ANALYSIS OF LIFE-CYCLE GREENHOUSE GAS EMISSIONS OF EU BUILDINGS AND CONSTRUCTION

FUTURE AVAILABILITY AND GENERATION OF DATA

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1. INTRODUCTION

This report is part of the project 'Analysis of life-cycle greenhouse gas emissions of EU buildings and construction', representing the deliverable D5.2, called Report on "Future availability and generation of data".

1.1 Objective

The objective of subtask 5.2 "Future availability and generation of data" is both to provide recommendations[1] on improving data availability and its quality (along with data generation processes) beyond the lifetime of the project as well as to devise a methodology to ensure the monitoring and continuous improvement of the dataset conceived at T3.2 ("Collection or generation of new data"), so to support future endeavours concerning the modelling of whole-life carbon (WLC) emissions and carbon removals at the building stock level.

1.2 Methodology, structure and content of the report

To carry out this task while aligning from the format of D.3.2 ("Collection or generation of new data") - and thereby ensuring continuity along the project -, **section 2** classifies the data needs collected in D.3.2 into specific categories.

Following this, **section** Error! Reference source not found. presents a series of recommendations aimed at improving the future availability and generation of data. These recommendations (based on input from previous reports and stakeholder engagement activities from the project along with additional research on the matter) are divided in two main types ("targeted" and "general"), each in a different subsection. On the one hand, **subsection 3.1** directly builds on this this classification in data categories made at section 2 to issue targeted recommendations, clearly described and accompanied by specific suggested actions for implementation and the main actors that would be involved to carry them out. On the other hand, **subsection 3.2** deals with general recommendations (applicable independently of the data category), aimed at the implementation of techniques intended to be consistently applied in future data collection and subsequent processing or generation efforts.

Then, **section 4** presents a methodology centred around these defined categories of data needs so to monitor and ensure the continuous improvement of the dataset produced in D3.2.

The report concludes with a summary of main findings, providing an overall analysis of the recommendations made to improve future availability and generation of data. It also explains the main characteristics of the methodology designed to monitor and continuously improve the dataset, so to provide guidance for decision-making purposes regarding their implementation in the future.

1.3 Executive summary

To present the main results of this report in a concise format, a series of summary tables are included. These tables provide an overview of section **Error! Reference source not found.** (on recommendations to improve future availability and generation of data) and section 3.2 (on providing a methodology for monitoring and continuous improvement of the dataset produced in D.3.2 "Collection or generation of new data)

[1] The recommendations were issued over and uniquely concern the data collected throughout D.3.2 ("Collection or generation of new data")

The targeted recommendations to improve future availability and generation of data identified per category of collected data needs are listed in the table 1 below and are allocated in different columns based on the implementability level of the suggested actions for their materialization (duly justified in section **Error! Reference source not found.**). To this end, three different implementability levels were defined as follows:

- **Easy to implement**. The suggested action(s) for the implementation of the recommendation present little challenges and the conditions for their execution are deemed favourable.
- **Moderately challenging to implement**. Mixed. The suggested action(s) for the implementation of the recommendation either require a significant effort with favourable conditions or even if the conditions are challenging, the efforts required aren't considerable.
- **Difficult to implement**. The suggested action(s) for the implementation of the recommendation require of significant effort and the conditions for their execution are deemed challenging.

Additionally, the assessed level of priority for each of these recommendations is provided, according to the potential impact in improving the model's accuracy and/or the data sourcing of its inputs. This assessment makes use of the scale presented below, used to highlight the recommendation name at Table 1:

- **Low priority**: The implementation of a recommendation categorized as such won't render significant improvements in the model accuracy or the data sourcing of its inputs, not at least for the core elements.
- **Medium priority**: The implementation of a recommendation categorized as such would have a noticeable effect in terms of accuracy of the model or the data sourcing of its inputs, at least for the core parts.
- **High priority**: The implementation of a recommendations categorized as such will have a significant impact in improving the accuracy of the model's outputs or the data sourcing of its inputs at the core parts.

Table 1. Targeted recommendations by data need category and implementability level, highlighted according to their assesed level of priority.

Data need category	Easily implementable recommendations	Moderately challenging to implement recommendations	Difficult to implement recommendations
Building stock general characteristics (BSTK)		• Enhance reporting on demolition activities across the EU	• Increase granularity level on new construction data
Construction materials (CMAT)	• Promote standardized reporting frameworks at the EU Level • Increase granularity of official databases		• Incentivize national data collection initiatives and transnational technical support collaboration

	concerning waste production		
Energy systems and on-site power generation (ENSY)		• Enhance granularity in renewable energy adoption tracking • Harmonize reporting practices on heating and cooling systems across the EU building stock	
Environmental impact and circularity (ENVI)	• Facilitate open access to emission factors via a central EU repository	• Develop a quantification method for WLC strategy conditions • Support the reporting on CCU, CCS, and CR strategies to national reporting requirements	
Forestry (FSTY)		• Standardize forestry stock and harvest reporting across countries	• Improve long-term projections of forest stock and harvest rates
Housing and occupancy (HSNG)		• Promote use of administrative registers and property tax records to improve housing data granularity • Include buildings metadata in rental statistics collection	
Transport and logistics (TRAN)		• Reinforce compliance on mandatory minimum reporting standards on freight transport for all EU countries • Support digital data collection solutions for freight transport across the EU	

As a complement to the table above, a summary of the involved actors and their roles for the implementation of the recommendations is provided in Table 2:

Table 2. Involved actors and their roles for the implementation of the targeted recommendations.

Data category	Recommendation name	Actors and roles
Building stock general characteristics (BSTK)	Enhance reporting on demolition activities across the EU	• ***National Governments*** *– Leading* • ***EU Institutions*** *(e.g., Eurostat, DG GROW) – Collaborating* • ***Regional and Local Authorities*** *– Collaborating* • ***Research organizations*** *- Being informed/ Collaborating*
	Increase granularity level on new construction data	• ***EU Institutions*** *(e.g., Eurostat, BSO responsibles) – Leading* • ***National Governments*** *– Collaborating* • ***Research organizations-*** *Collaborating* • ***Regional Authorities*** *– Being informed/Collaborating*
Construction materials (CMAT)	Promote standardized reporting frameworks at the EU Level	• ***EU Institutions*** *(e.g., DG ENV, Eurostat) - Leading* • ***National Governments -*** *Collaborating* • ***Research organizations -*** *Collaborating*
	Increase granularity of official databases concerning waste production	• ***EU Institutions*** *(e.g., Eurostat)* ***–*** *Leading* • ***National Governments –*** *Collaborating* • ***Industries (construction, recycling) –*** *Being informed / Collaborating*
	Incentivize national data collection initiatives and transnational technical support collaboration	• ***EU Institutions*** *(e.g., DG REGIO, DG ENV) – Leading* • ***National Governments (From lagging countries) –*** *Collaborating* • ***Front-runner National Governments –*** *Collaborating* • ***Research organizations –*** *Collaborating* • ***Industries*** *(data service providers, construction sector) – Being informed*
Energy systems and on-site power generation (ENSY)	Enhance granularity in renewable energy adoption tracking	• ***EU Institutions*** *(e.g., DG ENER, JRC, BSO responsibles)* ***–*** *Leading* • ***National Governments –*** *Collaborating* • ***Regional/Local Authorities –*** *Collaborating* • ***Research organizations*** *- Collaborating* • ***Industries*** *(EPC auditors, Solar panels manufacturers, tech firms) – Being informed/Collaborating*
	Harmonize reporting practices on heating and cooling systems	• ***EU Institutions*** *(e.g., DG ENER, Eurostat, BSO responsibles) – Leading* • ***National Governments –*** *Collaborating* • ***Regional/Local Authorities –*** *Being informed / Collaborating* • ***Research organizations -*** *Collaborating* • ***Industries*** *(HVAC sector, EPC professionals) – Being informed*

Environmental impact and circularity (ENVI)	Develop a quantification method for WLC strategy conditions	• ***EU Institutions*** *(e.g., JRC, DG CLIMA, DG ENV)* **– *Leading*** • ***Research organizations*** *- Collaborating* • ***National Governments*** *– Being informed/Collaborating*
	Support the reporting on CCU, CCS, and CR strategies to national reporting requirements	• ***EU Institutions*** *– Leading* • ***National Governments –*** *Collaborating* • ***Industries*** *(especially heavy industry)* **–** *Collaborating/Being informed* • ***Research organizations -*** *Collaborating*
	Facilitate open access to emission factors via a central EU repository	• ***EU Institutions*** *(e.g., JRC, Eurostat) – Leading* • ***National Governments –*** *Collaborating* • ***Research organizations*** *- Collaborating* • ***Civil society*** *(NGOs, think tanks) – Being informed*
Forestry (FSTY)	Improve long-term projections of forest stock and harvest rates	• ***EU Institutions*** *(e.g., DG ENV, JRC) – Leading* • ***National Governments*** *(e.g, Forestry Agencies)* **–** *Collaborating* • ***Private Sector*** *(Forestry companies)* **–** *Being informed/Collaborating* • ***Research organizations & Tech developers –*** *Collaborating*
	Standardize forestry stock and harvest reporting across countries	• ***EU Institutions*** *(e.g., DG ENV, Eurostat, JRC) – Leading* • ***National Governments*** *(e.g., Forestry Agencies) – Collaborating* • ***International Organizations*** *(e.g., FAO) – Collaborating* • ***Research organizations & Civil society –*** *Being informed*
Housing and occupancy (HSNG)	Promote use of administrative registers and property tax records to improve housing data granularity	• ***National Statistical Institutes*** *– Leading* • ***Tax Authorities/Land Registries*** *– Collaborating* • ***EU Institutions (e.g., Eurostat)*** *– Collaborating* • ***Data Protection Authorities*** *– Being informed/Collaborating*
	Include buildings metadata in rental statistics collection	• ***National Statistical Institutes –*** *Leading* • ***Private Rental Platforms/Agencies –*** *Collaborating* • ***EU Institutions (e.g., Eurostat) –*** *Collaborating* • ***Civil society (Tenants, Landlords) –*** *Being informed / Collaborating*
Transport and logistics (TRAN)	Reinforce compliance on mandatory minimum reporting standards on freight transport for all EU countries	• ***EU institutions*** *(DG MOVE, Eurostat)* **–** *Leading* • ***National Governments*** *(Transport Ministries)* **-** *Collaborating* • ***National Statistical Institutes –*** *Collaborating* • ***Transport sector stakeholders*** *(e.g., freight associations) – Being informed/Collaborating*
	Support digital data collection solutions for freight transport across the EU	• ***EU institutions*** *(DG MOVE, Eurostat) – Leading* • ***National Governments*** *(Transport Ministries) – Collaborating* • ***Technology providers & Logistics companies –*** *Collaborating*

- ***Transport sector stakeholders*** *(e.g., freight associations) – Being informed/Collaborating*

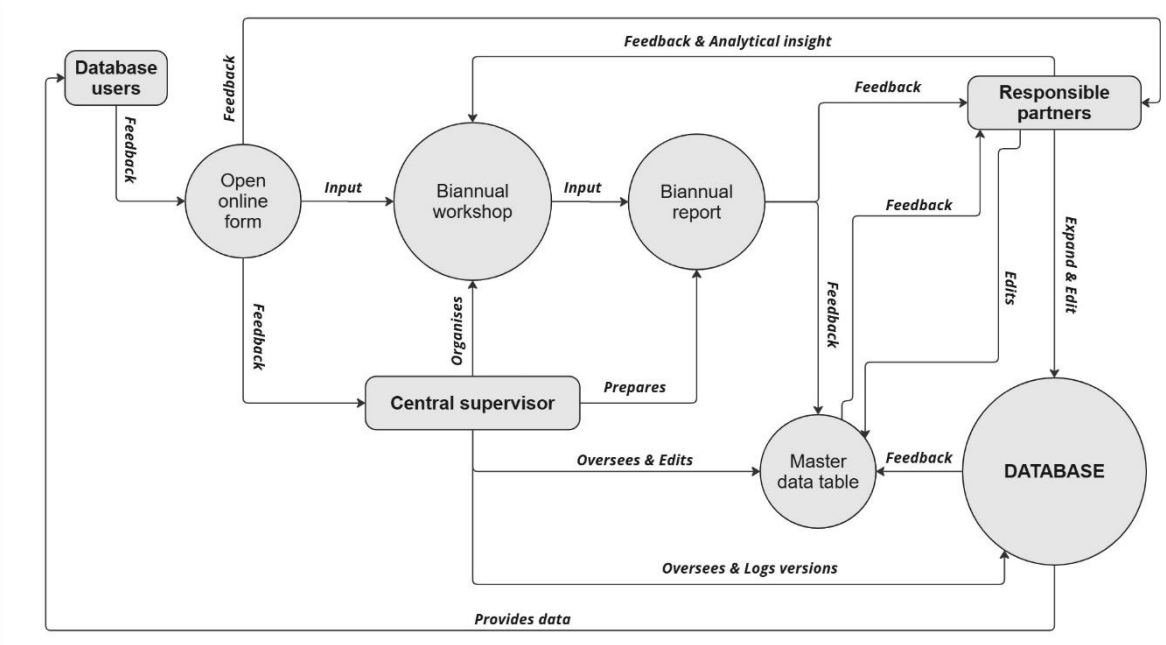
Adding to these category-specific, targeted recommendations, a series of general ones were also devised, meant to be always considered through future data collection and post-processing/generation efforts intending to optimize data quality by minimizing the effect of data flaws. These general recommendations (a total of 8) are presented below at Table 3, divided in two groups, (on improving data quality and data generation), according to which aspect of data sourcing they apply.

Table 3. General recommendations identified to improve data quality and data generation.

Data quality related general recommendations	Data generation related general recommendations
Apply cross-source consistency checks	**Apply interpolation and/or extrapolation**
Reorganizing or regrouping data to identify inconsistencies	**Fill missing values with a similar level of granularity**
Compare datasets to flag outlier data points	**Consider using alternative data granularities**
	Consider substitution with an alternative data need
	Consider the creation of new datasets deriving from existing ones

Finally, and with respect to the methodology conceived to monitor and ensure the continuous improvement of the dataset from D.3.2, the flow diagram below represents the devised data governance to this end, with the series and interrelations of actors, actions, roles and processes involved.

Figure 1. Data governance system for monitoring and continuous improvement of the database developed in D.3.2 ("Collection or generation of new data") ***Source: Own work***



2. IDENTIFIED CATEGORIES OF COLLECTED DATA NEEDS

This section presents a categorization of the collected data needs from D.3.2 ("Collection or generation of new data") . This categorization was done over the basis of the high correlation level observed among different groups of data needs as inputs to WLC modelling, and enabled the possibility to issue thematic recommendations aimed at improving future data availability and generation of data in the next section of the report.

The categories used for data clustering are:

- **Building stock general characteristics (BSTK),**
- **Construction materials (CMAT),**
- **Energy systems and on-site power generation (ENSY),**
- **Environmental impact and circularity (ENVI),**
- **Forestry, (FSTY)**
- **Housing and occupancy, (HSNG)** and
- **Transport and logistics (TRAN)**.

Table 4 presents the identified categories of collected data needs along with their description, as well as the collected data needs concerned by it. To complement this information, a full list of collected data needs from D.3.2 ("Collection or generation of new data") is also presented in the appendix, featuring also the new suggested code for each of them (In the original order following the codes from D.3.2 at Table-A 1 and clustered by categories ordered by the new suggested codes at Table-A 2), more coherent with the structure of the data governance system outlined in section 3.2.

Table 4. Identified categories of data needs with related abbreviation, description and enumeration of concerned data needs collected in D.3.2 ("Collection or generation of new data")

Category name with abbreviation	Description	Concerned D.3.2 collected data needs
Building stock general characteristics (BSTK)	It covers data on the number, type, and main statistical, geometrical and insulation level characteristics of buildings across different countries, such as floor area, occupancy levels, U-values (insulation performance), and construction/demolition trends. This type of data is fundamental to properly assess energy efficiency, magnitude of material requirements, and future trends in building development.	A1.1, A2.1, A3.1, A3.2, A5.1, A6.1, A7.1, A8.1, P10, P11, P14.1, P14.2, AD7, AD8 and AD9
Construction materials (CMAT)	This type of data needs revolve around the materials used in buildings and their lifecycle, such as their availability, prevalence in the building stock, replacement cycles, recycling rates and waste production. As construction materials play a fundamental role in determining the environmental, economic, and operational impacts of a building over its entire lifespan, this category of data is of paramount importance within the project.	A9.1, A10.1, A10.2, A14.1, A14.2, A15.1, A15.2, A16.1 and A16.2
Energy systems and on-site power generation (ENSY)	It includes data on heating, cooling, and on-site renewable energy production in buildings. Tracking these	A4.1, A4.2, AD12.1, AD12.2, AD13.1 and AD13.2

	metrics helps to assess progress on terms of energy efficiency in the building stock through active measures.	
Environmental impact and circularity (ENVI)	It covers data related to carbon emissions of energy carriers, circular economy strategies (CCU, CCS, CR), and waste management processes such as recycling and landfill rates. It thus provides insights into how materials, construction practices and energy systems contribute to emissions and environmental degradation and what strategies can minimize their impact.	A20.1, A21.1, A22.1, A23.1, P5, P6, P8, P19, AD4 and AD11
Forestry (FSTY)	This category includes data on forest stocks, harvest rates, and the availability of wood-based materials. Forestry is not simply a key resource for construction materials (e.g., timber) but also plays a very important from a WLC perspective, functioning as a carbon sink in the right conditions. The motivation behind this category is to track wood supply for construction within reasonable limits for forests to hold their capacity to provide a positive net effect in terms of reducing carbon emissions linked to the building sector.	A17.1, A17.2, A18.1, A18.2, and A19.1
Housing and occupancy (HSNG)	It focuses on residential trends, including household size, occupancy rates, overcrowding, and rental statistics. These factors influence housing demand, construction needs, and energy consumption patterns and allows to understand how people use residential space, which is key to design housing policies and future urban planning.	P15, P16, P17, P18.1, P20.1, P21.1, P22.1, and AD6
Transport and logistics (TRAN)	It deals with transportation distances, routes, and modes related to both construction materials and waste. Optimization of transport efficiency can contribute to reducing costs and emissions, hence its importance.	AD1.1, AD1.2, AD1.3, AD2.1, AD2.2 and AD2.3

3. RECOMMENDATIONS TO IMPROVE FUTURE AVAILABILITY AND GENERATION OF DATA

To provide targeted recommendations for improving future availability and generation of data by category of data need, a thorough analysis of the data gaps encountered along previous stages of the project was conducted, particularly those highlighted in section 5.1. of D.3.2 ("Collection or generation of new data"). These category-specific (targeted) recommendations are addressed in section 3.1.

In addition to these targeted recommendations, a set of general recommendations, based on the implementation of techniques meant to be always considered through future data collection and post-processing/generation efforts were also issued, featuring at section 3.2. These are meant to strengthen data quality and consistency, thus minimizing the effect of data flaws.

3.1 Targeted recommendations

Targeted recommendations (grouped per category of data need) are described in the subsections below and are accompanied by suggested actions for their implementation. The assessed implementability level of the suggested actions linked to each recommendation is also included and justified, as well as an oversight of the main flaws in terms of data availability that each category of data is facing that fundament them.

3.1.1 Building stock general characteristics (BSTK)

Current main flaws in data availability identified:

- Data on demolition figures is extremely scarce and mainly outdated
- There is no numerical data related to the reasons motivating new constructions
- General lack of granularity on types of buildings being built across EU countries
- Lack of direct reporting on number of new dwellings being built.

Recommendations:

Table 5. Identified recommendations to improve future availability and generation of data, with description, list of involved actors for its implementation, assessment on implementability level and level of priority, for Building stock general characteristics (BSTK) data needs.

Recommendation name	Description, suggested action(s) and involved actors for implementation	Assessed implementability level	Assessed level of priority
Enhance reporting on demolition activities across the EU	Figures on number of demolitions are fundamental to properly assess the evolution of the building stock. In lack of them, only indicative values (generally percentages) are used, with the consequent loss of accuracy. Additionally, the lack of understanding of the underlying reasons behind demolition affects the capacity to predict future figures in this regard, making building stock models less reliable. Suggested actions to materialize this recommendation are:	**Moderately challenging** Although the nature of the actions suggested based on this recommendation aren't particularly onerous to implement (at least to cover the most basic indicators	**High** Demolition data is critical for tracking the dynamics of the building stock, understanding obsolescence, and modelling material flows. The current

	1. **Standardize definitions and reporting methodologies for demolition indicators** (e.g. number of demolished buildings per building type, demolished floor area in m^2 per building type and reasons motivating demolition activities) in national databases. 2. **Introduce standardised demolition data reporting in EU-wide statistic platforms**, such as Eurostat 3. **Make link with relevant national registries, such as cadastral maps and data repositories** Involved actors for the implementation of this recommendation are the following: • **National Governments** – ***Leading***: Responsible for standardizing definitions and improving national reporting and data collection through statistical offices and cadastral agencies. • **EU Institutions (e.g., Eurostat, DG GROW)** – ***Collaborating***: Key to harmonizing methodologies at EU level and incorporating demolition data into EU statistical platforms. • **Regional and Local Authorities** – ***Collaborating***: Often have demolition permits and local data which need to be reported upwards. • **Research organizations - *Being informed/ Collaborating***: May assist in identifying methodologies and validating models for demolition trends.	concerning demolition figures, such as number of buildings being demolished per MS per year), the starting situation in terms of demolition data reporting across almost every EU country is very poor .	scarcity of this data in this regard is a major blind spot in Whole Life Carbon (WLC) modelling and stock evolution scenarios. Implementing standard and harmonized reporting would significantly enhance model accuracy.
Increase granularity level on new construction data	The lack of detailed yet consolidated information concerning new constructions across the EU undermines modelling efforts. For example, Eurostat can only provide information on one parameter, being this the number of m^2 of floor area built for Residential and Non-Residential uses. Although more detailed insight can be obtained for some countries through their statistic portals, the nature of the data (definitions, classifications, etc) is generally different for each country, which renders such National-sourced data difficult to compare to each other. Suggested actions to materialize this recommendation are: 1. **Standardize definitions and reporting methodologies so to be**	**Difficult** The technology for the implementation of satellite imagery solutions powered by AI with similar purposes is already existing, but to develop an approach tailored to the characteristics of the building stock of each MS along with data training efforts would be required, with considerable effort. The standardization of data inputs from	**High** The lack of harmonized and sufficiently granular construction data across the EU severely limits the ability to project future emissions, resource needs, and occupancy scenarios. A more detailed understanding of the new

	aligned with Building Stock Observatory (BSO) data structure for key indicators regarding construction activities across the EU 2. **Develop satellite image analysis models based on deep learning** to estimate building characteristics where official data is missing, in a similar fashion to JRC approach used for the Global Human Settlement Layer (GHSL) project for classifying urban settlements 3. **Use data from relevant national registries, where available, such as cadastral data repositories, construction permit databases, or similar** Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., Eurostat, BSO responsibles)** – ***Leading***: Key in setting common data standards and ensuring integration into EU-wide platforms. • **National Governments** – ***Collaborating***: Need to align national data structures with EU definitions and facilitate access to national databases (e.g., construction permits, cadastral records). • **Research organizations-*Collaborating***: Essential for developing and deploying satellite imagery and machine learning models to fill data gaps. • **Regional Authorities** – ***Being informed/Collaborating***: They generally hold useful complementary data (depending on the country) and may support data harmonization or contribute to increase granularity.	National official sources to match as good as possible the BSO structure is feasible and would mean a further step in aligning reporting practices in the built environment, which has been proven to be a troublesome endeavour.	stock is necessary for accurate WLC assessments and long-term planning.

3.1.2 Construction materials (CMAT)

Current main flaws in data availability identified:

- Completeness of data on material availability significantly differs across countries.
- Data on future projections for material availability is rather vague and differs among countries. In addition, it's only available for all types of materials for the whole EU (low granularity for modelling purposes)
- Data granularity on waste is coarse (Classed as "Mineral waste" only in general, for construction + demolition).

Recommendations:

Table 6. Identified recommendations to improve future availability and generation of data, with description, list of involved actors for its implementation, assessment on implementability level and level of priority, for Construction materials (CMAT) data needs.

Recommendation name	Description, suggested action(s) and involved actors for implementation	Assessed implementability level	Assessed level of priority
Promote standardized reporting frameworks at the EU Level	Encouraging all EU countries to adopt a harmonized approach to reporting material availability and construction waste would improve consistency across datasets. Suggested actions to materialize this recommendation are 1. **Develop and adopt a common EU-wide reporting template** to streamline data collection and allow for direct comparability among Member States. 2. **Bind the compliance with reporting practices to access to EU funds.** Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., DG ENV, Eurostat)** - ***Leading***: Responsible for developing the harmonized reporting template, aligning with EU environmental and circular economy policies, and setting conditionality rules for funding. • **National Governments** - ***Collaborating***: Must adopt and implement the reporting frameworks at national level and ensure compliance. • **Research organizations** - ***Collaborating***: Can support in refining templates and methodologies for materials accounting.	**Easy** Although it requires coordination and alignment across member states, there is a vast experience on this regard. There are already regulations in place supporting standard approaches to classify this kind of data across the EU (such as the European Waste Catalogue or the EU Construction Products Regulation for example), which should allow for a smooth alignment on reporting practices.	**High** Disparities in material data availability across countries severely affect the comparability and reliability of WLC estimates. A standardized EU-wide framework is thus essential to ensure consistency, facilitate benchmarking, and increase the credibility of scenario modeling. Additionally, tying compliance to EU funding adds a strong policy lever to secure implementation.
Increase granularity of official databases concerning waste production	The update of existing data systems to improve the granularity of material and waste categories would help to increase the accuracy of modelling outputs. A suggested action to materialize this recommendation is: 1. **Implement the disaggregation of waste categories in Eurostat.**	**Easy** Changes to allow for greater granularity on waste production data can be easily incorporated into existing data collection procedures by every Member State, as	**High** The current granularity level offered on Eurostat regarding construction waste is too low. Improving it would enable

	Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., Eurostat)** – ***Leading***: Should revise and implement new data classification schemes for disaggregated waste types (especially for construction and demolition waste). • **National Governments** – ***Collaborating***: Will need to adapt national data collection processes and systems to the updated categorization. • **Industries (construction, recycling)** – ***Being informed / Collaborating***: May be required to report more detailed data to comply with new classification systems.	the data taxonomy is already there, given waste materials must be properly classified by European Waste Catalogue codes across the whole EU.	better tracking of material cycles and supports policies aimed at circularity and carbon reduction. Enhancing database resolution is key for precise material flow analysis and stock turnover modelling.
Incentivize national data collection initiatives and transnational technical support collaboration	Low-population EU countries (that generally count with less capacity to put in place as well as manage highly detailed data collection systems) could benefit from targeted incentives and partnerships with countries with more experience in the matter. This also would help with the alignment of reporting practices. Suggested actions to materialize this recommendation are: 1. **Engage with National Agencies** (through workshops, for example) to adopt cloud-based data management tools aimed at the collection of material flows and recycling rates in the agreed template at EU level. 2. **Foster partnerships between front-runner countries and countries lagging** to improve their data collection capabilities. Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., DG REGIO, DG ENV)** – ***Leading***: Should establish incentives and provide funding mechanisms for capacity-building and cross-country collaborations. • **National Governments (from lagging countries)** – ***Collaborating***: Are the beneficiaries of support and must commit to data improvement strategies.	**Difficult** These endeavours will require substantial coordination and communication efforts. Although funding mechanisms already exist to support such initiatives, low administrative capacity to manage overhauling data collection systems renders it a highly challenging task.	**Medium** While not as immediately impactful as harmonization or granularity improvements, supporting lower-capacity countries is essential to close data gaps and ensure equitable data quality across the EU. This recommendation boosts long-term cohesion and alignment, especially for the assisted Member States.

- **Front-runner National Governments** – ***Collaborating***: Can share expertise and provide technical support.
- **Research organizations** – ***Collaborating***: Can offer training and host technical workshops.
- **Industries (data service providers, construction sector)** – ***Being informed***: May play a role in data provisioning and system implementation.

3.1.3 Energy systems and on-site power generation (ENSY)

Current main flaws in data availability identified:

- Granularity issues: Lack of detail on BPIV type and building use for share of buildings switching to RE.
- Lack of extensive data on energy efficiency for cooling devices across the building stock.
- Notable scarcity of data on future scenarios in general

Recommendations:

Table 7. Identified recommendations to improve future availability and generation of data, with description, list of involved actors for its implementation, assessment on implementability level and level of priority, for Energy systems and on-site power generation (ENSY) data needs.

Recommendation name	Description, suggested action(s) and involved actors for implementation	Assessed implementability level	Assessed level of priority
Enhance granularity in renewable energy adoption tracking	As happens with most technologies of relatively recent development in historical terms, on-site RE systems are still not yet accounted for in a standardized way across the EU, with Energy Performance Certificates (EPCs) being the tool with the most detailed level of accuracy to account for installed RE systems in the building stock. Working towards the harmonization of reporting practices concerning these technologies within the EU through already established channels is therefore a recommended path for action, as well as expanding successful examples of good practice concerning energy-harvesting potential already present in some places. Suggested actions to materialize this recommendation are:	**Moderately challenging** The suggestions made with respect to this recommendation are based in practices and technologies already present in some parts of the EU, and therefore a similar deployment in other zones shouldn't be troublesome. The challenge resides on	**Medium** Improved data on renewable systems adoption is important to monitor decarbonizatio n efforts in energy supply and plan future WLC scenarios. Underpinning the role of EPC data in this regard, as well as implementing

	1. **Recommend EU countries to adopt approaches in their EPCs to report for installed RE systems**, with the type of technology, installed power and, in the case of solar-powered (PV or thermal) systems, the surface area the panels take[2]. 2. **Encourage the development across the EU of solar potential estimation tools based on the combination of LiDAR scanning flights and GIS on a building-per-building basis**. These tools (already in place at some parts of the EU[3]), combined with analytic data processing can render a very accurate image on the harvesting potential and serve as basis to define evidence-based future scenarios. Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., DG ENER, JRC, BSO responsibles)** – ***Leading***: Should define reporting requirements and promote harmonization via EPC standards and solar potential mapping methodologies. • **National Governments** – ***Collaborating***: Responsible for integrating enhanced requirements in EPCs and promoting or supporting solar potential mapping at national level. • **Regional/Local Authorities** – ***Collaborating***: Especially relevant for deploying LiDAR and GIS tools as well as managing their datasets at building level. • **Research organizations - *Collaborating***: Can assist with methodology development and implementation of estimation tools. • **Industries (EPC auditors, Solar panels manufacturers, tech firms)** – ***Being informed/Collaborating***: May contribute with data and to help the deployment of solar potential tracking tools.	ensuring their implementation.	tools like solar can be highly relevant solutions for tracking their deployment at the building level.

[2] A good example in this regard would be the Netherlands, whose EPCs account with the installed power of PV (in Wp) installed within the building as well as the surface the panels occupy in m^2

[3] One example is the Zonnekaart in Flanders (Belgium), in which any citizen can get to know the solar potential of their building by introducing its address in the platform.

Harmonize reporting practices on heating and cooling systems across the EU building stock	Heating and cooling system data is often inaccessible outside of EPC calculations, non-standardized across EU countries and fragmented between several documents concerning the building itself. Therefore, improvement the availability of such data in a harmonized format is key to allow for more precise calculation of the energy consumption of buildings across the continent. Suggested actions to materialize this recommendation are: 1. **Introduce the obligation to report on EPCs the efficiency of each heating and cooling system present in the building, along with the heated and cooled surface area**. Failing that, request standard (tabulated) efficiency values from National calculation manuals to be provided instead. 2. **Link EPC data with National/European statistic portals** to allow for automatic update of these figures in a format compatible with the Building Stock Observatory (BSO) data structure. Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., DG ENER, Eurostat, BSO responsibles)** – ***Leading***: Should set harmonized rules for reporting on heating and cooling systems in EPCs and define links to BSO-compatible formats. • **National Governments** – ***Collaborating***: Need to enforce the inclusion of system efficiency and conditioned floor areas in EPCs and update national manuals with standard values when needed. • **Regional/Local Authorities** – ***Being informed / Collaborating***: Support EPC data reporting and may facilitate regional data alignment. • **Research organizations - *Collaborating***: Can help to validate and refine efficiency benchmarks or default values.	**Moderately challenging** The data is mostly already available, but generally very fragmented. Efforts to be carried out are pre-eminently related to its standardization, which although challenging due to the numerous countries involved, is not particularly onerous as the required parameters are rather basic (efficiency in % per system and the surface area they cover).	**High** Heating and cooling account for a substantial share of building energy use and related emissions, yet current data is fragmented and often incomplete. Harmonizing and systematizing this data, especially via EPCs, is a fundamental for accurate and easy to update energy modeling, WLC assessment, and policy planning.

- **Industries (HVAC sector, EPC professionals)** – ***Being informed***: They are affected by reporting requirements and should be consulted for system classification and standardization.

3.1.4 Environmental impact and circularity (ENVI)

Current main flaws in data availability identified:

- Data points on conditions for the application of WLC strategies are primarily qualitative (marked as Low/Medium/High), without a clear method to translate those into quantifiable indicators.
- The datasets on the expected share of use of CCU, CCS, and CR strategies per country and industry are rather incomplete. While CCS data is relatively more available, CCU and especially CR data are lagging behind, as the data availability is inconsistent across countries.
- Updated data on energy carriers' official emission factors requires of very lengthy research efforts (on a country-per-country basis) to gather without access to private centralized LCA databases (such as *ecoinvent*).

Recommendations:

Table 8. Identified recommendations to improve future availability and generation of data, with description, list of involved actors for its implementation, assessment on implementability level and level of priority, for Environmental impact and circularity (ENVI) data needs.

Recommendation name	Description, suggested action(s) and involved actors for implementation	Assessed implementability level	Assessed level of priority
Develop a quantification method for WLC strategy conditions	The evaluation methodology in place to assess the conditions for the application of WLC (Whole Life Carbon) from data need *P19/ENVI-8* could be reworked over the basis of a standardized, quantifiable scoring framework to translate qualitative WLC conditions into measurable indicators that enable comparability. Suggested actions to materialize this recommendation are: 1. **Develop quantitative indicators** (weights) for each of the qualitative ones per category of suitability conditions, through pairwise comparisons. 2. **Enable a tool** (based in the Analytic Hierarchy Process, for example) **to compare countries per category of suitability conditions**, using the weights previously defined. 3. **Test the tool** for a small selection of countries whose WLC strategies are	**Moderately challenging** It requires expert input and agreement on the criteria and their hierarchy level compared to each other, but the qualitative data already exists and can be gradually translated into quantitative values without having to start from scratch. Implementing the tool may take several iterations to optimize consistency.	**Low** While this recommendation adds analytical value to better compare WLC readiness across countries, its impact is indirect in terms of data availability, providing guidance on applicability of strategies. Thus, it is important for standardization and comparability,

	already well (or better) defined to verify consistency and refine assigned weights if needed. Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., JRC, DG CLIMA, DG ENV)** – ***Leading***: Responsible for defining the methodological framework and overseeing the standardization process at EU level. • **Research organizations - *Collaborating***: Key role in developing, testing, and refining the scoring framework and the tool based on methods like the Analytic Hierarchy Process. • **National Governments** – ***Being informed/Collaborating***: Will later apply or adapt the scoring framework to national assessments of WLC strategies.		but its urgency is lower than other aspects within this data category.
Support the reporting on CCU, CCS, and CR strategies to national reporting requirements	The expansion and enforcement of national reporting obligations to include consistent data on Carbon Capture and Utilization (CCU), Carbon Capture and Storage (CCS), and Carbon Removal (CR) would greatly increase data availability and consistency as well as simplify data collection endeavours, currently very cumbersome (having to consult a great number of different sources) Suggested actions to materialize this recommendation are: 1. **Introduce the mandatory reporting of these strategies** 2. **Define and distribute EU-wide, standardized reporting templates** across different industries on their uptake of CCU, CCS and/or CR technologies/methods. Involved actors for the implementation of this recommendation are the following: • **EU Institutions** – ***Leading***: Should set the reporting obligations and define the standard templates. • **National Governments** – ***Collaborating***: Responsible for enforcing reporting at national level and ensuring industry compliance.	**Moderately challenging** Legislation or policy changes are needed to introduce new reporting elements, and not all countries currently monitor the implementation of these methods/technologies. However, this is already being done in several EU countries, providing a basis over which to build on these efforts.	**Medium** Current data on CCU, CCS and CR is fragmented, and its absence hinders modelling of for negative/low-carbon scenarios. Integrating reporting into existing policy instruments is a feasible move to systematize and simplify the elaboration and update these datasets, improving predictions on future emissions and supporting forward-

	• **Industries (especially heavy industry)** – ***Collaborating/Being informed***: Primary data providers and beneficiaries of harmonized reporting guidance. • **Research organizations - *Collaborating***: Can support methodology design and help validate reporting templates.		looking climate policy design.
Facilitate open access to emission factors via a central EU repository	Energy carriers' emission factors vary across countries, and this information isn't currently standardized neither clustered together in public repositories. Therefore, its collection requires either to resort to private entities or to collect it in a country-per-country basis, which can be an onerous task. This would avoid licensing restrictions and greatly simplify research efforts for non-commercial actors. Suggested actions to materialize this recommendation are: 1. **Create and maintain an EU-hosted database of national emission factors** (e.g., for natural gas, electricity, biomass), updated on a yearly or bi-yearly basis. 2. **Integrate it into existing platforms**, such as the Building Stock Observatory (BSO) Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., JRC, Eurostat)** – ***Leading***: Should host and maintain the repository, and integrate it into existing data infrastructures, such as BSO. • **National Governments** – ***Collaborating***: Must supply regularly updated national emission factors and ensure consistency with international inventories. • **Research organizations - *Collaborating***: Will be among the main users; could help define format/usability features. • **Civil society (NGOs, think tanks)** – ***Being informed***: Would benefit from	**Easy** It builds on already existing national data and simply requires coordination and centralization.	**High** The current fragmentation of official emission factors is a major obstacle for transparent WLC accounting. Providing open access via a centralized EU platform would have broad and immediate positive impact on the quality and comparability of carbon emissions figures.

	public access to these data without licensing barriers		

3.1.5 Forestry (FSTY)

Current main flaws in data availability identified:

- Data on future projections is scarce, assumptions were required
- Lack of data for certain countries and years

Recommendations:

Table 9. Identified recommendations to improve future availability and generation of data, with description, list of involved actors for its implementation, assessment on implementability level and level of priority, for Forestry (FSTY) data needs.

Recommendation name	Description, suggested action(s) and involved actors for implementation	Assessed implementability level	Assessed level of priority
Improve long-term projections of forest stock and harvest rates	More accurate projections can prevent overexploitation and provide for more careful resource planning. Reporting practices as well as innovative technologies could help in these endeavours. Suggested actions to materialize this recommendation are: 1. **Enforce submission on forest harvesting plans** to companies in the sector under the principle of Sustainable Forest Management (SFM) developed by the European Commision within the framework of the EU Forest Strategy. In Ontario (Canada) the Forest Resource Inventory (FRI) mandates to provide for 10-year management plans on each management unit, with information on species, sizes and number of trees. 2. **Foster the implementation across the EU of LiDAR technology combined with AI techniques and GIS data models** to assess forest stock and its fluctuations in many parameters (such as biodiversity levels or health state of the trees) with high precision and periodicity. This has been already implemented and proven successful in Finland under private-public partnerships. Involved actors for the implementation of this recommendation are the following:	**Difficult** These measures require of multi-level cooperation of public organisms and companies in the forestry sector as well as investment in the development and implementation of technologies that even if they are reasonably mature, they are not yet widely spread across the continent for these purposes.	**High** Forest stocks are critical for climate policy and and biodiversity preservation. Better long-term projections and use of proven technologies (e.g., LiDAR + GIS) would drastically increase the reliability of forecasts and help avoid overharvesting, making this both urgent and impactful.

	• **EU Institutions (e.g., DG ENV, JRC)** – ***Leading***: Oversee the integration of forest projection reporting within EU frameworks and promote harmonized guidelines. • **National Governments (e.g., Forestry Agencies)** – ***Collaborating***: Implement mandatory long-term planning and enforce the use of new technologies like LiDAR and GIS for monitoring. • **Private Sector (Forestry companies)** – ***Being informed/Collaborating***: Required to submit management plans and comply with sustainable forest management rules. • **Research organizations & Tech developers** – ***Collaborating***: Support the technical aspects, such as AI-based forest health assessments.		
Standardize forestry stock and harvest reporting across countries	Currently, Eurostat data concerning forestry figures featuring at D.3.2 ("Collection or generation of new data") database usually makes use of data coming from other organizations (Food and Agriculture Organization of the United Nations – FAO - among the most important) or provided in a voluntary basis (such as that of European Forest Accounts, EFA). In order to ensure completeness, consistency and comparability of data, as well as alignment with EU environmental goals, efforts in implementing sound data collection paths are much needed. A suggested action to materialize this recommendation are: 1. **Align national forestry inventories with a common EU-wide framework with compulsory reporting**. The Forest Information System for Europe (FISE) could be a suitable platform to serve as a basis for this. Involved actors for the implementation of this recommendation are the following: • **EU Institutions (e.g., DG ENV, Eurostat, JRC)** – ***Leading***: Define the common framework and coordinate Member States through tools such as FISE. • **National Governments (e.g., Forestry Agencies)** – ***Collaborating***:	**Moderately challenging** Although there are already platforms in place that would support the implementation of this recommendation, alignment efforts require cross-country agreement.	**Medium** Although standardization would substantially enhance data consistency and completeness, the lack of direct enforcement mechanisms and reliance on multiple actors mean this is likely to be a gradual process, being realistically achievable in the medium-long term, which lowers its urgency.

	Update national inventories and ensure compulsory and consistent reporting. • **International Organizations (e.g., FAO)** – ***Collaborating***: Can help align EU efforts with global forest monitoring initiatives and facilitate interoperability of data. • **Research organizations & Civil society** – ***Being informed***: Beneficiaries of improved transparency and comparability of forest-related data.		

3.1.6 Housing and occupancy (HSNG)

Current main flaws in data availability identified:

- Missing granularity on building type for floor area of new construction (proxies were required)
- Lack of rental data per construction period (only per country and type of building)

Recommendations:

Table 10. Identified recommendations to improve future availability and generation of data, with description, list of involved actors for its implementation, assessment on implementability level and level of priority, for Housing and occupancy (HSNG) data needs.

Recommendation name	Description, suggested action(s) and involved actors for implementation	Assessed implementability level	Assessed level of priority
Promote use of administrative registers and property tax records to improve housing data granularity	Existing administrative sources like cadastral records and property tax databases can provide more detailed insights into housing characteristics, complementing existing data already public in official statistics portals. Suggested actions to materialize this recommendation are: 1. **Link building registries with rental data using anonymized IDs or georeferenced units**, enabling joint analyses by construction year and housing type (among other metrics) without compromising data privacy. 2. **Develop guidelines on best practices for integrating housing and tax data for statistical use**, helping countries to set up their data integration protocols. Involved actors for the implementation of this recommendation are the following: • **National Statistical Institutes** – ***Leading***: Coordinate the integration of	**Moderately challenging** This is technically feasible, especially in countries with already well-maintained registries, although ensuring effective data protection and overcoming institutional silos stand up as challenges.	**Medium** The reuse of existing administrative data is both cost-effective and powerful in increasing granularity and reliability of housing datasets, currently rather coarse, although still approachable through data gap techniques and auxiliary data.

	administrative registers (e.g., cadastral, tax data) with housing datasets. • **Tax Authorities/Land Registries** – ***Collaborating***: Provide access to property records and help define protocols for anonymized data sharing. • **EU Institutions (e.g., Eurostat)** – ***Collaborating***: Provide technical guidance and promote cross-country comparability through standards and best practices. • **Data Protection Authorities** – ***Being informed/Collaborating***: Ensure privacy-preserving methods (such as anonymization or secure linking) are correctly applied.		
Include buildings metadata in rental statistics collection	Household or rental market surveys currently used to collect rent data can be expanded to also include metadata such as the construction period of the dwelling, enabling a more accurate assessment of the occupied building stock. Suggested actions to materialize this recommendation are: 1. **Encourage private rental platforms or agencies to publish anonymized metadata.** 2. **Expand household surveys to ask the respondent to indicate metadata related to their dwelling.** Involved actors for the implementation of this recommendation are the following: • **National Statistical Institutes** – ***Leading***: Expand survey instruments and questionnaires to collect building metadata systematically. • **Private Rental Platforms / Agencies** – ***Collaborating***: Provide anonymized listings data with associated building characteristics. • **EU Institutions (e.g., Eurostat)** – ***Collaborating***: Recommend minimum standards for metadata in rent statistics to ensure EU-wide comparability. • **Civil society (Tenants, Landlords)** – ***Being informed / Collaborating:***	**Moderately challenging** The suggestions aren't at all far-fetched, but they involve coordination with statistical agencies and private actors, requiring highly consistent classification of the metadata to be collected.	**Low** While adding construction metadata to rental datasets would greatly enhance understanding of the occupied building stock, this relies on survey redesigns and private sector collaboration, which might take longer to implement (moreover across several countries), thus the lower urgency.

	Respond to surveys with relevant metadata to improve data coverage.	

3.1.7 Transport and logistics (TRAN)

Current main flaws in data availability identified:

- Recurrent cases of data missing from any given EU country: Proxies or direct assumptions were required to cover for those gaps.
- Lack of granularity concerning means of transport used (They were assumed as road transport)

Recommendations:

Table 11. Identified recommendations to improve future availability and generation of data, with description, list of involved actors for its implementation, assessment on implementability level and level of priority, for Transport and logistics (TRAN) data needs.

Recommendation name	Description, suggested action(s) and involved actors for implementation	Assessed implementability level	Assessed level of priority
Reinforce compliance on mandatory minimum reporting standards on freight transport for all EU countries	Although the EU legislation contemplates the reporting for every different mode of freight transport (road, rail, sea, air) constraints and flaws in the process (capacity to track and properly report can vary across countries and transport modes) ends up leading to data gaps in this regard, as the results from the data collection process for this project show. Ensure all EU countries provide transport data through standardized and enforceable minimum reporting requirements should help to reduce country-level data gaps. Suggested actions to materialize this recommendation are: 1. **Revise and clarify reporting protocols**: Provide tailored training (through workshops, for instance) and guidance documents for countries lagging behind that clarify how to collect and report data, making special focus on difficult categories, like multimodal freight. 2. **Set up a formal quality benchmarking and feedback mechanism**: Eurostat could issue regular public "scorecards" (for example in traffic light style) ranking Member States on data completeness and timeliness across all transport modes,	**Moderately challenging** The implementation of these suggestions builds on existing legal obligations, which simplifies everything, but it requires internal coordination between EU institutions (Like Eurostat and DG MOVE) and between EU institutions and member states, with the complexity that it entails.	**High** Missing data on transport by mode directly affects emissions and logistics modelling, and coverage gaps were significant in the project. Creating public benchmarks (scorecards) would add transparency and pressure, while tailored training can raise capacity where needed.

	intended to motivate other countries to improve their practices. Involved actors for the implementation of this recommendation are the following: • **EU institutions (DG MOVE, Eurostat)** – ***Leading***: Set enforceable standards, issue clear guidelines, and implement benchmarking tools. • **National Governments (Transport Ministries) - *Collaborating***: Improve national data collection and submit consistent, complete transport statistics. • **National Statistical Institutes** – ***Collaborating***: Assist in methodology harmonization and ensure timely reporting. • **Transport sector stakeholders (e.g., freight associations)** – ***Being informed/Collaborating***: Help to clarify reporting pathways across the sector and provide feedback on feasibility.		
Support digital data collection solutions for freight transport across the EU	Helping countries to modernize their transport data collection systems can significantly increase data quality in terms of accuracy and punctuality. Suggested actions to materialize this recommendation are: 1. **Incentivize the incorporation of automated data from tracking systems for all Member States**: Technologies such as GPS, RFID (Radio-Frequency Identification), or Electronic Transport Documents (ETDs) can prove useful, as changes in transport mode can be more simply registered and the data can directly be fed into freight databases in a standard way without human intervention. 2. **Introduce soft penalties and incentives linked to data quality**: Countries with complete datasets could get early access to transport-related funding calls, for example. This could motivate those countries lagging behind to ramp up their reporting capabilities and pave the way to adopt this type of technologies.	**Moderately challenging** Requires funding and cooperation (with the challenges that entails), but the tracking technologies are already mature. If properly implemented the data quality can dramatically improve.	**Medium** Digital solutions offer long-term gains in data accuracy and timeliness, automating data flows that are now prone to errors or gaps, particularly in countries where these technologies are less present. However, the initial investment and technical transition make it critical but requiring more effort and time to

	Involved actors for the implementation of this recommendation are the following: • **EU institutions (DG MOVE, Eurostat)** – **Leading**: Fund digitalization efforts, pilot automated data integration and define common data exchange formats so to ensure compatibility with reporting needs. • **National Governments (Transport Ministries)** – **Collaborating**: Roll out digital freight tracking systems and integrate them into national databases. • **Technology Providers & Logistics Companies** – ***Collaborating***: Implement systems (GPS, RFID, ETDs) and ensure interoperability. • **Transport sector stakeholders (e.g., freight associations)** – ***Being informed/Collaborating***: Provide feedback on feasibility.	implement uniformly across Member States, thus the medium priority.

3.2 General recommendations

These recommendations are based on the implementation of techniques meant to be always considered through future data collection and post-processing/generation efforts, regardless of the type of data. They are divided in two groups (data quality related and data generation related) and aim to strengthen data quality and consistency, minimizing the effect of data flaws.

3.2.1 Data quality related recommendations

Three general recommendations on improving data quality were issued, present at the following table:

Table 12. General recommendations on improving data quality.

Recommendation name	Description
Apply cross-source consistency checks	When the same data point is provided by multiple sources, their reported values should be compared to identify discrepancies. A key approach is to examine the range between the highest and lowest values provided. Large differences may indicate unreliable data, prompting further investigation into each value and its respective source.
Reorganizing or regrouping data to identify inconsistencies	Some data points, when slightly transformed or recalculated can be aligned and compared across different data needs to identify inconsistencies. This method is effective when the data relate to the same subject and share at least one common dimension or level of granularity (e.g., geography or building use type). Aligning such data enables quality checks by identifying inconsistencies that would otherwise go unnoticed.

Compare datasets to flag outlier data points	Data quality can also be evaluated by deriving a new metric from two or more different data sets (coming from other data needs) and then assessing its plausibility. For instance, combining floor area and number of buildings allows for the calculation of average floor area per building. Outliers (such as countries where this average is significantly higher or lower than expected) may reveal issues in the input data. Unlike direct comparison, this method relies on indirect indicators or benchmarks (such as EU-level averages) and may require additional data collection to validate findings.

3.2.2 Data generation related recommendations

There are five general recommendations on this regard, named and described in the table below:

Table 13. General recommendations on improving data generation.

Recommendation name	Description
Apply interpolation and/or extrapolation	When data are missing for a few specific time points within an otherwise complete time series, the missing values can be estimated using interpolation (within the range) or extrapolation (beyond the range). For example, if values for 2015, 2016, and 2019 are available, values for 2017 and 2018 can be linearly interpolated to fill the gap. This method assumes a steady progression between known values and is therefore useful for filling short-term temporal gaps.
Fill missing values with a similar level of granularity	Sometimes, data may be missing for specific points within a shared level of granularity (such as one country out of a regional group or one building type out of several, for example). If the available values are consistent and the countries share similar characteristics (e.g., geographic, economic, or cultural), the missing values may be assumed to match those of comparable countries. For instance, if Estonia and Lithuania report similar construction materials, it may be reasonable to apply the same material for Latvia.
Consider using alternative data granularities	When data are not available for the exact granularity required, it may be acceptable to collect data at an alternative aggregation level. For example, if separate data for single-family and multi-family houses are unavailable, a combined value for "other residential buildings" may be used. In some cases, proxy data can support disaggregation. For example, if the number of buildings is available for three building types, they can help break down floor area data originally provided in only two of the types.
Consider substitution with an alternative data need	When a specific data need cannot be collected due to unavailability or reliability issues, a related but different data set (an alternative or proxy) can be proposed. This substitution should be discussed and agreed upon with relevant partners. For example, if national-level data on recycled content in construction materials is unavailable, EU-level data may serve as a practical alternative, even though it constitutes a separate data need.

Consider the creation of new datasets deriving from existing ones	Derived data needs are not collected directly but are instead calculated using existing data. For example, average residential floor area per inhabitant can be obtained by dividing the total residential area by the population of a country. While the original data need might not exist independently, the required values can be generated by combining multiple collected indicators, including external ones such as national population statistics.

4. METHODOLOGY ON MONITORING AND CONTINUOUS IMPROVEMENT OF THE DATASET FROM T3.2. DATA GOVERNANCE SYSTEM.

While the recommendations described in the previous section provide an action path towards improving data availability in the future, the completeness and long-term relevance of the dataset provided at T3.2 requires of a systematic and structured approach with adaptability as a main priority and clear data governance in place for successful implementation, as it's safe to assume that both data needs featuring in the dataset as well as procedures for data collection are likely to evolve over time.

To support this, this section proposes a methodology for monitoring progress and enabling continuous improvement in data collection efforts. This approach is consistent with previous work as it builds directly on the structure of the existing dataset and the identified categories of data, constituting a data governance system outlined in three subsections titled *Actors, roles and tasks*, *Monitoring activities* and *Continuous improvement activities*, followed by a general overview subsection that provides a holistic picture of them and their interrelations.

4.1 Actors, roles and tasks

The conceived data governance system to enable monitoring and continuous improvement of the dataset works around three main different actors, with their roles and responsibilities described below. Details about each of the mentioned activities are provided in subsections 4.2 and 4.3.

- **Central Supervisor**
  - Oversees the entire process.
  - It can be a single individual or an organization.
  - Coordinates major biannual[4] reviews, organizing a workshop.
  - Has control over the master table across all data needs.
  - Assigns the priority level of the data needs featuring in the database, to guide efforts from responsible partners.
  - Manages the database versions, archiving them once the period is finished along with their log changes, to ensure traceability.
  - Registers main outcomes from each biannual workshop and issues a report to serve as main guidelines for responsible partners on further updates on the database.
- **Category responsibles**
  - Preferably one per data category (Called "Responsible partner". These can be the partner organizations that participated in the data collection process at D.3.2, for example)
  - In charge of coordinating data collection and documenting the updates they make on the database.
  - Report progress/issues to the Central Supervisor.
- **Dataset external users**
  - Provide structured feedback via the form (such as general remarks, suggestions on new data sources, flagging errors they may find, etc.).
  - Their input is collected continuously and reviewed in deep during the workshop.

[4] Biannual periodicity for conducting major reviews and logging versions was considered reasonable given the experience from the data collection process, showing certain delay on the availability of data from sources.

4.2 Monitoring activities

Monitoring activities revolve around a **master data table**, linked to the contents of the dataset for each of its versions[5] managed by a central supervisor/coordinator. This master data table contains the following data points:

- **Code of the data need**[6]
- **Category to which it belongs** (BSTK, CMAT…)
- **Responsible partner**
- **Priority level of the data need** (High/Medium/Low)
- **Data when it was added to the database**
- **Version of the database when the data need was initially added** (V1, V2…)
- **Last update** (When the data was edited for the last time)
- **Status** (Active/Inactive)[7]
    - Reason for inactive (if applicable)
    - Version of the database when the data needs become inactive (if applicable)
- **Changelog** (All updates conducted by the responsible partner on the data need since its introduction, with date and a brief description about them).
- **Comments/Remarks/Observations** (Anything relevant flagged by either the central supervisor or the responsible partner. These aren't updates and can be mere suggestions on future actions. They are not logged and meant to feature while they're still relevant)

4.3 Continuous improvement activities

The continuous improvement of the database is based on two main mechanisms:

- An **open online form**, where a constant stream of feedback from the database user can make any comments concerning any specific data need or the database in general, concerning:
    - The availability of better-suited data sources or methodologies,
    - Report data inconsistencies
    - Highlighting any sorts of errors

Another mechanism to be put in place to support the continuous improvement of the database is the organization of a **biannual[8] review workshop** by the central supervisor, aiming to:

- Identify bottlenecks or persistent issues in specific categories of data
- Analyse inputs from the open online form for them to be considered during the workshop and incorporated into the next round of recommendations where appropriate
- Reassess the priority level of data needs

[5] For each review period, there should be a logged version of the database, allowing for traceability of all conducted updates and status changes across the years for each data need.

[6] The new code as suggested in Table-A 1. This codification system allows for streamlined nomenclature of new data needs added to the database.

[7] Data needs that featured in the database at some point are never removed but marked as "inactive". They preserve their code and are meant to be filtered out for visualization by external users. A change on status should be regarded as an update and properly described in the comments cell.

[8] See footnote 4 for the justification on the periodicity

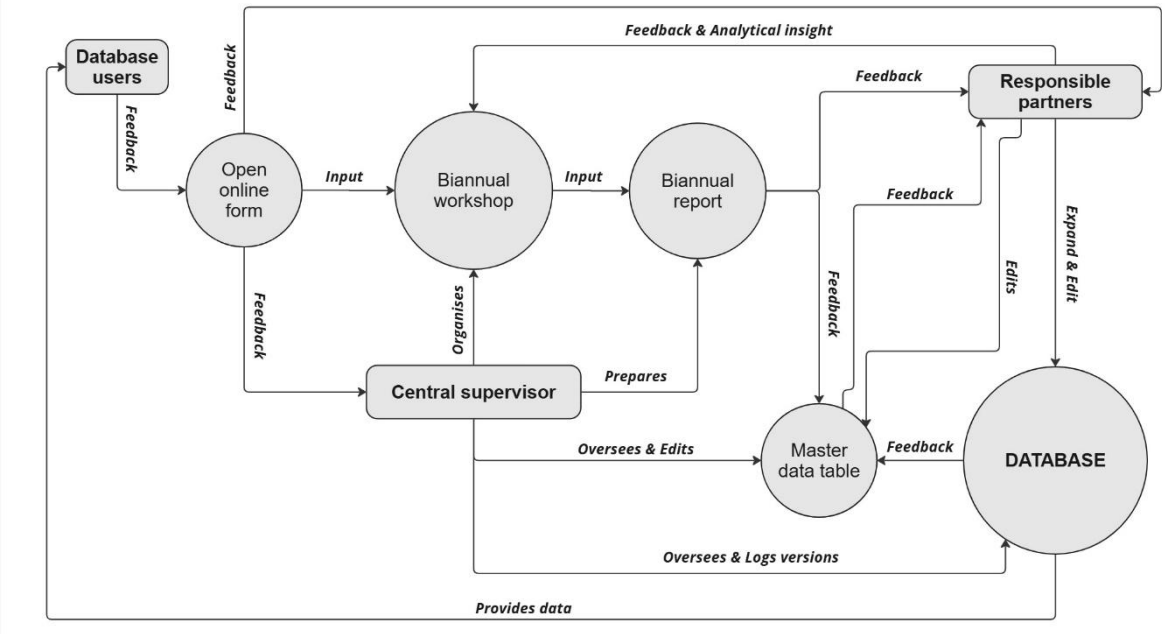
- Flag newly emerging needs not previously considered
- Suggest methodological improvements or more robust data sources for data collection

The main outcomes of this workshop are properly documented in a report, meant to serve as guidelines for the updates to be made in the next version of the database.

4.4 General overview

A visual overview of the data governance system described before is presented in the diagram below:

Figure 2. Data governance system diagram for monitoring and continuous improvement of the database



5. CONCLUSIONS

The review of the **targeted recommendations** (a total of 16) across the 7 data categories defined highlights both "quick wins" (fast and relatively simple to implement changes) and longer-term strategic-wise endeavours for improving EU-wide data coverage.

Easily implementable actions, such as

- promoting standardized reporting frameworks (CMAT),
- and facilitating open access to environmental emission factors (ENVI)

can provide reasonably fast gains in data availability and quality.

However, **more comprehensive improvements**, such as

- enhancing the granularity of construction (BSTK),
- enhancing renewable energy adoption data (ENSY), as well as
- incentivizing cross-border collaboration on materials data (CMAT), among others

present moderate to high implementation difficulty due to their technical and institutional complexity.

Last but not least, other data categories like housing (HSNG) and forestry (FSTY) demonstrate potential for improvement through a better use of existing administrative data and standardization of reporting methods.

All in all, these findings suggest that combining **standardization efforts with coordinated long-term investment in data systems will be key to closing data gaps** and supporting the materialization of EU policy goals regarding greenhouse emissions of the building stock.

Furthermore, 8 **general recommendations** concerning both data quality and data generation were issued, meant to strengthen data quality and consistency to **minimize the effect of data flaws.**

Concerning **monitoring and continuous improvement**, the proposed governance system for the dataset establishes a sound structure that balances coordination, accountability, and user engagement. By defining clear **roles**, these being

- a central supervisor,
- category-specific responsible partners, and
- external users,

the system enables transparent tracking of data evolution and encourages iterative refinement.

On the other hand, anchored around a central master data table, **monitoring activities** ensure traceability through detailed version control and changelogs. Meanwhile, continuous improvement is driven by a dual mechanism:

- a continuously open feedback channel via an online form and
- a structured biannual workshop

This cyclical review process captures user-driven insights but also facilitates the

- identification of errors and bottlenecks,
- reassessment of priorities, and
- incorporation of emerging data needs.

Overall, **this approach supports the long-term reliability, relevance, and adaptability of the database in alignment with an evolving environment**, both at a policy and technical level.

Appendix 1. TABLES ON DATA NEEDS CLASSIFICATION

Table-A 1. List of collected data needs from D.3.2 ("Collection or generation of new data") and their related category, with new suggested code.

D.3.2 Code	Data need name	Category associated	New suggested code
A1.1	Number of buildings, per country, per building use, per building occupancy level for current years	BSTK	**BSTK-1**
A2.1	Useful floor area of buildings, in m², per country, per building use for current years	BSTK	**BSTK-2**
A3.1	Average U-values of building elements, in W/m²/K, per country, per building use for current years	BSTK	**BSTK-3**
A3.2	Average U-values of building elements, in W/m²/K, per country, per building use for future years	BSTK	**BSTK-4**
A4.1	Average efficiency of heating and cooling systems, at EU level for current years	ENSY	**ENSY-1**
A4.2	Average efficiency of heating and cooling systems, at EU level for future years	ENSY	**ENSY-2**
A5.1	Total area of envelope elements of archetype buildings, in m², per country, per building use for current years	BSTK	**BSTK-5**
A6.1	Shape factor of archetype buildings, per country, for current years	BSTK	**BSTK-6**
A7.1	Element-to-envelope ratio for archetype buildings, per country, per building use, for past and current years	BSTK	**BSTK-7**
A8.1	Number of buildings, per country, per building use, per construction material, per building element, per construction, for current years	BSTK	**BSTK-8**
A9.1	Average replacement period of building elements, per construction material, for current years	CMAT	**CMAT-1**
A10.1	Construction material of archetype buildings, per country, per building use and per building element for current years	CMAT	**CMAT-2**
A10.2	Construction material of archetype buildings, per country, per building use and per building element for future years	CMAT	**CMAT-3**
A14.1	Total availability of materials (in tons) per country for past and current years	CMAT	**CMAT-4**
A14.2	Total availability of materials (in tons) per country for future years	CMAT	**CMAT-5**

A15.1	Total amount of construction waste, in tons/year, per country, per construction material, for past and current years	CMAT	**CMAT-6**
A15.2	Total amount of construction waste, in tons/year, per country, per construction material, for future years	CMAT	**CMAT-7**
A16.1	Average share of recycled content of construction materials in construction products, per country, per construction material, for past and current years	CMAT	**CMAT-8**
A16.2	Average share of recycled content of construction materials in construction products, per country, per construction material, for future years	CMAT	**CMAT-9**
A17.1	Forest standing stock per country in m^3/ha of wood for past and current years	FSTY	**FSTY-1**
A17.2	Forest standing stock per country in m^3/ha of wood for future years	FSTY	**FSTY-2**
A18.1	Forest stock in million m^3 of wood per country, for past and current years	FSTY	**FSTY-3**
A18.2	Forest stock in million m^3 of wood per country, for future years	FSTY	**FSTY-4**
A19.1	Forests harvest rate per country in absolute m^3 of wood for past, current, and future years	FSTY	**FSTY-5**
A20.1	Average recycling rate of construction materials, per country, per construction material for current years	ENVI	**ENVI-1**
A21.1	Average incineration rate of construction materials, per country, per construction material for current years	ENVI	**ENVI-2**
A22.1	Average landfill rate of construction materials, per country, per construction material for current years	ENVI	**ENVI-3**
A23.1	Average emission factors of energy carriers, in $kgCO_2/J$, per country, for current years	ENVI	**ENVI-4**
P5	Expected share of use of CCU strategy, per country, per industry, in %, until 2050	ENVI	**ENVI-5**
P6	Expected share of use of CCS strategy, per country, per industry, in %, until 2050	ENVI	**ENVI-6**
P8	Expected share of use of CR strategy, per country, per industry, in %, until 2050	ENVI	**ENVI-7**
P10	Number of buildings demolished per reason, per country, per building use	BSTK	**BSTK-9**
P11	Number of buildings constructed per reason, per country, per building use	BSTK	**BSTK-10**

P14.1	Number of constructed dwellings, per country, for past and current years	BSTK	**BSTK-11**
P14.2	Number of constructed dwellings, per country, for future years	BSTK	**BSTK-12**
P15	Average family size, per country, for past and current years	HSNG	**HSNG-1**
P16	Average newly constructed residential floor area per inhabitant, in m²/person, per country, per (residential) building use, for past and current years	HSNG	**HSNG-2**
P17	Average floor area per inhabitant in m²/person, for residential buildings, per country, for current years	HSNG	**HSNG-3**
P18.1	Average floor area per person, in office buildings, schools, hotels and restaurants for current years	HSNG	**HSNG-4**
P19	Conditions for the application of WLC strategies, per country, for current and future scenarios	ENVI	**ENVI-8**
P20.1	Number of rooms available in a household, per country, for past and current years	HSNG	**HSNG-5**
P21.1	Share of population living in an overcrowded household, per country, for past and current years	HSNG	**HSNG-6**
P22.1	Percentage of dwellings/units under rental contract, per country, per building use for current years	HSNG	**HSNG-7**
AD1.1	Transport scenarios: Average transport distance, in km, per country, per A4 phase route start and end, per product group, for current years	TRAN	**TRAN-1**
AD1.2	Transport scenarios: Share of transport distance, in %, per country, per A4 phase route start and end, per means of transport, per product group, for current years	TRAN	**TRAN-2**
AD1.3	Transport scenarios: Share of transport routes, in %, per country, per A4 phase route type, per product group, for current years	TRAN	**TRAN-3**
AD2.1	Transport scenarios: Share of sorted waste, in %, per sorting point, per waste fraction, per waste category, for current years	TRAN	**TRAN-4**
AD2.2	Transport scenarios: Share of waste transport distance, in %, per means of transport, per C2 route type, per waste category, for current years	TRAN	**TRAN-5**
AD2.3	Transport scenarios: Average transport distance, in km, per C2 route type, per waste category, for current years	TRAN	**TRAN-6**
AD4	Descriptive statistics on GWP of materials, per material class, per life cycle stages, for current years	ENVI	**ENVI-9**

AD6	Share of employees working from home, per number of days per week, per country	HSNG	**HSNG-8**
AD7	Number of dwellings split per building period, per country, for past and current years	BSTK	**BSTK-13**
AD8	Office floor area per person, per country, for past and current years	BSTK	**BSTK-14**
AD9	Useful floor area of vacant buildings, per country, per building use, for past and current years	BSTK	**BSTK-15**
AD11	Define emerging building practice (best examples) for low-carbon construction scenarios (acc. proposal) for future years	ENVI	**ENVI-10**
AD12.1	Share of buildings switching to renewable energy per building use, per country for current years	ENSY	**ENSY-3**
AD12.2	Share of buildings switching to renewable energy per building use, per country for future years	ENSY	**ENSY-4**
AD13.1	Area of building integrated photovoltaics (BIPV), per building use, per BIPV type, per country, for current years	ENSY	**ENSY-5**
AD13.2	Area of building integrated photovoltaics (BIPV), per building use, per BIPV type, per country, for future years	ENSY	**ENSY-6**

Table-A 2. List of collected data needs from D.3.2 ("Collection or generation of new data") clustered by category, ordered by the new suggested code.

BUILDING STOCK GENERAL CHARACTERISTICS (BSTK)		
New suggested code	**Data need name**	**D.3.2 code**
BSTK-1	Number of buildings, per country, per building use, per building occupancy level for current years	**A1.1**
BSTK-2	Useful floor area of buildings, in m², per country, per building use for current years	**A2.1**
BSTK-3	Average U-values of building elements, in W/m²/K, per country, per building use for current years	**A3.1**
BSTK-4	Average U-values of building elements, in W/m²/K, per country, per building use for future years	**A3.2**
BSTK-5	Total area of envelope elements of archetype buildings, in m², per country, per building use for current years	**A5.1**
BSTK-6	Shape factor of archetype buildings, per country, for current years	**A6.1**

BSTK-7	Element-to-envelope ratio for archetype buildings, per country, per building use, for past and current years	**A7.1**
BSTK-8	Number of buildings, per country, per building use, per construction material, per building element, per construction, for current years	**A8.1**
BSTK-9	Number of buildings demolished per reason, per country, per building use	**P10**
BSTK-10	Number of buildings constructed per reason, per country, per building use	**P11**
BSTK-11	Number of constructed dwellings, per country, for past and current years	**P14.1**
BSTK-12	Number of constructed dwellings, per country, for future years	**P14.2**
BSTK-13	Number of dwellings split per building period, per country, for past and current years	**AD7**
BSTK-14	Office floor area per person, per country, for past and current years	**AD8**
BSTK-15	Useful floor area of vacant buildings, per country, per building use, for past and current years	**AD9**
CONSTRUCTION MATERIALS (CMAT)		
New suggested code	**Data need name**	**D.3.2 code**
CMAT-1	Average replacement period of building elements, per construction material, for current years	**A9.1**
CMAT-2	Construction material of archetype buildings, per country, per building use and per building element for current years	**A10.1**
CMAT-3	Construction material of archetype buildings, per country, per building use and per building element for future years	**A10.2**
CMAT-4	Total availability of materials (in tons) per country for past and current years	**A14.1**
CMAT-5	Total availability of materials (in tons) per country for future years	**A14.2**
CMAT-6	Total amount of construction waste, in tons/year, per country, per construction material, for past and current years	**A15.1**
CMAT-7	Total amount of construction waste, in tons/year, per country, per construction material, for future years	**A15.2**
CMAT-8	Average share of recycled content of construction materials in construction products, per country, per construction material, for past and current years	**A16.1**
CMAT-9	Average share of recycled content of construction materials in construction products, per country, per construction material, for future years	**A16.2**
ENERGY SYSTEMS AND ON-SITE POWER GENERATION (ENSY)		

New suggested code	Data need name	D.3.2 code
ENSY-1	Average efficiency of heating and cooling systems, at EU level for current years	**A4.1**
ENSY-2	Average efficiency of heating and cooling systems, at EU level for future years	**A4.2**
ENSY-3	Share of buildings switching to renewable energy per building use, per country for current years	**AD12.1**
ENSY-4	Share of buildings switching to renewable energy per building use, per country for future years	**AD12.2**
ENSY-5	Area of building integrated photovoltaics (BIPV), per building use, per BIPV type, per country, for current years	**AD13.1**
ENSY-6	Area of building integrated photovoltaics (BIPV), per building use, per BIPV type, per country, for future years	**AD13.2**
ENVIRONMENTAL IMPACT AND CIRCULARITY (ENVI)		
New suggested code	**Data need name**	**D.3.2 code**
ENVI-1	Average recycling rate of construction materials, per country, per construction material for current years	**A20.1**
ENVI-2	Average incineration rate of construction materials, per country, per construction material for current years	**A21.1**
ENVI-3	Average landfill rate of construction materials, per country, per construction material for current years	**A22.1**
ENVI-4	Average emission factors of energy carriers, in kgCO2/J, per country, for current years	**A23.1**
ENVI-5	Expected share of use of CCU strategy, per country, per industry, in %, until 2050	**P5**
ENVI-6	Expected share of use of CCS strategy, per country, per industry, in %, until 2050	**P6**
ENVI-7	Expected share of use of CR strategy, per country, per industry, in %, until 2050	**P8**
ENVI-8	Conditions for the application of WLC strategies, per country, for current and future scenarios	**P19**
ENVI-9	Descriptive statistics on GWP of materials, per material class, per life cycle stages, for current years	**AD4**

ENVI-10	Define emerging building practice (best examples) for low-carbon construction scenarios (acc. proposal) for future years	**AD11**
FORESTRY (FSTY)		
New suggested code	**Data need name**	**D.3.2 code**
FSTY-1	Forest standing stock per country in m^3/ha of wood for past and current years	**A17.1**
FSTY-2	Forest standing stock per country in m^3/ha of wood for future years	**A17.2**
FSTY-3	Forest stock in million m^3 of wood per country, for past and current years	**A18.1**
FSTY-4	Forest stock in million m^3 of wood per country, for future years	**A18.2**
FSTY-5	Forests harvest rate per country in absolute m^3 of wood for past, current, and future years	**A19.1**
HOUSING AND OCCUPANCY (HSNG)		
New suggested code	**Data need name**	**D.3.2 code**
HSNG-1	Average family size, per country, for past and current years	**P15**
HSNG-2	Average newly constructed residential floor area per inhabitant, in m^2/person, per country, per (residential) building use, for past and current years	**P16**
HSNG-3	Average floor area per inhabitant in m^2/person, for residential buildings, per country, for current years	**P17**
HSNG-4	Average floor area per person, in office buildings, schools, hotels and restaurants for current years	**P18.1**
HSNG-5	Number of rooms available in a household, per country, for past and current years	**P20.1**
HSNG-6	Share of population living in an overcrowded household, per country, for past and current years	**P21.1**
HSNG-7	Percentage of dwellings/units under rental contract, per country, per building use for current years	**P22.1**
HSNG-8	Share of employees working from home, per number of days per week, per country	**AD6**
TRANSPORT AND LOGISTICS (TRAN)		
New suggested code	**Data need name**	**D.3.2 code**

TRAN-1	Transport scenarios: Average transport distance, in km, per country, per A4 phase route start and end, per product group, for current years	**AD1.1**
TRAN-2	Transport scenarios: Share of transport distance, in %, per country, per A4 phase route start and end, per means of transport, per product group, for current years	**AD1.2**
TRAN-3	Transport scenarios: Share of transport routes, in %, per country, per A4 phase route type, per product group, for current years	**AD1.3**
TRAN-4	Transport scenarios: Share of sorted waste, in %, per sorting point, per waste fraction, per waste category, for current years	**AD2.1**
TRAN-5	Transport scenarios: Share of waste transport distance, in %, per means of transport, per C2 route type, per waste category, for current years	**AD2.2**
TRAN-6	Transport scenarios: Average transport distance, in km, per C2 route type, per waste category, for current years	**AD2.3**

Appendix 2. ACRONYMS AND ABBREVIATIONS

AHP	Analytic Hierarchy Process
AI	Artificial Intelligence
BPIV	Building-Integrated Photovoltaics
BSO	Building Stock Observatory
BSTK	Building Stock General Characteristics
CCS	Carbon Capture & Storage
CCU	Carbon Capture & Use
CMAT	Construction Materials
CR	Carbon Removal
DG CLIMA	Directorate-General for Climate Action
DG ENER	Directorate-General for Energy
DG ENV	Directorate-General for Environment
DG GROW	Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs
DG MOVE	Directorate-General for Mobility and Transport
EC	European Commission
EFA	European Forest Accounts
ENSY	Energy systems and on-site power generation
ENVI	Environmental impact and circularity
EPC	Energy Performance Certificate
ETD	Electronic Transport Document
EU	European Union
Eurostat	European Statistical Office
FAO	Food and Agriculture Organization of the United Nations
FISE	Forest Information System for Europe
FRI	Forest Resource Inventory

FSTY	Forestry
GIS	Geograhpic Information System
GPS	Global Positioning System
HSNG	Housing and occupancy
HVAC	Heating, Ventilation and Air Conditioning
ID	Identification
JRC	Joint Research Center
LCA	Life Cycle Assessment
LiDAR	Light Detection And Ranging
MS	Member State
NECP	National Energy and Climate Plan
NGO	Non-Governmental Organization
PV	Photovoltaics
RE	Renewable Energy
RFID	Radio-Frequency Identification
SFM	Sustainable Forest Management
TRAN	Transport and logistics
WLC	Whole-Life Carbon

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