem 1,5-Grad-Pfad?, 2022

## (8) Country-specific parameters & Implications – examples explained in Steps

(8.1) Downscaling to national pathways on the basis of a random example

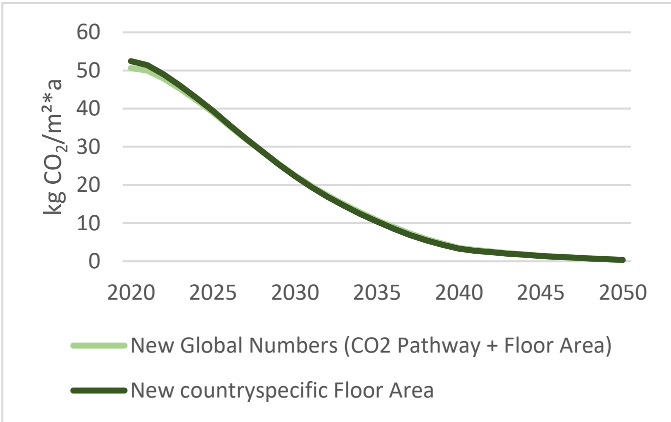
1. **Step: New Global Pathway as only revised input**

- Starting value does not change yet *(remember, starting intensities in countries are derived via kWh and EF and energy mix)*



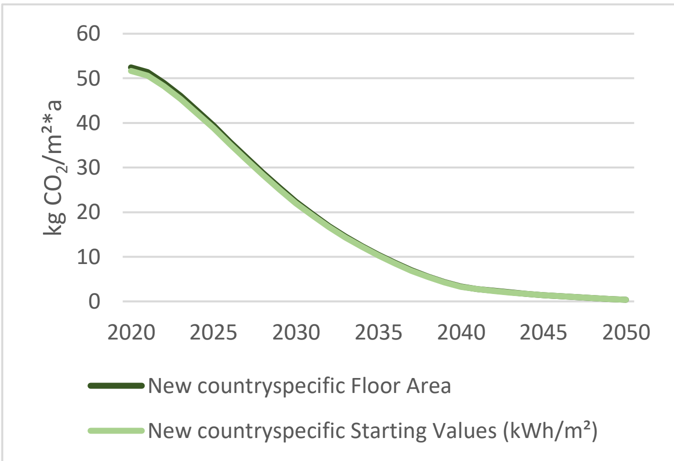

2. **Step: New country-specific Floor Area incorporated in SDA formula**

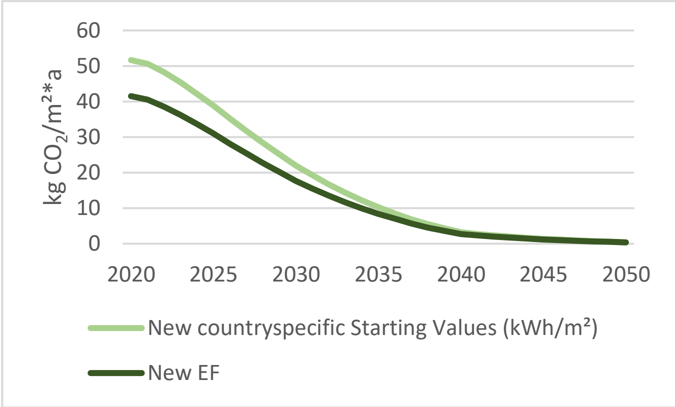
- Deviation (old vs. new floor space) is marginal, therefore the curve changes just slightly
- Starting point differs slightly, due to a *higher* change in CRE m² than anticipated *(remember the 2020 current CRREM figures are based on projections starting in 2018)*



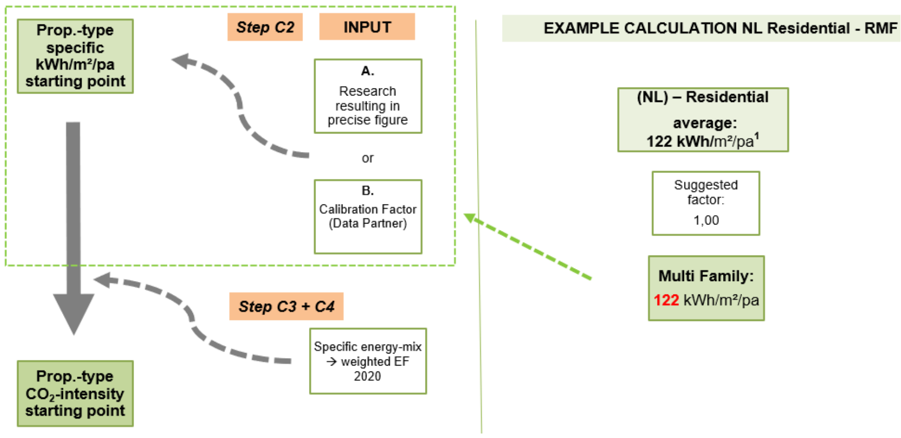
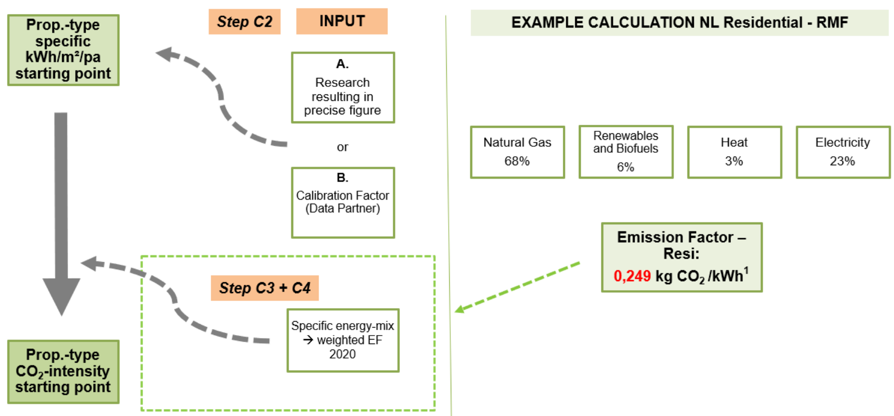

3. **Step: New country-specific starting figures for average kWh for commercial and residential real estate incorporated**

- change leads in isolation to lowering the curve, especially in the starting years due to (marginal) progress in energy efficiency *(remember this is country average and just two years of energetic retrofits and new building do not completely change the picture)*



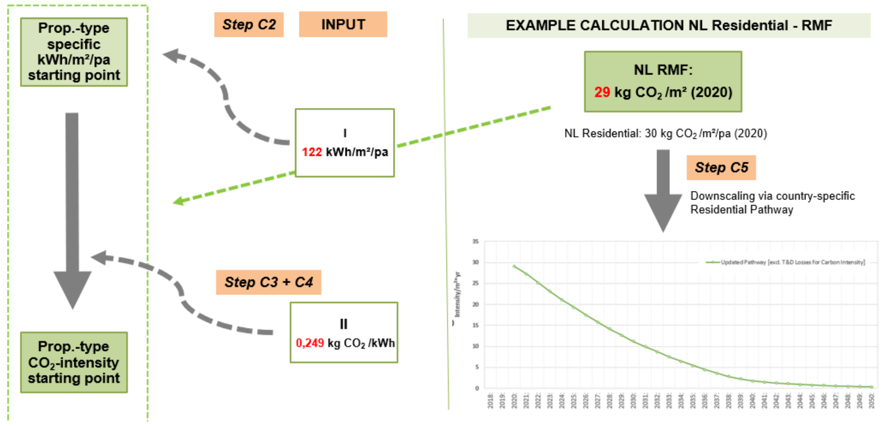
| | |
|---|---|
| **4. Step: The new weighted emission factor (EF) today and projection incorporated**<br><br>➢ Impact lowers the curve and results, already in the starting year with reduced intensity (due to achievements in grid decarbonization in Germany)<br>➢ In 2040, the differences are much lower. |  |

(8.2) Carbon intensities for sub-use-types, here e.g., Netherlands

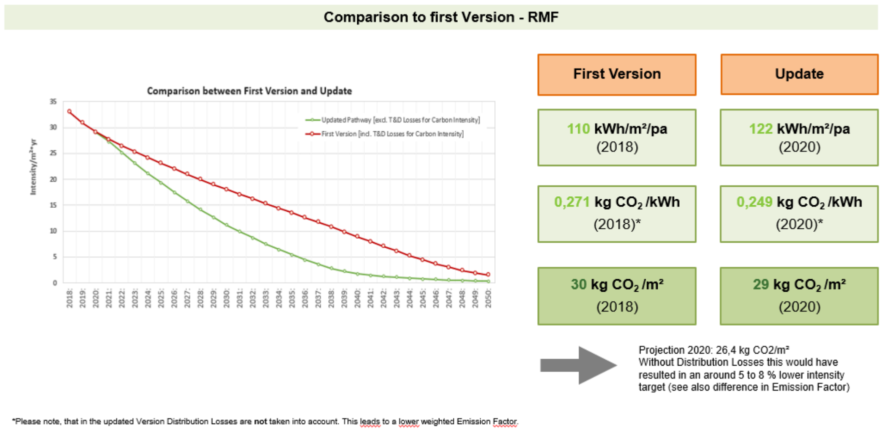
| | |
|---|---|
| **1. Step: Derive new property-type and country-specific starting values (kWh/m²)**<br><br>➢ Data partner /own research provides the country-specific starting values. |  |
| **2. Step: Weighted EF**<br><br>➢ Define the country- and property-type-specific energy-mix and EFs as well as development until 2050. |  |

**3. Step 3: GHG-intensity pathway**

Define a weighted EF pathway to derive the country- and property-type- specific carbon-intensity pathways.




**Comparing the first version to the updated CRREM values**



## (9) Where we want to get better in the future (one step in time)

The CRREM team is constantly working on improving the pathways and adding granularity. In the upcoming year, the CRREM initiative will place a focus on increasing granularity further for the USA. This will include establishing a working group with market and research leaders in the USA.

Potential next upcoming updates include:

- Further sub-regional pathways for Canada
- Further sub-regional pathways for China
- Further property types: e.g., elderly homes, etc.
- Further data transparency and alignment with further data partners e.g., working together with further national GBCs, etc.
- Providing a pathway for non-CRREM covered countries

BECOME A CRREM DATA PARTNER:

Our data partners provide and link us to national sources on country-specific data such as emission factors, energy-mix, energy-use intensities, floor area projections etc.

Please contact crrem@iioe.at if you would like to become a CRREM data partner.

## (10) DATA PARTNERS

| # | Country | Data Partner | Data Quality | Source |
|---|---|---|---|---|
| 1 | Austria | - | Medium requirement: internal research | See section 10, respective country |
| 2 | Belgium | - | | See section 10, respective country |
| 3 | Bulgaria | - | | See section 10, respective country |
| 4 | Republic of Cyprus | - | | See section 10, respective country |
| 5 | Czech Republic | - | | See section 10, respective country |
| 6 | Denmark | - | | See section 10, respective country |
| 7 | Estonia | - | | See section 10, respective country |
| 8 | Finland | - | | See section 10, respective country |
| 9 | France | - | | See section 10, respective country |
| 10 | Germany | - | | See section 10, respective country |
| 11 | Greece | - | | See section 10, respective country |
| 12 | Hungary | - | | See section 10, respective country |
| 13 | Ireland | - | | See section 10, respective country |
| 14 | Italy | - | | See section 10, respective country |
| 15 | Latvia | - | | See section 10, respective country |
| 16 | Lithuania | - | | See section 10, respective country |
| 17 | Luxembourg | - | | See section 10, respective country |
| 18 | Malta | - | | See section 10, respective country |
| 19 | Netherland | Dutch GBC | High | See section 10, respective country |
| 20 | Poland | - | | See section 10, respective country |
| 21 | Portugal | - | | See section 10, respective country |
| 22 | Romania | - | | See section 10, respective country |
| 23 | Slovakia | - | | See section 10, respective country |
| 24 | Slovenia | - | | See section 10, respective country |
| 25 | Spain | University Alicante | High | See section 10, respective country |
| 26 | Sweden | Swedish Prop. Fed. | High | See section 10, respective country |
| 27 | United Kingdom | UK GBC | High | See section 10, respective country |
| 28 | Croatia | - | | See section 10, respective country |
| 29 | Switzerland | SwissLife | High | See section 10, respective country |
| 30 | Norway | - | | See section 10, respective country |
| 31 | Australia | Australian GBC | High | See section 10, respective country |
| 32 | Brazil | - | | See section 10, respective country |
| 33 | Canada | Ivanhoé Cambridge Inc. | High | See section 10, respective country |
| 34 | China | - | | See section 10, respective country |
| 35 | Hong Kong | OCBC | High | See section 10, respective country |
| 36 | India | - | | See section 10, respective country |
| 37 | Japan | CSR Design | High | See section 10, respective country |
| 38 | Malaysia | - | | See section 10, respective country |
| 39 | Mexico | - | | See section 10, respective country |
| 40 | New Zealand | - | | See section 10, respective country |
| 41 | Philippines | - | | See section 10, respective country |
| 42 | Singapore | OCBC | High | See section 10, respective country |
| 43 | South Korea | - | | See section 10, respective country |
| 44 | USA | ULI, Measurabl, Lawrence Berkeley National Laboratory, etc. | High | See section 10, respective country |

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*The CRREM Global Industry Committee:*

*Aberdeen Standard, Land Securities, AEW Europe, IVANHOECAMBRIDGE, alstria, Metro AG, Nelson Group, BNP Paribas Real Estate Consult, NN Group, CSR Design, DWS Real Estate, PATRIZIA, ECE Projektmanagement, RE-sponsibility, ista International, Savills Investment Management, Allianz, Union Investment, Zurich Insurance Group, JLL, GOYOH Inc., Haven Green Capital Partners, BBP Better Buildings Partnership, INREV, BRE Group, UNEP FI, CDP, ULI Greenprint Center for Building Performance, DGNB German Sustainable Building Council, EPRA European Public Real Estate Association, DGBC Dutch Green Building Council, Finance Ideas, EEFIG De-risking Energy Efficiency Platform, CREFC Europe, GBC Australia, World Green Building Council, Guidehouse / PCAF, ZIA German Property Federation, The SBTi, Inrev, MSCI, GRESB, NAREIT, E-CORE, UKGBC, OECM Building Pathways, Madaster, Climate Finance Advisors.*

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*…and many more!!*

# (11) Data Sources

## GLOBAL (1.5 degree)

| Input Parameter | Source 2018 / First Version | Source 2020 / Update | Impact on the pathway (Global-level) |
|---|---|---|---|
| **Overall remaining global GHG Budget from 2020 - 2050** | Friends of the Earth FotE ('1.5FtoE')<br><br>IPCC (2018): IPCC 2018 SR 1.5 | IPCC (2021): Climate Change 2021, The Physical Science Basis.<br><br>IEA (2021): A global pathway to net-zero $CO_2$ emissions in 2050. Paris.<br><br>SBTi (2021) PATHWAYS TO NET ZERO SBTi Technical Summary<br><br>IPCC (2018): IPCC 2018 SR 1.5 | Comparing the 2018 (basis for first pathways) vs. the 2020 data (basis for updated CRREM pathways) the overall remaining anthropogenic GHG budget until 2050 changed just slightly for the period 2020 until 2050 (minus 10% overall absolute budget vs. first CRREM version). The emission reduction projected according to older data for 2020 could not be achieved. This is due to the fact that in 2018 and 2019 more GHG was emitted than projected for a 1.5 degree aligned path (overshoot).<br><br>This means, that the overall ambition level has slightly increased (also resulting in slightly lower carbon intensities per sqm). Therefore, the need for decarbonization in the near future has further intensified compared to the first CRREM version.<br><br>This has implications for further decarbonization within the next few years. The global path is initially above the forecast - as the starting point in 2020 is at the corresponding current 'as-is' level. After a few years, however, the path runs below the forecast in order to compensate for the excess emissions compared to the previous global path. New data sources show most reductions in the years 2030 until 2040 (incl. complete grid decarbonization until 2040) whereas older data projected most absolute reductions at the very beginning and lower ones at the end.<br><br>(Note: IPCC 500 Gt $CO_2$ vs. IEA 468 Gt $CO_2$ due to the energy related emissions of Non-$CO_2$ GHG) |
| **Building Stock & Growth rates** | Estimated for IEA 2DS scenario, based on information in UN Environment (2017): Towards a zero-emission, efficient, and resilient buildings and construction sector.<br><br>Global Status Report 2017. | Growth rate until 2050: IEA Net Zero by 2050 p. 141.<br><br>Total building stock in 2020, 2025, 2030: IEA (2021), Tracking Buildings 2021, IEA, Paris United Nations Environment Programme (2021). 2021 Global Status Report for Buildings and Construction: Towards a zero-emission, Efficient and Resilient Buildings and Construction Sector. Nairobi. | The starting value is at a similar level as in 2018. The forecast for 2020 in the original version is accordingly set slightly higher than the starting value in the update. Overall, the absolute growth of the global building stock (2020 until 2050) is insignificantly higher compared to the first version (+1.6%).<br><br>Since in the first two decades the projection is lower than before we see a mixed effect: This results ceteris paribus (leaving all other inputs unchanged) in slightly higher carbon intensities per sqm in the first 2 decades, and slightly lower intensities at the end of the observation period. |

| | | | |
|---|---|---|---|
| **Real Estate share and pathway distribution of overall remaining $CO_2$-Budget** | Friends of the Earth FotE ('1.5FtoE') via Global Calculator | IEA (2021): A global pathway to net-zero $CO_2$ emissions in 2050. Paris.<br><br>Direct Combustion Emissions: Figure 02_03<br><br>Electricity Demand Building Sector: 03_09<br><br>Global Grid Emission Factor: AnnexA World_Indic | 108 Gt $CO_2$ new absolute budget for the Real Estate Sector vs. 111 Gt $CO_2$ applied in the first version (both starting 2020). The deviation of approx. 3% in the total building budget can again be explained by the overshoot in the past years (Based on like-for-like comparison including T&D losses). The relative share of buildings in-use-phase of all anthropogenic emissions until 2050 remains at 22.95% (vs. 21.42% before) and is largely unchanged.<br><br>The starting point (including T&D-losses) is (since no major progress was made) largely unchanged compared to 2018 and even increased slightly (41,86 kg/$CO_2$/m² in 2020 within updated version vs. 40,16 kg/$CO_2$*m² 2018 in first version). The higher intensities and absolute emissions in the first years from 2020 onwards (and the overshoot in 2018 and 2019) are resulting in the need for higher ambition and steeper decarbonization in later years.<br><br>The real estate $CO_2$-only-budget is calculated based on emissions from direct combustion, the share of the building sector in the electricity sector (taking into account the increasing demand for electricity in the sector, 'electrification' of buildings) and the emissions from district heating.<br><br>The reduced overall emissions result in an increased reduction requirement for the GHG intensity of the buildings. Due to the strong decarbonization of the grid by 2040 and the resulting real estate share from the grid, the ambition for real estate increase until 2040.<br><br>While the old Global $CO_2$ pathway data (all sectors) shows an initially high absolute reduction that slows down over time, the new $CO_2$ pathway shows a constant and slightly declining trend within the next few years and a strong decline again around 2030 until 2040 (due to the grid decarbonization). This is also reflected in the real estate related emissions pathway.<br><br>For this update the EF including T&D-losses were just used for a like-for-like comparison (see above) on global level.<br><br>Excluding T&D-losses reduces the applied EF for a given energy consumption of the sector, resulting in lower $CO_2$emissions and therefore lower intensities per sqm. The effect of excluding distribution losses results in approx. 17% lower $CO_2$-only intensities in the first year and overall (2020-2050) 18% less emissions budget. The global carbon intensity per sqm amounts to 41.86 kg/ $CO_2$*m² (incl. T&D-losses) vs. 34.92 kg/ $CO_2$*m² (excl. T&D-losses). |

| | | | |
|---|---|---|---|
| **Energy intensity target figures (EUI in kWh/m² in 2050)** | / | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Pathways will end at the specific energy target on commercial and residential level. Since most energy sources will be fully decarbonized in 2050 the allocation of available renewable energy will define the limitation of energy use per sqm. |
| **F-Gas/ 'e' (all sectors)** | IPCC (2018): IPCC 2018 SR 1.5 | The effective emissions of Other GHG in 2018 and 2019 have been taken from J.G.J. Olivier and J.A.H.W. Peters; Trends in global $CO_2$and total greenhouse gas emissions: 2020 Report | The total budget projected by the IPCC has been reduced accordingly by consumption in 2018 and 2019.<br>320 Gt $CO_{2e}$ from 2018 until 2050 minus 29 Gt $CO_{2e}$ in 2018 & 2019 combined resulting in 291 Gt $CO_{2e}$ remaining from 2020 onwards. |
| **F-Gas/ 'e' (real estate share)** | Due to data limitation the approach was a factor surcharge (add-on) based on the real emission ratio of global $CO_2$ to other GHG. | United States Environmental Protection Agency: NON-$CO_2$ Greenhouse Gas Data Tool<br>Distribution via Kigali Amendment to the Montreal Protocol | New available data enabled a significant increase of precision and a reduction of the overall allowance. Therefore, lower intensities. The global $CO_{2e}$ intensities for other GHG (especially F-Gases) for the real estate sector is 2,45 kg/ $CO_{2e}$/m² in 2020. The overall share of other GHG to Co2-only until 2050 amounts to 9,84%. |
| **Overall assessment:** | • Global budget slightly lower: The global budget of all sectors slightly decreased compared to the old forecast due to the overshoot experienced in the past years. The overall budget until 2050 from 2020 onwards is therefore slightly less (difference of -9.84% deviation new vs old budget (from 2020 onwards)).<br>• Overshoot and grid decarbonization: From 2040 onwards, projections assume a fully decarbonized electric grid and therefore a sharper reduction of Scope 2 emissions between 2030 and 2040. This results in a steeper curve for the Real Estate sector until 2040. The curve flattens from 2040 onwards as only Direct Combustion and District Heating are resulting in emissions from 2040 onwards. The distribution of the overall carbon budget is therefore different from before: starting now at higher absolute figures (due to overshoot) and reducing sharper (especially between 2030 and 2040). Globally, as well as in relation to the real estate sector, this results in a steeper curve until 2040. The ambition for the energy sector globally is therefore high and the real estate industry must play its part and in particular promote the reduction of the electricity required.<br>• Building stock projections largely constant: Forecast of global building stock with only marginal changes with an overall delta of 1.6% in the last projected year compared to the 2018 projection.<br>• Excluding distribution losses: Major change is driven by the methodological switch from including T&D-losses in the EF for electricity before and now excluding these.<br>• Real estate-related relative share largely constant in the aggregate: The relative share of real estate ($CO_2$) only was 21.42% for the old pathways and 22.95% for the new pathways (like-for-like). Pure $CO_2$-intensity started at 40.16 kg/m²*a in 2018 and was expected to fall to 34.61 kg/m²*a by 2020 - which did not happen. Instead, the world remained at a level of 41.71 kg/m²*a - which was actually a slight increase. Overshoot in the previous years leads to higher ambition and sharper intensity reduction in the future.<br>• Add-on factor for other GHG reduced: More granular data shows a (lower) relevance but still the other GHG amount an overall share of other GHG to $CO_2$-only until 2050 of 9.84% (and 2.45 kg/$CO_{2e}$/m² in 2020). | | |

## EU (1.5 degree)

| Input Parameter | Source 2018 / First Version | Source 2020 / Update |
|---|---|---|
| **Building Stock [m²]** | GABC (2016): Global Status Report 2016. Online: https://www.worldgbc.org/news-media/global-status-report-2016.<br><br>European Commission (2016): EU Buildings Stock Observatory. | EC (2022): Long term renovation strategies (country specific sources). Online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en |
| **Building Stock Development Residential / Commercial** | GABC (2017): Global Status Report 2017. Online: https://www.worldgbc.org/news-media/global-status-report-2017. | EC (2022): Long term renovation strategies (country specific sources). Online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en<br><br>EC (2017): EU Building Stock Database. Online: https://ec.europa.eu/energy/eu-buildings-database_en. |
| **Energy intensities – starting values RESI and CRE [kWh/m²*a]** | INSPIRE project: Deliverable 2.1a – Survey on the energy needs and architectural features. | Eurostat Energy balances: https://ec.europa.eu/eurostat/web/energy/data/energy-balances |
| **Energy intensities – starting values Sub-uses [kWh/m²*a]** | EC (2016): Energy Efficient Buildings. Online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_e<br><br>EU Building Stock Observatory (2016): Eurostat. | Preferably detailed research in countries or via data partners on starting figures for Sub-uses or aggregated stats from partners for relationship of Sub-use to Residential or CRE (please see country specific sources). |
| **Emission Factors & Development**<br><br>**[KgCO₂/kWh]** | 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.<br><br>Moro A., Lonza L., (2018): Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. (Used for electricity emission factors). | EC (2021): Summary report: Energy, transport and GHG emissions in the FF55 scenario. Online: https://energy.ec.europa.eu/excel-files-mix-cp-scenario_en<br><br>EC (2020): Energy Modelling. EU Reference Scenario 2020. Online: https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en<br><br>Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com<br><br>Grid emission factor: AIB (2020)<br><br>EFs incl. development for 2020-2030 were derived from the FF55. The projected development from 2031-2050 is based on the YoY changes from the Reference Scenario. For baseline EF the FF55 was checked via energy balances. In cases of smaller deviations, the higher number was applied due to a conservative methodology. |
| **Energy mix & energy mix development** | ECF European Climate Foundation, ClimateWorks Foundation: CTI 2050 Roadmap Tool. https://stakeholder.netzero2050.eu/ | EC (2020): Energy Modelling. EU Reference Scenario 2020. Online: https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en |
| **F-Gas Phase down** | No specific phase down source has been used. | UN (2020): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category |

| | |
|---|---|
| **Other Sources** | ***Please note:*** also, country specific sources have been used to derive to individual starting values certain countries.<br>**Other sources:**<br>- Energiforsk (2016): European Price Series.<br>- Calibration factors have been used from GRESB 2018 data. New GRESB 2020 used for the update.<br>- Portugal: FA via m²/capita: Estimating the sufficiency potential in buildings: the space between under dimensioned and oversized Anja Bierwirth.<br>- Netherlands: Energy Intensity, Online: https://repository.tno.nl/islandora/object/uuid%3A9e207b70-cabb-4ac4-ba1f-2dc5e864c1f1.<br>- Netherlands: Energy Intensity residential, Online: https://opendata.cbs.nl/#/CBS/nl/dataset/81528NED/table?ts=1656510329799.<br>- Netherlands: Floor area: https://www.pbl.nl/publicaties/klimaat-en-energieverkenning-2021.<br>- Belgium: Residential: https://statbel.fgov.be/en/themes/housing/building-stock#panel-11. |
| **Overall assessment per most relevant countries:** | • ***The course of the carbon intensities of the pathway follows the new global curve, i.e. one can see a clear 'dip' in both the residential and the commercial sector by 2040 (decarbonization of the electr. grid).***<br>• ***- It is also evident that the impact of global sales through the new convergence on the new target value in 2050, which is significantly below the old targets.***<br>• ***CRE: Whereas in a lot of countries there was no major progress in terms of the overall EUIs (e.g. Austria, France etc.), some countries had a positive reduction in energy intensity (e.g. Germany, Italy, Sweden, etc.).***<br>• ***On average starting figures for EUIs were seeing minor changes of around 10%. It is clear that the savings for a 1.5-degree compliant scenario were not realized by the board. The industry thus continues to lag behind the necessary savings lines. While the naïve European average of the EUI in 2018 is quoted at 247 kWh (including UK, Norway & Switzerland) as the starting value of the old data, this is now 232 kWh/m² and thus 5% less. However, the 1.5-degree compliant value for 2020 of 222 kWh/m²/pa is exceeded by 6% based on the new starting value.***<br>• ***Residential: The picture here is basically similar to that for the CRE stock. However, the deviations between old and new source data were even smaller. While the naïve European average of the EUI in 2018 is listed as the starting value of the old data at 166 kWh, this is now 160 and thus 3% less. However, the 1.5-degree compliant value for 2020 of 149 kWh/m²/pa is exceeded by 8% based on the new starting value.***<br>• ***A significant influence was also exerted by the change electr. EF. On the one hand, these fell due to the switch to EF excl. T&D losses, but the decarbonization of electricity also made welcome progress in many countries through the increased use of renewable energy.***<br>• ***Building space: Europe is largely 'built'. Against this background, no further substantial (net) increases in space are expected.***<br>• ***Countries with higher projected land growth than the average global thus have a higher relative requirement for decarbonization per unit of land (respectively, this leads to decreasing intensities).***<br>• ***Countries with decreasing growth rate respectively, have increasing intensities.*** |

| United Kingdom (United Kingdom (UK)) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | GABC (2016): Global Status Report 2016. Online: https://www.worldgbc.org/news-media/global-status-report-2016. | Building Energy Efficiency Survey - BEES (2014/15). Online: https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees<br>English Housing Survey, MHCLG (2017).<br>For 2020 onwards modeled data from UKGBC and Arup. | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial [m²]** | GABC (2017): Global Status Report 2017. Online: https://www.worldgbc.org/news-media/global-status-report-2017. | UKGBC Task Group Input, Population projections, ONS (2018).<br>For 2020 onwards modeled data from UKGBC and Arup. | If the increase is steeper to the previous growth rates, then via the SDA approach there is a decrease in intensities |
| **Energy intensities – starting values [kWh/m²*a]** | UK Department for Business, Energy & Industrial Strategy (2016): Building Energy Efficiency Survey (BEES). https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees<br>Better Buildings Partnership (2019), 2019 Real Estate Environmental Benchmarks. Retrieved from: https://www.betterbuildingspartnership.co.uk/sites/default/files/media/attachment/BBP_REEB%20Benchmarks%202019_0.pdf | CRE - Building Energy Efficiency Survey - BEES (2014/15). Online: https://www.gov.uk/government/publications/building-energy-efficiency-survey-bees<br>Office - 2020 Real Estate Environmental Benchmark (REEB), BBP, https://www.betterbuildingspartnership.co.uk/sites/default/files/media/attachment/2020%20Real%20Estate%20Environmental%20Benchmarks.pdf<br>Resi - Energy Consumption UK, BEIS (2018)<br>(Note: Non-domestic National Energy Efficiency Data Framework (ND-NEED), 2022 – the dataset was after alignment with UKGBC not applied here - https://www.gov.uk/government/statistics/non-domestic-national-energy-efficiency-data-framework-nd-need-2022) Please Note: ND NEED EUI intensity was used for Office. | Starting values were aligned with UKGBC.<br>The commercial sector: improved the energy-intensity in the last years. This results that the baseline intensity is at a slightly lower point compared to the previous pathway.<br>For residential, however, a higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Emission Factors & Development**<br>**[KgCO₂/kWh*a]** | 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.<br>Moro A., Lonza L., (2018): Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. (Used for electricity emission factors). | HM Treasury Green Book, UK GHG Inventory, BEIS (2018). CCC Hydrogen in a Low Carbon Economy.<br>GOV UK (2020): Government conversion factors for company reporting of greenhouse gas emissions. Online: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal | A much faster grid decarbonization results in a lower weighted emission factor in the baseline year as well until 2050.<br>Further, a lower grid emission factor excluding distribution and transmission losses is used. |

| | | | |
|---|---|---|---|
| **Energy mix & energy mix development** | ECF European Climate Foundation, ClimateWorks Foundation: CTI 2050 Roadmap Tool. https://stakeholder.netzero2050.eu/ | GOV UK (2020): Valuation of energy use and greenhouse gas emissions for appraisal. Online: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal | The energy-mix: a higher share of electricity until 2050 is assumed. So progressing electrification of the sector. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UNFCCC GHG Data Interface (2022): Annual greenhouse gas (GHG) emissions | | F-Gases have been attributed to the pathways respective to the phase down. |

| Switzerland (CH) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | GABC (2016): Global Status Report 2016. Online: https://www.worldgbc.org/news-media/global-status-report-2016.<br><br>European Commission: EU Buildings Stock Observatory. | Wüest Partner AG (2021): Bundesamt für Energie BFE, Energiebezugsflächen. Flächen in EBF.<br><br>Calculations scheme for EBF: https://www.energiepaket-bl.ch/assets/content/files/Definition_Energiebezugsflaeche.pdf | More precise reference to EBF conversion to GIA is leading to slight increase in starting figures for EUIs.<br><br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial [m²]** | GABC (2017): Global Status Report 2017. Online: https://www.worldgbc.org/news-media/global-status-report-2017. | Wüest Partner AG (2021): Bundesamt für Energie BFE, Energiebezugsflächen. Flächen in EBF.<br><br>Please note: Conversion to GIA (*0,9). Source: Erweiterung des Gebäudeparkmodells gemäss SIA-Effizienzpfad Energie | If the increase of floor space is steeper compared to the previous growth rate, therefore via the SDA approach this results in decreasing intensities/ higher ambition. |
| **Energy intensities – starting values [kWh/m²*a]** | EC (2016): Energy Efficient Buildings. Online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_e<br><br>EU Building Stock Observatory (2016): Eurostat. | Bundesamt für Energie BFE (2016): Erweiterung des Gebäudeparkmodells gemäss SIA-Effizienzpfad Energie. Schlussbericht (s.173 & s.181). | Starting values were aligned with our data partner (SwissLife).<br><br>The commercial sector: improved the energy-intensity in the last years. This results that the baseline intensity is at a slightly lower point compared to the previous pathway.<br><br>For residential: improved the energy-intensity in the last years. This results that the baseline intensity is at a slightly lower point compared to the previous pathway. |
| **Emission Factors & Development**<br><br>**[$KgCO_2$/kWh*a]** | BAFU Bundesamt für Umwelt (2018): Data on CO2 emissions of households. http://www.bafu.admin.ch | Intep (2022): Treibhausgas-Emissionsfaktoren für den Gebäudesektor. Bestimmung von Emissionsfaktoren nach den Bilanzierungsregeln der KBOB und des GHG Protocols.<br><br>Intep (2022): Das Forschungs- und Beratungsunternehmen für Umwelt, Wirtschaft und Gesellschaft, THG-Emissionsfaktoren_Energieträger.<br><br>Schweizerische Gesamtenergiestatistik (2021): Gesamtenergiestatistik. https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/gesamtenergiestatistik.html/. | A much faster grid decarbonization results in a lower weighted emission factor in the baseline year as well until 2050. |
| **Energy mix & energy mix development** | ECF European Climate Foundation, ClimateWorks Foundation: CTI 2050 Roadmap Tool. https://stakeholder.netzero2050.eu/ | Intep (2022): Das Forschungs- und Beratungsunternehmen für Umwelt, Wirtschaft und Gesellschaft, THG-Emissionsfaktoren_Energieträger. | The energy-mix: a higher share of electricity until 2050 is assumed. |

| | | | |
|---|---|---|---|
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ ‘e’** | UN (2020): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the phase down. |

| NORWAY | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | GABC (2016): Global Status Report 2016.Online: https://www.worldgbc.org/news-media/global-status-report-2016. | EC (2020): LTR. Online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | GABC (2017): Global Status Report 2017. Online: https://www.worldgbc.org/news-media/global-status-report-2017. | EC (2020): LTR. Online: https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | INSPIRE project: Deliverable 2.1a – Survey on the energy needs and architectural features. | Enova (2018): Enovas byggstatistikk 2017. Rapporten presenterer analyser og statistikk om energibruk fordelt etter bygningstyper, samt variasjoner avhengig av alder, størrelse og oppvarmingssytem.<br><br>Statistics Norway (2019): Emissions to air. https://www.ssb.no/en/klimagassn | Starting values were aligned with our data partner.<br>Generally, for the commercial sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve.<br><br>For the residential sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Emission Factors & Development**<br>**[KgCO₂/kWh]** | 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.<br>Moro A., Lonza L., (2018): Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. (Used for electricity emission factors). | Grid emission factor: AIB (2020)<br>Nordic Energy Research (2020): Tracking Nordic Clean Energy Progress 2020. Online: https://www.nordicenergy.org/wp-content/uploads/2020/04/Tracking-Nordic-Clean-Energy-Progress-2020.pdf. | The GHG-intensity is now higher due to two factors: a higher weighted emission factors and higher energy-intensities in the baseline year. |
| **Energy mix & energy mix development** | ECF European Climate Foundation, ClimateWorks Foundation: CTI 2050 Roadmap Tool. https://stakeholder.netzero2050.eu/ | Enova statistics (2020): Energy-mix for commercial & residential buildings. Online: https://presse.enova.no/news/ny-byggstatistikk-og-nye-graddagstall-er-ute-358849 | Generally, for the commercial sector a high electrification can be noticed. This results in a very low weighted emission factor as the grid is already highly decarbonized. The residential sector has a slightly higher weighted EF due to a lower proportion of grid in the mix. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ ‘e’** | UNFCCC GHG Data Interface (2022): Annual greenhouse gas (GHG) emissions. | | F-Gases have been attributed to the pathways respective to the phase down. |

## NON-European SOURCES

| JAPAN | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | Statistics Bureau of Japan (2016): Japan Statistical Yearbook 2016. | Ministry of Land, Infrastructure, Transport and Tourism: https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00600940&bunya_l=08&tstat=000001115375&cycle=7&year=20180&month=0&result_back=1&tclass1val=0 | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Commercial [m²]** | World Green Building Council (2016): Global Status Report 2016. Online: https://www.worldgbc.org/news-media/global-status-report-2016. | Ministry of Land, Infrastructure, Transport and Tourism: https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00600940&bunya_l=08&tstat=000001115375&cycle=7&year=20180&month=0&result_back=1&tclass1val=0 | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy consumption** | GIO Greenhouse gas Inventory Office of Japan (2019): National GHG Inventory Report of JAPAN.<br>Emission Factor Development (Scenario 2 'Made-In-Japan' used)<br>IGES Institue for Global Environmental Strategies (n.y.): Japan 2050 Low Carbon Navigator. http://www.en-2050-low-carbon-navi.jp.<br>TEPCO (2017): TEPCO CO2 Emissions Factor FY 2016. Online: https://www.tepco.co.jp/en/press/corp-com/release/2017/1447967_10469.html. | GIO Greenhouse gas Inventory Office of Japan (2019): National GHG Inventory Report of JAPAN.<br>Emission Factor Development (Scenario 2 'Made-In-Japan' used)<br>IGES Institue for Global Environmental Strategies (n.y.): Japan 2050 Low Carbon Navigator. http://www.en-2050-low-carbon-navi.jp.<br>TEPCO (2017): TEPCO CO2 Emissions Factor FY 2016. Online: https://www.tepco.co.jp/en/press/corp-com/release/2017/1447967_10469.html. | Commercial: The starting point increased slightly, showing that not enough measures have been undertaken in the past years.<br>Residential: A lower starting intensity in the baseline year results a lower starting point in the respective year. |
| **Energy intensity – starting values [kWh/m²*a]** | The current starting point intensities of Japan (2018): DECC Data Set.<br>Otsuka, A. (2018): Regional Determinants of Energy Efficiency: Residential Energy Demand in Japan. In: Energies, 11(6):1557.<br>Japan Sustainable Building Consortium (n.y.): DECC (Data-base for Energy Consumption of Commercial Buildings). Online: http://www.jsbc.or.jp/decc. | Residential: survey conducted by Tokyo Metropolitan Government, online: https://www.kankyo.metro.tokyo.lg.jp/climate/home/energy.files/syouhidoukouzittaityousa26honpen_3.pdf#page=52.<br>The current starting point intensities of Japan (2018): DECC Data Set.<br>Otsuka, A. (2018): Regional Determinants of Energy Efficiency: Residential Energy Demand in Japan. In: Energies, 11(6):1557.<br>Japan Sustainable Building Consortium (n.y.): DECC (Data-base for Energy Consumption of Commercial Buildings). Online: http://www.jsbc.or.jp/decc. | Commercial: A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.<br>Residential: New updated data, results in a higher starting point for Japan. Figures are from our data partner CSR Design. |

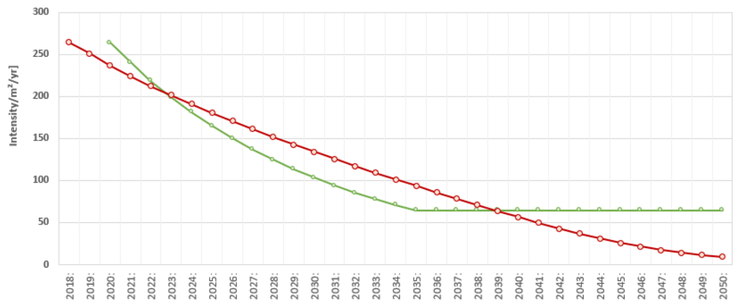
| | | | |
|---|---|---|---|
| **Emission Factors & Development [$KgCO_2$/kWh]** | *Emission Factor Development (Scenario 2 'Made-In-Japan' used)*<br>IGES Institue for Global Environmental Strategies (n.y.): Japan 2050 Low Carbon Navigator. http://www.en-2050-low-carbon-navi.jp. | EF 2030 & grid decarbonization: Agency for Natural Resources and Energy: The 6th Strategic Energy Plan. https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf<br>https://www.fepc.or.jp/environment/warming/keikaku/index.html<br>Ministry of the Environment: https://ghg-santeikohyo.env.go.jp/files/calc/r03_coefficient.pdf<br>Ministry of the Environment: https://ghg-santeikohyo.env.go.jp/files/calc/itiran_2020_rev.pdf<br>The Federation of Electric Power Companies of Japan: https://www.fepc.or.jp/environment/warming/keikaku/index.html<br>Japan 2050 Low Carbon Navigator: http://www.2050-low-carbon-navi.jp/pathways/11321212222222111111111111121121132211213212 31/three_e_s | / |
| **Energy mix & energy mix development** | GIO Greenhouse gas Inventory Office of Japan (2019): National GHG Inventory Report of JAPAN. | GIO Greenhouse gas Inventory Office of Japan (2019): National GHG Inventory Report of JAPAN. | / |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UNFCCC GHG Data Interface (2022): Annual greenhouse gas (GHG) emissions, in kt $CO_2$ equivalent | | F-Gases have been attributed to the pathways respective to the phase down. |
| **Other Sources** | Berraho, D. (2012): Options for the Japanese electricity mix by 2050.<br>CarbonBrief (2019): The Carbon Brief Profile: Japan.<br>Kikp Network (2014): Japan Climate Vision 2050: An energy future independent of nuclear power and fossil fuels.<br>Tokyo Metropolitan Government (2019): Dataset on carbon intensity of commercial properties. | | |

<table>
<tr><th>IMPACT / REASONING</th><th>PATHWAY COMPARISON</th></tr>
<tr><td>

**OFFICE kWh**

- ➔ Starting values have been aligned with data partners from Japan.
- ➔ The starting point increased slightly, showing that not enough measures have been undertaken in the past years.
- ➔ Higher starting intensities due to the result of use density increasing.
- ➔ New energy targets result the pathway levelling off around 2032.

</td><td>



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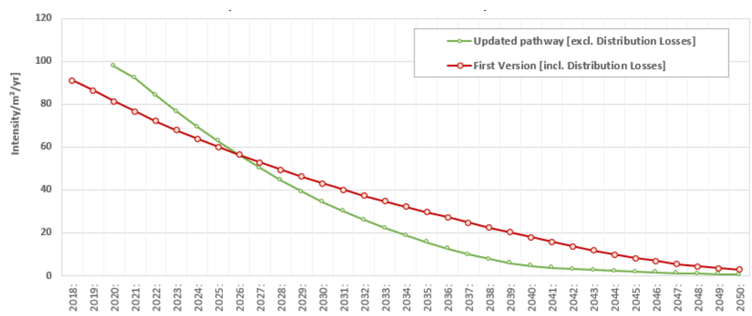
**OFFICE $CO_2$**

- ➔ No significant changes in the overall energy-mix and weighted emission factor.
- ➔ A higher energy-intensity starting point with an unchanged emission factor, results in a higher GHG-intensity starting point.
- ➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.

</td><td>

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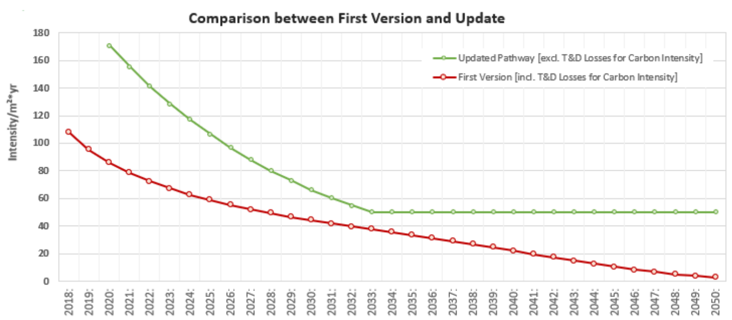
<tr><td>

**RESIDENTIAL kWh**

- ➔ Starting values have been aligned with data partners from Japan.
- ➔ A higher starting intensity in the baseline year results a higher starting point in the respective year.
- ➔ New energy targets result the pathway levelling off around 2032.

</td><td>

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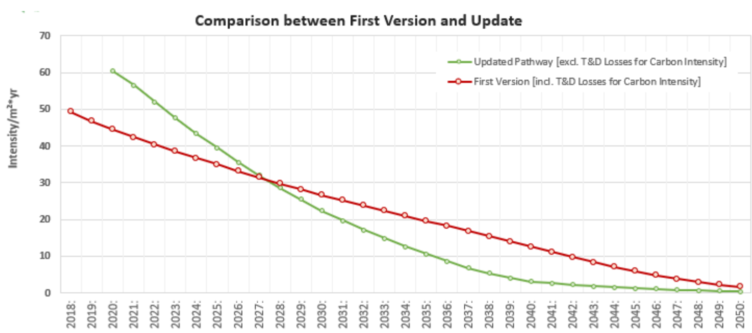
**RESIDENTIAL $CO_2$**

- ➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.

</td><td>

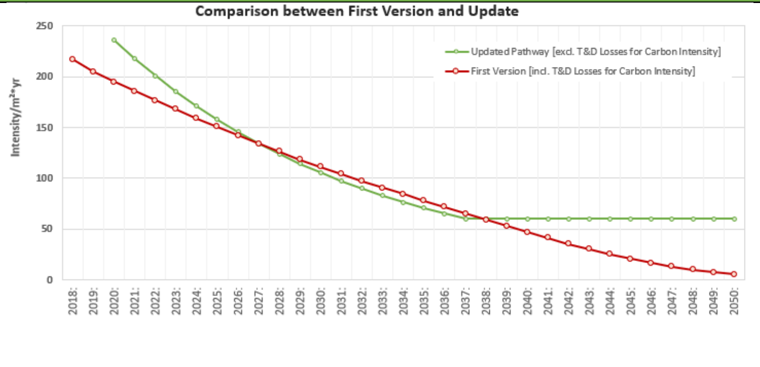
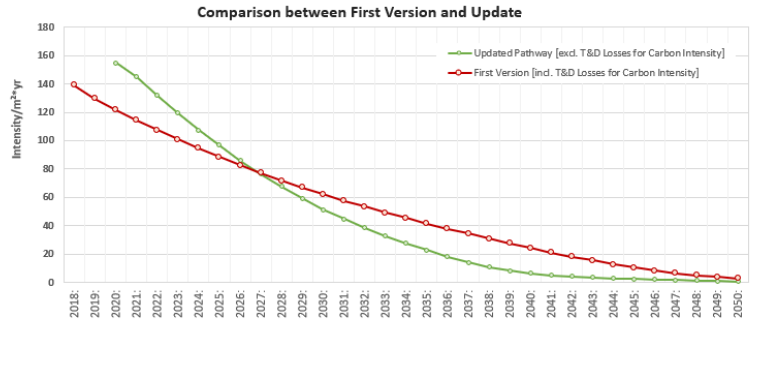
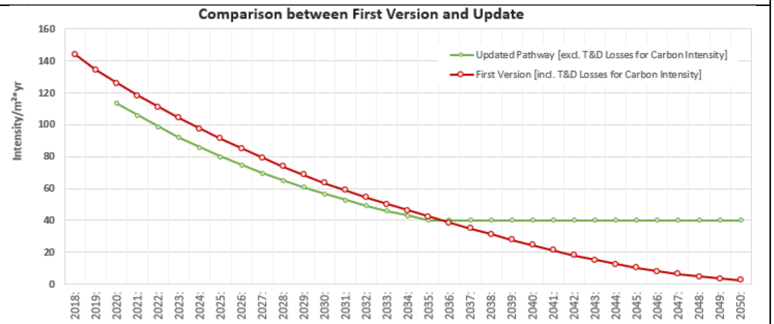
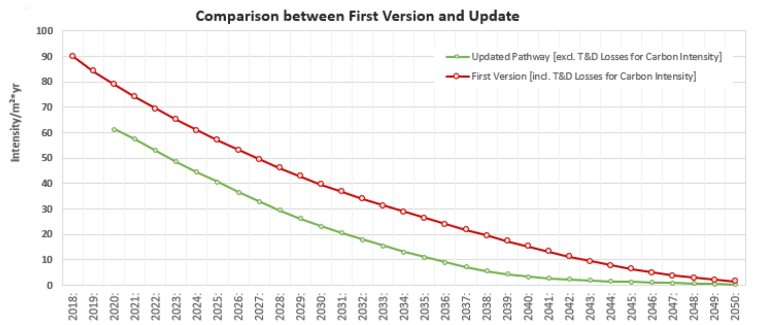



</td></tr>
</table>

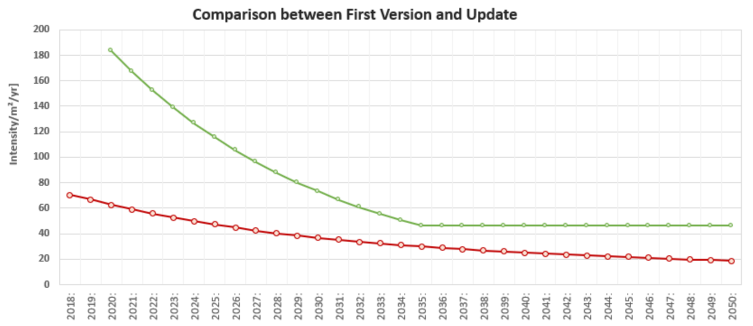
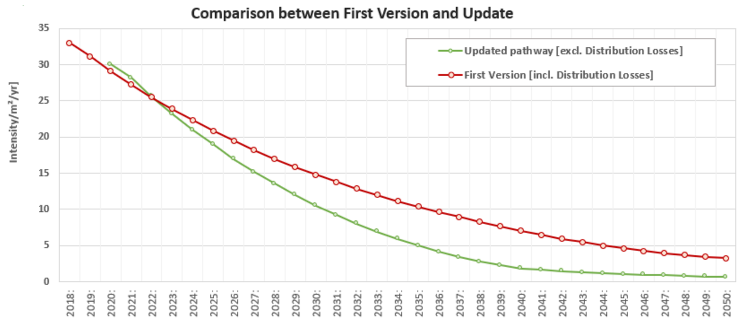
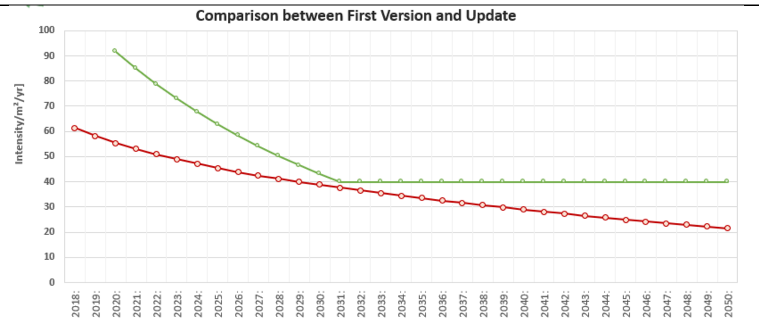
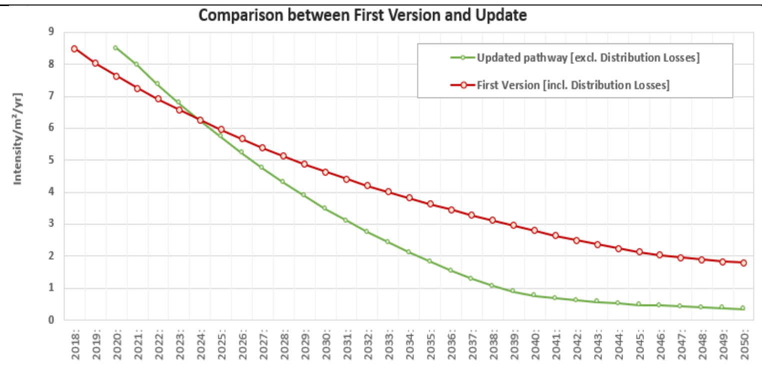
| AUSTRALIA (AUS) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | de Jong, P., van Oss, S. C. F., Wamelink, H. (2007): High Rise Ability. In: Earthquake Resistant Engineering Structures VI, p. 1-11.<br><br>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 | ABS (2020): New houses being built on smaller blocks. Online: https://www.abs.gov.au/articles/new-houses-being-built-smaller-blocks | No direct impact on the energy-intensity in the first year.<br><br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | The Global Status Report (2017): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC). | The Global Status Report (2019): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC).<br><br>IEA (2021): Tracking Buildings. Online: https://www.iea.org/reports/tracking-buildings-2021<br><br>NHFIC (2020): State of the Nation's Housing, https://www.nhfic.gov.au/research/thematics/state-of-the-nations-housing/. | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | Department of the Environment and Energy (2019): Australian Energy Statistics, September 2019.<br><br>Department of the Environment and Energy (2019): Australian Energy Update 2019.<br><br>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 | Climate Transparency (2020): CLIMATE TRANSPARENCY REPORT. Online: www.climate-transparency.org<br><br>GOV AU (2022): Baseline Energy Consumption and Greenhouse Gas Emissions - In Commercial Buildings in Australia. Online: https://www.energy.gov.au/publications/baseline-energy-consumption-and-greenhouse-gas-emissions-commercial-buildings-australia<br><br>ABS (2020): Residential: ttps://www.abs.gov.au/statistics/industry/energy/energy-account-australia/latest-release | For the commercial sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve.<br><br>The residential sector however, improved the energy-intensity in the last years. This leads to a baseline intensity which is slightly lower compared to the previous pathway. |
| **Emission Factors & Development**<br><br>**[$KgCO_2$/kWh]** | ClimateWorks (2016): Gas-Electricity substitution projections to 2050. https://www.energynetworks.com.au/resources/reports/gas-electricity-substitution-projects-to-2050/ | Australian Government Dept of Environment & Energy Emissions Factors, Table 5 and Table 46 for regional factors (August 2021 report) National Greenhouse Accounts Factors – August 2021, online: www.industry.gov.au, https://www.dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-factors.<br><br>AEMO (2020): 2022 Integrated System Plan (ISP), https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp. | Over the last years no significant improvement was recorded in regards to grid decarbonization. However, string grid decarbonization projected going forward from 2020 onwards.<br><br>The energy-mix also remained mostly the same for the commercial sector.<br><br>For the residential sector the weighted EF is lower, due to a higher share of natural gas (which has in Australia a lower EF compared to the current electric grid). |

| | | | |
|---|---|---|---|
| **Energy mix & energy mix development** | ClimateWorks (2016): Gas-Electricity substitution projections to 2050. https://www.energynetworks.com.au/resources/reports/gas-electricity-substitution-projects-to-2050/ | NABERS (2020): Energy efficiency in commercial buildings, May 2022.<br><br>Energy Networks Australia (2021): Reliable and clean gas for Australian homes.<br><br>GOV (2022): Energy consumption, online: www.soe.epa.nsw.gov.au/all-themes/human-settlement/energy-consumption#energy-use-by-fuel-type-and-sector-status-and-trends | A revised energy-mix for residential buildings, results in a lower weighed emission factor for residential property. This results in a lower GHG-intensity in the baseline year. |
| **Energy target 2050 [kWh/$m^2$*a])** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UNFCCC GHG Data Interface (2022): Annual greenhouse gas (GHG) emissions for Australia, in kt $CO_2$ equivalent | | F-Gases have been attributed respective to the AUS phase down. |
| **Other Sources / Notes** | - Australian Bureau of Statistics (2021): Energy Account, Australia. https://www.abs.gov.au/ausstats/abs@.nsf/0/5E025753112D1A80CA2578800019C952?Opendocument<br><br>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.<br><br>Department of the Environment and Energy (2019): National Inventory by Economic Sector 2017.<br><br>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<br><br>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.<br><br>JLL (2019): Australian Cities for a Metropolitan Age.<br><br>Oldfield, P., Swinbourne, R., Symons, K. (2019): Decarbonising Commercial Buildings. In Decarbonising the Built Environment (pp. 163-191). Palgrave Macmillan, Singapore.<br><br>*GHG Emissions*<br><br>COAG Council of Australian Governments - Energy Council (2018): Trajectory for low energy buildings.<br><br>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. | | |
| **Data Partner** | - Australia GBC, NAB | | |

| **AUSTRALIA – SUB REGIONS** | |
|---|---|
| **SOURCES** | **Climate Zones:**<br>- GOV AU (2022): Australian Climate Zones. Online : https://www.yourhome.gov.au/getting-started/australian-climate-zones.<br>**Energy intensities – starting values (kWh/m2/a):**<br>- NABERS (2020): NABERS energy. Online: https://www.nabers.gov.au/ratings/ (whole building).<br>**Energy targets:**<br>- IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28.<br>**Energy-mix:**<br>- NABERS (2020): Energy efficiency in commercial buildings, May 2022.<br>**EF Grid:**<br>- Australian Government Dept of Environment & Energy Emissions Factors, Table 5 and Table 46 for regional factors (August 2021 report) National Greenhouse Accounts Factors – August 2021, online: industry.gov.au.<br>- AEMO (2022): 2022 Integrated System Plan (ISP), Australian Energy Market Operator. Online: https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp |

| IMPACT / REASONING | PATHWAY COMPARISON |
|---|---|
| **OFFICE kWh**<br>➔ Starting values have been aligned with data partners from Australia.<br>➔ The starting point increased slightly, showing that not enough measures have been undertaken in the past years.<br>➔ Higher starting intensities due to the result of use density increasing.<br>➔ New energy targets result the pathway levelling off around 2037. |  |
| **OFFICE $CO_2$**<br>➔ No significant changes in the overall energy-mix and weighted emission factor.<br>➔ A higher energy-intensity starting point with an unchanged emission factor, results in a higher GHG-intensity starting point.<br>➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve. |  |
| **RESIDENTIAL kWh**<br>➔ Starting values have been aligned with data partners from Australia.<br>➔ The starting point decreased slightly, showing that the energy efficiency has improved in Australia on average.<br>➔ A lower starting intensity in the baseline year results a lower starting point in the respective year.<br>➔ New energy targets result the pathway levelling off around 2035. |  |
| **RESIDENTIAL $CO_2$**<br>➔ Slightly lower weighted emission factor for residential buildings.<br>➔ Lower energy-intensity in the baseline year with a lower emission factor results in a lower GHG-intensity in the baseline year. |  |

| BRAZIL (BRA) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | IFC International Finance Corporation – World Bank Group (n.y.): Green Buildings Market Intelligence – Brazil Country Profile.<br>UN United Nations (2017): Household Size and Composition Around the World 2017 | IFC International Finance Corporation – World Bank Group (n.y.): Green Buildings Market Intelligence – Brazil Country Profile.<br>UN United Nations (2017): Household Size and Composition Around the World 2017 | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Energy intensities – starting values [kWh/m²*a]** | Lamberts, R. / LabEEE-UFSC (n.y.): Brazil's non-domestic energy and buildings context.<br>Borgstein, E. (2018): Towards policy for efficient buildings in Brazil. | Climate Transparency (2020): Brazil - CLIMATE TRANSPARENCY REPORT.<br>CNPq (2019): Design ecovisions: research on design and sustainability in Brazil – Volume 2 | Commercial: Starting values have been adjusted and are now higher in the baseline year.<br>Residential: Starting values have been adjusted and are now higher in the baseline year. |
| **Emission Factors & Development [KgCO$_2$/kWh]** | *GHG Emissions*<br>USAID (2019): Greenhouse Gas Emissions in Brazil.<br>Greenpeace (2016): Energy [R]evolution. For a Brazil with 100% clean renewable energy. | Carbon footprint (March 2022): Country specific electricity grid greenhouse gas emission factors. Online: www.carbonfootprint.com | For the commercial sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve.<br>For the residential sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Energy mix & energy mix development** | EIA U.S. Energy Information Administration (2019): Global energy consumption driven by more electricity in residential, commercial buildings.<br>EPE Empresa de Pesquisa Energética (2019) : Balanco Energético Nacional 2019 ano base 2018.<br>EPE Empresa de Pesquisa Energética, Ministério de Minas e Energia, Brasil Governo Federal (2017) : Anuário Estatístico de Energia Elétrica 2017 ano base 2016. | IEA Energy Technology Perspective 2017, online: https://www.iea.org/data-and-statistics/data-product/energy-technology-perspectives-2017-2 | A revised energy-mix for commercial buildings, results in a lower weighed emission factor for commercial property. This results in a lower GHG-intensity in the baseline year.<br>A revised energy-mix for residential buildings, results in a lower weighed emission factor for residential property. This results in a lower GHG-intensity in the baseline year. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources** | / | | |

| IMPACT / REASONING | PATHWAY COMPARISON |
|---|---|
| **OFFICE kWh**<br>➔ Starting values have been updated with more accurate sources.<br>➔ The starting point increased slightly, showing that not enough measures have been undertaken in the past years<br>➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.<br>➔ New energy targets result the pathway levelling off around 2035. |  |
| **OFFICE $CO_2$**<br>➔ No significant changes in the overall energy-mix and weighted emission factor.<br>➔ A higher energy-intensity starting point with an unchanged emission factor, results in a higher GHG-intensity starting point. |  |
| **RESIDENTIAL kWh**<br>➔ Starting values have been aligned with data partners from Australia.<br>➔ The starting point decreased slightly, showing that the energy efficiency has improved in Australia on average.<br>➔ A lower starting intensity in the baseline year results a lower starting point in the respective year.<br>➔ New energy targets result the pathway levelling off around 2031. |  |
| **RESIDENTIAL $CO_2$**<br>➔ Slightly lower weighted emission factor for residential buildings.<br>➔ Lower energy-intensity in the baseline year with a lower emission factor results in a lower GHG-intensity in the baseline year. |  |

| CANADA (CAN) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | Point2 Homes (2017): Canadians enjoy second-most living space per person: Global survey.<br><br>Statistics Canada (2017): Census in Brief - Dwellings in Canada.<br><br>Survey of Commercial and Institutional Energy Use (SCIEU) (2014): Buildings 2014 – Data Tables, Table 19. | Point2 Homes (2017): Canadians enjoy second-most living space per person: Global survey.<br><br>Statistics Canada (2017): Census in Brief - Dwellings in Canada. | No direct impact on the energy-intensity in the first year.<br><br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | The Global Status Report (2017): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC). | The Global Status Report (2017): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC). | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | Government of Canada (2015): Survey of Commercial and Institutional Energy Use (SCIEU) – Buildings 2014.<br><br>CEA Canadian Electricity Association (2018): Electricity 101.<br><br>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. | Energy Star (2019): Canadian Energy Use Intensity by Property Type, Portfolio Manager. Online: www.energystar.gov.<br><br>NRCAN (2020): Commercial and Institutional Building Energy Use Survey. Median values (score 50). | For the commercial and residential sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Emission Factors & Development**<br><br>**[$KgCO_2$/kWh]** | 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<br><br>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. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com | New emission factor for grid used (without distribution & transmission losses).<br><br>Emission factor for grid now lower than 2018.<br><br>Total weighted EF now slightly lower for residential & commercial buildings. |
| **Energy mix & energy mix development** | CERI Canadian Energy Research Institute (2017): Greenhouse Gas Emissions Reductions in Canada Through Electrification of Energy Services. | CERI Canadian Energy Research Institute (2017): Greenhouse Gas Emissions Reductions in Canada Through Electrification of Energy Services. | No significant change in the energy-mix of the commercial and residential sector. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |

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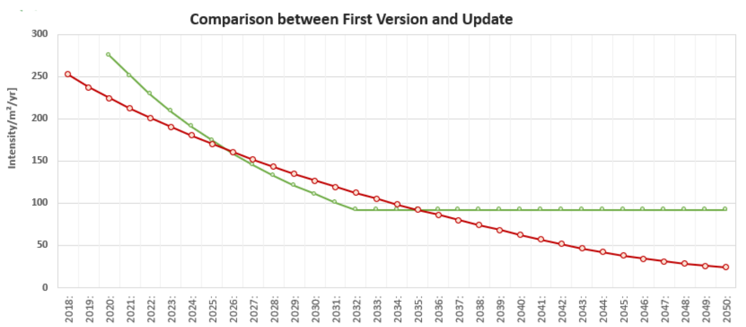
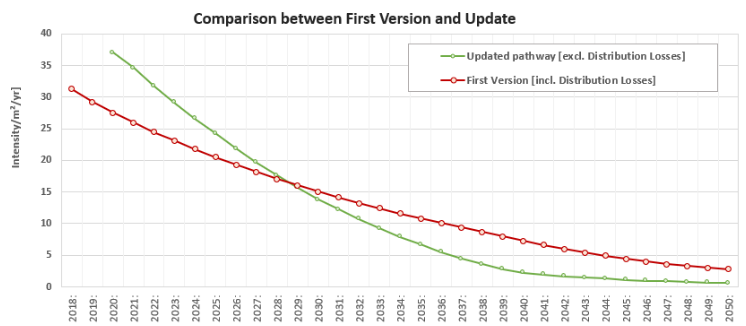
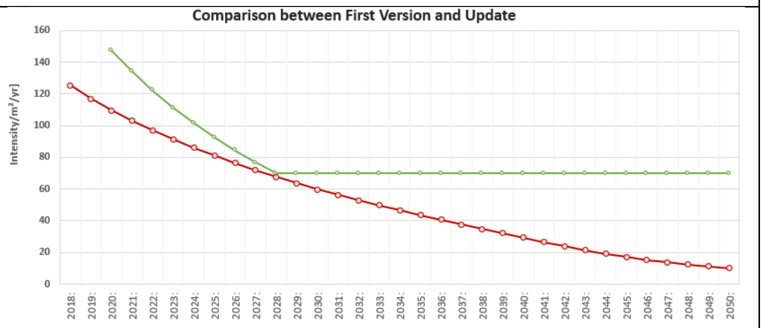
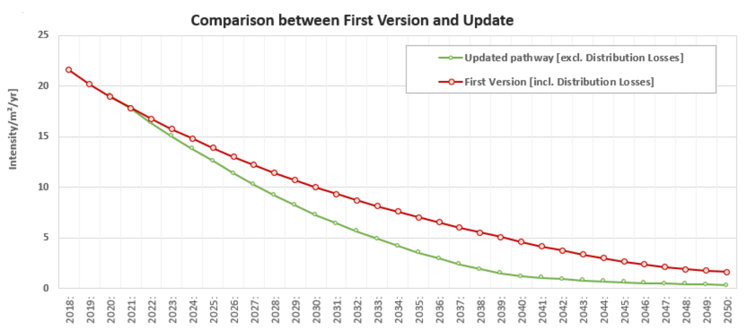
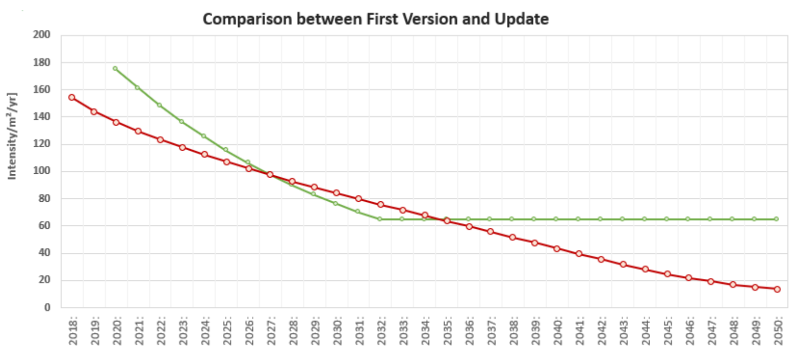
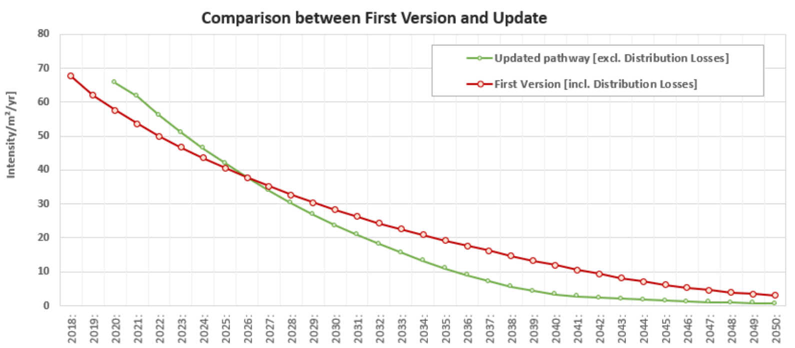
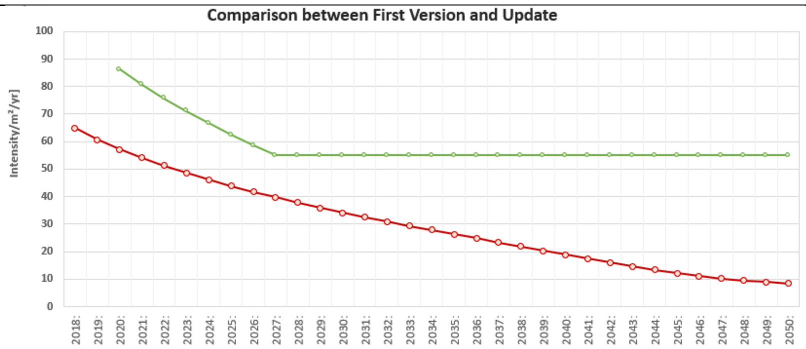
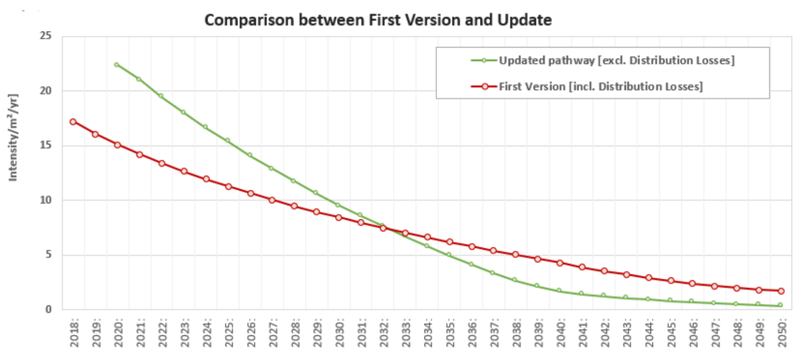
|---|---|---|
| **F-Gas/ 'e'** | EPA (2022): Non-CO2 Greenhouse Gas Data Tool. Online: https://cfpub.epa.gov/ghgdata/nonco2/ | F-Gases have been attributed to the pathways respective to the non-Art 5 phase down. |
| **Other Sources / Notes** | / | |

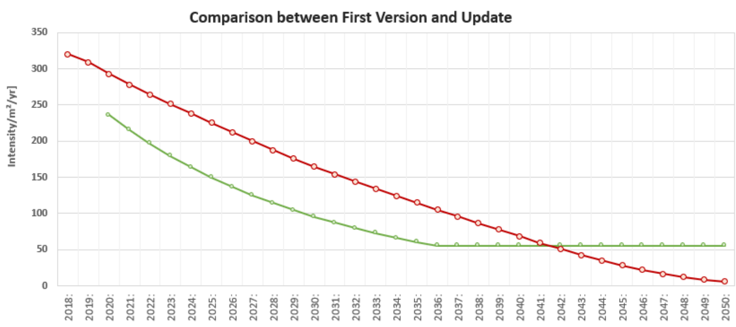
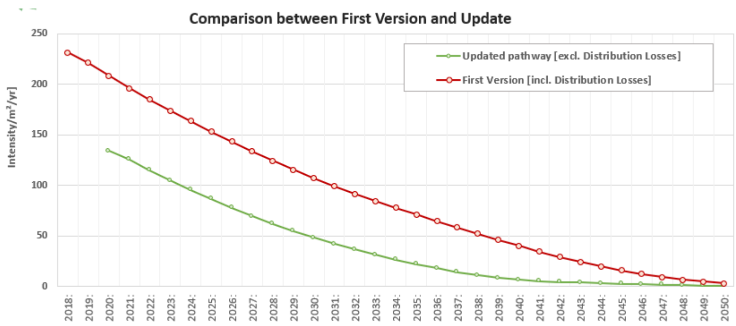
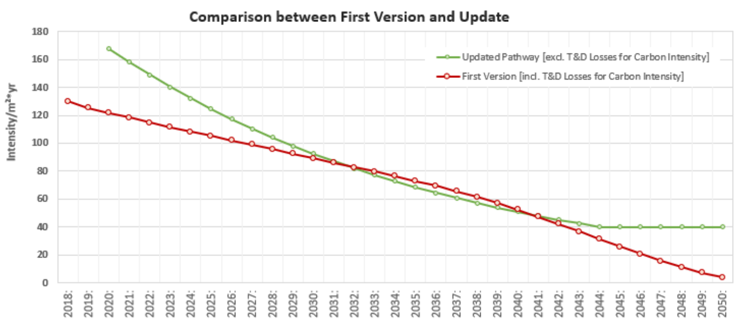
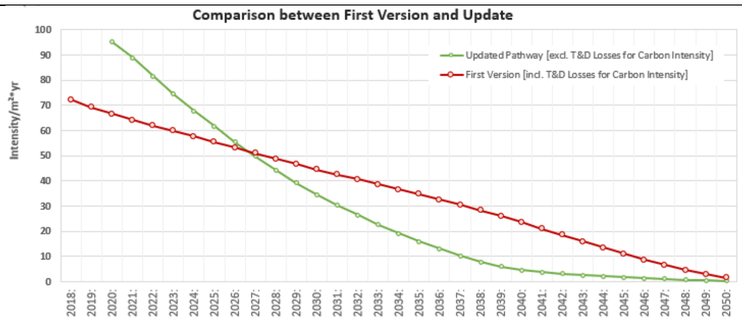
| IMPACT / REASONING | PATHWAY COMPARISON |
|---|---|
| **OFFICE kWh**<br>➔ The starting point increased slightly, showing that not enough measures have been undertaken in the past years.<br>➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.<br>➔ New energy targets result the pathway levelling off around 2031. |  |
| **OFFICE $CO_2$**<br>➔ No significant changes in the overall energy-mix and weighted emission factor.<br>➔ A higher energy-intensity starting point with only a minor emission factor reduction, results in a higher GHG-intensity starting point. |  |
| **RESIDENTIAL kWh**<br>➔ The starting point increased slightly, showing that not enough measures have been undertaken in the past years.<br>➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.<br>➔ New energy targets result the pathway levelling off around 2028. |  |
| **RESIDENTIAL $CO_2$**<br>➔ Slightly lower weighted emission factor for residential buildings.<br>➔ A higher energy-intensity starting point with only a minor emission factor reduction, results in a higher GHG-intensity starting point. |  |

| CHINA (CHI) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | GBPN Global Buildings Performance Network (2019): China: the world's largest single market in new construction. | GBPN Global Buildings Performance Network (2019): China: the world's largest single market in new construction. | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | The Global Status Report (2017): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC). | The Global Status Report (2017): Global Status Report of the International Energy Agency (IEA) for the Global Alliance for Buildings and Construction (GABC). | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | Jiang, Y., Yan, D., Hu, S., Guo, S., Cui, Y., Peng, C. (2016): China Building Energy Survey 2016. | Energy Policy (2013): Commercial building energy use in six cities in Southern China.<br>Climate Transparency (2020): China - CLIMATE TRANSPARENCY REPORT. Online: www.climate-transparency.org | For the commercial sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve.<br>The residential sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Emission Factors & Development [KgCO₂/kWh]** | GES Institute for Global Environmental Strategies (2019). IGES List of Grid Emission Factors.<br>Fridley, D. G., Zheng, N., Zhou, N. (2008): Estimating total energy consumption and emissions of China's commercial and office buildings. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com | Over the last years no significant improvement was recorded in regards to grid decarbonization.<br>Grid EF without distribution losses has been used. |
| **Energy mix & energy mix development** | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data.<br><br>EDGAR Emissions Database for Global Atmospheric Research (2019): Fossil CO2 and GHG emissions of all world countries, 2019 dataset. | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | A revised energy-mix for residential buildings, results in a higher weighed emission factor for residential property. This results in a higher GHG-intensity in the baseline year. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources / Notes** | / | | |

| IMPACT / REASONING | PATHWAY COMPARISON |
|---|---|
| **OFFICE kWh**<br>➔ Starting values have been corrected and are now higher.<br>➔ The starting point increased, showing that not enough measures have been undertaken in the past years.<br>➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.<br>➔ New energy targets result the pathway levelling off around 2032. |  |
| **OFFICE $CO_2$**<br>➔ Minimal grid decarbonization, however reduction in grid EF due to exclusion of D&T losses.<br>➔ Corrected weighted emission factor however no improvement on energy-mix, resulting in a higher starting point and steeper curve. |  |
| **RESIDENTIAL kWh**<br>➔ Starting values have been corrected and are now higher.<br>➔ The starting point increased, showing that not enough measures have been undertaken in the past years.<br>➔ New energy targets result the pathway levelling off around 2027. |  |
| **RESIDENTIAL $CO_2$**<br>➔ No significant changes in the weighted emission factor, however a higher energy-intensity in the baseline year results a higher GHG starting point. |  |

| HONG KONG (HK) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | Hong Kong Transport and Housing Bureau (2019): Housing in Figures 2019.<br><br>Hong Kong Transport and Housing Bureau (2018): Hong Kong: The Facts (Housing). | Hong Kong Transport and Housing Bureau (2019): Housing in Figures 2019.<br><br>Hong Kong Transport and Housing Bureau (2022): Hong Kong: The Facts (Housing). | No direct impact on the energy-intensity in the first year.<br><br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | Hong Kong Rating and Valuation Department (2019): Hong Kong Property Review 2019. | Hong Kong Rating and Valuation Department (2019): Hong Kong Property Review 2019.<br><br>Hong Kong Rating and Valuation Department (2022): Hong Kong Property Review 2022. | - |
| **Energy intensities – starting values [kWh/m²*a]** | Hong Kong Census and Statistics Department (2018): Hong Kong Energy Statistics. 2018 Annual Report.<br><br>Hong Kong Council for Sustainable Development (2011): Combating Climate Change: Energy Saving and Carbon Emission Reduction in Buildings.<br><br>Hong Kong Electrical and Mechanical Services Department (2019): Hong Kong Energy End-use Data 2019.<br><br>Hong Kong Environment Bureau (2015): Climate Change Report 2015. | CRE - EMSD (2022): Energy Consumption Indicators and Benchmarks, online: https://ecib.emsd.gov.hk/index.php/en/energy-utilisation-index-en/commercial-sector-en.<br><br>CRE -Twinview (2022): Benchmarking commercial energy use per square foot. Online: https://www.twinview.com/insights/benchmarking-commercial-energy-use-per-square-foot<br><br>Resi - EMSD (2022): Energy Consumption Indicators and Benchmarks, online: https://ecib.emsd.gov.hk/index.php/en/energy-utilisation-index-en/residential-sector-en.<br><br>Please note: Factor of 1,15 has been applied to convert leasable area into GIA for residential EUI. | For the commercial sector: A lower starting intensity in the baseline year results a lower starting point in the respective year, indicating that the country has improved the energy efficiency on average (e.g. for office buildings).<br><br>For some CRE building types like retail SC and retail HS sources indicated slightly higher consumptions figures.<br><br>For residential properties the average starting intensities were higher compared to older sources applied previously. |
| **Emission Factors & Development**<br><br>**[KgCO₂/kWh]** | HKSAR Planning Department (2016): Hong Kong 2030+: Towards a Planning Vision and Strategy Transcending 2030. Baseline Review: Population, Housing, Economy and Spatial Development Pattern.<br><br>Hong Kong Business Environment Council (2018): Investing in Buildings Energy Efficiency. How to enhance Hong Kong's Policy Framework. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com.<br><br>Government of HK (2022): Hong Kong's Climate Action Plan 2050, Online: https://www.climateready.gov.hk/files/pdf/CAP2050_booklet_en.pdf | Regarding the development of the grid decarbonization a new source was used, indicating a string grid decarbonization until 2050 (HK climate Action Plan). |
| **Energy mix & energy mix development** | 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). | GRESB (2022): GRESB Energy Use Data Hong Kong for 2020.<br><br>Government of HK (2022): Hong Kong's Climate Action Plan 2050, Online: https://www.climateready.gov.hk/files/pdf/CAP2050_booklet_en.pdf | The energy mix and development remained the same. |

| | | | |
|---|---|---|---|
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | EPA (2022): Non-CO2 Greenhouse Gas Data Tool. Online: https://cfpub.epa.gov/ghgdata/nonco2/ | | F-Gases have been attributed to the pathways respective to the non-Art 5 phase down. |

<table>
<tr><th>IMPACT / REASONING</th><th>PATHWAY COMPARISON</th></tr>
<tr><td>OFFICE kWh[41]<br>➔ A lower starting intensity in the baseline year results a lower starting point in the respective year, indicating that the country has improved the energy efficiency on average for office buildings.<br>➔ New energy targets result the pathway levelling off around 2035.</td><td>
</td></tr>
<tr><td>OFFICE $CO_2$<br>➔ Slightly lower weighted emission factor for CRE buildings.<br>➔ Lower energy-intensity in the baseline year with a lower emission factor results in a lower GHG-intensity in the baseline year. Also due to the exclusion of T&D-losses.</td><td>
</td></tr>
<tr><td>RESIDENTIAL kWh<br>➔ A higher energy-intensity in the baseline year results a higher GHG starting point.<br>➔ New energy targets result the pathway levelling off around 2045</td><td>
</td></tr>
<tr><td>RESIDENTIAL $CO_2$<br>➔ Higher weighted emission factor for residential buildings and higher energy intensity results in a higher carbon intensity in the baseline year.</td><td>
</td></tr>
</table>

[41] EUI reduction is therefore more ambitious compared to the government plans according to the Hong Kong's Climate Action Plan 2050: 'The goal is to reduce the electricity consumption of commercial buildings by 30 per cent to 40 per cent and that of residential buildings by 20 per cent to 30 per cent from the 2015 level by 2050…'.

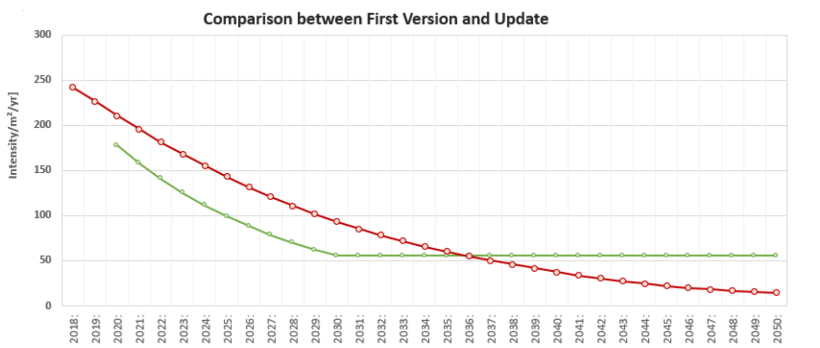
| INDIA (IND) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | Kumar, S., Yadav, N., Singh, M., Kachhawa, S. (2018): Estimating India's commercial building stock to address the energy data challenge. | Kumar, S., Yadav, N., Singh, M., Kachhawa, S. (2018): Estimating India's commercial building stock to address the energy data challenge. | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | Kachhawa, S., Kumar, S., Singh, M. (2019): Decoding India's residential building stock characteristics to enable effective energy efficiency policies and programs. | Kachhawa, S., Kumar, S., Singh, M. (2019): Decoding India's residential building stock characteristics to enable effective energy efficiency policies and programs. | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | Indian Bureau of Energy Efficiency (n.y.): Energy benchmarks for commercial buildings.<br>GBPN Global Buildings Performance Network (2014): Residential Buildings in India: Energy use projections and savings potentials. | Indian Bureau of Energy Efficiency (n.y.): Energy benchmarks for commercial buildings.<br>K. Nagaraju (2017): An Overview of Energy Sector in India. ISSN: 2319-7064. | For the commercial sector: A lower intensity in the baseline year results a higher lower point in the respective year.<br>The residential sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Emission Factors & Development [KgCO₂/kWh]** | Indian Ministry of Power / Central Electricity Authority (2018): CO2 Baseline Database for the Indian Power Sector.<br>CarbonBrief (2019): The Carbon Brief Profile: India. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com. | Over the last years no significant improvement was recorded in regards to grid decarbonization.<br>- Grid EF without distribution losses has been used. |
| **Energy mix & energy mix development** | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | / |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources / Notes** | AEEE Alliance for an Energy Efficient Economy (2019): Building Stock Modelling. Key enabler for driving energy efficiency at national level.<br>Deshmukh, A. A. (2015): Building Energy Performance in India. Thoughtful Cooling ToT: Cooling Interiors Efficiently and Sustainably.<br>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<br>World Resources Institute / Ross Center (2018): A first step down the road to zero-carbon buildings in India. | | |

<table>
<tr><th>IMPACT / REASONING</th><th>PATHWAY COMPARISON</th></tr>
<tr><td>

**OFFICE kWh**

- ➔ Slight decrease in the average starting point, showing that energy efficiency has improved slightly over the past years for the commercial sector.
- ➔ New energy targets result the pathway levelling off around 2030.

</td><td>

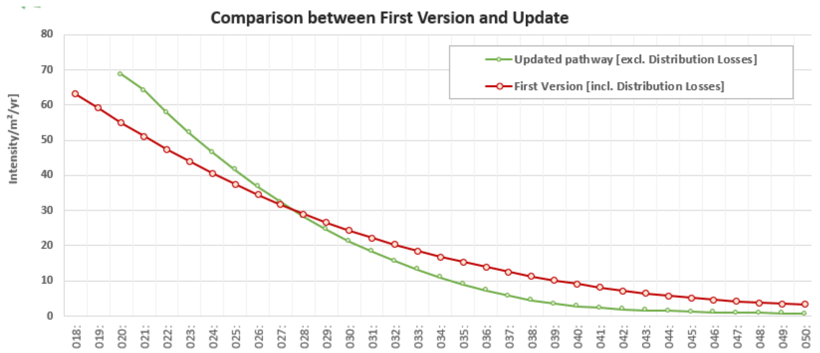



</td></tr>
<tr><td>

**OFFICE $CO_2$**

- ➔ Minimal grid decarbonization, however reduction in grid EF due to exclusion of D&T losses.
- ➔ Corrected weighted emission factor however no improvement on energy-mix, resulting in a higher starting point and steeper curve.

</td><td>

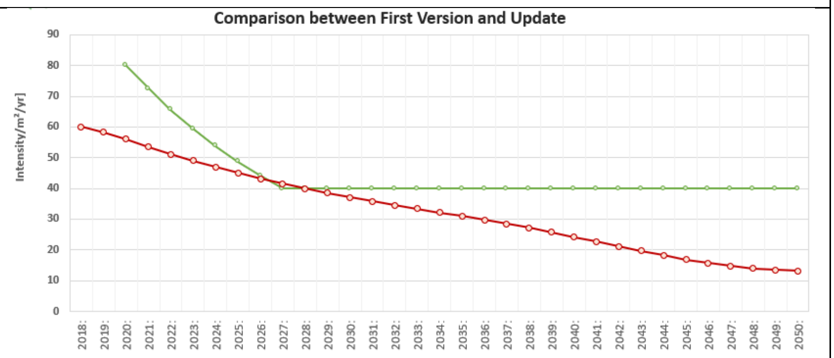



</td></tr>
<tr><td>

**RESIDENTIAL kWh**

- ➔ Starting values have been corrected and are now higher.
- ➔ The starting point increased, showing that not enough measures have been undertaken in the past years.
- ➔ New energy targets result the pathway levelling off around 2027.

</td><td>

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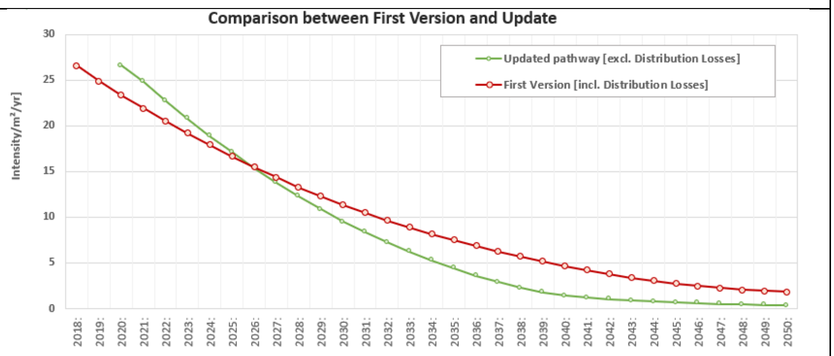
<tr><td>

**RESIDENTIAL $CO_2$**

- ➔ No significant changes in the weighted emission factor, however a higher energy-intensity in the baseline year results a higher GHG starting point.

</td><td>

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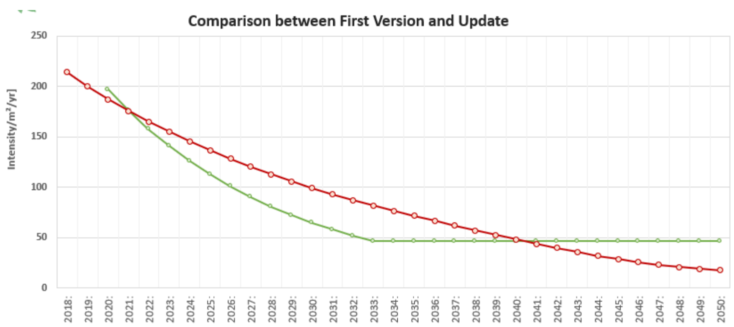
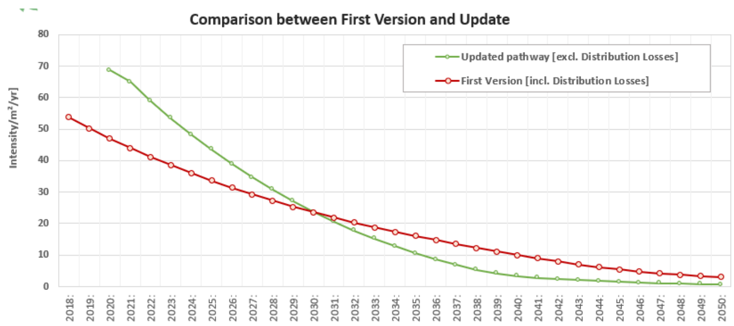
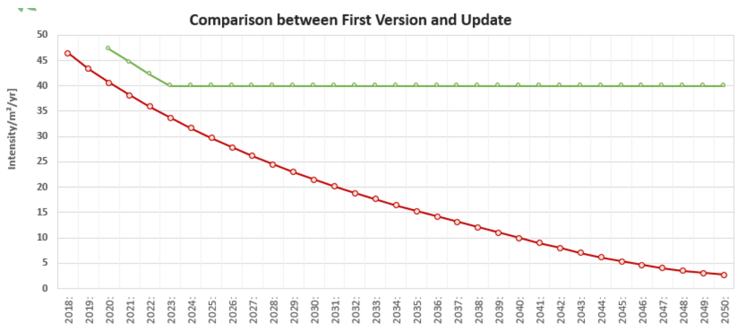
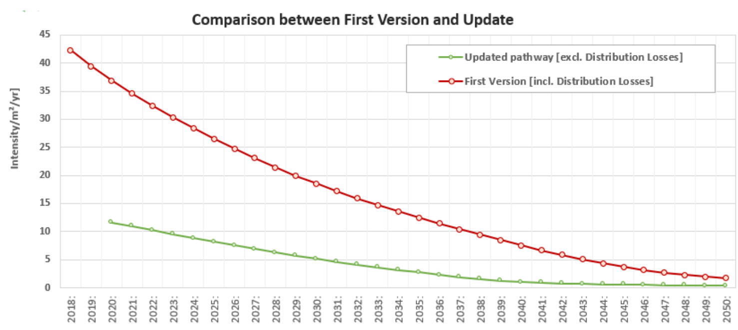
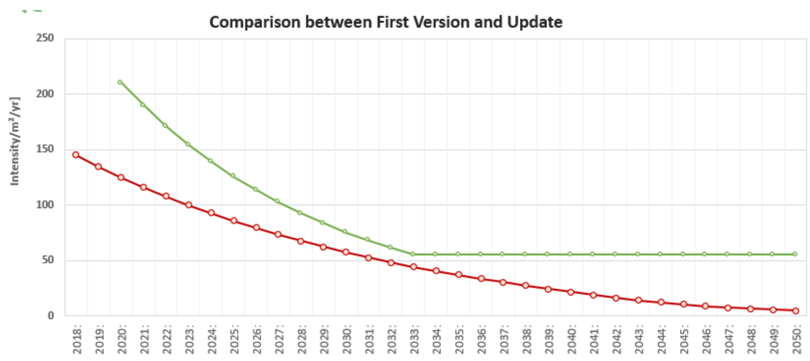
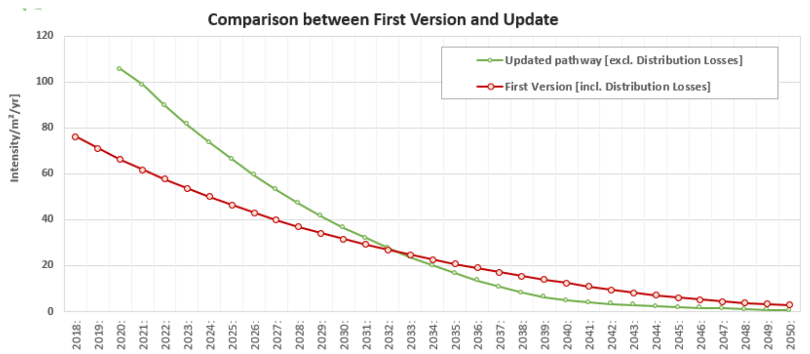
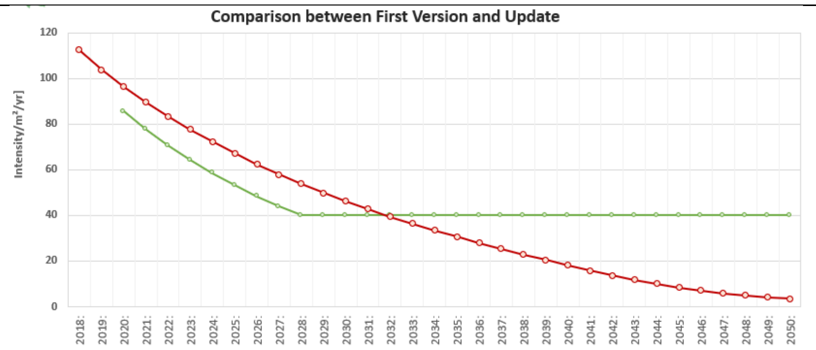
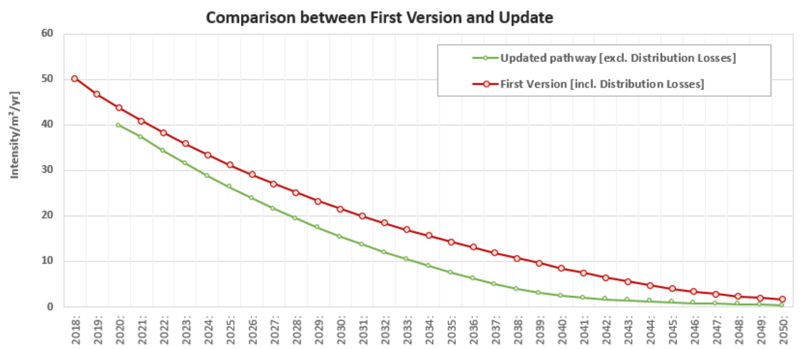
</table>

| MEXICO (MEX) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | INEGI Instituto Nacional de Estadística y Geografía (2015): Households and housing units. https://en.www.inegi.org.mx/temas/vivienda/ | INEGI Instituto Nacional de Estadística y Geografía (2015): Households and housing units. https://en.www.inegi.org.mx/temas/vivienda/ | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | NAMA apoyada para la Vivienda Nueva en México. Acciones de Mitigación y Paquetes Financieros (2017): Vivienda sustentable en México. Vivienda nueva. | NAMA apoyada para la Vivienda Nueva en México. Acciones de Mitigación y Paquetes Financieros (2017): Vivienda sustentable en México. Vivienda nueva. | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | Climate Transparency (2017): Brown to Green 2017.<br>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 | Climate Transparency (2020): Mexico - CLIMATE TRANSPARENCY REPORT. Online: www.climate-transparency.org. | For the commercial sector and residential sector, the country did not improve the energy-efficiency significantly, therefore, the starting values remain at a similar level. |
| **Emission Factors & Development**<br>**[KgCO$_2$/kWh]** | UNEP SBCI Sustainable Buildings & Climate Initiative (2009): Greenhouse Gas Emission Baselines and Reduction Potentials from Buildings in Mexico. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com. | The energy-mix for the residential sector was corrected leading to a lower total EF.<br>The energy-mix also remained mostly the same for the commercial sector. |
| **Energy mix & energy mix development** | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | A revised energy-mix for residential buildings, results in a lower weighed emission factor for residential property. This results in a lower GHG-intensity in the baseline year. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources / Notes** | / | | |

| IMPACT / REASONING | PATHWAY COMPARISON |
|---|---|
| **OFFICE kWh**<br>➔ No energy-efficiency measures have been taken and the country average still remains unchanged.<br>➔ New energy targets result the pathway levelling off around 2033. |  |
| **OFFICE $CO_2$**<br>➔ No significant changes in the overall energy-mix and weighted emission factor.<br>➔ A higher energy-intensity starting point with an unchanged emission factor, results in a higher GHG-intensity starting point. |  |
| **RESIDENTIAL kWh**<br>➔ No energy-efficiency measures have been taken and the country average still remains unchanged.<br>➔ New energy targets result the pathway levelling off around 2022. |  |
| **RESIDENTIAL $CO_2$**<br>➔ A revised energy-mix for residential buildings, results in a lower weighed emission factor for residential property. This results in a lower GHG-intensity in the baseline year.<br>➔ Lower energy-intensity in the baseline year with a lower emission factor results in a lower GHG-intensity in the baseline year. |  |

| MALAYSIA (MAL) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | 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). | 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). | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | UNDP United Nations Development Programme (2016): UNDP Strategic Plan Environment and Sustainable Development. | UNDP United Nations Development Programme (2016): UNDP Strategic Plan Environment and Sustainable Development. | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | 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.<br>IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | APREC (2018): Measuring energy efficiency in residential/buildings sector. Data collection in selected APEC economies. | For the commercial sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve.<br>The residential sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Emission Factors & Development**<br>**[$KgCO_2$/kWh]** | 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.<br>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. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com. | Over the last years no significant improvement was recorded in regards to grid decarbonization.<br>Grid EF without distribution losses has been used. |
| **Energy mix & energy mix development** | 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.<br>Ministry of Natural Resources and Environment Malaysia (2015): Malaysia. Biennial Update Report to the UNFCCC. | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data – ASEAN IEA Data. | The weighted emission factors shows no significant changes for both residential and commercial compared to the first version. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources / Notes** | / | | |

CRREM | IIÖ Institut für Immobilienökonomie

| IMPACT / REASONING | PATHWAY COMPARISON |
|---|---|
| **OFFICE kWh**<br>➔ The starting point increased, showing that not enough measures have been undertaken in the past years.<br>➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.<br>➔ New energy targets result the pathway levelling off around 2033. |  |
| **OFFICE $CO_2$**<br>➔ Minimal grid decarbonization, however reduction in grid EF due to exclusion of D&T losses.<br>➔ Due to higher starting point in energy-intensity however unchanged weighted emission factor, the GHG-intensity is now also slightly higher. |  |
| **RESIDENTIAL kWh**<br>➔ The starting point decreased, showing that enough measures have been undertaken in the past years.<br>➔ New energy targets result the pathway levelling off around 2028. |  |
| **RESIDENTIAL $CO_2$**<br>➔ Only slight changes in the energy-mix and grid decarbonization result in no significant changes in the weighted emission factor.<br>➔ Slightly lower CO2 starting point due to lower energy-intensity, however increased GHG-intensity due to F-gas add-on. |  |

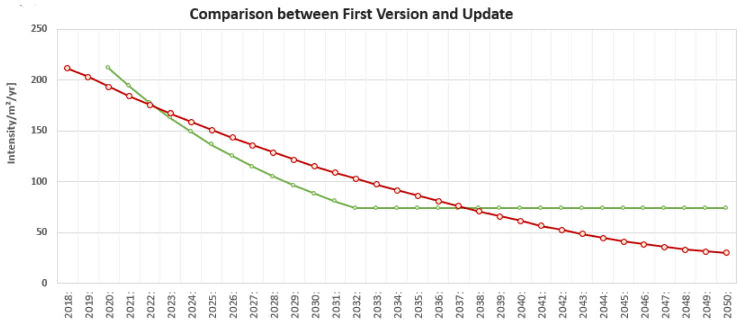
| NEW ZEALAND (NZL) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | de Jong, P., van Oss, S. C. F., Wamelink, H. (2007): High Rise Ability. In: Earthquake Resistant Engineering Structures VI, p. 1-11. | de Jong, P., van Oss, S. C. F., Wamelink, H. (2007): High Rise Ability. In: Earthquake Resistant Engineering Structures VI, p. 1-11. | No direct impact on the energy-intensity in the first year.<br><br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | de Jong, P., van Oss, S. C. F., Wamelink, H. (2007): High Rise Ability. In: Earthquake Resistant Engineering Structures VI, p. 1-11.<br><br>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 | de Jong, P., van Oss, S. C. F., Wamelink, H. (2007): High Rise Ability. In: Earthquake Resistant Engineering Structures VI, p. 1-11.<br><br>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 | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | Amitrano, L. (2014): BEES Building Energy End-use study.<br><br>EECA Energy Efficiency and Conservation Authority (2017): Programme Review Commercial Buildings.<br><br>Ministry of Business, Innovation & Employment (2019): Energy in New Zealand 2019. | Amitrano, L. (2014): BEES Building Energy End-use study.<br><br>EECA Energy Efficiency and Conservation Authority (2017): Programme Review Commercial Buildings.<br><br>Ministry of Business, Innovation & Employment (2019): Energy in New Zealand 2019. | For the commercial sector: No improvement noticed in the market in the past years in energy-efficiency.<br><br>The residential sector: No improvement noticed in the market in the past years in energy-efficiency. |
| **Emission Factors & Development**<br><br>**[KgCO₂/kWh]** | 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/ | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com | Over the last years no significant improvement was recorded in regards to grid decarbonization. Lower grid emission factor due to the use of the factor excluding distribution & transmission losses. |
| **Energy mix & energy mix development** | McDonagh, J. (2010): Electricity Use Trends in New Zealand Office Buildings, 1990-2008.<br><br>Ministry for the Environment (2018): New Zealand's Greenhouse Gas Inventory 1990-2017. | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | Slight change in the energy-mix results a slightly higher weighed EF for both residential and commercial assets. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | EPA (2022): Non-CO2 Greenhouse Gas Data Tool. Online: https://cfpub.epa.gov/ghgdata/nonco2/ | | F-Gases have been attributed to the pathways respective to the non-Art 5 phase down. |

<table>
<tr><th>IMPACT / REASONING</th><th>PATHWAY COMPARISON</th></tr>
<tr><td>

**OFFICE kWh**

- ➔ The starting point remains the same, indicating that no improvement in energy-efficiency was done in the past years.
- ➔ New energy targets result the pathway levelling off around 2031.

</td><td>

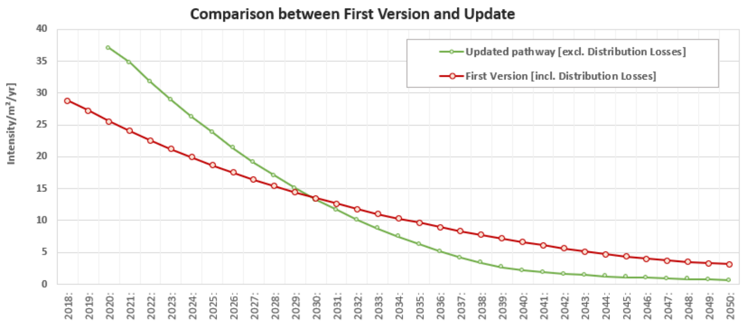



</td></tr>
<tr><td>

**OFFICE $CO_2$**

- ➔ Lower grid emission factor due to the use of the factor excluding distribution & transmission losses.
- ➔ However, adjusted energy-mix and slightly higher weighted EF results in a higher GHG intensity in the baseline year and a steeper curve.

</td><td>

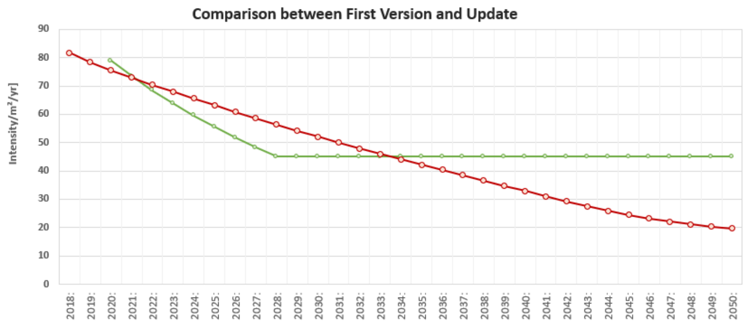



</td></tr>
<tr><td>

**RESIDENTIAL kWh**

- ➔ The starting point remains the same, indicating that no improvement in energy-efficiency was done in the past years.
- ➔ New energy targets result the pathway levelling off around 2031.

</td><td>

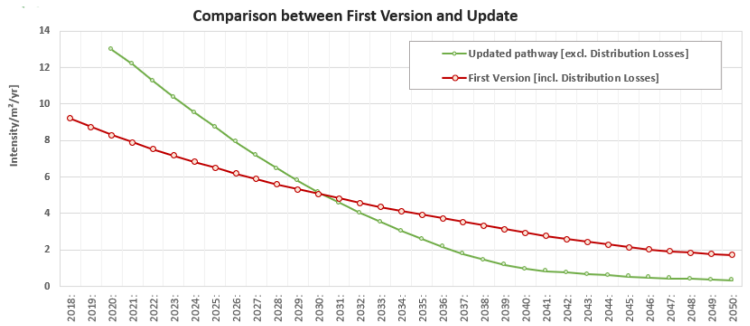



</td></tr>
<tr><td>

**RESIDENTIAL $CO_2$**

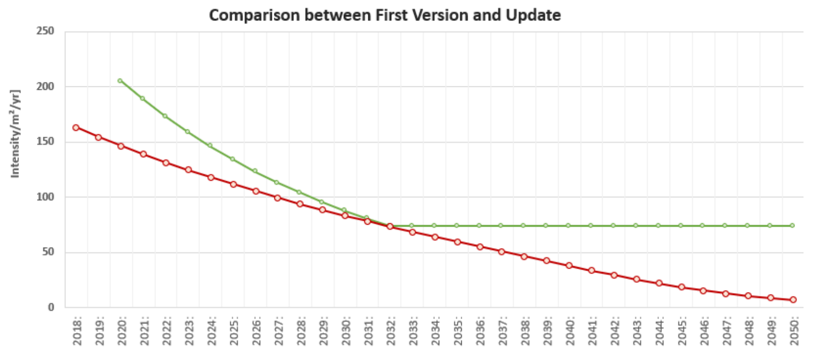
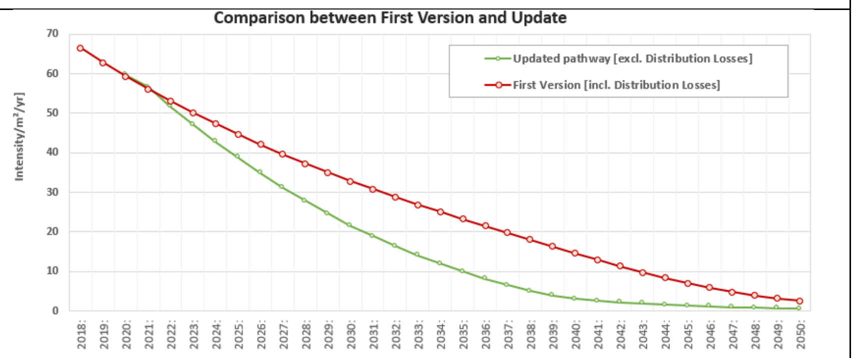
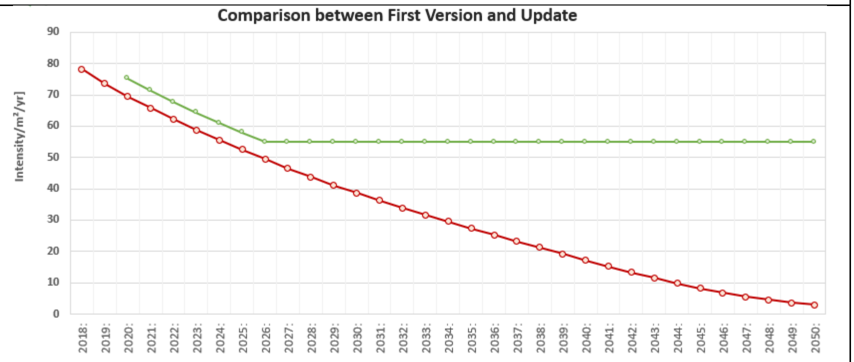
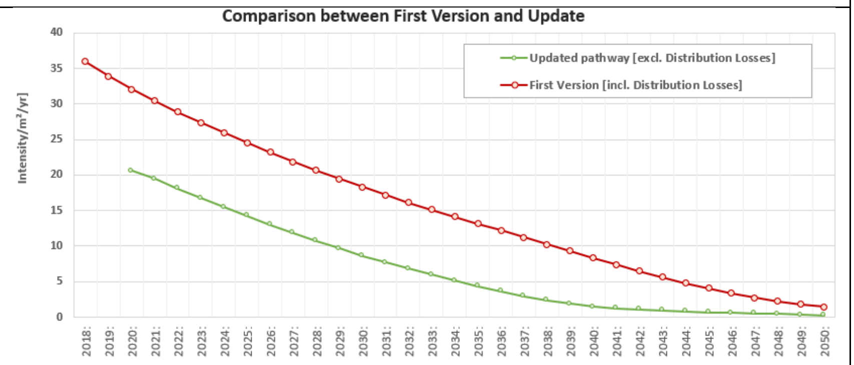
- ➔ Lower grid emission factor due to the use of the factor excluding distribution & transmission losses.
- ➔ However, adjusted energy-mix and slightly higher weighted EF results in a higher GHG intensity in the baseline year and a steeper curve.

</td><td>




</td></tr>
</table>

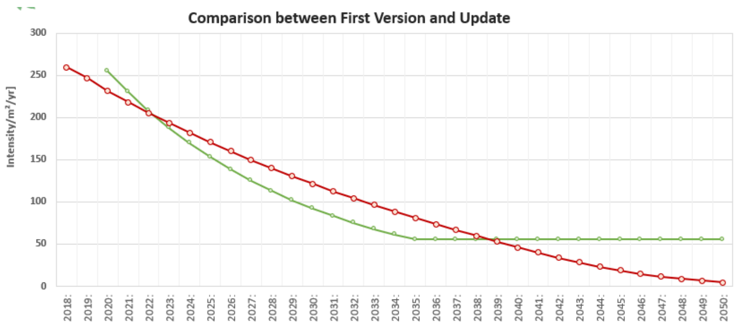
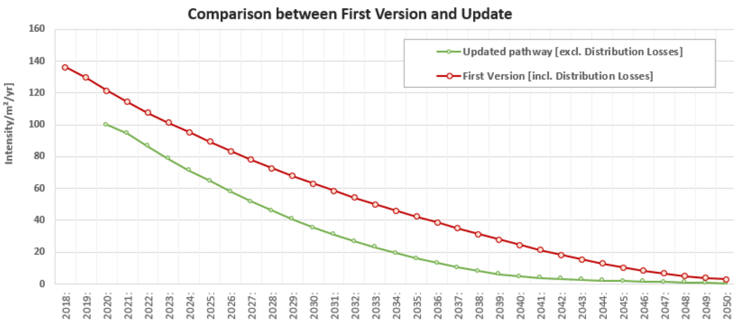
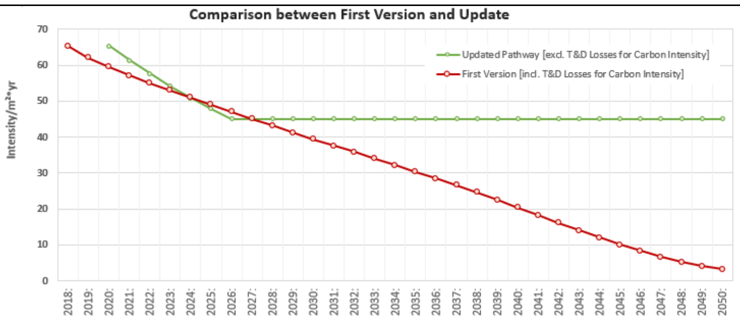
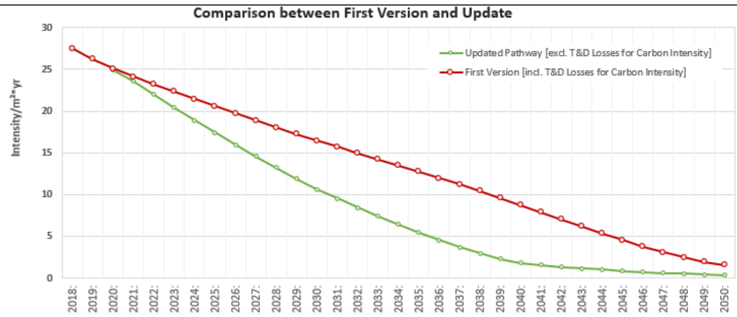
| SOUTH KOREA (KOR) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | IEA International Energy Agency (2019): Data and statistics. https://www.iea.org/data-and-statistics | IEA International Energy Agency (2019): Data and statistics. https://www.iea.org/data-and-statistics | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | IEA International Energy Agency (2019): Data and statistics. https://www.iea.org/data-and-statistics | IEA International Energy Agency (2019): Data and statistics. https://www.iea.org/data-and-statistics | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | 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).<br>Chung, S. Y., Cheon, D. K., Chang, H., Kwak, H. (2013): The case of Korea: the quantification of GHG reduction effects achieved by ICTs. | Chung, S. Y., Cheon, D. K., Chang, H., Kwak, H. (2013): The case of Korea: the quantification of GHG reduction effects achieved by ICTs. | For the commercial sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve.<br>The residential sector: the sector has improved efficiency, however, not enough. Therefore, only a marginal difference can be seen to the old pathway. |
| **Emission Factors & Development [KgCO₂/kWh]** | Chung, S. Y., Cheon, D. K., Chang, H., Kwak, H. (2013): The case of Korea: the quantification of GHG reduction effects achieved by ICTs. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com. | Grid EF without distribution losses has been used, resulting in a lower grid EF.<br>The new grid EF also lowers the weighted EF for both Resi & CRE. |
| **Energy mix & energy mix development** | Climate Transparency (2018): Brown to Green 2018. | EIA (2022): analysis Korea. Online: https://www.eia.gov/international/analysis/country/KOR | The residential sector: A higher intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources / Notes** | / | | |

| IMPACT / REASONING | PATHWAY COMPARISON |
| --- | --- |
| **Office kWh**<br>➔ Starting values have been corrected and are now higher.<br>➔ The starting point increased, showing that not enough measures have been undertaken in the past years.<br>➔ A higher starting intensity in the baseline year results a higher starting point in the respective year, resulting a steeper curve.<br>➔ New energy targets result the pathway levelling off around 2031. |  |
| **Office $CO_2$**<br>➔ Slight grid decarbonization and also reduction in grid EF due to exclusion of D&T losses.<br>➔ Lower weighted emission factor however higher starting energy-intensities result in a higher GHG-intensity. |  |
| **RESIDENTIAL kWh**<br>➔ Starting values have been corrected and are now slightly higher than the projected 2020 values. However, a slight improvement in energy-efficiency but not enough in the sector. |  |
| **RESIDENTIAL $CO_2$**<br>➔ No marginal changes in the starting energy-intensity, however the lower weighted EF results in a lower GHG starting point. |  |

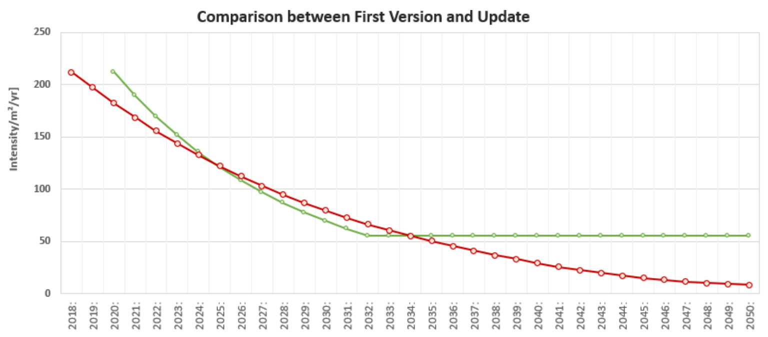
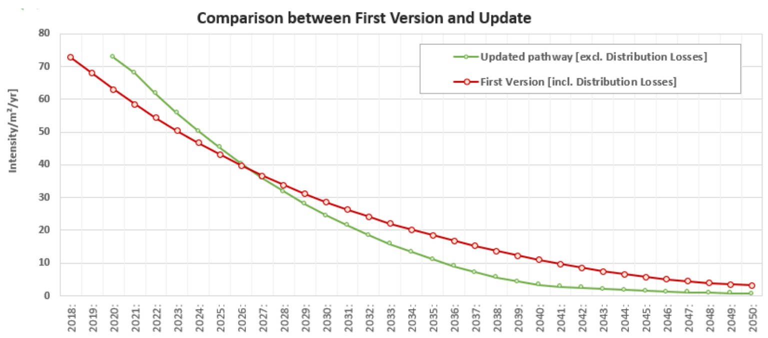
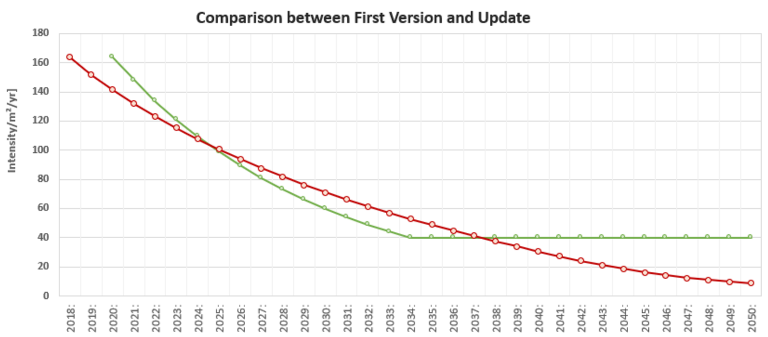
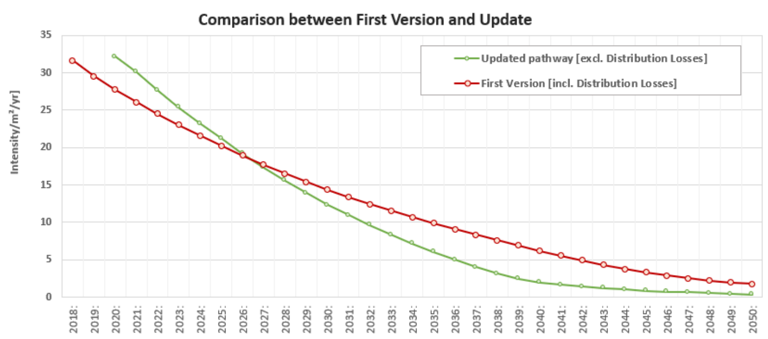
| SINGAPORE (SGP) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | Department of Statistics Singapore (2019): Households. Statistics on resident households compiled by the Singapore Department of Statistics. https://www.singstat.gov.sg/find-data/search-by-theme/households/households/latest-data | Department of Statistics Singapore (2022: 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<br><br>URA GOV (2022): STOCK & VACANCY AND SUPPLY IN THE PIPELINE AS AT END OF 3RD QUARTER 2022. Online: https://www.ura.gov.sg/-/media/Corporate/Media-Room/2022/Oct/pr22-38e1.pdf | No direct impact on the energy-intensity in the first year.<br><br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | Singapore Urban Redevelopment Authority (2019): Release of 3rd Quarter 2019 real estate statistics.<br><br>van der Heijde, J. (2017): Innovations in Urban Climate Governance Voluntary Programs for Low-Carbon Buildings and Cities. | Singapore Urban Redevelopment Authority (2019): Release of 3rd Quarter 2019 real estate statistics.<br><br>van der Heijde, J. (2017): Innovations in Urban Climate Governance Voluntary Programs for Low-Carbon Buildings and Cities. | - |
| **Energy intensities – starting values [kWh/m²*a]** | Singapore Building and Construction Authority (2018): BCA Building Energy Benchmarking Report.<br><br>Singapore Building and Construction Authority (2018): Super low energy building. Technology roadmap. | Singapore Building and Construction Authority (2020): BCA Building Energy – Benchmarking Report (Statistics and Figures).[42]<br><br>SLEB (2022): Energy Benchmarking. Online: https://sleb.sg/DashBoard/EnergyBenchmarking.<br><br>Singapore's Climate Action Plan (2016): FOR A CARBON-EFFICIENT SINGAPORE. Online: https://sustainabledevelopment.un.org/content/documents/1545Climate_Action_Plan_Publication_Part_1.pdf.<br><br>Please note GRESB factors have been applied for all property-types apart from Office and Retail SM. | For the commercial sector: A slightly higher than projected intensity in the baseline year results a higher starting point in the respective year, resulting in a steeper curve. Basically, intensities remained at the same level compared to 2018 staring year. Indicating no major progress regarding the overall reduction regarding energy intensities.<br><br>The residential sector: Intensities remained at the same level compared to 2018 staring year. Indicating no major progress regarding the overall reduction regarding energy intensities. |
| **Emission Factors & Development (KgCO₂/kWh)** | National Climate Change Secretariat (2016): Singapore's Climate Action Plan: Take Action Today, For a Carbon-Efficient Singapore. | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com | Over the last years no significant improvement was recorded in regards to grid decarbonization.<br><br>However, the emission factor without T&D losses was used (which is lower |

[42] Please note: in the data source applied from the Energy Market Authority, National Environment Agency and Deportment of Statistics and GRESB 'As electricity is the main source of energy used in Singapore's buildings, other energy sources were excluded in the computation of EUI. EUI is measured by the total electricity used within a building in a year, expressed as kilowatt hour (kWh), per gross floor area (m²).' We applied an add on for CRE of 7 % for Gas and 12 % for Resi. / For Hotels gas/laundry needs to be added accordingly.

| | | | |
|---|---|---|---|
| | | EMA (2022): Singapore's power sector targets net-zero emissions by 2050. Online: https://www.straitstimes.com/singapore/environment/importing-more-clean-energy-among-ways-to-help-singapores-power-sector-reach-net-zero-emissions-by-2050-report. | compared to the one applied for the first version inkl. T&D losses). |
| **Energy mix & energy mix development** | 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 | Energy Market Authority (2018): Singapore Energy Statistics. | A revised energy-mix for commercial buildings, results in a lower weighed emission factor for commercial property. This results in a lower GHG-intensity in the baseline year.<br>For residential properties the starting point remains the same, however the grid decarbonization results in a steeper curve. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources / Notes** | / | | |

| IMPACT / REASONING | PATHWAY COMPARISON |
|---|---|
| **OFFICE kWh**<br>➔ Energy efficiency in Singapore has not improved in the last years, resulting in a largely identical starting point as in 2018.<br>➔ New energy targets result the pathway levelling off around 2035. |  |
| **OFFICE $CO_2$**<br>➔ A lower grid emission factor was used (without distribution and transmission losses).<br>➔ This results in a lower overall emission factor and hence a lower starting point. |  |
| **RESIDENTIAL kWh**<br>➔ Energy efficiency in Singapore has not improved in the last years, resulting in a largely identical starting point as in 2018. New energy targets result the pathway levelling off around 2025. |  |
| **RESIDENTIAL $CO_2$**<br>➔ Similar weighted EF and energy-intensity, results in the same starting point as previously. Due to a faster grid decarbonization, however, the curve is steeper. |  |

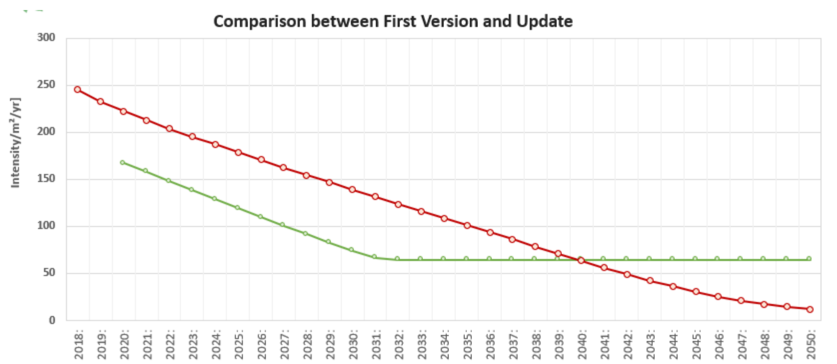
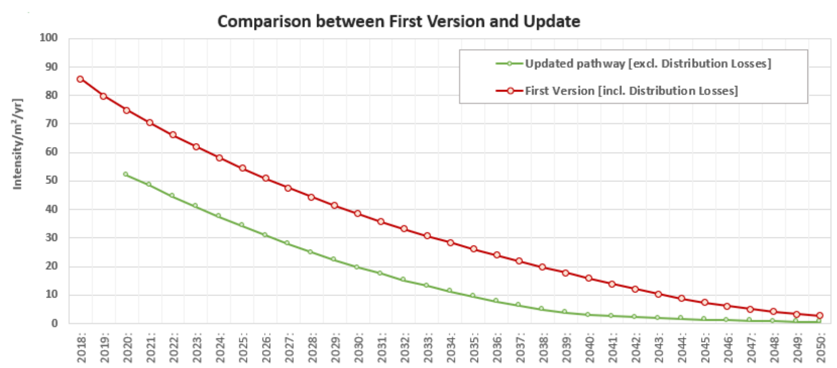
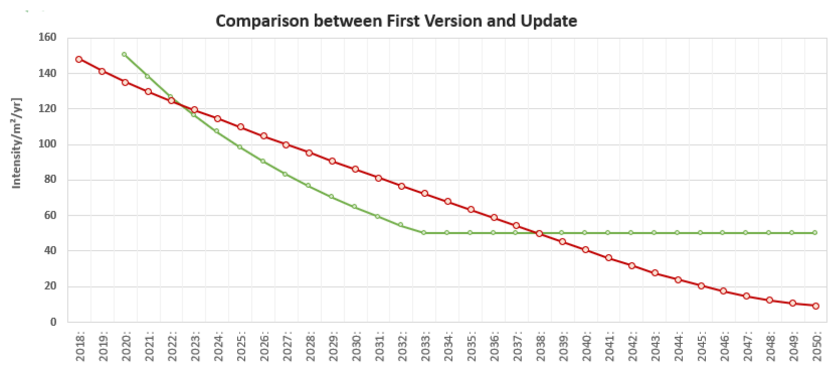
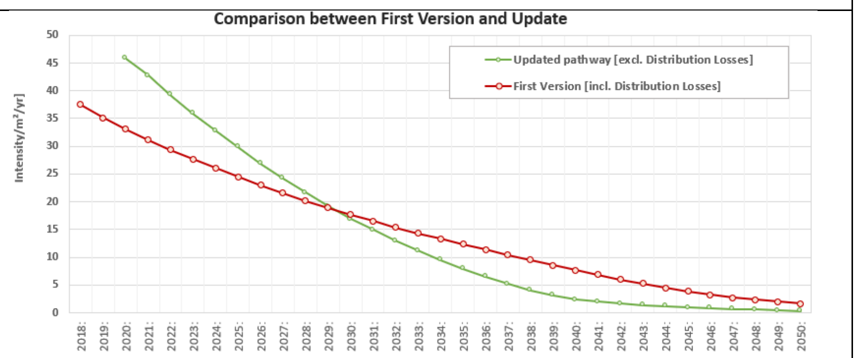
| PHILIPPINES (PHI) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **Building Stock** | Philippine Statistics Authority (2019): Construction Statistics from Approved Building Permits: Second Quarter 2019 (Preliminary Results). | Philippine Statistics Authority (2019): Construction Statistics from Approved Building Permits: Second Quarter 2019 (Preliminary Results). | No direct impact on the energy-intensity in the first year.<br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | Philippine Statistics Authority (2019): Construction Statistics from Approved Building Permits: Second Quarter 2019 (Preliminary Results). | Philippine Statistics Authority (2019): Construction Statistics from Approved Building Permits: Second Quarter 2019 (Preliminary Results). | If the increase is steeper to the previous GR, then via the SDA approach there is a decrease in intensities. |
| **Energy intensities – starting values [kWh/m²*a]** | Arcadis (2018): Arcadis Insider Environmental Sustainability 10-Year Anniversary Special Edition | Arcadis (2018): Arcadis Insider Environmental Sustainability 10-Year Anniversary Special Edition | Energy efficiency in the Philippines has not improved in the last years, resulting in a same starting point. |
| **Emission Factors & Development**<br>**($KgCO_2$/kWh)** | IGES Institute for Global Environmental Strategies (2019): IGES List of Grid Emission Factors. | IGES Institute for Global Environmental Strategies (2019): IGES List of Grid Emission Factors. | No new updated figures available for the Philippines. |
| **Energy mix & energy mix development** | IFC International Finance Corporation (n.y.): Green Buildings Market Intelligence. Philippines Profile. | IFC International Finance Corporation (n.y.): Green Buildings Market Intelligence. Philippines Profile. | / |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the Article 5 country phase down. |
| **Other Sources / Notes** | / | | |

| IMPACT / REASONING | PATHWAY COMPARISON |
| --- | --- |
| **OFFICE kWh**<br>➔ Energy efficiency in the Philippines has not improved in the last years, resulting in a same starting point.<br>➔ New energy targets result the pathway levelling off around 2032. |   |
| **OFFICE $CO_2$**<br>➔ A steeper starting point is a result of the improved data regarding F-Gases and all other GHG's. |   |
| **RESIDENTIAL kWh**<br>➔ Energy efficiency in the Philippines has not improved in the last years, resulting in a same starting point.<br>➔ New energy targets result the pathway levelling off around 2032. |   |
| **RESIDENTIAL $CO_2$**<br>➔ No updated values regarding the emission factor or grid decarbonization.<br>➔ A steeper starting point is a result of the improved data regarding F-Gases and all other GHG's. |   |

| United States of America (USA) | | | |
|---|---|---|---|
| **Input Parameter** | **Source 2018 / First Version** | **Source 2020 / Update** | **Impact on the pathway (country-level)** |
| **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.<br><br>U.S. Energy Information Administration (EIA) (2015): Commercial Buildings Energy Consumption Survey (CBECS) Table B7. Building size, floorspace, 2012,<br><br>U.S. Energy Information Administration (EIA) (2017): Residential Building Survey, 2015.<br><br>U.S. Census Bureau (2019): Quarterly Starts and Completions by Purpose and Design. | U.S. Energy Information Administration (EIA) (2020): Residential Energy Consumption Survey (RECS), Table HC10.1 Total square footage of U.S. homes, 2020<br><br>U.S. Energy Information Administration (EIA) (2015): Commercial Buildings Energy Consumption Survey (CBECS), Table B7. Building size, floorspace, 2015.<br><br>U.S. Census Bureau (2019): Quarterly Starts and Completions by Purpose and Design.<br><br>CoStar (2020): Floor Area: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi1w6q7n738AhXuQ_EDHecYBoAQFnoECBEQAQ&url=https%3A%2F%2Fwww.costar.com%2Fdocs%2Fdefault-source%2Fbrs-lib%2Fcostar_buildingratingsystem-definition.pdf&usg=AOvVaw2MEelTKoYLMVlcop0dzkOT.<br><br>Center for sustainable systems / University of Michigan (2019): Residential Buildings Factsheet. | No direct impact on the energy-intensity in the first year.<br><br>Generally, a slight increase for both residential and commercial floor area. |
| **Building Stock Development Residential / Commercial** | 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<br><br>Global Status Report (2017): Building Stock development for North America. | 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<br><br>NREL (2020): U.S. Building Stock Characterization Study. Online: https://resstock.nrel.gov/page/typology.<br><br>Global Status Report (2022): Building Stock development for North America. | Slight increase in the growth rate for CRE & Residential building stock until 2050. |
| **Energy intensities – starting values [kWh/m²*a]** | 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).<br><br>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<br><br>U.S. Energy Information Administration (EIA) (2017): Residential Building Survey, 2015. Table CE1.1 Summary | CBECS (2020): Commercial Buildings Energy Consumption Survey. Online: https://www.eia.gov/consumption/commercial/.<br><br>Energy Star (2020): U.S. Energy Use Intensity by Property Type, Portfolio Manager. Online: www.energystar.gov. | For the commercial sector: For most asset-types data from data partners have been used, indicating an improvement of efficiency in the sector over the past years.<br><br>The residential sector: A similar starting point shows no improvement in energy efficiency in the residential sector. |

| | | | |
|---|---|---|---|
| | annual household site consumption and expenditures in the U.S.—totals and intensities, 2015. | | |
| **Emission Factors & Development**<br><br>**[$KgCO_2$/kWh]** | EPA United States Environmental Protection Agency (2018): Emission Factors for Greenhouse Gas Inventories.<br><br>EIA U.S. Energy Information Administration (2019): Annual Energy Outlook 2019 with projections to 2050.<br><br>IEA U.S. Energy Technology Perspective (2017): Reference Technology Scenario (Building). | Carbon footprint (2022): Country Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com<br><br>IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data for USA. | Over the last years no significant improvement was recorded in regards to grid decarbonization.<br><br>Grid EF without distribution losses has been used. |
| **Energy mix & energy mix development** | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data. | IEA International Energy Agency (2017): Energy Technology Perspective 2017. Scenario data for USA. | A revised energy-mix for residential buildings, results in a higher weighed emission factor for residential property. This results in a higher GHG-intensity in the baseline year. |
| **Energy target 2050 [kWh/m²*a]** | No targets yet defined. | IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28. | Energy targets result a higher end-point in terms of energy-intensity by 2050. |
| **F-Gas/ 'e'** | UN (2022): Greenhouse Gas Inventory Data - Comparison by Category. Online: https://di.unfccc.int/comparison_by_category | | F-Gases have been attributed to the pathways respective to the USA country phase down. |
| **Other Sources / Notes** | 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<br><br>Center for sustainable systems / University of Michigan (2019): Residential Buildings Factsheet.<br><br>Center for sustainable systems / University of Michigan (2019): Commercial Buildings Factsheet.<br><br>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). | | |
| **Data Partner** | Energy Star, ULI Greenprint, LBNL | | |

| **USA – SUB REGIONS** | |
|---|---|
| **SOURCES** | **Energy intensities – starting values [kWh/m²*a]:**<br>- BPD (2022): Building Performance Database. Online: https://bpd.lbl.gov/explore (Site EUI).<br>**Energy targets:**<br>- IEA NZE (2020): Net Zero Emissions by 2050 Scenario (NZE), Table 03_28.<br>**Energy-mix:**<br>- IEA (2017): IEA Energy Technology Perspective 2017 – USA.<br>**EF Grid:**<br>- Carbon footprint (2022): Country & State specific Factors - Specific Electricity Grid Greenhouse Gas Emission Factors. Online: www.carbonfootprint.com<br>- NREL (2022): Scenario Viewer. Online: https://scenarioviewer.nrel.gov/?project=c3fec8d8-6243-4a8a-9bff-66af71889958&layout=Default%20Layout&mode=download |

| IMPACT / REASONING | PATHWAY COMPARISON |
| --- | --- |
| **OFFICE kWh**<br>➔ Starting values have been corrected and are now lower. Direct data from data partners have been used.<br>➔ A lower starting intensity in the baseline year results a lower starting point in the respective year, resulting a flatter curve.<br>➔ New energy targets result the pathway levelling off around 2031. |  |
| **OFFICE $CO_2$**<br>➔ Corrected weighted emission factor and lower energy intensities in the baseline year (due to improved energy efficiency in the last years) results in a lower starting point. |  |
| **RESIDENTIAL kWh**<br>➔ Starting values have been corrected and are now higher.<br>➔ New data from our data partners have been used. The starting point increased, showing that not enough measures have been undertaken in the past years.<br>➔ New energy targets result the pathway levelling off around 2032. |  |
| **RESIDENTIAL $CO_2$**<br>➔ A slightly higher weighted emission factor and a higher energy-intensity in the baseline year results a slightly higher GHG starting point. |  |