HOW TO CALCULATE GHG EMISSIONS IN THE BUILDINGS SECTOR

A STEP-BY-STEP GUIDE

INSTITUTO TORCUATO DI TELLA

PEEB
PARTNERSHIP FOR ENERGY EFFICIENCY IN BUILDINGS

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About PEEB Climate Finance Incubator
PEEB Climate Finance Incubator (CFI) is a programme under the umbrella of the Partnership for Energy Efficiency in Buildings (PEEB) that lays the foundation for climate finance through support for a clear data baseline on greenhouse gas emissions from buildings, pioneering work on Article 6 mechanisms for buildings, and innovative incentive mechanisms that mobilise private investments.

For more information, please visit https://peeb.build/peeb-climate-finance/.

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LIST OF ABBREVIATIONS

BAU	Business-as-Usual
CDM	Clean Development Mechanism
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air Conditioning
ICT	Information and Communications Technology
IPCC	International Panel on Climate Change
LCA	Life Cycle Assessment
MRV	Monitoring, Reporting and Verification
PV	Photovoltaic
ROI	Return on Investment
SER	The Sufficiency, Efficiency, Renewable Framework
UNFCCC	United Nations Framework Convention on Climate Change

SUMMARY: GHG EMISSIONS IN THE BUILDINGS SECTOR

This document is intended for public and private sector practitioners involved in efforts to reduce GHG emissions in buildings. It offers a standardised approach to calculate Greenhouse Gas (GHG) emissions in the buildings sector according to the building lifecycle.

In 2019, buildings accounted for 21% of global GHG emissions (12 GtCO_2-eq), with 57% from indirect emissions (electricity and heat), 24% from direct emissions (on-site energy use), and 18% from embodied emissions (materials like cement and steel) (International Panel on Climate Change – IPCC, Sixth Assessment Report). Buildings also consumed 31% of global final energy and 18% of global electricity, with residential buildings using 70% of total building energy demand. Between 1990 and 2019, CO_2 emissions from buildings increased by 50%, while energy and electricity demand grew by 38% and 161%, respectively.

Key drivers of increase in emissions include population growth, larger dwellings, inefficient new buildings, low renovation rates, and rising appliance use, especially for Information and Communications Technology (ICT) and cooling. Reliance on carbon-intensive energy sources further exacerbates emissions.

The Sufficiency, Efficiency, Renewable (SER) framework offers solutions. Sufficiency measures, like compact designs, shared spaces, and repurposed buildings, could cut 17% of sector emissions by 2050 (IPCC, Sixth Assessment Report). Efficiency improvements in appliances and construction will become standard by 2050, with low or zero additional costs in developed countries. Zero-energy and zero-carbon buildings are expanding, driven by integrated approaches that lower costs and prevent lock-in effects. The 2020–2030 decade is crucial for accelerating skills, achieving cost reductions, and scaling up high-efficiency buildings to fully decarbonise the sector.

Given the contribution of the buildings sector to global GHG emissions, it is important to be able to calculate how much carbon emissions a singular building produce. Such calculations must include embodied carbon from the manufacturing and shipping of construction materials, as well as the emissions from the construction and operations of the building. In summary, the entire lifecycle of a building must be considered in the calculations.

Data collected from these calculations can be used to verify the financial benefits of investing in energy efficiency in buildings. In many countries, there is insufficient information on long-term cost benefits, such as energy bill savings, maintenance cost reductions and a potential increase in property value. The lack of a standardised emissions calculation methodology (with lifecycle and cost-benefit analysis) makes it difficult to accurately assess and communicate the return on investment (ROI) of adopting energy efficiency standards.

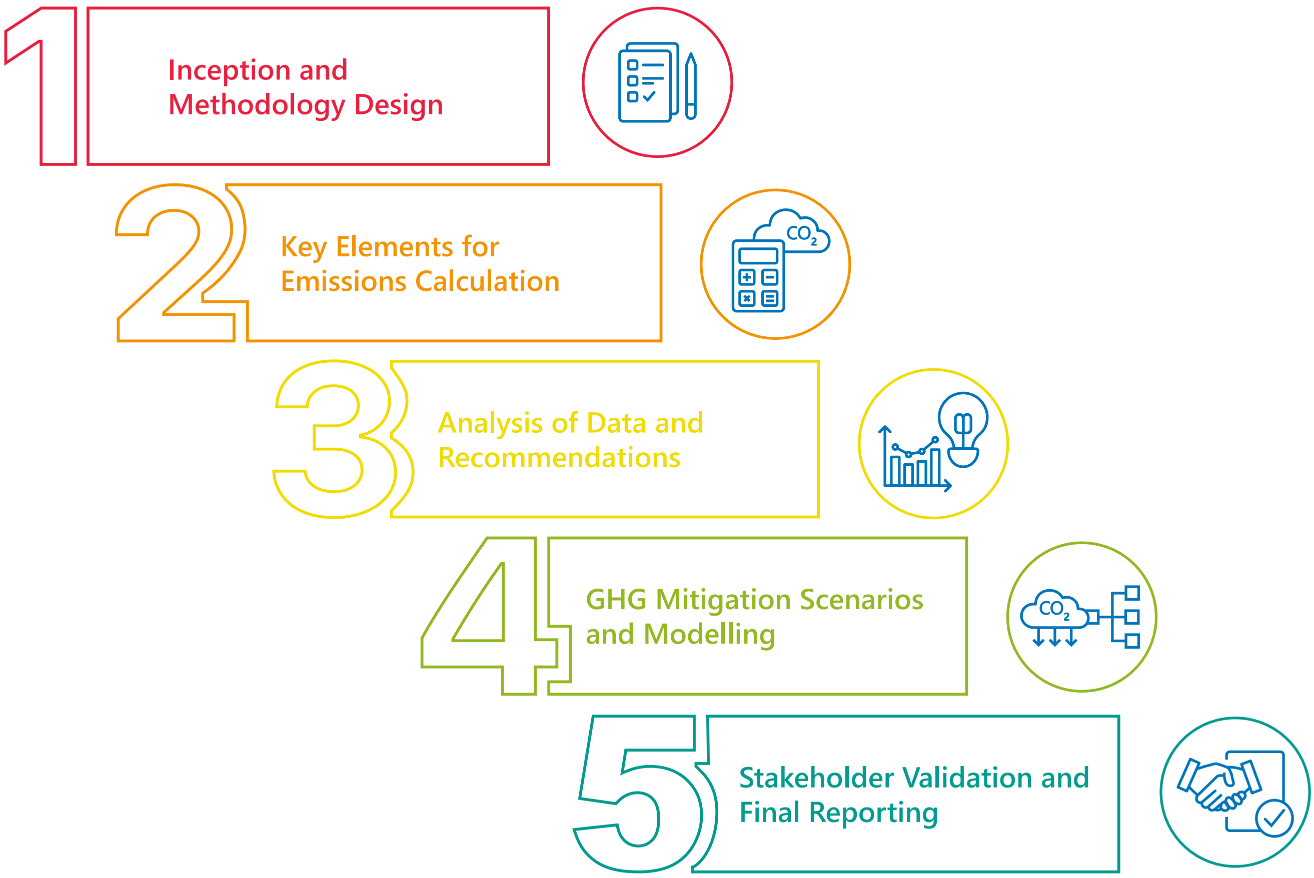
OBJECTIVE OF CALCULATING GHG EMISSIONS IN THE BUILDINGS SECTOR

The calculation of the baseline GHG emissions of a singular building will begin with an analysis of the carbon emitted at each stage of the lifecycle of a building. This includes emissions from insufficient design, construction, the energy consumption from operation of the building, and disposal.

Following this, there are mitigation scenarios that could help assess the potential impact of policies or technological measures on emission reductions. Finally, this information, as well as a consideration of future emissions drivers, will allow for forecasts and projections of future emissions calculations.

FIVE STEPS TOWARDS EMISSIONS QUANTIFICATION

Calculating direct and embodied GHG emissions in the buildings sector can be done in five steps.



Step 1 | Inception and Methdology Design

Developing a context-appropriate methodology for calculating GHG emissions in the buildings sector is a foundational step for evidence-based decision-making. This process should draw on internationally recognised standards and norms, including the IPCC Guidelines for National GHG Inventories, ISO 14064 International Standard for GHG Emissions Inventories and Verification, the GHG Protocol for Buildings, and the EN 15978:2011 standard for life cycle assessment in buildings.

There are established approaches under the Clean Development Mechanism (CDM), widely used voluntary standards such as developed by Verra and the Gold Standard, and the emerging Article 6.4 methodologies. These methodologies define how baseline development, additionality testing, and Monitoring, Reporting and Verification (MRV) should be done.

The figure below, taken from the United Nations Framework Convention on Climate Change (UNFCCC) CDM Booklet, lists methodologies related to energy efficiency interventions in households and the buildings sector.

Cookstove	AMS-II.C.	AMS-II.G.		
Water pumping	AMS-II.C.	AMS-II.S.		
Water purifier	AM0086	AMS-II.C.	AMS-III.AV.	
Water saving	AMS-II.M.			
Refrigerators/chillers	AM0060	AM0070	AM0120	AMS-II.C.
	AMS-II.O.	AMS-III.X.		
Lighting	AM0046	AM0113	AMS-II.N.	AMS-II.J.
	AMS-II.L.	AMS-II.N.	AMS-III.AR.	
Whole building	AM0091	AMS-II.E.	AMS-II.Q.	AMS-II.R.
	AMS-III.AE.			
Others/various technologies	AMS-II.C.	AM0117		

Methodologies for Calculating GHG Emissions Related to Energy Efficiency Interventions in Households and the Buildings Sector. UNFCCC, Clean Development Mechanism Booklet

However, to ensure relevance and applicability, countries must adapt these methodologies to reflect their national circumstances, local data availability, climate action policies, and construction sector characteristics.

Methodology development should begin by identifying the building lifecycle stages relevant to the national context. These typically include:

- **Design:** involving planning documents, blueprints, and the selection and manufacturing of materials
- **Construction:** encompassing the transportation of materials and construction site activities
- **Operations:** covering the full spectrum of energy use within the building, including heating, cooling, and lighting
- **Disposal:** addressing deconstruction, demolition processes, and material disposal at end-of-life

A) Key buildings categories

The methodology should also account for key building categories that reflect the structure of the national built environment. At a minimum, this could include:

- Residential buildings (e.g. housing and apartment blocks)
- Commercial buildings (e.g. office spaces and retail facilities)
- Public health facilities (e.g. clinics and hospitals)
- Education buildings (e.g. university campuses, schools)

In addition to the building category, it would be needed to consider other factors: building typology, urban or rural location and climate zone.

Residential buildings could be divided into sub-categories, according to the income of the people in the neighbourhood and size. Industrial buildings and government buildings may require specific methodologies for each building.

To estimate embodied emissions, the methodology should identify and classify materials commonly used in construction, such as:

- Cement and concrete
- Steel
- Windows, particularly those using aluminium frames and glass
- Wood and wood-based composites

A well-designed data collection strategy is critical for accuracy and comprehensiveness. Countries should combine desk-based reviews of available documents (e.g. energy audits, construction blueprints, prior assessments, Life Cycle Assessment studies) with primary data collection, including surveys and interviews with relevant stakeholders such as hospital administrators, construction companies, and building operators. To enhance buy-in and validation countries are encouraged to engage key stakeholders early in the process. This allows for review and feedback on the proposed methodology and helps confirm the feasibility of data collection given available resources and information systems.

Ultimately, the national methodology should be seen not as a static technical exercise but as an enabling tool to align GHG emissions tracking with national policy objectives, building code development, and long-term low-emissions development strategies. Like all good policy instruments, it should be ambitious yet practical – reflecting current capacities, while also encouraging sector-wide transformation through data-informed interventions.

B) Definitions: baseline and project emissions

Baseline emissions are the emissions corresponding to the business-as-usual (BAU) scenario. In the case of buildings, baseline emissions are the emissions resulting from the construction and the operation of the building that would have been built in the absence of policies and measures aiming for emissions reductions. In the case of retrofit of a building, baseline emissions are the emissions resulting from the operation of the project building without any change.

Project emissions are the emissions resulting from the construction and operation of the project building.

C) Approaches to determine baseline and project emissions

The methodology must consider two different cases:

1) new buildings and

2) retrofit of existing buildings.

CO_2	**Baseline emissions**	**Project emissions**
New buildings 	Emissions from the construction and the operation (use) of the building that would have been built in the absence of the policies and measures to reduce emissions from buildings	Emissions from the construction and the operation (use) of the new project building
Retrofit of existing buildings 	Emissions from the operation (use) of the existing building before the retrofit	Emissions from the retrofit and the operation (use) of the project retrofitted building

Step

2

Key Elements for Emissions Calculation

Once the national GHG emissions calculation methodology has been developed and adapted to the local context, the next step involves calculating the emissions across the entire lifecycle of the buildings. This calculation is essential to identify the key emission sources and quantify their magnitude, which in turn enables prioritisation of mitigation actions. Following the calculation at each stage of the building lifecycle, the data must be summarised and presented in a coherent manner for analysis and evaluation in the following steps.

First, it is important to consider the activities across the lifecycle of the building. In this case, energy consumption and technical data specific to the building can be gathered using energy bills, blueprints and energy audits. The activity data must be accompanied by emission factors, which correspond to the greenhouse gas emissions per unit of the activity.

The estimation of activity data for the production/design, construction and use would require a database of the buildings of similar typology and similar climate region that have been built in the last five years. To develop this database, consultations with local experts and key stakeholders will be needed.

Emissions factors can be taken from local information utilized to prepare the National Inventories or from internationally accepted guidelines such as the IPCC Emission Factor Database.

The formula for calculating baseline and project GHG emissions is as follows:

GHG Emissions = Activity Data × Emission Factor

To ensure comprehensive coverage, the baseline should assess activities across four main building lifecycle stages:

PRODUCT/DESIGN STAGE	CONSTRUCTION STAGE	USE STAGE	END OF LIFE STAGE
• Types of materials • Quantities of materials	• Transportation • Construction processes	• Operations of buildings • Energy / water consumption	• Demolishing or repurposing of building

PRODUCT/DESIGN STAGE

Projects should begin by identifying the quantities and types of materials used in typical building construction or renovation – such as cement, steel, aluminium-framed windows, and wood-based products. Emissions at this stage are calculated by multiplying the material quantities (per tonne or another unit of measurement accepted by international standards) by their respective embodied emission factors, derived from the National Inventories or from reliable sources like the IPCC. This quantification provides insight into the upstream climate impacts of material production and processing and allows for comparison across building types and categories.

For the case of buildings retrofit, it is necessary to compare the emissions from the period before the retrofit with the emissions after the retrofit. To determine the emissions before the retrofit, it is necessary to collect information on parameters that are presented in the Use stage section for a period (e.g. five years) before the retrofit.

CONSTRUCTION STAGE

At this stage, emissions arise from the transportation of materials to the construction site, from the energy and water used during construction processes and from the waste disposed during this stage. Construction and renovation operations include the use of machinery to assemble building components into finished structures, as well as the removal of waste biproducts. The activity data gathered includes:

- Estimate the material inputs (in tonnes) required for construction
- Determine average transportation distances and the modes of transport (road, rail, water)
- Apply standard fuel use rates (litres of fuel per tonne-km) for each material and transport mode
- Factor in material-specific characteristics (e.g., lighter materials may require more trips per tonne)
- Multiply tonnage, distance, and fuel rates to determine total fuel consumption, then apply fuel-specific GHG emission factors to derive emissions

This approach allows for a granular understanding of transport-related emissions and identifies hotspots where interventions (e.g., local sourcing, transport mode shifts) can reduce impacts.

USE STAGE

The activities at the use stage of the building lifecycle are characterised by the operations of the building including heating/cooling, lighting, energy consumption, water consumption and more. Emissions during building use are among the most persistent and significant, especially in urban environments. The emissions calculated here must include monitoring of activity data of the following parameters:

- Electricity use for lighting, appliances, ICT equipment, and Heating, Ventilation, and Air-Conditioning (HVAC) systems
- District heating/cooling and other off-site energy sources
- Direct fossil fuel and biomass (renewable or non-renewable) use for cooking, water heating, and space conditioning
- On-site renewable energy generation (e.g., solar photovoltaic [PV], solar thermal, heat pumps)

It is important to consider the number of occupants of a building, the periodic maintenance incurred, and other systems at work. In addition to direct energy consumption, emissions from ongoing maintenance, repairs, and renovations should be included to reflect the dynamic nature of building use over time.

END OF LIFE STAGE

This final lifecycle stage encompasses the emissions associated with demolishing or deconstructing the building, transporting and disposing of materials, and any material reuse or recycling activities. These emissions can be significant, especially in urban redevelopment scenarios, and should be included in the baseline to enable circular economy planning and end-of-life emissions mitigation. Therefore, it is important to gather activity data of all the end-of-life processes to calculate correctly the emissions.

Step
3

Analysis of Data and Recommendations

Once all the data has been calculated, a thorough analysis is required to make informed recommendations for emissions reductions. In-depth analysis is needed to examine future emission pathways, which can also be impacted by changes in climate conditions (e.g. higher temperatures) or market dynamics (e.g. widespread adoption of more efficient technologies). A sensitivity analysis of changing electricity grids and fuel mixes may be useful in this case. The analysis of the data and calculations should identify data gaps and propose improvements in data collection and emissions in the country for future baseline studies.

Recommendations can include methodologies for improving data collections systems for buildings, strengthening material efficiency standards and finally integrating GHG monitoring into green building certifications. It is important that any policy recommendations are clear and actionable. These models must include detailed analysis and calculations on the material substitutions or efficiency upgrades such as insulated windows, use of low-carbon materials, or sourcing them locally. Other building systems' improvements related to HVAC or integrating renewable sources of energy must also be factored in.

It may be pertinent to perform a lifecycle cost-benefit assessment of the recommendations and changes for energy efficiency. In this way, one can link GHG reductions to financial and operational savings.

Step **4**

GHG Mitigation Scenarios and Modelling

Following the calculation of the emissions activity and emissions factors, it is important to consider how to mitigate GHG emissions in the future. For this reason, this step is centred around modelling mitigation scenarios and projections based on the biggest drivers of emissions.

Firstly, it is recommended to model a BAU scenario in order to project the GHG emissions of the buildings sector over a certain period. The project provides insight into the state of the buildings sector and its emissions in the absence of intervention.

Projecting future GHG emissions reductions and patterns demands consideration of the key drivers of emissions in the future. This includes demand of different materials for construction, the technical advancements of the sector, changes in cost of living, population and behaviour, as well as socioeconomic development of the country. Other political, market and sectoral trends may also be factored into the assessment.

Secondly, a projection of the GHG emissions under an intervention scenario (based on the recommendations from the previous step) must be conducted for later comparison with the BAU scenario. This comparison will show whether the recommendations for intervention in the sector will have an impact in reducing emissions and can later be used for implementation purposes.

When it comes to modelling GHG reduction potential, project interventions may include:

- Material substitutions or efficiency upgrades (e.g., better insulated windows, low-carbon cement, local sourcing)
- Building system improvements (e.g., efficient HVAC, refrigerant replacement, renewable energy integration)

To compare the GHG emissions under an intervention scenario with the BAU scenario, a cost-benefit analysis should be conducted. This involves estimating both the direct and indirect costs associated with implementing each intervention and quantifying the benefits. The analysis enables assessment of impact or returns on investment in terms of climate impact and economic viability of the recommendations for intervention and helps relevant stakeholders make informed decisions about which interventions are most cost-effective and scalable.

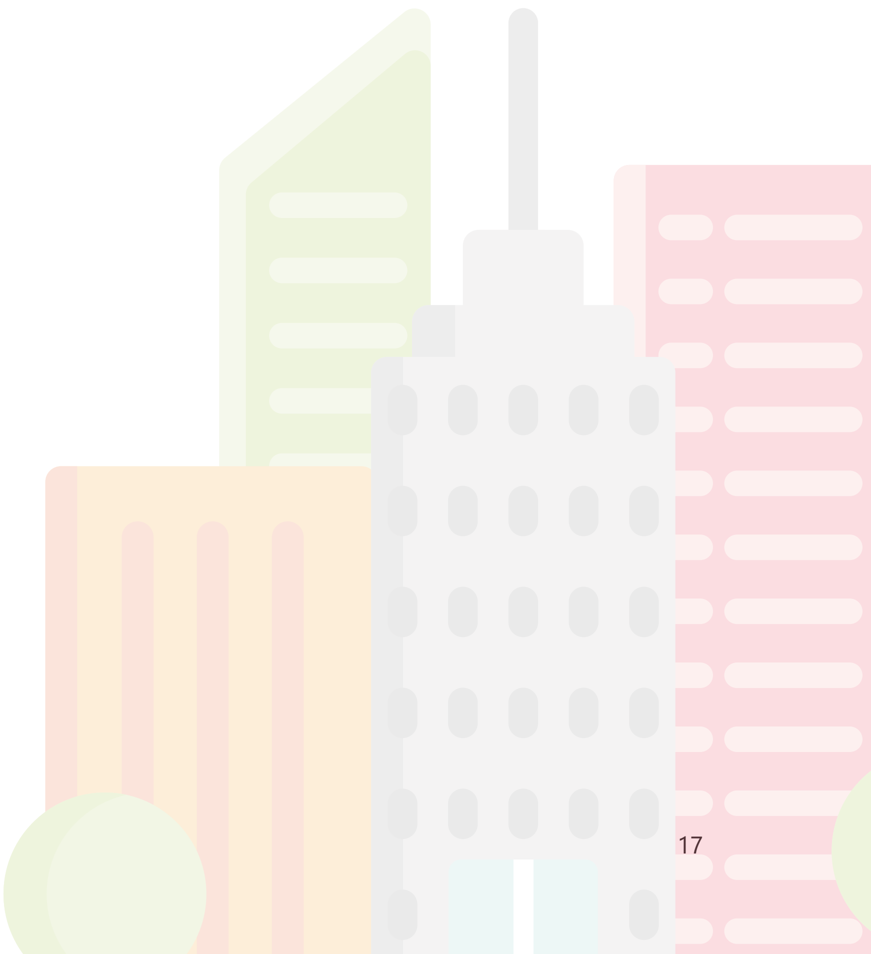
Step 5 | Stakeholder Validation and Final Reporting

After calculations and projections will have been completed, a draft report will be compiled and presented for review to relevant stakeholders (including government ministries, private sector experts, etc.). This should incorporate clear results of the baseline calculations, emissions at each stage of the building lifecycle, BAU scenarios, forecasting and projects of future emissions. This step is crucial not only to gather feedback on the robustness of the methodology, but also to review the recommendations based on the calculated data. It is important here to consider the original objective of the study, which may include creating policies or recommendations for scaling up low-emission practices. The feedback should be integrated into any proposal on future implementation of energy efficiency or low carbon practices.

OUTPUTS

Key deliverables

Number	Deliverables
1	• Inception report with building typologies, selected materials, methodology, data collection approach, and work plan
2	• Baseline GHG emissions for each building and material type • Summary of energy efficiency and thermal performance
3	• Analysis of data and recommendation proposals including marginal abatement costs and comparative analysis
4	• Mitigation scenario planning with future emission pathways, comparison of BAU and intervention scenarios
5	• Final report and stakeholder feedback



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