D3.3 Quality control process

MODERATE

Marketable Open Data Solution for Optimized Building-related Energy Services

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List of Abbreviations

CDW	Construction Demolition Waste
DSM	Digital Surface Model
EC	European Commission
EPC	Energy Performance Certificate
EU	European Union
GDPR	General Data Protection Regulation
GHG	Greenhouse gas
GIS	Geographic Information System
HEU	Horizon Europe
ICC	Intraclass Correlation Coefficient
IoU	Intersection over Union
NUTS	Nomenclature of Territorial Units for Statistics
PV	Photovoltaic
T	Task
URI	Uniform Resource Identifier
WP	Work Package

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Executive Summary

The development of Task 3.3 (T3.3) is consequential to the completion of Task 3.1 (T3.1, Dynamic Building Stock Analysis) and Task 3.2 (T3.2, Static Building Stock Analysis) of the Horizon Europe (HEU) project MODERATE, Work Package 3 – Data Collection. The aim is to report the datasets analyzed in T3.1 and apply a quality control (QC) process for guaranteeing high quality data provision.

Two primary approaches were employed for collecting data on the building stock: the top-down approach, which relies on aggregated data at the national or regional level derived from statistical models and assumptions, and the bottom-up approach, which involves gathering data on individual buildings. Top-down data is useful for analyzing building stock dynamics and overarching trends on a broader scale. However, this type of data lacks granularity, making it insufficient for the implementation of specialized strategies. On the other hand, the bottom-up approach offers detailed information, but it comes at a considerable cost and is time-intensive.

In the realm of data-driven research and analysis, the collection and organization of metadata are vital processes to ensure the usability and reliability of datasets. The second chapter of this document outlines the comprehensive metadata collection approach that was undertaken for various datasets obtained within the Work Package 3 of the Horizon Europe MODERATE project, including dynamic datasets from Task 3.1, static datasets from Task 3.2, and datasets provided by industrial partners. The metadata provision responds to a request for FAIR data (findable, accessible, interoperable and reusable). The purpose of this effort is to create a structured repository of metadata, enabling researchers, analysts, and stakeholders to gain a deeper understanding of each dataset's characteristics, origins, and accessibility.

The data obtained by the dynamic building stock analysis is validated in Chapter 3 via three case studies. The accuracy of the results of the performed case studies is evaluated through different methods, each one of them tailored for the methodology uses in the case study.

In the first case study, we propose a method for automatically classifying building energy performance certificates (EPCs) based on the analysis of satellite images. This method utilises machine learning algorithms to extract building features from satellite images and link them to building EPCs. To evaluate the performance of the trained models in the classification of EPCs, different evaluation metrics are considered. Given the imbalanced presences of EPCs classes, it was determined to compute precision, recall, and F1 scores for each different class. Subsequently, macro-averaged F1 scores are computed. In this situation each class contributes equally to the final score, regardless of the number of samples in the class. Similarly, the weighted-average F1 score and the balanced accuracy score are also computed. Overall, the considered metrics allow the evaluation of the performance of the trained models in the classification of EPCs taking into account the imbalanced presences of EPCs classes.

The second case study involves the automatic detection of photovoltaic (PV) installations and the estimation of their capacity. The achieved accuracy result of 67% is evaluated with a score of Mean Intersection over Union (mIoU), which measures the number of pixels common between the ground truth and prediction masks divided by the total number of pixels present across both masks. Intersection Over Union (IoU) is a number that quantifies the degree of overlap between two boxes.

Finally, the third case study focuses on an analysis of the distribution of PV installations in industrial and residential areas in an urban context. The results suggest that the larger amount of PV surface is present in industrial areas connotated by lower building density. This outcome finds its validation in

the literature about the Spanish building stock and PV presence within the urban morphology, highlighting the differences between residential and industrial buildings.

Concerning each of the three case studies, the main challenges and limits are also acknowledged and described. The limits mostly relate to the quality of the imagery input data on which the models were built. Furthermore, challenges in image recognition are also presented by false positives (e.g. solar thermal panels, roof windows, etc.).

Later, it is analysed how the methodologies for top-down dynamic analysis deployed in Task 3.1 can be used to obtain a dataset that is comparable to the one obtained by the bottom-up analysis of Task 3.2. The majority of the characteristics can be determined with an analysis from satellite or aerial imagery with different degrees of accuracy. Measurements and morphology can be calculated with a relative high degree of accuracy while the presence of specific heating and cooling elements, the land use and the use of certain materials can be estimated with a higher margin of error. Other features such as the current use or vacancy of the building present evident challenges in being studied with top-down methodologies.

Data reliability is a crucial aspect of any research or analysis process and ensuring that the data used is both accurate and consistent is paramount. In Chapter 4, we outline the methods employed to assess data reliability, which includes statistical analysis and expert interviews. The primary goal is to gauge the relatedness between the MODERATE data and a trusted reference dataset (Hotmaps building stock data) and to validate the findings through expert opinions. Statistical analysis of the dataset of Task 3.2 using ICC indicator, comparing the dataset with a referenced one, indicates the reliability of the results. The results of the statistical analysis showed an ICC greater than 0.5 for 50 out of the 60 variables analysed, suggesting a high degree of relatedness for these variables between the datasets of Moderate and the trusted reference dataset of Hotmaps, and therefore a high degree of reliability. The interviews to experts also strengthens the usability of the data by providing more recent data sources.

1. Introduction

The European Commission's announcement of the Green Deal in 2019 marked the European Union's commitment to achieving climate neutrality by 2050 [1] . This ambitious initiative encompasses a wide array of policy measures aimed at reducing GHG emissions, promoting sustainable energy usage, and enhancing energy efficiency across various economic sectors. One critical sector requiring significant transformation to meet the Green Deal's objectives is the building sector.

1.1. European building stock impact

The building sector bears significant responsibility for GHG emissions and energy consumption, making it a focal point for action. According to the United Nations Environment Programme, this sector contributes substantially to global energy consumption and GHG emissions, accounting for 36% of worldwide energy use and 37% of energy-related GHG emissions [2].

GHG emissions and energy consumption within the building sector are influenced not only by operational aspects of existing buildings, such as heating, cooling, lighting, and ventilation but also by the environmental footprint of construction materials and emissions generated during new building construction. In fact, a substantial portion of GHG emissions associated with the building sector stems from the production of building materials and building operations. The construction industry stands as the largest global consumer of raw materials, utilizing nearly 60% of all materials worldwide. The extraction, transportation, manufacturing, and assembly of building materials require significant energy, contributing significantly to GHG emissions within the building sector. Recent reports indicate that about 11% of GHG emissions linked to the building sector result from the manufacturing of building materials and products, with around 28% arising from building operation [2], [3], [4] – [7].

Additionally, the building sector generates substantial volumes of construction and demolition waste (CDW), posing significant environmental challenges. This waste includes materials like concrete, wood, and steel, which contribute to resource depletion and GHG emissions [8]. In the European Union, CDW constitutes approximately 25-30% of the total generated solid waste [9].

1.2. European Strategy for building stock efficiency

The Green Deal acknowledges the need for prompt action to address the environmental impact of the building sector and outlines a comprehensive set of policy initiatives aimed at advancing the transition to a climate-neutral building sector.

The Renovation Wave strategy, established by the European Commission (EC), focuses on enhancing building energy efficiency and promoting renewable energy sources in the building sector. This strategy aims to double the rate of building renovations in the European Union (EU) by 2030, generating new job opportunities, stimulating economic growth, and reducing energy consumption and GHG emissions. It seeks to make EU buildings more energy-efficient, comfortable, and healthy while mitigating energy poverty through support for the renovation of various types of buildings [10].

The Energy Performance of Buildings Directive (EPBD) is another policy initiative striving to improve the energy efficiency of buildings in the EU. It defines minimum energy performance standards for both new and existing buildings, promotes the use of smart technologies, and aims to make buildings more sustainable and climate friendly. This directive obliges EU countries to develop long-term renovation strategies for their building stock, incorporating energy-efficient measures, renewable energy utilization, and GHG emissions reduction [11].

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The New European Bauhaus, also established by the EC, aims to create a framework for designing and constructing sustainable, inclusive, and aesthetically pleasing environments in the EU. It merges design, sustainability, and innovation to craft buildings that are not only functional but also visually appealing and eco-friendly. The initiative seeks to drive social and economic development by creating a new generation of energy-efficient, accessible, inclusive buildings that contribute to the well-being of both people and the environment [12].

Moreover, the EU has introduced a comprehensive plan to promote a sustainable built environment through Circular Economy (CE) principles. The EU Strategy for a Sustainable Built Environment integrates CE principles throughout the building lifecycle, endorsing strategies for urban mining and the reuse of building materials, thus recognizing waste as a valuable resource. The strategy encourages sustainable construction practices to reduce waste production and boost the use of recycled materials. The H2020 Building As Materials Banks (BAMB) project aims to enhance the value of building materials and extend their durability by developing innovative approaches to material recovery and reuse within the building sector [13].

Overall, these policy initiatives are essential in reducing energy consumption within the building sector by setting new energy efficiency standards and promoting the renovation of the existing building stock. They aim to make buildings more sustainable, comfortable, and healthy, thereby addressing energy poverty and reducing GHG emissions. Furthermore, the implementation of CE principles can lead to a more sustainable and resource-efficient construction industry.

1.3. Building stock data collection

Two main approaches are employed for collecting building stock data:

- Top-Down Approach: This approach uses aggregated national or regional data, relying on statistical models and assumptions. It provides a general overview of the building stock's characteristics and trends at a national level but may not reflect specific regional characteristics accurately.
- Bottom-Up Approach: This approach collects data on individual buildings through surveys and on-site measurements, offering accurate and detailed information about specific buildings but being more time-consuming and expensive.

Remote sensing is a valuable complement to bottom-up data collection, as it allows for high-resolution, spatially defined data collection. It involves acquiring information about objects or areas without physical contact, using technologies like aerial photography, radar and satellite imagery. Remote sensing provides detailed data on building characteristics such as size, shape, and location, which can be used to model energy performance, structural attributes, and environmental characteristics. It can support both top-down and bottom-up approaches, enhancing the granularity and spatial definition of data.

Various studies have demonstrated the potential of remote sensing in collecting building stock data, including deep learning techniques for energy performance estimation, material stock mapping, and quantification of building stock using multi-source remote sensing data.

2. Metadata analysis

2.1. Methodology

FAIR data refers to data that is Findable, Accessible, Interoperable, and Reusable. It's a set of principles and practices designed to enhance the quality and utility of research data, making it easier for researchers to discover, access, integrate, and reuse data effectively [15]. Metadata provision plays a crucial role in making data FAIR by enhancing its findability and usability.

- **Findable:**
  Metadata makes data findable by providing information about the dataset. This includes details like the dataset's title, author, description, keywords, and unique identifiers (e.g., DOIs). These metadata elements enable search engines and data repositories to index the data effectively, making it discoverable through search queries.
- **Accessible:**
  Metadata can contain information about access policies and restrictions. Researchers can include access permissions, licensing information, and terms of use in the metadata. This helps potential users understand how they can access and use the data, ensuring transparency and compliance with data sharing policies.
- **Interoperable:**
  Metadata standards and formats can be used to ensure that data can be effectively integrated with other datasets. By using standardized metadata schemas and controlled vocabularies, metadata helps structure and describe the data consistently. This promotes interoperability, as others can understand the data's structure and content, facilitating data integration.
- **Reusable**:
  Metadata provides essential context for data interpretation. It includes information about data collection methods, processing steps, and any data transformations. Clear and comprehensive metadata enable researchers to understand how the data was generated and processed, making it easier to interpret and reuse effectively. Properly documented metadata also includes information on how to cite the dataset, further promoting its reuse.

When researchers adhere to metadata standards and best practices, they enhance the value of their data, make it easier for others to use, and support data sharing, collaboration, and the advancement of science across various domains.

For the purpose of Work Package 3 of the project, metadata was collected for the dynamic datasets from T3.1, the static datasets from T3.2, and the datasets provided by the industrial partners.

Metadata was collected via each dataset's respective repository or, if the dataset was not available online (i.e. with many of the datasets provided by the industrial partners), then the metadata was requested directly from the dataset creator.

The metadata fields have been listed with the respective descriptions in the following table (please see Table 1):

Table 1: Metadata Fields for the MODERATE datasets

Name of Metadata Field	Description of Metadata Field
Title	Title of the dataset
Description	Brief description of the dataset

Methodology	Methodology used to create the dataset
Accuracy	Any information or assessment of the overall accuracy of the dataset
Completeness	Description of completeness, including any blanks or missing values
Spatial Granularity	Spatial resolution (e.g., NUTS level)
Identifier	Identifier number or link
Identifier Type	Type of identifier (e.g., URL or DOI)
Reference	Citable reference of the dataset
Publication Year	Year that the dataset was published or last updated
Uniform Resource Identifier	Dataset URI with link
Content (keywords)	Some keywords describing the dataset
Geographical extension	Countries/region that is covered by the dataset
Access conditions	Denotes whether the dataset is open to the public for download or closed
License	Denotes the type of license used
Terms of use	Describes the terms of using the dataset
Availability	Describes if the dataset is available for download on the web

2.2. Results

For Task 3.1, five different data sources have been used for retrieving the data which has then been modelled in order to obtain results for the three different case studies. As an example of Metadata, please see Table 2, covering a database for EPCs for the Italian region of Lombardy which has served as ground truth data [14]. This data served to evaluate the results of the model built from satellite imagery data obtained from Copernicus SENTINEL-2 Satellite Images [16].

Please see Annex A for the complete metadata.

Table 2: Metadata for CENED Database

ID	1
Title (with Hyperlink)	Database CENED+2 - Certificazione ENergetica degli Edifici
Description (in brief)	Data regarding the buildings EPCs in the Italian region of Lombardy. This dataset includes around 1.39 million data entries regarding dwellings and buildings EPCs ranging from rom A (most efficient) to G (least efficient).
Methodology	Register of Energy Performance Certificates (EPCs) for the buildings in the Lombardy Region
Accuracy	High quality
Completeness	Datasets have no blank/missing values.
Spatial Granularity	Single building information
Identifier Type	Uniform Resource Locator (URL)
Reference	Regione Lombardia, 'Database CENED+2 - Certificazione ENergetica degli EDifici | Open Data Regione Lombardia', 2023.
Publication Year	2023

URLs	https://www.dati.lombardia.it/Energia/Database-CENED-2-Certificazione-ENergetica-degli-E/bbky-sde5
Content (keywords)	Energy performance certificates
Geographical extension	Lombardy, Italy
Access conditions	Open - download
License	CC0 1.0 Universal
Terms of use	https://creativecommons.org/publicdomain/zero/1.0/legalcode
Availability	Available on the web

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3. Quality control of dynamic building stock analysis

In order to perform a consistent quality control of the data obtained by the dynamic building stock analysis, the project made use of three case study to test, perform and validate the proposed approach. Data obtained through top-down approaches are typically employed for the analysis of building stock dynamics and overall trends on a larger scale. These findings serve as valuable resources for informing policymakers and monitoring national-level environmental performance. Nevertheless, top-down data collection yields highly summarized results that may not accurately represent the unique characteristics of buildings within a specific region. This limitation significantly restricts the usefulness of top-down data for implementing specialized strategies.

Effective planning and application of dedicated strategies necessitate precise and comprehensive data pertaining to individual buildings, a level of detail that can only be acquired through a bottom-up approach. Only by gathering data with a high degree of granularity and spatial accuracy can tailored solutions be assessed and put into action. However, it is important to note that bottom-up approaches are exceptionally time-consuming and costly. In this context, remote sensing emerges as a valuable supplementary approach capable of mitigating these challenges.

The accuracy of the results of the case studies performed have been evaluated through different methods, each one of them tailored for the methodology used in the case study.

In the first case study, we proposed a method for automatically classifying building EPCs based on the analysis of satellite images. This method utilises machine learning algorithms to extract features from satellite images and link them to building EPCs. This approach has the potential to provide an efficient and cost-effective method for assessing the energy performance of buildings on a large scale, which could inform policies and interventions for energy efficiency in the built environment.

In the second case study, we presented an approach based on aerial images to detect installed PV panels and estimate the installed PV capacity on rooftops in urban areas. This approach uses high-resolution aerial images combined with object-based image analysis and machine learning techniques to identify and classify PV panels on rooftops. Following this approach, large scale area can be evaluated, and results could provide valuable information for urban planners and policymakers in promoting renewable energy adoption.

In the third case study, we investigated the relationship between urban residential and industrial areas with respect to presence of PV installations. First, footprints of buildings are detected by machine using a Geographic Information System (GIS) plugin and integrated with the previously detected PV installations. Then, the vectorial data is merged with a normalized Digital Surface Model (DSM) and with bottom-up information on the land use. This allows for the analysis of different variables: land use of the area, either residential or industrial; number of buildings with PV installations; total area of PV installations; height of buildings with PV installations and square footage of roofs hosting PV installations.

3.1. Methodology and results

3.1.1. Case Study I

To evaluate the performance of the trained models in the classification of EPCs, different evaluation metrics were considered. The Italian region Lombardy, freely provides a detailed dataset covering all the buildings EPCs in its territory; Database CENED+2 - Certificazione ENergetica degli EDifici [14]. This dataset includes around 1.39 million data entries regarding dwellings and buildings EPCs ranging from rom A (most efficient) to G (least efficient). This dataset was used to compare and evaluate the results of the algorithm.

Given the imbalanced presences of EPCs classes, it was determined to compute precision, recall, and F1 scores for each different class. The F1 score is a measure used to evaluate the accuracy of a classification model, like one used in machine learning. It's a single number that tells how well the model can correctly identify elements.

It's based on two other measures: precision and recall. Precision is about how many of the things the model identified as positive (e.g., determined EPCs) are actually correct. Recall is about how many of the actual positive things (e.g., all the correct EPCs) the model found.

The F1 score combines precision and recall into a single number to provide a balanced idea of how well the model is doing. It's especially useful when the objective is to find all the positives (recall) and not making too many mistakes (precision).

In simple terms, the F1 score helps you understand how well a model can find and correctly classify elements, by considering both how many it finds (recall) and how many it gets right (precision).

Subsequently, macro-averaged F1 scores were computed. Macro-averaged F1 score is a way to calculate the F1 score for a multi-class classification problem, where the classes may be imbalanced. In this situation each class contributes equally to the final score, regardless of the number of samples in the class. Similarly, the weighted-average F1 score (i.e., the F1 scores calculated independently for each class are averaged across all classes considering weights inversely proportional to class frequencies in the data) and the balanced accuracy score (i.e., the average of recall obtained on each class considering weights inversely proportional to class frequencies in the data) were also computed. Overall, the considered metrics allowed the evaluation of the performance of the trained models in the classification of EPCs taking into account the imbalanced presences of EPCs classes.

To evaluate the performance of the trained models in the classification of EPCs, we considered different evaluation metrics. Given the imbalanced presences of EPCs classes, we computed precision, recall, and F1 scores for each different class. Precision is the number of true positive predictions divided by the total number of positive predictions (please see Equation (1) below). It measures the percentage of positive predictions that are actually correct, or the proportion of correctly identified positive instances out of all instances that were predicted as positive. A high precision indicates that the model is making few false positive errors.

$$Precision = \frac{True\ Positive}{True\ Positive + False\ Positive} \tag{1}$$

Recall is the number of true positive predictions divided by the total number of actual positive instances in the data - please see Equation (2) below. It measures the percentage of positive instances that are correctly identified, or the proportion of correctly identified positive instances out of all actual positive instances. A high recall indicates that the model is making few false negative errors.

$$Recall = \frac{True\ Positive}{True\ Positive + False\ Negative} \tag{2}$$

F1 score is the harmonic mean of precision and recall, given by Equation (3). It balances precision and recall and provides a single score that summarizes the performance of the model. A high F1 score indicates that the model is performing well in both precision and recall.

$$F1\ Score = \frac{2}{\frac{1}{Recall} + \frac{1}{Precision}} \qquad (3)$$

Overall, the considered metrics allowed us to evaluate the performance of the trained models in the classification of EPCs taking into account the imbalanced presences of EPCs classes. Note that all scores motioned above range between 0 and 1 with higher values indicating better performances.

3.1.2. Case Study II

The results of the second case study, involving the detection of PV installations and the estimation of their capacity, was evaluated with a score of Mean Intersection over Union (mIoU), which measures the number of pixels common between the ground truth and prediction masks divided by the total number of pixels present across both masks. Intersection Over Union (IoU) is a number that quantifies the degree of overlap between two boxes. In the case of object detection and segmentation, IoU evaluates the overlap of the Ground Truth and Prediction region (please see Figure 1 below).

The village of Crevillent, in Spain, was chosen as a representative case study thanks to the access of bottom-up data provided by the Instituto Valenciano de la Edificación (IVE), which served as faithful ground truth data against which the result of the work could be compared and evaluated. Bottom-up data on PV installations in Crevillent have been provided by Enercoop, the energy cooperative managing the electricity network of the town. The data was in the form of a list of 98 addresses with PV installations as of 2022 and the relative installed inverter capacity expressed in Watts.

The results of the logistic regression are compared against the manual annotations of PV installations used as ground truth. The performance of the model is measured by Mean Intersection over Union (mIoU), which measures the number of pixels common between the ground truth and prediction masks divided by the total number of pixels present across both masks. Intersection Over Union (IoU) is a number that quantifies the degree of overlap between two boxes. In the case of object detection and segmentation, IoU evaluates the overlap of the Ground Truth and Prediction region [15]. The model used for identifying PV installations achieved a mIoU of 67%.

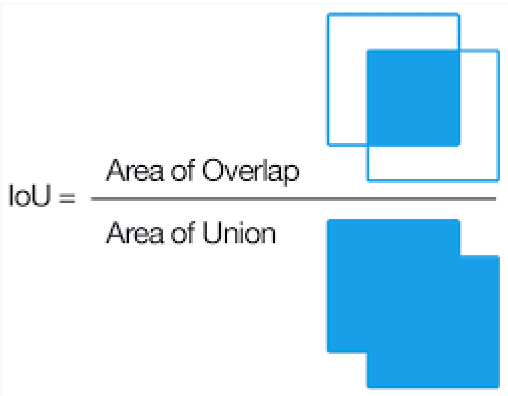

Figure 1: Graphic representation of Mean Intersection over Union

Concerning each of the three case studies, the main challenges and limits were also acknowledged and described. The limits mostly relate to the quality of the imagery input data on which the models were built. Furthermore, challenges in image recognition are also presented by false positives (e.g., solar thermal panels, roof windows, etc.) [23].

PV systems can be easily mistaken for various objects that share similar visual characteristics. These objects may include solar hot water systems, skylights, edges of houses, cables, and even swimming pools. Performing the image detection only on roofs limits possible error sources, such as vehicles windscreens and swimming pools, but the issue still persists to a certain extent.

False negatives present another challenge in the development of this typology of project. PV systems can present a significant identification challenge, even for experienced human annotators, in various situations. For instance, this may occur when black panels are installed on black rooftops, especially when the image resolution is inadequate. Difficulties in identifying such systems even by manual annotators can result in lower quality of training sets, leading to less precise classification or segmentation. Additionally, small, or atypically configured PV systems, which are not rare on residential rooftops, can be particularly challenging to identify. A similar issue is presented by new technologies that integrate photovoltaic installations in materials and styles developed to be less visible as possible, rejecting the common style of photovoltaic panels in favour of tiles and wall mounted installations [23].

3.1.3. Case Study III

After the automatic detection of the building stock of Crevillent and the spatial join with the normalized Digital Surface Model, it has been necessary to filter out the data that is not usable for the calculations required in the following steps. In the first step, the software Mapflow automatically detected 2925 buildings, 1758 of which located in residential areas, while 1167 located in industrial areas.

Incorrect results of the detection and outlier have been filtered by roof surface area and height. The final dataset of buildings will contain only buildings with a Roof Surface Area wider larger than 40 square meters and a height over 2 meters.

The cutting values have been based on minimum realistic measurements that a residential and industrial building can have to be considered usable. The 40 m2 for the roof surface area can still be considered a small value for this purpose, however in a few cases the same roof was not detected as a unique polygon, but it was composed of more polygons by the recognition algorithm. In order to prioritize roof surface area for the purpose of calculations concerning photovoltaics, these values have been maintained. Following this selection, 686 residential buildings and 464 industrial buildings were fitting the chosen parameters, for a total number of 1150 buildings.

Examining the literature on the topic of PV installations on different building morphologies [25][26], residential and industrial areas, it can be clear how they differ in several ways, as following:

• Scale: Industrial PV installations are typically larger in scale than residential installations, due to the higher energy demand in industrial areas. Industrial installations can generate several megawatts of power, while residential installations usually generate a few kilowatts of power.

• System Design: Industrial PV installations often have more complex system designs and include more components, such as energy storage systems, power conversion systems, and monitoring systems, to meet the specific energy needs of industrial facilities. Residential PV installations are generally simpler, with fewer components.

• Cost: Industrial PV installations are typically more expensive than residential installations due to their larger size and more complex design. However, the cost per kilowatt of electricity generated is often lower for industrial installations due to economies of scale.

The fragmentation of PV installations is also tackled: The fragmentation of photovoltaic (PV) systems in residential areas refers to the dispersed and decentralized nature of small-scale PV installations in homes and buildings. Unlike large-scale solar farms and utility-scale installations, residential PV systems are typically smaller in size and capacity and are installed on individual buildings rather than on centralized sites. The fragmentation of PV systems in residential areas has several benefits. For example, it enables households and building owners to take advantage of local renewable energy resources and reduce their dependence on non-renewable energy sources. This can lead to cost savings for households and businesses, as well as reducing greenhouse gas emissions and contributing to the transition to a low-carbon energy system. However, the fragmentation of PV systems in residential areas can also bring challenges and limitations. One of the key challenges is the integration of small-scale PV systems into the grid, which requires coordination and interconnection between the different systems. This can be complex and time-consuming, particularly in areas where there is a high concentration of PV systems. Another challenge is the lack of standardization in the design and installation of PV systems in residential areas. This can result in variability in the performance and quality of the systems, which can have impacts on the efficiency of the grid and the reliability of energy supply. To address these challenges, there is a need for clear and consistent guidelines and standards for the installation of PV systems in residential areas. In addition to these technical challenges, there are also social and economic considerations to take into account. For example, the fragmentation of PV systems in residential areas can lead to a lack of coordination and collaboration between households and building owners and can limit the potential for collective action and community engagement.

3.1.4. Bridging the gap between dynamic and static data collection

In this section, it is analyzed how the methodologies for top-down dynamic analysis deployed in task 3.1 can be used to obtain a dataset that is comparable to the one obtained by the bottom up analysis of task 3.2.

The majority of characteristics can be determined with an analysis from satellite or aerial imagery with different degrees of accuracy. Measurements and morphology can be calculated with a relative high degree of accuracy while the presence of specific heating and cooling elements, the land use and the use of certain materials can be estimated with a higher margin of error. Other features such as the current use or vacancy of the present evident challenges in being studied with top-down methodologies.

Concerning the age of buildings, for instance, the literature suggests that it can be using machine learning techniques. Zeppelzauer [17] proposed a two-stage approach that learns characteristic visual patterns from photographs to estimate building age, outperforming human evaluators. Tooke [21] used LiDAR data and random forests to predict building age with high accuracy, while Li [19] proposed a method using deep learning and image processing techniques to estimate building age from Google Street View images. Bijieki [18] also provided techniques for the identification of building age using 3DGIS. These findings demonstrate the potential of machine learning in determining the age of buildings.

As for the determination of the number of floors, a simple calculation had to be used to determine

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this information. By knowing the height of each building from a Digital Surface Model (DSM) topographic database, it was divided by the standard inter floor height, which is 3 meters.

$$Number\ of\ floors = building\ height\ (m)\ /\ 3\ (m). \qquad (4)$$

Concerning the next step, the urban composition is effectively captured by the ‘surface to volume ratio’ (S/V), which holds significant importance. The term "building envelope" refers to the external physical components of a structure that serve as a barrier between the inside and outside environments. The term "exposed building envelope per unit volume" measures the proportion of the building envelope that is visible relative to the total volume of the building. This measurement finds various practical applications, such as estimating the quantity of paint required for the façade of a specific urban area based on the building's exposed envelope per unit of volume [20].

Theoretically, to minimize heat transfer through the building envelope the building shape should be as compact as possible, tending toward a cube. In hot dry climates the S/V ratio should be as low as possible to minimize heat gain. In cold-dry climates S/V ratio should also be as low as possible to minimize heat losses [20].

In warm humid climates, the primary concern is to create airy spaces; this might not, however, necessary minimize the S/V ratio.

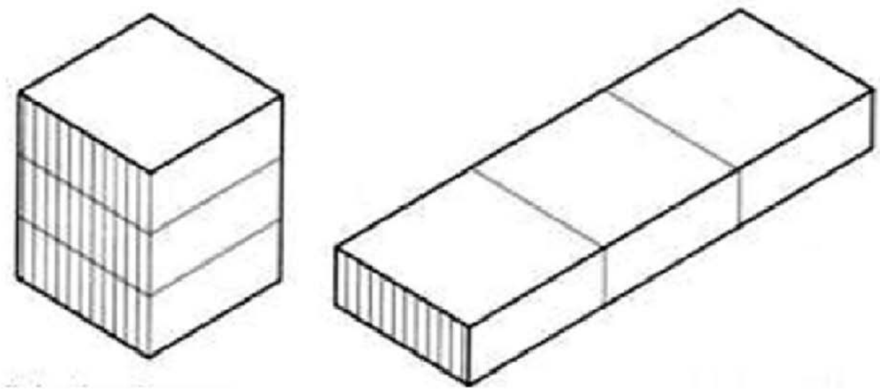

Figure 2: Graphic representation of blocks with different Surface to Volume Ratio

These methodologies have been applied to the context of Crevillent, Spain.

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Figure 3: Number floors per building in Crevillent, Spain

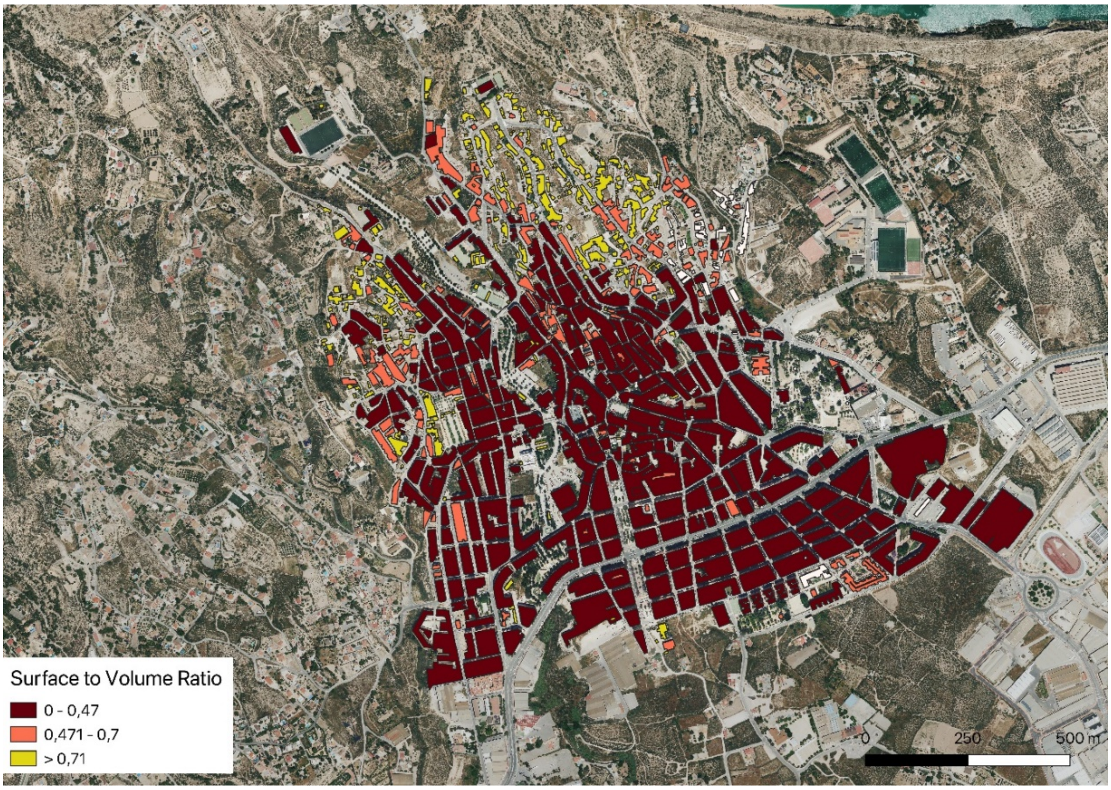

Figure 4: Surface to Volume Ratio per building in Crevillent

4. Statistical analysis and expert interviews

4.1. Methodology

Data reliability is a crucial aspect of any research or analysis process and ensuring that the data used is both accurate and consistent is paramount. In this chapter, we outline the methods employed to assess data reliability, which includes statistical analysis and expert interviews. The primary goal was to gauge the relatedness between the MODERATE data and a trusted reference dataset (Hotmaps building stock data) [22] and to validate the findings through expert opinions.

To determine the degree of relatedness between the MODERATE data and the trusted reference data (Hotmaps building stock data), we utilized the Intraclass Correlation Coefficient (ICC). ICC measures the consistency and agreement between different sets of data. The ICC quantifies the proportion of the total variance in a dataset that can be attributed to between-group variability (i.e., variability among different subjects or items) relative to the total variance, including within-group variability (i.e., variability within the same subject or item). In other words, it helps to determine how much of the variation in your data is due to differences between subjects or items compared to random variation within subjects or items. In this case, it was used to assess how closely the Moderate data aligned with the reference data.

The MODERATE data [24] was systematically compared with the Hotmaps building stock data [22], with the aim of assessing the compatibility. It was the only possibility of data comparison figured out due to the specificities of the MODERATE data concerning data types, construction periods, and building types.

An ICC coefficient close to 1 indicates a high degree of relatedness between the datasets, suggesting that the MODERATE data is reliable. Conversely, a low ICC coefficient suggests a lack of relatedness, potentially indicating data quality issues. To draw a clear line between related and unrelated data, an ICC coefficient threshold of 0.5 was used. Data with ICC coefficients below this threshold were considered too unrelated and potentially less reliable.

To validate the findings from the statistical analysis and gather expert opinions, two representatives from each EU Member State (MS) were interviewed. The selection process aimed to ensure representation from a broad cross-section of experts.

For privacy reasons, the names and surnames of the experts interviewed cannot be reported. However, in the table below the institutions for each country from which the experts have been contacted are listed.

Table 3: Host institutions of experts interviewed

Country	Institution
Austria	Austrian Institute of Technology
Austria	Institute of Building Research & Innovation
Belgium	University of Liege
Belgium	University of Liege
Bulgaria	EnEffect
Bulgaria	Black Sea Energy Research Centre (BSERC)
Croatia	Energy Institute Hrvoje Požar (EIHP)

Croatia	Faculty of Mechanical Engineering and Naval Architecture of Zagreb University FSB
Cyprus	Spidernet
Cyprus	The Cyprus Institute
Czech Republic	Czech Academy of Sciences
Czech Republic	Brno University Of Technology (VUTBR)
Denmark	Planenergie
Denmark	Ramboll
Estonia	Palmiste
Estonia	Taltech
Finland	(Finnish Metereological Institute) FMI
Finland	Planora
France	French Government
France	University of La Rochelle
Germany	WIP Renewable Energies
Germany	Fraunhofer
Greece	Aristotle University of Thessaloniki (AUTH)
Greece	University of New South Wales (UNSW)
Hungary	Budapest University of Technology and Economics (BME)
Hungary	Central European University (CEU)
Ireland	Carrig Conservation International Ltd.
Ireland	Irish Metereological Service (MET)
Italy	Zabala
Italy	EHP
Latvia	Riga Technical University (RTU)
Latvia	Riga Technical University (RTU)
Lithuania	Vilpra
Lithuania	VDU University
Luxembourg	University of Luxembourg
Luxembourg	Luxembourg Institute of Science and Technology (LIST)
Malta	University of Malta
Malta	University of Malta
Netherlands	University of Groningen
Netherlands	Huygen
Poland	Wrocław University of Science and Technology (PWR)
Poland	Bialystok University of Technology
Portugal	Univeristy of Alviero
Portugal	University of Algarve
Romania	Technical University of Cluj-Napoca (Utcluj)
Romania	Termo
Slovakia	Technical University of Kosice (Tuke)
Slovakia	Technical University of Kosice (Tuke)
Slovenia	UL FGG

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Slovenia	Construction Cluster of Slovenia
Spain	Aiguasol
Spain	Diei
Sweden	Research Institutes of Sweden (Rise)
Sweden	Linköping University

The interviews were conducted in accordance with the General Data Protection Regulation (GDPR) guidelines to ensure the ethical and legal aspects of data collection were adhered to.

During the interviews, the experts were presented with the results obtained from the statistical analysis. Each ICC coefficient value was explained to the interviewees to provide a clear understanding of the data relatedness assessment. The experts were also informed about the significance of the 0.5 threshold.

The experts were then asked to provide their opinions on the validity of the comparison results. This step was critical in understanding whether the observed data-relatedness (or lack thereof) was consistent with their expertise. If there were discrepancies or differing opinions between the two representatives from a given EU MS, a third expert was identified and interviewed to obtain a balanced and comprehensive view.

4.2. Results

The results of the statistical analysis showed an ICC greater than 0.5 for 50 out of the 60 variables analysed, suggesting a high degree of relatedness for these variables between the datasets of Moderate and the trusted reference dataset of Hotmaps, and therefore a high degree of reliability. See Table 4 for the ICC coefficients of the selected variables. The ones presenting a value below 0.5 are marked in red.

Table 4: ICC coefficients of analyzed variables

Variable	ICC
area_Mm2	1
area_heated_Mm2	1
area_cooled_Mm2	1
build_M	0.52
dwellings_M	1
owner_occupied_M	1
private_rented_M	0.97
social_housing_M	0.19
occupied_M	1
vacant_M	1
secondary_M	1
u_roof_W_m2K	-0.239
u_walls_W_m2K	-0.070
u_windows_W_m2K	-0.20
u_floor_W_m2K	-0.111
walls_material_brick_NA	1

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walls_material_concrete_NA	1
walls_material_wood_NA	1
walls_material_other_NA	1
walls_methodology_solidWall_NA	1
walls_methodology_solidWall_insulation	1
walls_methodology_cavityWall_NA	1
walls_methodology_cavityWall_insulation	1
walls_methodology_honeycombBricksHollowBlocksWall_NA	1
walls_methodology_honeycombBricksHollowBlocksWall_insulation	1
walls_methodology_other_NA	1
windows_material_wood_NA	1
windows_material_syntheticPvc_NA	1
windows_material_aluminium_NA	1
windows_methodology_singleGlazing_NA	1
windows_methodology_doubleGlazing_NA	1
windows_methodology_doubleGlazing_low-e	1
windows_methodology_tripleGlazing_NA	1
windows_methodology_tripleGlazing_low-e	1
roof_material_wood_NA	1
roof_material_concrete_NA	1
roof_material_concreteBricks_NA	1
roof_methodology_tiltedRoof_NA	1
roof_methodology_tiltedRoof_insulation	1
roof_methodology_flatRoof_NA	1
roof_methodology_flatRoof_insulation	1
floor_material_wood_NA	1
floor_material_concrete_NA	1
floor_material_concreteBricks_NA	1
floor_material_other_NA	1
floor_methodology_concreteSlab_NA	1
floor_methodology_concreteSlab_insulation	1
floor_methodology_woodenFloorRaftersBoards_NA	1
floor_methodology_woodenFloorRaftersBoards_insulation	1
floor_methodology_other_NA	1
ued_sh_kWh_m2	0.25
ued_sc_kWh_m2	0.34
ued_dhw_kWh_m2	-0.3073
tot_ued_sh_dhw_TWh	0.88
tot_ued_sc_TWh	0.98
fec_sh_kWh_m2	0.18
fec_sc_kWh_m2	0.82
fec_dhw_kWh_m2	-0.174
tot_fec_sh_dhw_TWh	0.88
tot_fec_sc_TWh	0.97

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The interviews with the experts provided more recent sources of data that had not been previously explored in the work. Therefore, the final dataset [24] has been actualized accordingly, boosting their accuracy and usability.

5. Conclusions

In the pursuit of robust data reliability, the project employed a multi-faceted approach, combining statistical analysis and expert interviews to assess the accuracy and consistency of data obtained through dynamic building stock analysis. The comprehensive validation process was conducted through three distinct case studies, each with its own unique challenges and methodologies.

The initial recognition that top-down data, such as that provided by Hotmaps building stock data, is invaluable for large-scale analysis and trend monitoring, but may lack the granularity required for specialized strategies, led to the need for more precise bottom-up data. While bottom-up data offers enhanced accuracy, it is often time-consuming and costly to acquire. To address this, remote sensing was identified as a supplementary approach capable of mitigating these challenges, bridging the gap between top-down and bottom-up data.

In the age of big data and information abundance, thorough metadata collection and documentation are indispensable. The metadata for dynamic, static, and industrial partner datasets, encompassing various essential fields, ensures that these valuable resources are well-documented and accessible to researchers, policymakers, and stakeholders. This structured approach not only fosters data transparency but also empowers users to make informed decisions about dataset selection and utilization. Metadata for Task 3.1 and Task 3.2 of Work Package 3 of MODERATE, have been provided, responding to a request for FAIR data (findable, accessible, interoperable and reusable).

The case studies each offered valuable insights, and their results were rigorously evaluated. In Case Study I, the use of machine learning for classifying building energy performance certificates demonstrated potential for efficient large-scale assessments, which could inform energy efficiency policies effectively.

Case Study II, focused on the detection and estimation of photovoltaic panels, utilized the Mean Intersection over Union (mIoU) score as a metric to measure the performance of the model. The mIoU score of 0.67 reflected the capability of the model to identify PV installations on rooftops accurately.

Case Study III, which analyzed the presence of PV installations in urban residential and industrial areas, drew validation from existing data at different scales. This comparative approach enhanced the credibility of the results and their relevance at both local and national levels.

Nevertheless, each case study faced challenges and limitations, mainly stemming from the quality of input imagery data. Issues such as false positives and false negatives were acknowledged, highlighting the complexities of image recognition and classification. Later, it has been analyzed how the methodologies for top down dynamic analysis deployed in Task 3.1 can be used to obtain a dataset that is comparable to the one obtained by the bottom up analysis of Task 3.2. The majority of the characteristics can be determined with an analysis from satellite or aerial imagery with different degrees of accuracy. For instance, for the city of Crevillent the number of floors and the surface to volume ration have been calculated and mapped. Measurements and morphology can be calculated with a relative high degree of accuracy while the presence of specific heating and cooling elements, the land use and the use of certain materials can be estimated with a higher margin of error. Other features such as the current use or vacancy of the present evident challenges in being studied with top down methodologies. Finally, the statistical analysis of the dataset of Task 3.2 through the use of ICC indicator, comparing the dataset with a referenced one, proved the reliability of the results. The results of the statistical analysis showed an ICC greater than 0.5 for 50 out of the 60 variables analysed, suggesting a high degree of relatedness for these variables between the datasets of Moderate and the trusted reference dataset of Hotmaps, and therefore a high degree of reliability. The interviews to experts also strengthened the usability of the data by providing more recent data sources.

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6. Annex

6.1. Annex A

Table 5: Metadata of Task 3.1

ID	Title (with Hyperlink)	Description (in brief)	Methodology
1	Database CENED+2 - Certificazione ENergetica degli Edifici	Data regarding the buildings EPCs in the Italian region Lombardy. This dataset includes around 1.39 million data entries regarding dwellings and buildings EPCs ranging from rom A (most efficient) to G (least efficient).	n/a
2	Copernicus SENTINEL-2 Satellite Images	SENTINEL-2 satellite is part of the Copernicus Programme operated by the European Space Agency (ESA). It provides Earth observation data for environmental monitoring and security purposes with high-resolution multispectral imagery of the Earth's surface. Obtained images have a spatial resolution up to 10 meters and data are provided for 13 different spectral bands, ranging from visible and near-infrared to shortwave infrared, at different spatial resolutions.	Captured using satellite imagery.
3	Open Street Maps	OpenStreetMap is a collaborative, open-source platform for mapping and geospatial data, where contributors can add and edit information such as building footprint polygons, roads, and other features.	n/a
4	Copernicus Climate Data Store ERA5	ERA5 (fifth generation of atmospheric reanalysis of the global climate) is a dataset produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) that provides hourly estimates of a range of atmospheric, oceanic and land surface variables. In particular, we considered the temperature of air at 2 meters above the surface of land.	https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=overview
5	Orthophoto of 2022 of the Valencian Community in RGBI and 25 cm resolution	Mosaic of orthophotographs in natural color (RGB) and infrared false color (IRG) that covers the Valencian Community, prepared at 25 cm resolution, based on the RGBI digital photogrammetric flight carried out during the period from 05/08/2022 to 06/11/ 2022. The orthophoto is distributed by 1:5,000 sheets, being accessible for download in ECW (3-band RGB) and TIFF (4-band RGBI) formats. Color depth at 8 bits per band. Geodetic reference system is ETRS89 and UTM projection in zone 30.	Captured using aerial imagery.

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6.2. Annex B

Table 6: Metadata of Task 3.2

ID	Title (with Hyperlink)	Description (in brief)
1	Energy Performance Indicator Tracking Schemes for the Continuous Optimisation of Refurbishment Processes in European Housing Stocks	The EPISCOPE project focused on the energy refurbishment of houses in 20 European countries. Among the collected information, data regarding the construction period (different classes are defined in each country) and the building type (single-family, terraced house, multi-family house and apartment block) may be useful for risk assessment of large geographic areas.
2	Social Housing in Germany	The concept of social housing (Sozialer Wohnungsbau) has undergone dramatic changes over the past two-and-a-half decades in Germany. The amount of market housing paid for with housing benefit by households with limited incomes or special housing needs has grown considerably. Virtual social housing provides safe and affordable housing without the negative spatially accumulative factors that are often associated with estates of de jure and de facto social housing. This chapter begins with a discussion on the development of the social housing sector from the late 19th century up to the present. There has always been a wide spectrum of owners involved in the provision of social dwellings, reflecting the overall ownership structure of German housing; the ownership structure is illustrated in the chapter. Finally, the chapter discusses strategies which many municipal housing companies have developed to work more actively to improve the socioeconomic situations of their tenants.
3	A New Method for Contrasting Energy Performance and Near-Zero Energy Building Requirements in Different Climates and Countries.	In this study a robust method enabling one to compare the energy performance in different climates was developed. Derived normalization factors allow "to move" the building from one climate to another with corresponding changes in heating, cooling, and electric lighting energy. Degree days, solar-air temperature and economic insulation thickness were used to normalize space heating and cooling needs. Solar-air temperature based degree days resulted in 5% accuracy in space heating and dry-bulb air temperature based cooling degree days were trustworthy in cooling need normalization. To overcome the limitation of the same thermal insulation in all climates, an economic insulation thickness was applied. Existing and nearly zero energy requirements were contrasted in four countries with a reference office building to analyze the impacts of climate and national regulation on primary energy use. By applying standard energy calculation input data and primary energy factors from European standards to buildings with national technical solutions, nearly zero energy building requirements comparison with European Commission benchmarks was possible to conduct. Generally, in Central and North Europe comparison, national input data caused much more difference than the climate.

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4	H2020 AmBIENCe. D4.1: Database of grey-box model parameter values	Deliverable D4.1 “Database of grey-box model parameter values for EU building typologies” describes the development of a European building stock database, collecting information and data on parameters needed for both the assessment of the Energy System Impact and the creation of the performance models. These grey-box model parameters characterize the dynamic thermal behaviour of the respective buildings which is needed to assess the impact of building flexibility.
5	Social Housing in the Netherlands	The social rented housing stock in the Netherlands is one of the largest in Europe, after France and the United Kingdom. The construction of social housing was first allowed by the Housing Act of 1901. Housing associations work as a revolving fund: they sell dwellings as a core component of their business and use the revenues for new investments. Rents are related to housing quality rather than tenant income. Quality is measured by a point system, where points are provided for amenities and the size of the house. Rents for social housing are lower than for private housing. Social housing is intended for people who cannot manage to find a dwelling on their own. This chapter provides information about social housing tenants. The legal basis for social housing is the Housing Act in 1901, which laid down the duties and responsibilities of housing associations. These are discusses in the chapter.
6	Zebra2020: Share of new dwellings in residential stock	Building stock data including data for energy efficiency trends in buildings as well as data for net zero energy buildings.
7	Social Housing in Spain	Housing policy in Spain fundamentally emphasises home ownership. The most important social housing is the so-called Vivienda de Protección Oficial (literally ‘officially protected housing’ (VPO)). This chapter illustrates the main characteristics of Spanish housing plans since the end of the 1980s, and provides a summary of the historical development of the social housing sector. The structure of the social housing sector consists of a wide spectrum of providers including the state, regional governments and municipalities. The main form of subsidy to VPO housing is through the provision of free or cheap land for construction by municipal landowners. Additional costs of VPO social housing are financed through the public budget and the banking system. The chapter provides a comparison of the VPO and market house prices, and discusses access to VPO housing among households. It ends with a brief discussion on the current social housing policy in Spain.
8	Energy efficiency in French homes	A strong cut in heat consumption can be realized by the thermal renovation of buildings: this article gives an assessment of energy savings achievable in the French residential stock and their associated investment costs. A bottom-up approach, using a dataset on material and labor costs for renovations and a thermal model (including a representation of the 'rebound effect') is applied to a description of existing dwellings in France. Renovation investment costs increase with the efficiency target of the housing stock: two inflection points are identified, for 40% and 60% reduction targets. If the first inflection is driven by a quantity effect, the second one is pushed by a price effect. Specificities of

		the thermal renovation market imply a lock-in risk: at the micro-scale, the discount rate could induce households to realize low ambition renovations, whereas at the macro-scale, having successive short-term objectives triggers important over-costs, above 15% of the optimized investment costs. We suggest that policy-makers take the risk of low ambition renovations into account, as it may nip the potential of energy savings in the bud. Relevant policies would set today the long-term efficiency target and earmark public incentives, like tax credits or interest-free loans, to ambitious renovations.
9	Sustainability assessment of renovation packages for increased energy efficiency for multi-family buildings in Sweden	In this paper, we propose a method for assessing renovation packages drawn up with the goal of increasing energy efficiency. The method includes calculation of bought energy demand, life-cycle cost (LCC) analysis and assessment of the building according to the Swedish environmental rating tool Miljöbyggnad (MB). In this way the methodology assesses economic, indoor environmental quality (IEQ) and specifically environmental aspects associated with energy demand of such packages from a sustainability point-of-view. Through MB, energy efficiency packages are placed in context with other necessary measures required to improve environmental performance in buildings, providing a consistent and systematic basis other than simply financial performance by which to compare capital improvements. The method is further explained and analyzed by applying it in three case studies. In each case study a multi-family building representing a typologically significant class in the Swedish building stock is considered, and for each building a base case and two renovation packages with higher initial investment requirement and higher energy efficiency are defined. It is shown that higher efficiency packages can impact IEQ indicators both positively and negatively and that packages reducing energy demand by approx. 50% have somewhat higher LCC. Identified positive IEQ impacts point to added value for packages that may not otherwise be communicated, while negative impacts identify areas where packages need to be improved, or where MB indicators may be referred to as specifications in procurement procedures.
10	Vacant housing stock: Analysis and action proposal	Three distinct phases. The first is an updated and detailed characterization of the Portuguese housing stock, particularly the vacant housing stock. The characterization will be made using the available statistical data, in particular form censuses surveys. The second phase corresponds to the framing of vacant houses problem by defining vacant houses, the reasons why they are vacant and its main consequences. There will be also carried out the theme framework in the international context. In the third phase will be evaluated the public rental of houses in the private market for affordable housing, as well as move forward with proposals for its implementation.
11	European residential buildings and empirical assessment of the Hellenic building stock, energy consumption,	The existing building stock in European countries accounts for over 40% of final energy consumption in the European Union (EU) member states, of which residential use represents 63% of total energy consumption in the buildings sector. Consequently, an increase of building energy performance can

	emissions and potential energy savings	constitute an important instrument in the efforts to alleviate the EU energy import dependency (currently at about 48%) and comply with the Kyoto Protocol to reduce carbon dioxide emissions. This is also in accordance to the European Directive (EPBD 2002/91/EC) on the energy performance of buildings, which is currently under consideration in all EU member states. This paper presents an overview of the EU residential building stock and focuses on the Hellenic buildings. It elaborates the methodology used to determine the priorities for energy conservation measures (ECMs) in Hellenic residential buildings to reduce the environmental impact from CO2 emissions, through the implementation of a realistic and effective national action plan. A major obstacle that had to overcome was the need to make suitable assumptions for missing detailed primary data. Accordingly, a qualitative and quantitative assessment of scattered national data resulted to a realistic assessment of the existing residential building stock and energy consumption. This is the first time that this kind of aggregate data is presented on a national level. Different energy conservation scenarios and their impact on the reduction of CO2 emissions were evaluated. Accordingly, the most effective ECMs are the insulation of external walls (33–60% energy savings), weather proofing of openings (16–21%), the installation of double-glazed windows (14–20%), the regular maintenance of central heating boilers (10–12%), and the installation of solar collectors for sanitary hot water production (50–80).
12	Social Housing in France	French habitation à loyer modéré (HLMs) includes standard, lower and upper social housing, defined by the level of rent and level of income for allocation. The loan types for these programmes are known respectively as PLUS, PLAI, and PLS loans. This chapter discusses the organisation of the social housing sector. One-third of housing allowances go to social housing tenants. Rents in the social rental sector are determined by formulas linked to the original cost of construction and the way the building was then financed. Social housing units are allocated through a complex system involving various actors: social landlords, municipalities, associations and the government's local representatives. There is a contrast between the way foreign experts see housing in France and the discussion in France. The main challenges for the French housing system in coming years will be to preserve the current diversity of tenures and to avoid social polarisation.
13	Number of dwellings by region, type of building and period of construction	The statistics present the number of apartments in the dwelling stock. The dwelling stock is presented in the Statistical Database by type of building, period of construction, type of ownership, tenure and size (living area). The regional breakdown of statistics consists of national, county and municipal levels. Other regional levels can be produced on commission.
14	Finland National Report: Housing Solutions for People who are homeless	National report on housing solutions for homeless people in Finland.

15	Social Housing in the Czech Republic	The Czech Republic is a country with extremely fragmented social housing policies and no de facto central coordination or regulation. Municipalities are the only owners of long-term rental housing provided at below-market rents and without special social services to tenants. After 1948, Czechoslovakia's economy shifted to central planning and housing construction began to be fully and centrally controlled by the state. Recent estimates indicate that municipal housing now makes up less than 10% of the housing stock. It comprises both pre-war brick buildings and post-war pre-fab buildings. Even though housing policy and public housing management were decentralised to the local level, new municipal/social housing output is critically dependent on funds from the state budget. For a long time the Czech housing system maintained a very conservative rent-control regime, which applied to existing tenancies in both municipal and private ownership.
16	Inquérito ao Consumo de Energia no Sector Doméstico - 2020	The ICESD 2020 had as main objective the updated knowledge of energy consumption in households in Portugal and resulted from the collaboration between Statistics Portugal (INE) and the Directorate General for Energy and Geology (DGEG), entity that financed the project. In Portugal, the Survey on Energy Consumption in Households (ICESD), currently in the 4th edition, had previous editions in 1989, 1996 and 2010.
17	Analysis of financial benefits for energy retrofits of owner-occupied single-family houses in Germany	In many industrialized countries, a significant number of buildings were constructed prior to any energy-related building construction standards. Today, single-family houses (SFHs) from this time still have a comparably poor thermal quality. This paper aims to examine and model the incentive effects of the German energy retrofit funding schemes for owners of SFHs constructed shortly before the introduction of the first German thermal insulation ordinance in 1979. We develop a novel mixed-integer economic optimization model that determines the financially optimal energy retrofit configuration for owner-occupied SFHs. In a case study, we consider German framework conditions such as governmental incentives, standards, regulations, retrofit costs, and energy prices. We calculate economic burdens and benefits in 48 different retrofit scenarios for two representative SFHs constructed in the 1960s and 1970s. In the majority of cases, the return on investment is positive. For heating system retrofits, energy savings are comparatively small, but the cost-benefit ratios of retrofits are better than for measures on the building envelope. Overall, we find retrofits to decrease operational costs to between 15% and 62% of the initial value. The financial incentive effect of the German funding instruments can lead to financially optimal savings of CO_2 emissions in the range of 82–94%, however our findings show that the conditions of the German funding programs are not designed to maximize CO_2 savings per funded euro. We show that the funding invested to reduce the annual tons of CO_2 ranges from 493 € to 3747 € in our case study.
18	Population and Housing Censuses 2011 Detailed data	The data presented is from the Population and Housing Censuses 2011. For the first time, the census has been developed under a European Union regulation (see Regulation No 763/2008 of the European Parliament and of the Council),

		which, apart from implementing the legal obligation to carry out the census during the year 2011, ensures the comparability of results within the European Union.
19	BOL101: Dwellings by region, type of resident, use, tenure, ownership and year of construction	The purpose of the housing statistics is to analyze the total housing stock and population housing. The statistics is used in the municipal equalization system. The housing statistics has been conducted annually since 1981. The statistics is comparable from 2010 onwards.
20	INSEE: Statistics and studies	On 1st January 2021, French housing stock, excluding Mayotte, amounted to 37.2 million housing units. In mainland France, 82% of housing units were main residences and 55% were individual housing units. The proportion of main residences has slightly decreased for about 15 years, in favour of vacant accomodations and second homes more recently. 16% of main residences were located in the Paris region, while 37% of second homes or occasional accomodations were situated in non-urban units. The proportion of home-owners had increased until 2010 and remained stable around 58% since then. Housing stock has grown more quickly in the overseas territories than in mainland France, approximately 2.4% annually on average since 1982, compared to 1.1% in mainland France.
21	Number of dwellings by region, type of building and tenure	The statistics present the number of apartments in the dwelling stock. The dwelling stock is presented in the Statistical Database by type of building, period of construction, type of ownership, tenure and size (living area). The regional breakdown of statistics consists of national, county and municipal levels. Other regional levels can be produced on commission.
22	Housing and property markets in Germany 2020	The booklet informs you about the key developments and challenges of the housing and property markets in Germany.
23	Social Housing in the Republic of Ireland	This chapter focuses on how social housing is provided in Ireland. It first presents a general overview of the housing system in order to place social housing in context. The chapter then looks at how social housing is provided directly by local authorities and housing associations and indirectly through rent supplements or housing allowances and, in more recent years, by what have been termed social housing leasing schemes, whereby social landlords rent housing for tenants from private landlords. Rural local authority tenants have enjoyed the right to buy their homes since the 1930s, and this right was extended to their urban counterparts by the Housing Act of 1966. In the local authority sector, construction costs are met mainly by central government grants. Low-income tenants in the private rented sector who are not in full-time employment can rent from private landlords and claim 'rent supplement' for a portion of their rent.
24	Social Housing in Hungary	In terms of building type, the urban social housing stock in Hungary can be divided into three categories: tenement houses; units in housing estates;

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		individual apartments. The chapter analyses the dynamics of housing affordability, the public rental sector and support for home ownership. After the political changes that took place at the end of the 1980s, housing policy went through four stages, more or less following the macro housing trends. During the socialist period, both rent and utility costs in public (state-owned) housing were deeply subsidised and unrelated to actual economic costs, resulting in permanent excess demand and long waiting lists. The chapter concludes that consistent strategies for social-housing policy after 1989 were absent, as policies were set by fragmented public and private institutions in different sectors (energy, water, construction, social care, etc.) and newly decentralised local governments.
25	ENTRANZE: Share of owner occupied dwellings in residential stock	Building stock data including floor area of residential and non-residential buildings, heating/AC system data, and energy use by sector.
26	Entranze/Inspire: U-value roofs residential buildings	Building stock data including floor area of residential and non-residential buildings, heating/AC system data, and energy use by sector.
27	U-value floors residential buildings	The EU Building Stock Observatory (BSO) was established in 2016 as part of the Clean energy for all Europeans package, and aims to provide a better understanding of the energy performance of the building sector through reliable, consistent and comparable data. Its main objective is to provide more transparent information on the EU's building stock support the monitoring of current EU energy policies and measures contribute to future policy making processes. The BSO is designed to include a database, a data mapper and factsheets for monitoring the energy performance of buildings across Europe. The updated version of the tool will cover a broad range of energy related topics and provide information on the building stock, energy consumption, building elements and technical building systems installed, energy performance certificates, nearly zero-energy buildings and renovation rates, but also areas like energy poverty and financing aspects.
28	Classification of European building stock in technological and typological classes	Nowadays it is known that the European building stock is energy-intensive and insecure: constructions need interventions both to solve performance and structural deficiencies and to reduce the current unsustainable energy waste. An intelligent retrofit for existing structures should offer an intervention integrating all the different performance requirements, such as structural safety, energy efficiency and architectural quality together with optimization of construction processes and costs. To this purpose, it is, therefore, essential to improve knowledge on the composition of the existing building stock. In this work, by analysing and processing the quantitative and qualitative data available from different countries, it has been possible to define an accurate building technologies map showing both the seismic-resistant structures and the envelope systems, the latter to evaluate also the environmental behaviour of buildings in terms of Life Cycle Assessment (LCA) and energetic consumptions. Afterwards, the seismic and climatic characteristics of all the

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		European countries have been considered, so leading towards the definition of zones with different combined hazard conditions. Through all the possible combinations between these seismic and climatic zones, it has been conceived a hazard matrix, where different case studies can be placed aiming at showing potentialities of different retrofit solutions from seismic and energy viewpoints. The investigation of these case studies, which will be analysed in a companion paper, allows to cover all the possible constructions and hazards detected at European level, so to implement an analysis method to be used in every Countries in Europe.
29	Bulgarian Statistical National Institute, National Statistical Institute, NSI, 2011. www.nsi.bg/	Newly built dwellings by number of rooms and by type of settlement, newly built residential buildings by structure of buildings and by type of settlement, useful floor space of the newly built dwellings and by type of settlement, residential buildings, dwellings and useful floor space of the dwellings destroyed.
30	Building stock characteristics and energy performance of residential buildings in Eastern-European countries	Countries in Eastern-Europe have similar characteristics due to their common historical and economic backgrounds. A large part of the housing stock has been built during the Soviet era, applying uniform solutions and similar standards, but similarities extend to other periods as well. On the other hand, the differences should also be noted – although the climate is mainly continental, there are significant variations between South and North and between mountainous and flat areas. In this paper, a detailed comparative analysis is presented for Bulgaria, Serbia, Hungary and the Czech Republic. The results are based on the residential building typologies developed within the TABULA/EPISCOPE project co-funded by the Intelligent Energy Europe Programme. Typical building types will be presented, covering building structures and systems. Important energy performance indicators are identified and compared, supported by available statistical data about the housing stock. The added value of the paper consists of the analysis of heterogeneous data sources and collecting and comparing the information of the housing stock under a common comparison framework of building typology data between countries, and the contribution in the harmonization of the building typology approach.
31	Social Housing in Austria	The social housing sector in Austria responds to publicly defined goals and principles such as economic, ecological and social sustainability. The main provisions are that rents should cover costs, profits are limited and the companies have an obligation to reinvest. The funds for the housing systems are financed by a fixed, earmarked proportion of income tax, as well as corporation tax and 'housing contributions' paid by all employees. Austria has a strong rent regulation. In principle, both social and private rents are regulated and cost-based. The social housing debate in Austria is dominated by the themes of market liberalisation, privatisation of public housing, the retreat of corporatist governance traditions, and immigrant and social exclusion issues, all against the backdrop of an economic crisis that itself has implications for the housing subsidy system.

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Table 7: Metadata of Task 3.2

ID	Title (with Hyperlink)	Methodology
1	Energy Performance Indicator Tracking Schemes for the Continuous Optimisation of Refurbishment Processes in European Housing Stocks	The determination of the monitoring indicators includes a certain effort of summarising and condensing. The EPISCOPE idea of "Average Buildings" is to take advantage of the exist-ence of the scenario indicators from national models to set up a very simple calculation scheme in parallel: The total values of all relevant input, interim and output quantities (number of apartments, floor area, envelope area, energy need for heating, final energy consumption, etc.) are divided by the number of buildings counted in the building stock subgroup. So, "average buildings" are being constructed which are theoretical (synthetical) buildings with geometrical and thermo-physical characteristics equal to the average of the building stock subset which they represent. The annual energy balance for heating and DHW of average buildings are calculated in the same manner as for real buildings. Projections to the building stock can be done by multiplying the single building related figures with the total number of buildings.
2	Social Housing in Germany	Data are gathered from national statistics
3	A New Method for Contrasting Energy Performance and Near-Zero Energy Building Requirements in Different Climates and Countries.	In this study two methods, a simple normalization factor and reference building energy simulation method, were developed and tested for energy performance comparison of office buildings in different climates.
4	H2020 AmBIENCe. D4.1: Database of grey-box model parameter values	The database development includes two main tasks: First, defining the database structure and fields, and secondly populating the database. The database was developed through the series of steps: 1. Definition of potential data sources and their comparison with the database requirements 2. Final selection of the data sources 3. Transformation of data provided by data sources, which included other relevant inputs, such as information on properties of building construction materials 4. Defining and filling the data gaps 5. Merging residential and non-residential databases into a final single database 6. Adding the relevant grey-box model parameters. Steps 1-4 were performed in parallel for residential and non-residential buildings, which resulted in two separate databases available at the end of the step 4. In the step 5 these two databases were merged into one. Step 6 is described in more detail in chapter 2. Steps 3 and 4 – data transformation and filling the data gaps, were the most important steps of the database development. These aimed at simplifying the raw data available from the data sources, adjusting data to the needs of the database, and enabling a final merge of residential and non-residential databases.

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5	Social Housing in the Netherlands	Data are gathered from national statistics.
6	Zebra2020: Share of new dwellings in residential stock	Data in the Zebra2020 Data Tool are gathered from a variety of national sources, including Statistik Austria for Austrian data, Istat for Italian data, and the Direction générale Statistique et Information écon for French data.
7	Social Housing in Spain	Data are gathered from national statistics.
8	Energy efficiency in French homes	The characterization of house and building archetypes enables us to assess an efficiency indicator of the thermal envelope in each case: the mean U-value UG, the envelope's overall heat transfer coefficient. This indicator is calculated as the average of each envelope component's U-value weighted by its relative importance in the envelope surface.
9	Sustainability assessment of renovation packages for increased energy efficiency for multi-family buildings in Sweden	The method includes: -energy demand calculations, -life-cycle cost (LCC) analysis, -assessment by MB, the Swedish environmental rating tool.
10	Vacant housing stock: Analysis and action proposal	This article will be divided into three distinct phases. The first is an updated and detailed characterization of the Portuguese housing stock, particularly the vacant housing stock. The characterization will be made using the available statistical data, in particular form censuses surveys. The second phase corresponds to the framing of vacant houses problem by defining vacant houses, the reasons why they are vacant and its main consequences. There will be also carried out the theme framework in the international context. In the third phase will be evaluated the public rental of houses in the private market for affordable housing, as well as move forward with proposals for its implementation.
11	European residential buildings and empirical assessment of the Hellenic building stock, energy consumption, emissions and potential energy savings	Various ECMs were implemented on the corresponding Hellenic residential building stock that need refurbishment, in order to quantify the specific energy savings and reduction of CO_2 emissions. A total of 14 ECMs were assessed.
12	Social Housing in France	Data are gathered from national statistics.
13	Number of dwellings by region, type of building and period of construction	Data are gathered from national statistics.

14	Finland National Report: Housing Solutions for People who are homeless	Data are gathered from national statistics.
15	Social Housing in the Czech Republic	Data are gathered from national statistics.
16	Inquérito ao Consumo de Energia no Sector Doméstico - 2020	The results are based on survey data.
17	Analysis of financial benefits for energy retrofits of owner-occupied single-family houses in Germany	The concept of the optimization model is developed as a mixed-integer problem (MIP/pl. MIPs) and specified in a case study with data for two German buildings, German framework conditions, and exemplary retrofit scenarios. The case study is implemented as a program in GAMS, a programming language that has the advantage of describing an optimization problem in a way that is very similar to its mathematical description. For solving MIPs, GAMS uses branch and bound algorithms.
18	Population and Housing Censuses 2011 Detailed data	The methodology of the Census 2011 combines the use of administrative registers with the information of a great sample formed by 1,621,643 households and 4,107,465 persons. In order to obtain a representative sample, information from all Spanish municipalities has been collected (8,116). The national sampling fraction for the population is close to the 9.0%. The information related to persons (migrations, studies, mobility, relationships, etc.), households (composition of the household) and family nuclei is obtained from the treatment of the information collected in the individual questionnaire. On the other hand, information related to the characteristics of the main dwellings (tenancy regime, heating, hygiene, bath or shower, Internet, water supply system, useful area and number of bedrooms) comes from the dwelling questionnaire.
19	BOL101: Dwellings by region, type of resident, use, tenure, ownership and year of construction	Data are gathered from national statistics.
20	INSEE: Statistics and studies	Data are gathered from national statistics.
21	Number of dwellings by region, type of building and tenure	The register is being updated by the municipalities responsible for the updating with help of information from the countrys property owners.
22	Housing and property markets in Germany 2020	Data are gathered from national statistics.

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23	Social Housing in the Republic of Ireland	Data are gathered from national statistics.
24	Social Housing in Hungary	Data are gathered from national statistics.
25	ENTRANZE: Share of owner occupied dwellings in residential stock	Entranze includes data collected from numerous sources--including Odyssee, Building Performance Institute Europe, Tabula, and Eurostat--and and presents them in an online data mapping tool.
26	Entranze/Inspire: U-value roofs residential buildings	Entranze includes data collected from numerous sources--including Odyssee, Building Performance Institute Europe, Tabula, and Eurostat--and and presents them in an online data mapping tool.
27	U-value floors residential buildings	EU Building Stock Observatory (BSO) monitors data from the European building stock and extrapolates measures based on monitored and survey data.
28	Classification of European building stock in technological and typological classes	The statistical institutes of each country provide generic data about the building stock found on their territories. Mostly, these data consider the number of residential buildings grouped by construction periods. Such erection times are characterized by defined construction materials, design criteria and architectures, but also changes in the legal requirements for the thermal properties of the construction envelope.
29	Bulgarian Statistical National Institute, National Statistical Institute, NSI, 2011. www.nsi.bg/	The statistical questionnaire includes indicators which are harmonized according to the requirements of Regulation 1165/98 on EC concerning short-term statistics.
30	Building stock characteristics and energy performance of residential buildings in Eastern-European countries	https://www.sciencedirect.com/science/article/pii/S0378778816305515?via%3Dihub#sec0010
31	Social Housing in Austria	Data are gathered from national statistics.

Table 8: Metadata of Task 3.2

ID	Title (with Hyperlink)	Identifier	Identifier Type	Reference	Publication Year	URLs	Content (key words)	Geogr. extension
1	Energy Performance	https://episcope.eu/com	Uniform Resource	Diefenbach N. et al. Energy	2015	https://episcope.eu/commu	Building stock -	Germany

	Indicator Tracking Schemes for the Continuous Optimisation of Refurbishment Processes in European Housing Stocks	munication/download/	Locator (URL)	Performance Indicator Tracking Schemes for the Continuous Optimisation of Refurbishment Processes in European Housing Stocks. 2015. https://episcope.eu/fileadmin/episcope/public/docs/pilot_actions/DE_EPISCOPE_NationalCase_Study_IWU.pdf		nication/download/	energy efficiency	
2	Social Housing in Germany	https://doi.org/10.1002/9781118412367.ch11	Digital object identifier (DOI)	Droste, C., and Knorr-Siedow, T. Social Housing in Germany. 2014. https://doi.org/10.1002/9781118412367.ch11	2014	https://doi.org/10.1002/9781118412367.ch11	Social housing	Germany
3	A New Method for Contrasting Energy Performance and Near-Zero Energy Building Requirements in Different Climates and Countries.	https://doi.org/10.3390/en11061334	Digital object identifier (DOI)	Ahmed, K., et al. A New Method for Contrasting Energy Performance and Near-Zero Energy Building Requirements in Different Climates and Countries. 2018. https://doi.org/10.3390/en11061334	2018	https://doi.org/10.3390/en11061334	Energy performance	Belgium
4	H2020 AmBIENCe. D4.1: Database of	https://ambience-project.eu/wp-	Uniform Resource Locator (URL)	H2020 AmBIENCe. D4.1: Database of grey-box	2021	https://ambience-project.eu/a-database-that-	Energy performance	Hungary

	grey-box model parameter values	content/uploads/2022/03/AmBIENCe_Deliverable-4.1_Database-of-greybox-model-parameter-values.xlsx		model parameter values. 2021. https://ambience-project.eu/a-database-that-aims-to-improve-the-field-of-building-energy-performance/		aims-to-improve-the-field-of-building-energy-performance/		
5	Social Housing in the Netherlands	https://doi.org/10.1002/9781118412367.ch2	Digital object identifier (DOI)	Elsinga, M., and Wassenberg, F. Social Housing in the Netherlands. 2014. https://doi.org/10.1002/9781118412367.ch2	2014	https://doi.org/10.1002/9781118412367.ch2	Social housing	The Netherlands
6	Zebra2020: Share of new dwellings in residential stock	https://zebra-monitoring.enerdata.net/overall-building-activities/share-of-new-dwellings-in-residential-stock.html	Uniform Resource Locator (URL)	H2020 ZEBRA. Energy efficiency trends in buildings Data Tool. 2015. https://zebra-monitoring.enerdata.net/overall-building-activities/share-of-new-dwellings-in-residential-stock.html#wall-u-values-building-codes.html	2015	https://zebra-monitoring.enerdata.net/overall-building-activities/share-of-new-dwellings-in-residential-stock.html#wall-u-values-building-codes.html	Building stock - energy efficiency	Sweden
7	Social Housing in Spain	https://doi.org/10.1002/9781118412367.ch13	Digital object identifier (DOI)	Baralides, A. Social Housing in Spain. 2014. https://doi.org/10.1002/9781118412367.ch13	2014	https://doi.org/10.1002/9781118412367.ch13	Social housing	Spain
8	Energy efficiency in	https://doi.org/10.13140/	Digital object	Civel, E. and Elbeze, J.	2016	http://www.chaireeconomi	Energy efficiency	France

	French homes	RG.2.2.23375.28321	identifier (DOI)	Energy efficiency in French homes: how much does it cost? 2016. http://www.chaireeconomieduclimat.org/RePEc/cec/wpaper/16-05-Cahier-R-2016-03-Civel-Elbeze.pdf		educlimat.org/RePEc/cec/wpaper/16-05-Cahier-R-2016-03-Civel-Elbeze.pdf		
9	Sustainability assessment of renovation packages for increased energy efficiency for multi-family buildings in Sweden	https://doi.org/10.1016/j.buildenv.2012.11.019	Digital object identifier (DOI)	Brown, N.W.O. et al. Sustainability assessment of renovation packages for increased energy efficiency for multi-family buildings in Sweden. 2013. https://doi.org/10.1016/j.buildenv.2012.11.019	2013	https://doi.org/10.1016/j.buildenv.2012.11.019	Energy efficiency	Sweden
10	Vacant housing stock: Analysis and action proposal	https://fenix.tecnico.ulisboa.pt/downloadFile/1689244997256146/Extended%20Abstract.pdf	Uniform Resource Locator (URL)	Cardoso, J.P.H. Vacant housing stock: Analysis and action proposal. 2016. https://fenix.tecnico.ulisboa.pt/downloadFile/1689244997256146/Extended%20Abstract.pdf	2016	https://fenix.tecnico.ulisboa.pt/downloadFile/1689244997256146/Extended%20Abstract.pdf	Vacant housing stock	Portugal
11	European residential buildings and empirical assessment of the Hellenic	https://doi.org/10.1016/j.buildenv.2005.11.001	Digital object identifier (DOI)	Balaras, C.A. et al. European residential buildings and empirical assessment of the Hellenic	2005	https://www.sciencedirect.com/science/article/pii/S0360132305004671	Energy consumption	Greece

	building stock, energy consumption , emissions and potential energy savings			building stock, energy consumption, emissions and potential energy savings. 2005. https://www.sciencedirect.com/science/article/pii/S0360132305004671				
12	Social Housing in France	https://doi.org/10.1002/9781118412367.ch8	Digital object identifier (DOI)	Lévy-Vroelant, C. et al. Social Housing in France. 2014. https://onlinelibrary.wiley.com/doi/epdf/10.1002/9781118412367.ch8	2014	https://onlinelibrary.wiley.com/doi/epdf/10.1002/9781118412367.ch8	Social housing	France
13	Number of dwellings by region, type of building and period of construction	https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BO__BO0104__BO0104D/BO0104T02/table/tableViewLayout1/	Uniform Resource Locator (URL)	National statistics of Sweden. Number of dwellings by region, type of building and period of construction. 2021. https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BO__BO0104__BO0104D/BO0104T02/table/tableViewLayout1/	2021	https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BO__BO0104__BO0104D/BO0104T02/table/tableViewLayout1/	Building stock	Sweden
14	Finland National Report: Housing Solutions for People who are homeless	https://www.feantsa.org/download/finland_housing_homelessness_2008387891179536436699.pdf	Uniform Resource Locator (URL)	FEANTSA. Finland National Report: Housing Solutions for People who are homeless. 2008.	2008	https://www.feantsa.org/download/finland_housing_homelessness_2008387891179536436699.pdf	Housing for homeless	Finland

				https://www.feantsa.org/download/finland_housing_homelessness_2008387891179536436699.pdf				
15	Social Housing in the Czech Republic	https://doi.org/10.1002/9781118412367.ch10	Digital object identifier (DOI)	Lux, M. Social Housing in the Czech Republic. 2014. https://doi.org/10.1002/9781118412367.ch10	2014	https://doi.org/10.1002/9781118412367.ch10	Social housing	Czech Republic
16	Inquérito ao Consumo de Energia no Sector Doméstico - 2020	978-989-25-0596-1	International Standard Book Number (ISBN)	Instituto Nacional de Estatística. Inquérito ao Consumo de Energia no Sector Doméstico - 2020. 2021. https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=527966882&PUBLICACOESmodo=2	2021	https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_publicacoes&PUBLICACOESpub_boui=527966882&PUBLICACOESmodo=2	Energy consumption	Portugal
17	Analysis of financial benefits for energy retrofits of owner-occupied single-family houses in Germany	https://doi.org/10.1016/j.buildenv.2021.108722	Digital object identifier (DOI)	Mayer, Z. et al. Analysis of financial benefits for energy retrofits of owner-occupied single-family houses in Germany. 2022. https://doi.org/10.1016/j.buildenv.2021.108722	2022	https://doi.org/10.1016/j.buildenv.2021.108722	Energy retrofit	Germany

18	Population and Housing Censuses 2011 Detailed data	https://www.ine.es/en/prensa/np824_en.pdf	Uniform Resource Locator (URL)	Instituto Nacional de Instituto Nacional de Estatística. Population and Housing Censuses 2011 Detailed data. 2011. https://www.ine.es/en/prensa/np824_en.pdf	2011	https://www.ine.es/en/prensa/np824_en.pdf	Population and housing	Spain
19	BOL101: Dwellings by region, type of resident, use, tenure, ownership and year of construction	https://www.statbank.dk/BOL101	Uniform Resource Locator (URL)	Statistics Denmark. BOL101: Dwellings by region, type of resident, use, tenure, ownership and year of construction. 2022. https://www.statbank.dk/BOL101	2022	https://www.statbank.dk/BOL101	Population and housing	Denmark
20	INSEE: Statistics and studies	https://www.insee.fr/en/statistiques/5887128	Uniform Resource Locator (URL)	The National Institute of Statistics and Economic. Statistics and studies. 2018. https://www.insee.fr/en/statistiques/5887128	2018	https://www.insee.fr/en/statistiques/5887128	Building stock	France
21	Number of dwellings by region, type of building and tenure	https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BO__BO0104__BO0104D/BO0104T04/	Uniform Resource Locator (URL)	National statistics of Sweden. Number of dwellings by region, type of building and tenure. 2022. https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START	2022	https://www.statistikdatabasen.scb.se/pxweb/en/ssd/START__BO__BO0104__BO0104D/BO0104T04/table/tableViewLayout1/	Dwellings	Sweden

				__BO__BO0104__BO0104D/BO0104T04/table/tableViewLayout1/				
22	Housing and property markets in Germany 2020	https://www.bbsr.bund.de/BBSR/EN/publications/AnalysenKompakt/Issues/ak-08-2021-dl.pdf?__blob=publicationFile&v=2	Uniform Resource Locator (URL)	Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). Housing and property markets in Germany 2020. 2020. https://www.bbsr.bund.de/BBSR/EN/publications/AnalysenKompakt/Issues/ak-08-2021-dl.pdf?__blob=publicationFile&v=2	2020	https://www.bbsr.bund.de/BBSR/EN/publications/AnalysenKompakt/Issues/ak-08-2021-dl.pdf?__blob=publicationFile&v=2	Housing market	Germany
23	Social Housing in the Republic of Ireland	https://doi.org/10.1002/9781118412367.ch9	Digital object identifier (DOI)	Redmond, D. and Norris, M. Social Housing in the Republic of Ireland. 2014. https://doi.org/10.1002/9781118412367.ch9	2014	https://doi.org/10.1002/9781118412367.ch9	Social housing	Ireland
24	Social Housing in Hungary	https://doi.org/10.1002/9781118412367.ch12	Digital object identifier (DOI)	Hegedüs, J. Social Housing in Hungary. 2014. https://doi.org/10.1002/9781118412367.ch12	2014	https://doi.org/10.1002/9781118412367.ch12	Social housing	Hungary
25	ENTRANZE: Share of owner occupied dwellings in	https://entranze.enerdata.net/share-of-dwellings-connected-	Uniform Resource Locator (URL)	ENTRANZE Project. Share of owner occupied dwellings in	2008	https://entranze.enerdata.net/share-of-owner-occupied-	Building stock - energy efficiency	Latvia

	residential stock	to-district-heating.html		residential stock. 2008. https://entranze.enerdata.net/share-of-owner-occupied-dwellings-in-residential-stock.html		dwellings-in-residential-stock.html		
26	Entranze/Inspire: U-value roofs residential buildings	https://entranze.enerdata.net/share-of-dwellings-connected-to-district-heating.html	Uniform Resource Locator (URL)	Entranze/Inspire Project. U-value roofs residential buildings. 2017. https://ec.europa.eu/energy/eu-buildings-database_en	2017	https://ec.europa.eu/energy/eu-buildings-database_en	Building stock - energy efficiency	Cyprus
27	U-value floors residential buildings	https://energy.ec.europa.eu/document/download/6185004a-1b8c-4cb2-bbdf-437ad5b4969c_en?filename=25012023-EU_BSO_Database.xlsx	Uniform Resource Locator (URL)	Building Stock Obervatory. U-value floors residential buildings. 2017. https://ec.europa.eu/energy/eu-buildings-database_en	2017	https://ec.europa.eu/energy/eu-buildings-database_en	U-value	Luxembourg
28	Classification of European building stock in technological and typological classes	https://doi.org/10.1016/j.jobe.2021.103482	Digital object identifier (DOI)	Landolfo R. et al. Classification of European building stock in technological and typological classes. 2022. https://doi.org/10.1016/j.jobe.2021.103482	2022	https://doi.org/10.1016/j.jobe.2021.103482	Energy performance	Cyprus
29	Bulgarian Statistical National Institute, National Statistical	https://www.nsi.bg/en/content/3135/newly-built-residential-	Uniform Resource Locator (URL)	Bulgarian Statistical National Institute, National Statistical	2011	www.nsi.bg/	Building construction	Bulgaria

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	Institute, NSI, 2011. www.nsi.bg/	buildings-completed		Institute, NSI, 2011. www.nsi.bg/				
30	Building stock characteristics and energy performance of residential buildings in Eastern-European countries	https://doi.org/10.1016/j.enbuild.2016.06.062	Digital object identifier (DOI)	Csoknyai T. et al. Building stock characteristics and energy performance of residential buildings in Eastern-European countries. 2016. https://doi.org/10.1016/j.enbuild.2016.06.062	2016	https://doi.org/10.1016/j.enbuild.2016.06.062	Energy performance	Hungary
31	Social Housing in Austria	https://doi.org/10.1002/9781118412367.ch4	Digital object identifier (DOI)	Reinprecht, C. Social Housing in Austria. 2014. https://doi.org/10.1002/9781118412367.ch4	2014	https://doi.org/10.1002/9781118412367.ch4	Social housing	Austria

6.3. Annex C

Table 9: Metadata of industrial partners

ID	Title	Description (in brief)
1	ENERCOOP: Electric load profiles	Data on annual electric load profiles. Files could be downloaded via ENERCOOP's tool once the profiles are synthetised or aggregated. The tool will provide CSV files containing fields for consumed energy, exported energy, reactive energy, and contracted power.
2	IVE: EPC data	The partner supplied an open data portal for the registry of certificates of energy efficiency in the Valencian community where data can be downloaded by year and province. The year corresponds to the year of completion and presentation before the Administration of the registry of the CEE (payment of the fee). The data is updated monthly and may vary between downloads (files deleted, updated, corrections resulting from inspections, etc.).
3	KÖHLER&MEINZER: Yearly energy data	Yearly energy data (demand of energy for heat and DHW generation) of single flats and multi-family homes with up to 10 parties. Energy bill and building ontology for 580 apartments from approximately 80 apartment buildings, including energy consumption data from utility bills of single flats (anonymized).

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4	KÖHLER&MEINZER: Survey data	The partner also provided survey data carried out among the member companies of KOHLER's professional association BFW-BW (Landesverband freier Immobilien- und Wohnungsunternehmen Baden-Württemberg).
5	SOLAR TIROL: Solar data	Yearly solar irradiance (kWh/m2/y), Energy yield of PV systems (kWh/kWp), Buildings vectorial layer, including information on building ID, surface area, coordinates
5,1	SolarCadastre: irradiance and economic data in Crevillent	Yearly solar irradiance (kWh/m2/y), Energy yield of PV systems (kWh/kWp), Buildings vectorial layer, including information if available, surface area, coordinates, area suitable for PV.
6	SYNAVISION: Comprehensive metering and BMS data	Office consumption data from two buildings: 1) a public administration office that was built in 2007 and is approximately 7,000 m^2 in size that uses district heating and 2) a school that was built in 2020 and is approximately 6,700 m^2 in size that uses heat pumps with geothermal ground probes. Both buildings have a high level of energy efficiency. SYNAVISION has monitored these buildings as part of research projects and has comprehensive metering data as well as BMS data.
7	VEOLIA: Energy consumption data	Two datasets were provided in CSV format which include information about two buildings: a residential building and a health center. The two buildings with monitored data along with additional files describing the respective variables. Variable fields include energy consumption - space heating, DHW, and temperature—all with a resolution of 15 minutes—as well as floor area, number of floors, and insulation.
8	VITO: Electricity consumption	Individual electricity consumption data of 100 anonymized digital meters. The consumptions are measured with 15 min frequency and available for the 2016 calendar year (01/Jan-31/Dec). This dataset is not owned by VITO and it is publicly available.
9	VITO: Individual gas consumption data	Individual gas consumption data of 100 anonymized digital meters. The consumptions are measured with 15 min frequency and available for the 2018 calendar year (01/Jan-31/Dec). This dataset is not owned by VITO and it is publicly available.
10	VITO: Street level consumption data per energy type	Street level consumption data per energy (electricity/gas), injection/purchase and per main municipality at street level. The consumptions were aggregated to a calendar year. This dataset is not owned by VITO and it is publicly available.
11	VITO: Building 3D geometrical data	Building 3D geometrical data in Flanders, including building footprint and height. This dataset is not owned by VITO and it is publicly available.
12	VITO: EPC data	Flemish EPC datasets published by the Flemish energy and climate agency (VEKA), including geometrical parameters, construction properties, HVAC installation, renewables, EPC results (for public buildings). This dataset is not owned by VITO and it is publicly available.

13	WÜRTH - monitoring data of their sale points in Italy: retail shops/stores currently operating at the remote-control level in CSV format.	The data provided by WÜRTH, refer to monitoring data of their sale points in Italy: retail shops/stores currently operating at the remote control level. The data has been provided in a CSV format. The files provided contain a list of the anagraphic data of 21 retail shops/stores, such as identifier, name, surface area in square meters, geographic coordinates in decimal degrees, and the number of active areas located inside the stores from which WÜRTH collected HVAC temperature and power consumption data. The store-specific files, contain the temporal remote control data currently available since the remote control system was installed, such as the indoor temperatures (in degrees Celsius) taken for the various areas in the store and the outdoor temperature (in degrees Celsius) taken from OpenWeather data, the HVAC power consumption in kWh, and the total power consumption of the entire store in kWh. Moreover, the CSV file specifies if the store is covering the whole building or not. The kWh indicated in the CSV file is the average power aggregated at 15 minutes.

Table 10: Metadata of industrial partners

ID	Title	Methodology
1	ENERCOOP: Electric load profiles	Smart meter readings which need to be synthesised or aggregated for ensuring anonymity and compliance with GDPR.
2	IVE: EPC data	Dataset is based on the EPC collected by IVACE from Valencian Community (NUTS2).
3	KÖHLER&MEINZER: Yearly energy data	Building ontology: based on data from construction period energy consumption: data from energy provider energy demand: measured and (partially) calculated consumptions according to German heating ordinance, datasets are relevant for accounting
4	KÖHLER&MEINZER: Survey data	Survey carried out in a business association datasets were submitted by companies themselves relevant data points: consumption (per m²), energetic standard of the thermal envelope, supply structure
5	SOLAR TIROL: Solar data	Data available from Geokatalog http://geokatalog.buergernetz.bz.it/geokatalog/#!
5,1	SolarCadastre: irradiance and economic data in Crevillent	Data processed by Eurac Research from Building (https://geocataleg.gva.es/#/search?uuid=spaicvBcv05Serie2015) and DEM (https://geocataleg.gva.es/#/search?uuid=spaicv030421_2016PALI0100), CRS EPSG 25830
6	SYNAVISION: Comprehensive metering and BMS data	All data has been metered in demo projects with scientific support.

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7	VEOLIA: Energy consumption data	Own data
8	VITO: Electricity consumption	Load profile generation
9	VITO: Individual gas consumption data	Load profile generation
10	VITO: Street level consumption data per energy type	Disaggregation
11	VITO: Building 3D geometrical data	Archetype detection
12	VITO: EPC data	Archetype detection
13	WÜRTH - monitoring data of their sale points in Italy: retail shops/stores currently operating at the remote-control level in CSV format.	CSV data extraction from time series database.

Table 11: Metadata of industrial partners

ID	Title	Identifier	IT	Ref.	Publication Year	URLs	Content (keywords)	Geographic extension
1	ENERCOOP: Electric load profiles	n/a	n/a	moderate@eurac.edu	n/a	https://moderate.enercoop.es/ (Currently offline)	electricity demand	Crevillent, Spain
2	IVE: EPC data	An example of an EPC: E2018VJ089241 E: Existing (N: New construction, R: Renovation) 2018: Initial Registration Year V: Residential Use (T: Tertiary Use) J: Random control letter 089241: Consecutive registration number	n/a	moderate@eurac.edu	2013-2023	The Open dataset:https://gceedadesobertes.aven.es/dadesobertes/	energy performance certificates	Valencian Community Spain (NUTS2)

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3	KÖHLER&MEINZER: Yearly energy data	internal project identifier	n°	moderate@eurac.edu	2016-today	available in a database or as csv	energy demand	Karlsruhe, Germany
4	KÖHLER&MEINZER: Survey data	numerical, based on supplier	n°	moderate@eurac.edu	2022	available as csv	energy survey	Baden-Württem--berg, Germany
5	SOLAR TIROL: Solar data	n/a	n/a	moderate@eurac.edu	2012	http://geokatalog.buergernetz.bz.it/geokatalog/#!	solar irradiance, buildings	South-Tyrol
5,1	SolarCadastre: irradiance and economic data in Crevillent	n/a	n/a	moderate@eurac.edu	n/a	n/a	solar irradiance, economic analysis, buildings	Crevillent
6	SYNAVISION: Comprehensive metering and BMS data	n/a	n/a	moderate@eurac.edu	n/a	n/a	energy consumption	Germany
7	VEOLIA: Energy consumption data	n/a	n/a	moderate@eurac.edu	2023	n/a	energy consumption	n/a
8	VITO: Electricity consumption	n/a	n/a	moderate@eurac.edu	n/a	https://opendata.fluvius.be/explore/dataset/1_04-werkelijke-verbruiksprofielen-huishoudelijke-klanten-elektriciteit/information/	electricity consumption	n/a
9	VITO: Individual gas consumption data	n/a	n/a	moderate@eurac.edu	n/a	https://opendata.fluvius.be/explore/dataset/1_05-100-geanonimiseerde-60-verbruiksprofielen-aardgas/information/	gas consumption	n/a
10	VITO: Street level consumption data per energy type	n/a	n/a	moderate@eurac.edu	n/a	https://opendata.fluvius.be/explore/dataset/1_03-verbruiksgegeve	energy consumption	n/a

						ns-op-straatniveau/information/		
11	VITO: Building 3D geometrical data	n/a	n/a	moderate@eurac.edu	n/a	https://overheid.vlaanderen.be/informatie-vlaanderen/producten-diensten	building characteristics	n/a
12	VITO: EPC data	n/a	n/a	moderate@eurac.edu	n/a	https://eur02.safelinks.protection.outlook.com/?url=https%3A%2F%2Fopendata.vlaanderen.be%2Fdataset%3Forganization%3Dvlaams_energie_en_klimaatagentschap_veka%26q%3D&data=05%7C01%7C%7C6130f5fa805e410524d508dab2000a8b%7C9e2777ed82374ab992782c144d6f6da3%7C0%7C0%7C638018010496629472%7CUnknown%7CTWFpbGZsb3d8eyJWIjoiMC4wLjAwMDAiLCJQIjoiV2luMzIiLCJBTiI6Ik1haWwiLCJXVCI6Mn0%3D%7C3000%7C%7C%7C&sdata=16Z7ZxjZFK6a4F%2FHRxJe8IDBEG2bEnrE7kFlI3o%2FMN0%3D&reserved=0	energy performance certificates	n/a
13	WÜRTH - monitoring data of their sale points in Italy: retail shops/stores	Sale point identifier	String	moderate@eurac.edu	n/a	n/a	energy consumption	Italy

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	currently operating at the remote-control level in CSV format.							

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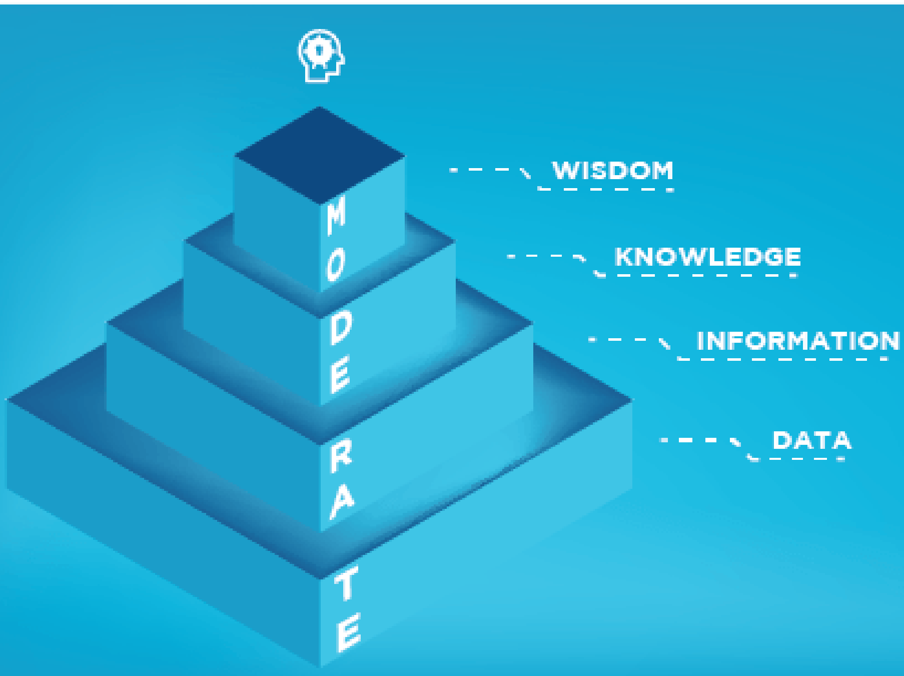

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