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JRC-IDEES-2021: the Integrated Database of the European Energy System – Data update and technical documentation

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Contents

Abstract

The Joint Research Centre's Integrated Database of the European Energy System (JRC-IDEES) incorporates in a single database a rich set of information allowing for highly granular analyses of the dynamics of the European energy system, so as to better understand the past and create a robust basis for future policy assessments. JRC-IDEES provides a consistent set of disaggregated energy-economy-emissions data for each Member State of the European Union, covering all sectors of the energy system for the 2000-2021 period. This data complies with Eurostat energy balances while providing a plausible decomposition of energy consumption into specific processes and end uses. In each sector, JRC-IDEES uses a vintage-specific approach to quantify the characteristics of the energy-using equipment in operation, along with the average operation of the equipment stock. It accordingly identifies different drivers and provides insights on their role by sector while accounting for structural differences across countries. As such, JRC-IDEES has several key applications for energy system modelling, research, and policy analysis, such as the parameterization of energy models and the assessment of past and prospective policies.

JRC-IDEES is freely accessible to the general public since 2018. This report documents the 2024 update (JRC-IDEES-2021), which is available through the JRC Data Catalogue and introduces a number of methodological refinements while extending the time coverage until 2021.

Acknowledgements

This report describes the 2024 update of the JRC-IDEES database, a tool that was first released to the public in 2018. As such, both tool and report crucially draw upon the prior pivotal work of the initial developers of JRC-IDEES: the authors of this report wish to especially acknowledge the essential contributions of Leonidas Mantzos and Tobias Wiesenthal, as well as of Eamonn Mulholland, Nicoleta Anca Matei, and Stéphane Tchung-Ming. Finally, the JRC-IDEES database has benefited from the initial contributions made by numerous National Experts of the EU Member States, and from the feedback of many JRC-IDEES users including energy modellers, researchers, analysts and policymakers.

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1 Introduction

1.1 Motivation

Quantitative models are extensively used for research and policy analysis in the areas of energy, climate action, and transport. Such modelling tools generally need to be parameterized with historical input data at a level of detail that exceeds official statistics, for instance to match the scope of technology-focused policies. In turn, this requires assumptions on how to disaggregate official statistics into modelling inputs.

These parameterization choices can have a major impact on model outputs and policy conclusions (1,2). However, despite progress within individual sectors of the energy system (3–6), there is still a scarcity of broadly accepted, comprehensive, and open-access sources of historical data that can provide a common basis for modelling across the whole energy system (7,8). This yields redundant efforts in the energy research community (7) and makes it difficult to disentangle the effects of different parameterizations from structural choices in modelling studies.

To help address this gap for the energy system of the European Union (EU), the Joint Research Centre of the European Commission has developed and published the Integrated Database of the European Energy System (JRC-IDEES). Initially designed to serve as the essential data input to the POTEnCIA model (9,10) and first released in 2018 (11), this analytical database provides comprehensive open data that can support energy-related modelling, research, and policy analysis at the level of individual EU Member States (MS). The initial JRC-IDEES-2015 release, which covered the time horizon of 2000–2015, has accordingly been used across multiple sectors of the European energy system (e.g., (12–20)). This technical report describes the JRC-IDEES-2021 release, which updates JRC-IDEES with data for the 2000-2021 timeframe and implements a number of methodological improvements enabled by recent advances in data availability.

1.2 Overview of JRC-IDEES

The energy system is a vastly complex entity, and while there is a multitude of energy-related primary statistics, there is a lack of comprehensive sources that are both coherent across sectors and detailed enough to serve the analytical needs of current policy discussions. JRC-IDEES addresses this need of a comprehensive, coherent and detailed dataset by compiling what is to be understood as an *analytical* database, rather than a strictly statistical database. As such, it compiles existing statistical data across sectors of the energy system – which in itself may prove useful for policy analysts and researchers – and, concurrently, decomposes most of these statistical data into detailed processed data (Figure 1). This decomposition is based on own estimates but remains strictly consistent with primary statistics from Eurostat energy balances.

Figure 1. Overview of primary statistical and processed data in JRC-IDEES.

Primary statistical data	Processed data
Macro-economic data Demographics Energy balances Emissions Physical industrial production Transport mobility	Equipment characterisation • Technology deployment • Stock-related data Structural and behavioural features • Detailed energy use data • Behavioural patterns • Operating characteristics

Source: JRC analysis.

On the one hand, JRC-IDEES thus gathers the key statistical data that are relevant to the energy system, combining energy balances with macro-economic, demographic, and industrial and transport activity statistics. It primarily draws on Eurostat statistics complemented by information from United Nations databases and the statistical offices of the EU Member States, as well as other sources. This compilation collects extensive information on the factors that influence a given sector's energy demand at an aggregate level. On the other hand, JRC-IDEES provides processed data at a higher level of disaggregation, with the aim of capturing in finer detail the historical evolution of the energy system and its drivers – for instance by characterizing technological change in a given sector. To this end, the database decomposes historical time series of energy consumption and production into individual energy end uses while respecting available aggregate statistics for 2000-2021. This decomposition is applied for each Member State (MS), and for five key energy sectors that together account for the entire supply and demand of energy: industry, residential, tertiary and agriculture, transport, and power & heat generation. This approach enables several key functions that are beyond the reach of primary statistics alone, such as:

- Estimating the contribution of individual processes and end uses to a sector's energy demand;
- Distinguishing structural factors from energy equipment-related factors in the observed variation of energy intensities across MS;
- Distinguishing the impacts of technological change and behavioural change on a sector's energy demand;
- Supporting research on the impact of implemented policies at a finer sectoral scale;
- Supporting research on the scope and potential for further technological improvement or policy intervention.

This report provides methodological documentation for the current version of the database (JRC-IDEES-2021). JRC-IDEES-2021 reports annual data for 2000-2021 (Box 1) and is an update of the previous JRC-IDEES-2015 version, which covered the time horizon of 2000-2015. However, backwards compatibility is not ensured (including over the previous 2000-2015 horizon) because *i*) additional data sources have become available and enabled refinements in the methodology and technical assumptions used to disaggregate primary statistics, and *ii*) the primary statistics themselves are revised by statistical authorities over time.

Box 1. Key data reported in JRC-IDEES-2021.

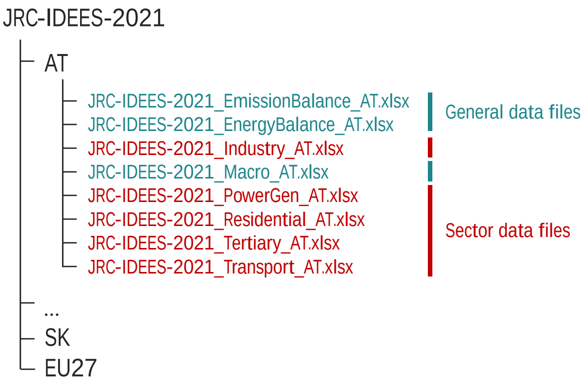
JRC-IDEES-2021 reports the following key annual data for 2000-2021 and for each Member State:

- a description of macro-economic and activity structure by sector;
- enhanced energy balances that match Eurostat statistics by sector;
- a detailed decomposition of energy use (both final and useful) into processes and end uses for each sector, with energy intensities by representative unit (e.g. per tonne of output, per household, etc.);
- a corresponding decomposition of CO_2 emissions by sector;
- detailed estimates for energy equipment by sector, including estimated conversion efficiencies, utilization rate, and installed capacities;
- a comprehensive power & heat generation dataset derived from plant-level data for over 65,000 generation plants, which harmonises energy balance statistics with installed capacities for 260 plant types.

1.3 Accessing and using JRC-IDEES

JRC-IDEES is provided as open data under the CC BY 4.0 license and can be downloaded from the Joint Research Centre Data Catalogue: https://data.jrc.ec.europa.eu/collection/id-0110. The database is provided in Excel format and structured by individual subfolders for each Member State and the EU (Figure 2). Each subfolder contains general data files (documented in Section 2) and sector-specific data files (documented in Section 3).

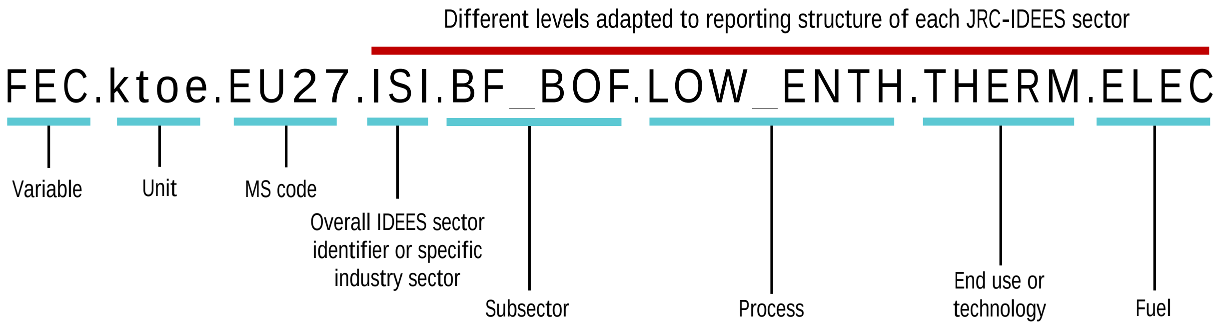
Figure 2. JRC-IDEES file structure.



Source: JRC analysis.

These data files are designed to be human-readable and machine-readable. For this purpose, all files report 2000-2021 time series across data columns, while the row and sheet structure is tailored to each sector. Column DA of the sector-specific data files additionally contains unique identifiers by row for key data items that originate either from primary statistics or from the JRC-IDEES decomposition. These unique identifiers are formatted as period-delimited strings (Figure 3) that can be disaggregated for further processing, e.g. to read the data into a Python *pandas* multi-indexed data frame. For clarity, these identifiers are not provided for data items that originate from internal formulas within the data file, or from primary statistics that already have existing unique identifiers (e.g. Eurostat energy balances with unique fuel codes across rows). The *Variable* and *Unit* levels are self-documenting based on the full labels in column A of the data files. The *Fuel* level corresponds to Eurostat energy balance fuel codes for each sector, following Annex, Table 11.

Figure 3. Unique data identifiers provided in JRC-IDEES sector-specific data files.



Source: JRC analysis.

The rest of this report documents the structure, methodology, and main assumptions used throughout JRC-IDEES. Section 2 describes the overall reporting structure of JRC-IDEES, key primary statistics, and general approach for their decomposition. Section 3 then details the specific structure and decomposition used in each sector of JRC-IDEES. Section 4 concludes.

2 Methodology

The JRC-IDEES database compiles an extensive set of primary statistics covering energy, emissions, macro-economic and other activity, and demographic data for 2000-2021. Corresponding statistics are reported directly or after minor reprocessing in three general data files, for each of the 27 MS and the EU as an aggregate: *EnergyBalance*, *EmissionBalance*, and *Macro*. Sector-specific sources are then used to decompose the primary statistics into processed data that describe in detail the energy use and activity levels of each MS, for five main sectors of the energy system[1]: *industry, residential, tertiary and agriculture*[2]*, transport, and power & heat generation*. These sectors are reported within individual data files for each MS and the EU, following a decomposition into suitable combinations of subsectors, processes, and end-use technology/fuel options (Figure 4). This decomposition structure is adapted to each sector; for instance, in transport, each end-use technology/fuel option represents the combination of a means of transport and a fuel or powertrain type, such as gasoline-powered passenger vehicles.

The remainder of this section first presents the main aggregate statistics that underpin the sectoral decomposition. It then introduces the general decomposition approach followed across sectors. The specific reporting structure, decomposition, and references for each sector are detailed in Section 3.

Figure 4. Decomposition structure in each sector of JRC-IDEES.

Industry	11 industry sectors 21 industry subsectors	6 – 11 processes per subsector	1-10 technology/fuel options per process
Residential	9 household types 9 appliance types	43 combined space and water heating types	135 total technology/fuel options
Tertiary and agriculture	4 thermal uses 6 appliance types		47 total technology/fuel options
Transport	5 modes	20 transport means	35 total technology/fuel options
Power & heat generation	Nuclear, thermal, and renewable generation	10 fuel types 7 renewable energy types	1 – 4 technology options per type 1 – 4 installation sizes per type

Source: JRC analysis.

[1] A limited number of specific energy uses, such as refineries, pipeline compressors, or non-energy use of hydrocarbons outside the chemical industry sector, are not decomposed and are reported in JRC-IDEES under energy balances.

[2] Besides services, the agriculture, forestry, and fishing sector is also reported with the tertiary sector in JRC-IDEES.

2.1 Key primary statistical data

This section describes the main primary statistical data sources used in JRC-IDEES. Table 1 summarizes these sources by type, along with the JRC-IDEES data file where corresponding data can be found for each MS, generally as a relevant subset of the full primary statistical datasets. Additional sector-specific data from the energy-related statistical sources are included in the JRC-IDEES sector files (Section 3).

Table 1. Main primary statistical data sources for JRC-IDEES.

Type	Source	JRC-IDEES data file
Energy	Eurostat - Complete energy balances (21) Eurostat - Production and exchange of electricity and derived heat (22–24) Eurostat - Share of energy from renewable sources (25)	JRC-IDEES-2021_EnergyBalance
Climate	Eurostat - Cooling and heating degree days by country (26)	JRC-IDEES-2021_Macro
CO_2 emissions	IPCC - Guidelines for National Greenhouse Gas Inventories (27) European Commission - Implementing Regulation (EU) 2018/2066 (28) UNFCCC - National inventory submissions (29)	JRC-IDEES-2021_Emissions
Macro-economic	Eurostat - National accounts (30) Eurostat - Structural business statistics (31)	JRC-IDEES-2021_Macro
Demographic	Eurostat - Population (32) Eurostat - Household composition (33,34)	JRC-IDEES-2021_Macro

Source: JRC analysis.

Energy-related data (21–25) rely on Eurostat statistical reporting for each MS. In particular, the JRC-IDEES decomposition takes the Eurostat energy balances as a strict constraint. While these energy balances are never altered at the sector level, a limited number of adjustments are introduced to address clear lower-level inconsistencies. Such inconsistencies may be caused by singular data errors in the original time series: for instance, comparing the demand reported for a certain fuel across the residential and services sectors may show that the fuel was likely misallocated in a given year. Inconsistencies may also be caused by changes in the default allocation of unspecified energy use to the best-fitting sector – for example, charging an electric vehicle at home may be attributed either to the residential or transport sector. These adjustments to the energy balances are fully traceable and available upon request. The resulting adjusted energy balances are reported in the *JRC-IDEES-2021_EnergyBalance* file for each MS.

Some discrepancies may also appear between the original energy balances and macro-economic statistics reported for each MS. A country may for instance report final energy consumption (FEC) in an industry sector where no concurrent economic activity was reported, or vice versa. In these cases, energy balance statistics are prioritized: activity is reallocated from a different industry sector to plausibly account for reported FEC, after comparing activity and FEC data across industry sectors to identify the most likely candidate for reallocation. Conversely, activity is reallocated away from the industry sector if no FEC is reported.

Climate data (26) for annual heating and cooling degree-days are obtained from Eurostat and reported without further processing in the *JRC-IDEES-2021_Macro* file. Heating degree-days are expressed for a base temperature of 18°C, only counting days with a daily mean air temperature ≤15°C following the methodology described in metadata for ref. (26). Cooling degree-days use a corresponding base temperature of 21°C with a daily mean air temperature threshold of ≥24°C.

Energy-related CO_2 emissions data (27–29) are primarily based on fuel-specific CO_2 emission factors from IPCC Guidelines for National Greenhouse Gas Inventories and the Commission Implementing Regulation (EU) 2018/2066 on monitoring and reporting of greenhouse gas emissions. Country-specific CO_2 emissions factors for solid fuels are additionally sourced from the UNFCCC emissions inventory database. For each MS, the *JRC-IDEES-2021_EmissionBalance* file presents the resulting emissions factors and corresponding CO_2 emissions computed from JRC-IDEES energy balances. The *EU27/JRC-IDEES-2021_EmissionsComparison_UNFCCC* file compares these emission balances with UNFCCC national inventory submissions; discrepancies between the two sources are generally minor and caused by different reported activity levels.

Macro-economic data (30,31) are obtained from Eurostat, harmonised with energy balances as described in Energy-related data, and reported in the *JRC-IDEES-2021_Macro* file. Gross domestic product (GDP), household consumption expenditure, and gross value added (GVA) are reported in current prices, as well as constant prices of €2015. Constant prices are calculated by applying the implicit deflators based on chain-linked volumes for GDP, household consumption expenditure, and aggregate GVA to the corresponding current price data. The aggregate GVA deflator is also used to calculate value added in each sector, instead of the sector-specific deflators provided by Eurostat that are based on chain-linked volumes[3]. This choice, as well as the general use of constant prices instead of chain-linked volumes for JRC-IDEES, is motivated by:

— the non-additivity of chain-linked volume measures of GDP aside from the reference year, which makes it difficult to analyse structural shifts in the economy without bottom-up re-adjustments to match GVA statistics;

— the need for compatibility with structural business statistics reported in current prices, which are used extensively in JRC-IDEES to decompose NACE64 sectors into subsectors (e.g. splitting the manufacture of basic metals into ferrous and non-ferrous metals);

— the need for consistency between historical data and projections that are by default expressed in constant €, when using JRC-IDEES as an input for modelling.

Therefore, the data reported in JRC-IDEES directly coincide with Eurostat's chain-linked €2015 volumes only for GDP, household consumption expenditure, and aggregate GVA.

Demographic data (32–34) are obtained from Eurostat and reported in *JRC-IDEES-2021_Macro*. These data describe the total population, average household size (inhabitants per household), and the distribution of households by household size. JRC-IDEES additionally estimates the total number of households by dividing total population by the corresponding household size. The database does not identify dwellings, assigning them implicitly to the households (without distinguishing secondary residence or vacant dwellings).

2.2 Decomposition

The decomposition approach of JRC-IDEES uses a consistent methodology across MS, while allowing sufficient flexibility to accommodate key MS specificities and respect the individual structure of the energy system in each MS. The purpose of the decomposition is to disaggregate high-level

[3] *JRC-IDEES-2021_Macro* additionally reports subsector-level value added that is estimated during sector decomposition (Section 3).

statistics, such as national energy consumption by sector, into detailed processed data at the level of individual end-use technologies – for instance, the share of electric space heating in new houses, or total passenger-kilometres driven by diesel-powered cars.

This decomposition proceeds on a yearly basis by iterating a series of steps for each MS:

— For each sector, the energy-relevant structure, in terms of subsectors, processes, and end uses (e.g. natural gas space heating), is identified by reviewing existing literature.

— For each end use, energy equipment is characterised through the number of representative installations (e.g. the number of household gas boilers) and their size. This follows a vintage-specific approach that tracks the existing stock of installations, new installations that replace retired installations or satisfy additional demand, and retirements. Technical characteristics are identified for the existing stock of installations and for new installations.

— The operation of the installed energy equipment is quantified. This explicitly distinguishes technology dynamics and the behaviour of energy consumers: for instance, the average energy efficiency of information and communication technology (ICT) equipment vs. its average operating hours.

— For each end use, the total final and useful energy demand (Box 2) can then be quantified, along with an equivalent energy intensity per representative agent (e.g. per household or per tonne of industrial output). Where possible, the contribution of factors other than energy-using equipment in satisfying energy demand is also captured. For example, in the residential and services sectors, the thermal integrity of the building envelope affects the final space heating end use.

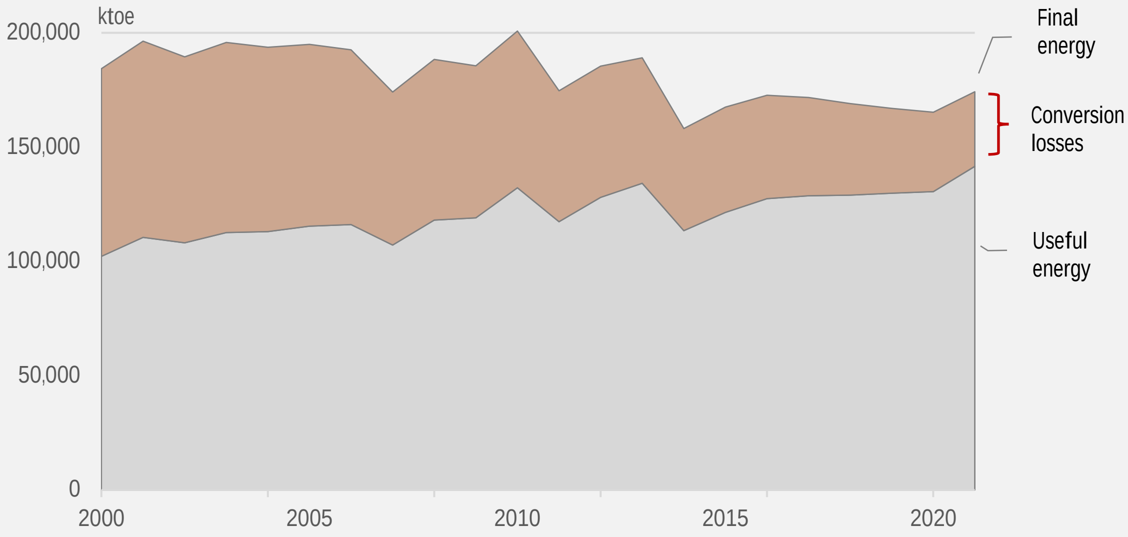
The resulting decomposition *i)* respects sector-level energy balances and activity data, without exception; *ii)* harmonises the characterization of energy equipment with changes over time in sector-level energy balances, under plausible limits for the evolution of end-use energy efficiency and fuel mix; *iii)* considers, if available, official country-specific information.

This iterative approach tends to result in improved quality of the more recent processed data over the decomposition timeframe of 2000-2021. Specifically, data on new equipment installations are more reliable than for the existing stock of installations. Given the vintage-specific approach used to track and characterise existing stock and new installations, the characteristics of the existing stock evolve over time following the stock turnover. As older equipment is retired and replaced by better-characterised new equipment, uncertainty on the overall energy performance of the existing stock tends to decrease. To a certain extent, this iteration also feeds back across MS. For a given installation, there should not be a great disparity in useful energy use between countries – for instance, if two MS require a different order of magnitude in useful energy to produce one tonne of steel with the same type of process/equipment, the underlying statistics or assumptions should clearly be revised. This approach can thus help address data quality issues across MS.

Box 2. The concept of useful energy.

Observed energy intensities can vary significantly across Member States. Attributing this variation solely to differences in the efficiency of installed energy equipment would be insufficient, as Member States also differ by sector structures and product mixes/grades. Disentangling the role of energy equipment from structural and product-related factors is then necessary to explain variations in energy intensities, to compare the performance of energy equipment across countries, and ultimately to quantify the potential for technical improvements given structural differences.

Final and useful energy consumption for space heating by households in the EU



Source: JRC analysis.

To create a common basis and make energy equipment comparable across countries, JRC-IDEES uses the concept of *useful energy* for thermal energy uses. In that context, useful energy is the amount of energy required for the specific purpose of a given sector, e.g. the amount of energy required to produce one tonne of steel. It is reported after all conversion losses, and is related to final energy by the estimated technical efficiency and operating characteristics of the energy equipment.

Useful energy provides an additional level of detail when analysing end uses, as there should not be major discrepancies when comparing Member States in this regard. For example, the useful energy needed to produce one tonne of steel with the same characteristics should in theory be constant over time and across Member States. In practice, some differences will be caused by different processes (for instance due to different product types, qualities, or inputs), and by differences or inefficiencies in how the equipment is used. By assessing final and useful energy separately, variations across Member States can then be clearly attributed either to energy equipment differences, or to structural and product-related factors.

3 Detailed methodology by sector

3.1 Industry sector

3.1.1 Overview and reporting structure

The JRC-IDEES industry sector combines top-down statistics with bottom-up technical data to ensure a plausible representation of technical characteristics that are consistent with statistics on physical and economic output, energy consumption, and emissions in each main industrial sector. Key top-down statistics are collected from Eurostat (energy balances (21), statistics on production of manufactured goods (35), energy accounts (36), national accounts for economic output (30,31)), the US Geological Survey (37) and British Geological Survey (38), the UNFCCC National GHG Inventory (29) (for process emissions), and industry association statistics (39,40). The bottom-up technical characterization of energy use is based on industry sector-specific studies and reports such as the Best Available Techniques Reference Documents (BREFs), sectoral studies from the International Energy Agency, US Department of Energy footprint reports, and other research studies (41–138). Physical output statistics are further processed to suitably represent key industrial products as described in section 3.1.2.

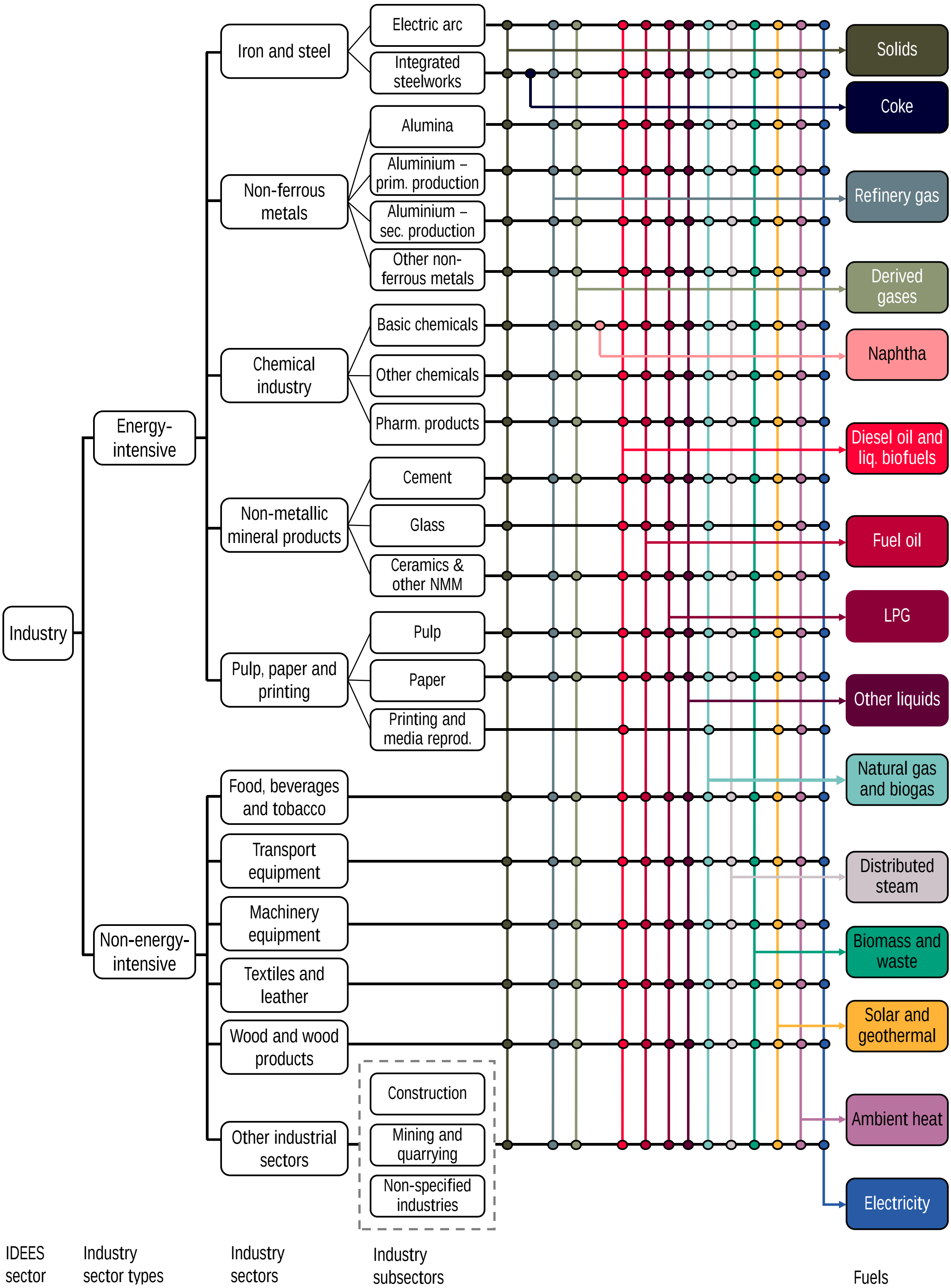
The resulting reporting structure for industry in JRC-IDEES (Figure 5) describes eleven industry sectors: five energy-intensive sectors (Annex, Table 12) which account for approximately 60% of EU final energy consumption in industry, and six non-energy-intensive sectors (Annex, Table 13). This structure directly follows Eurostat energy balance statistics and is mapped to economic output statistics using the NACE code correspondence in Annex, Table 14-Table 15. Energy-intensive sectors are further split into subsectors that go beyond the disaggregation available from Eurostat. For instance, *Non-metallic mineral products* are split into cement, glass, and ceramics & other non-metallic mineral (NMM) products. This level of detail enables the database to better reflect the different patterns of energy use and emissions of key industrial production routes. Section 3.1.3 describes the calibration process used to disaggregate energy-intensive sectors into subsectors.

A final layer of disaggregation is required at the level of individual industrial processes within each subsector and non-energy-intensive sector, to suitably capture the technical characteristics, energy requirements, and scope for improvement of each main production process. Each subsector and non-energy-intensive sector is thus decomposed into three types of energy end uses (Annex, Table 12-Table 13):

- Process-related energy uses that represent specific production processes in each (sub)sector, such as smelting, reheating, or product finishing.
- Process-related non-energy use, which is modelled for the *Basic chemicals* subsector to distinguish the consumption of chemical feedstocks, given that this consumption may be subject to significantly different dynamics than energy use. Other non-energy uses (e.g. for asphalt or solvents) are not decomposed and are reported in the energy balance data files.
- Non-process-related energy uses that represent cross-cutting technologies used in all (sub)sectors: lighting, air compressors, motor drives, fans and pumps, and low-enthalpy heat.

Within each end use, available technology/fuel options are defined from literature. The share of each end use within the total energy consumption of the (sub)sector, and the share of each technology/fuel option within each end use, are then balanced with a matrix scaling approach to ensure they are consistent with sector-level fuel consumption statistics (section 3.1.3).

Figure 5. Industry structure in JRC-IDEES.



Notes

NMM: Non-metallic minerals. End use decomposition is omitted for clarity and shown in Annex, Table 12-Table 13. Construction, Mining and quarrying, and Non-specified industries are calibrated individually but reported as aggregate Other industrial sectors.

Source: JRC analysis.

For each industry sector and individual subsector, the resulting dataset harmonises physical output, economic output (i.e. gross value added), and energy and emissions indicators (e.g. estimated final and useful energy consumption by end use). Table 2 summarizes the main indicators correspondingly reported by the JRC-IDEES industry data files and their source.

Table 2. Main reported indicators for the industry sector and their source.

Level of reporting	Reported indicator	Source
All sectors	Physical output	Energy-intensive sectors: Aggregate of subsector-level estimates. Non-energy-intensive sectors: Estimated from gross value added (section 3.1.2)
	Gross value added	Statistics (30,31)
	Installed production capacity, investment and decommissioning	Own estimate (section 3.1.3), based on estimated physical output (section 3.1.2)
	Total FEC by fuel	Statistics (21)
	Total energy-related CO_2 emissions	Computed from total FEC using fuel-specific emissions factors (27,28)
	Total process-related CO_2 emissions	Statistics (29)
Energy-intensive subsectors	Physical output	Processed statistics for subsectors of Iron and steel (40), Non-ferrous metals (35,37,38), Non-metallic mineral products (29,35,37–39) (except Ceramics & other NMM), and Pulp, paper and printing (139,140) (except Printing and media reproduction). Own estimate in other subsectors (section 3.1.2)
	Gross value added	Processed statistics (30,31) for subsectors of Non-ferrous metals, Chemicals industry, Non-metallic minerals, and Pulp, paper and printing. Own estimate from sector-level statistics for Iron and steel subsectors
	Installed production capacity, investment and decommissioning	Own estimate (section 3.1.3), based on estimated physical output (section 3.1.2)
	Total FEC by fuel	Processed statistics (36) for Pharmaceutical products and Printing and media reproduction. Own estimate from sector-level statistics for other subsectors (section 3.1.3)
	Total process-related CO_2 emissions	Computed from subsector characteristics and sector-level process emissions
Energy-intensive subsectors Non-energy-intensive sectors	FEC by end use and fuel option	Own estimate (section 3.1.3)
	Useful energy demand by end use and fuel option	Computed from corresponding FEC and subsector-specific technical characteristics
	Energy-related CO_2 emissions by end use and fuel option	Computed from corresponding FEC using fuel-specific emissions factors (27,28)

Notes
FEC: final energy consumption. NMM: Non-metallic minerals.

Processed statistics used for subsector-level indicators originate from primary statistics but are adjusted during calibration.
Sector-level indicators derived from statistics are constrained to the original source, with minimal adjustments if needed to address clear data quality issues.

Fuel code labels used in the JRC-IDEES-2021_Industry data files are mapped to Eurostat energy balance codes in Annex, Table 11.

Source: JRC analysis.

3.1.2 Industrial physical output

The type of physical output associated with each subsector varies across the JRC-IDEES industry reporting structure (Table 3). Certain subsectors have an easily quantifiable output, such as tonnes of steel in both subsectors of *Iron and steel*. However, a representative output is required for subsectors which still have a heterogeneous output under this structure. For example, the *Other non-ferrous metals* subsector represents the production of copper, lead, manganese, nickel, tin, and zinc. These individual metals would be complex to model and report individually, and the energy balances and economic activity statistics required for calibration are only available at a higher level of aggregation. Physical output statistics for each of these individual metals are therefore aggregated to a representative output of tonnes of lead-equivalent, using a typical energy intensity of production of each metal relative to lead. This representative output creates a common reference point which makes it easier to compare the energy use of the subsector over time and across MS.

Table 3. List of industrial outputs.

Output type	Subsector	Unit	Definition	Main reference
Physical output	Integrated steelworks Electric arc furnace	t steel	-	(40)
	Alumina production	t alumina	-	(37,38)
	Aluminium production	t aluminium	-	(35,37,38)
	Cement production	t cement	-	(35,37,38)
	Glass production	t glass	Container glass and other glass types are modelled separately and aggregated for reporting	(29,35,39)
	Pulp production	t pulp	All pulp types excluding recovered pulp consumed on-site	(139,140)
	Paper production	t paper	All paper types	(139,140)
Equivalent tonnes of output	Other non-ferrous metals	t lead eq.	Based on estimated subsector FEC, output of six key metals, and relative energy intensities of production of each metal	(21,37,38)
	Basic chemicals Other chemicals Pharmaceutical products	t ethylene eq.	Based on estimated sector FEC, subsector value added, and estimated relative energy and value added intensities of five key product groups	(21,30,31,36)
	Ceramics & other NMM	t bricks eq.	Based on estimated subsector FEC and energy intensity of production relative to cement	(21)
	Printing and media reproduction	t paper eq.	Based on estimated subsector FEC and energy intensity relative to paper production	(21,36)
Physical output index	Non-energy-intensive sectors	Output index	Sector gross value added, adjusted within technically plausible bounds for useful energy efficiency	(30,31)

Source: JRC analysis.

A similar approach is used in the *Chemical industry* sector, where a representative output of *tonnes of ethylene-equivalent* is modelled in each subsector. These outputs are derived from sector-level energy balances and subsector-level value added statistics, combined with the estimated relative energy intensity and value added intensity of five product types: petrochemicals; ammonia and nitrogen compounds; other organic and inorganic basic chemicals; other chemicals such as paints and detergents; and pharmaceuticals. In the *Ceramics & other NMM* and *Printing and media reproduction* subsectors, representative outputs of *tonnes of bricks-equivalent* and *tonnes of paper-equivalent* are derived from the total energy consumption assigned to each subsector during calibration (section 3.1.3), and from the estimated energy intensity of each product relative to cement and paper production, respectively.

These representative outputs enable a distinction between the effect of different industrial structures or products on energy consumption, and the effect of installed energy equipment. In turn, this makes the energy equipment-related share of the production process comparable across countries. For example, when using the total physical output of individual metals, the average energy intensity per tonne in *Other non-ferrous* metals would differ by a factor of 16.1 across MS in 2019. Such a discrepancy would clearly exceed plausible energy equipment-related differences across MS. When using the representative output of tonnes of lead-equivalent, the difference in average energy intensity is reduced to a factor of 2.5 across MS, which can be more easily ascribed to technical differences in production facilities, infrastructure, and product characteristics.

For non-energy-intensive sectors, industrial output is modelled and reported using a *Physical output index*. This index is derived from the gross value added of the sector, but discrepancies in energy intensities across MS are limited by scaling the index to keep the resulting estimated useful energy efficiency within technically plausible bounds.

3.1.3 Decomposition and calibration approach

To harmonise the estimated physical output, gross value added, and energy and emissions indicators for each (sub)sector, two calibration steps are carried out for each MS individually. First, sector-level statistics on energy consumption and economic output are combined with a simplified model of industrial production capacity. For energy-intensive sectors, this step further disaggregates sector-level statistics across subsectors based on plausible assumptions on energy intensities and value added intensities of subsector output. Secondly, the share of each end use within the total energy consumption of each (sub)sector, and the share of each technology/fuel option within each end use, are balanced in each year with a matrix scaling approach.

In the first calibration step, a simplified vintage-based model of the installed production capacity for each (sub)sector is set up using representative capacity utilization rates and energy intensities per unit of physical output. Capacity additions and retirements for each year are modelled based on (sub)sector output, expected equipment lifetime, and typical unit size (i.e. annual output capacity of a typical production plant in each (sub)sector). An exogenous improvement in energy intensity is assumed for new capacity. For energy-intensive sectors, changes over time in total sector energy consumption and value added (21,30,31) are then iteratively disaggregated across subsectors using a set of assumed elasticity factors. This disaggregation is harmonised with subsector-level physical energy flow accounts for the *Pharmaceuticals and other products* and *Printing and media* *reproduction* subsectors (36)[4], and with subsector-level value added statistics when available (31). For non-energy-intensive sectors, sector-level statistics are combined directly with the production capacity model. This yields a set of time series for total energy consumption, value added, and production capacity for each (sub)sector.

To ensure consistency with the total consumption reported by fuel in sector-level energy balances, the second calibration step then harmonises the share of each end use within the total energy consumption of each (sub)sector, and the share of each technology/fuel option within each end use. The share of each end use within total (sub)sector energy consumption is first estimated from bottom-up technical studies. These initial end use estimates are adjusted at MS level using known structural features. For instance, electric process consumption in the *Basic chemicals* subsector is assumed to be primarily driven by production of chlor-alkali (141), while steam use for precasting in the *Cement* subsector is estimated from production data for precast concrete elements (35). Within each end use, initial shares of technology/fuel options in each MS are then estimated from sector-level energy balances, so that fuels that are available for a given end use are distributed in proportion to these fuels' total sector-level consumption. These initial estimates are set up for each year independently.

A multi-regional generalized RAS algorithm for matrix scaling (142) is then applied to these initial estimates to ensure that *i)* total energy consumption by (sub)sector is equal to the corresponding total energy consumption obtained from the first calibration step, and that *ii)* the total consumption by fuel in the sector matches energy balances. The algorithm robustly handles uncertain data by first allowing specified elements to be fixed, such as end use shares that correspond to known structural features like chlor-alkali production. Uncertain elements, such as initial assumptions on end use shares of generic cross-cutting technologies or technology/fuel shares within each end use, are then allowed to vary to meet the energy balance constraints. The algorithm identifies values of these uncertain elements that respect the energy balances while minimizing information loss relative to initial assumptions.

[4] These are the two subsectors where Eurostat physical energy flow accounts are more granular than energy balances. The different scope between physical energy flow accounts and energy balances is not expected to significantly affect the calibration output.

3.2 Residential sector

3.2.1 Overview and reporting structure

The JRC-IDEES residential sector characterises households in each MS by combining Eurostat statistics on demography, household consumption expenditure[5] and heating degree-days, together with energy balances and disaggregated final energy consumption reported in household statistics. Additional reports and studies are used to complement these data by representing the operating characteristics of end-use equipment/appliances (143–203). National official statistics and studies are used when available.

Demographic data at the MS level are used to estimate the number of households over the years: population (32), average household size (inhabitants per household) (33), and the distribution of households by household size (34). The total number of households in a given year is obtained by dividing total population by the corresponding household size. JRC-IDEES does not identify dwellings, assigning them implicitly to households without distinguishing secondary residences or vacant dwellings. The number of new households in a specific year is assumed to be the increase in total number of households compared to the previous year. The number of renovated households is estimated from the technical lifetime assumed for buildings before a deep renovation or full reconstruction. This lifetime varies across MS in a range between 39 and 51 years.

The total households' useful surface area in a MS is obtained from national statistics when available (e.g. (204)), which usually provide total useful surface area or average surface area per household. In the latter case, total useful surface area is calculated from the number of households. When national statistics are not available, total useful surface area is estimated from the average size of dwelling by MS provided by the Eurostat Housing conditions database (205). Ref. (205) provides data only for 2012, so that other years are estimated by extrapolation. The EU Building Stock Observatory (BSO) (4), which provides total useful area per MS for 2020, is used to calibrate and check the resulting estimate; for MS where the BSO reports data within possible range of the initial estimate, the JRC-IDEES total useful area for 2020 is calibrated to BSO. The useful surface areas for new and renovated households are calculated from the number of new and renovated households per year and the corresponding average surface area per household. This average surface area for new and renovated households is estimated across the years considering various drivers, including household consumption expenditure (30).

To characterise in detail the energy use of this estimated household stock while matching aggregate statistical sources, the JRC-IDEES residential sector is decomposed into the reporting structure shown in Figure 6. This structure covers two types of end uses: *electrical appliances* and *thermal uses*. *Electrical appliances* cover eight end uses that represent appliances consuming electricity for non-thermal purposes. *Thermal uses* cover four end uses: space heating, space cooling, cooking, and water heating. End uses then have up to nine different fuel group options. This disaggregation goes beyond the sector-level energy balance statistics (21) by integrating additional data sources such as Eurostat's final energy consumption statistics for households (206).

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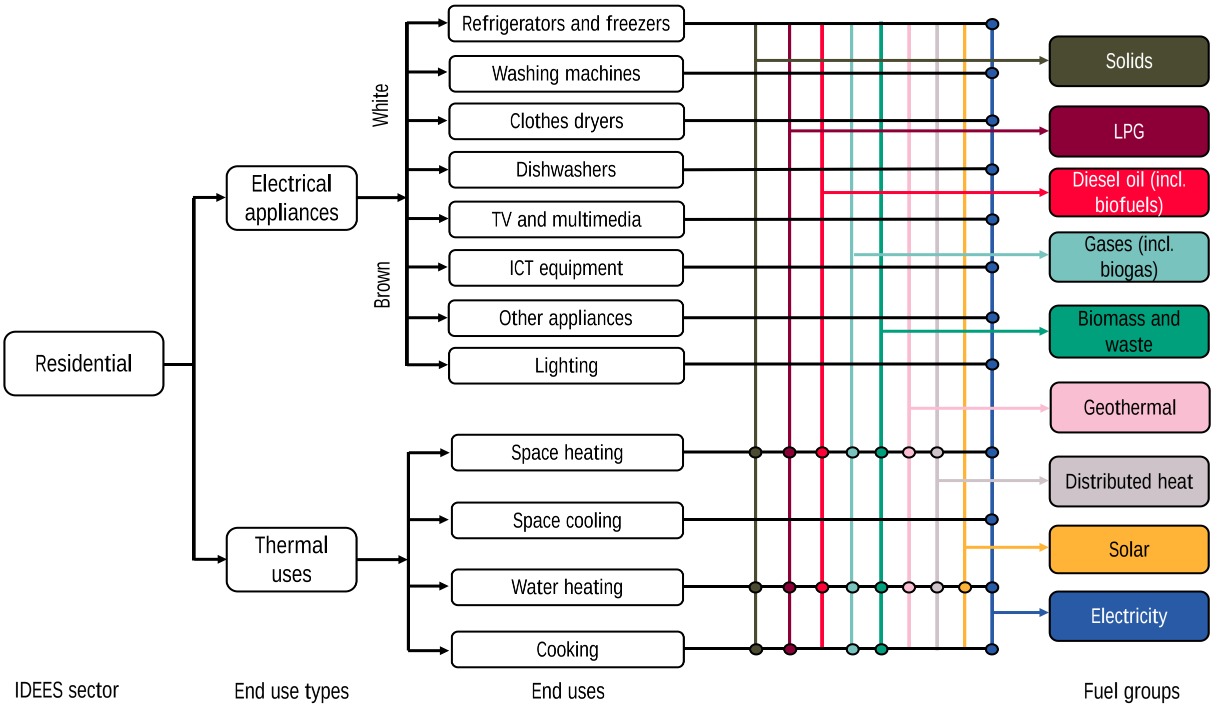
[5] Household consumption expenditure here refers to the Eurostat definition for Household and Non Profit Institutions Serving Households (NPISH) final consumption expenditure (P31_S14_S15): "*Final consumption expenditure consists of expenditure incurred by resident institutional units on goods or services that are used for the direct satisfaction of individual needs or wants or the collective needs of members of the community (ESA 2010 3.94)*". This definition should not be confused with the consumption expenditure of households in satisfying their energy needs.

Figure 6. Residential structure in JRC-IDEES.



Source: JRC analysis.

Each end use is characterised by total stock, new and replaced installations, and technical specifications such as power, operating hours and efficiencies. This in turn allows the quantification of final energy consumption (FEC), useful energy consumption and CO_2 emissions. These variables are calculated at the representative household level (e.g., kWh/household), at the surface area level (e.g., kWh/m^2), and at the aggregate level for all households. Table 4 summarizes the main indicators correspondingly reported in the JRC-IDEES residential data files and their sources. The next two subsections detail the decomposition process used to disaggregate and characterise household thermal uses and electrical appliances, while respecting aggregate statistical sources.

Table 4. Main reported indicators for the residential sector and their source.

Level of reporting	Reported indicator	Source
Sector	Population	Statistics (32)
	Heating degree-days	Statistics (26)
	Number of existing, new and renovated households	Existing households: own estimate (section 3.2.2), based on population and household size New and renovated households: own estimate (section 3.2.2), based on estimated household stock evolution and own assumptions on lifetime
	Total useful surface area for existing, new and renovated households[a]	Existing households: national statistics if available, or own estimate (section 3.2.2), based on average size of dwelling (4,205) and number of households New and renovated households: own estimate (section 3.2.2), based on number of new and renovated households and their estimated average surface area
	Household size (inhabitants per household)	Statistics (33)
	Households' consumption expenditure[a]	Statistics (30)
	Total FEC by fuel	Statistics (21)
	Total energy-related CO_2 emissions by fuel	Computed from total FEC using fuel-specific emissions factors (27,28)

Thermal uses	Number of existing, new and renovated households by installed heating equipment	Own estimate (section 3.2.2)
	FEC by thermal use and by fuel [b]	Own estimate, based on (206)
	Thermal energy service by thermal use and by fuel [b]	Own estimate, based on (206) and own assumptions on equipment efficiency (based on (207))
	Energy-related CO_2 emissions by thermal use and by fuel [b]	Computed from FEC using fuel-specific emissions factors (27,28)
Electrical appliances	Number of existing, new and replaced appliances [c]	Existing appliances: national statistics if available, or own estimate (section 3.2.3) based on penetration of appliances per household New and replaced appliances: own estimate (section 3.2.3), based on stock evolution and assumed lifetime (based on (207))
	Penetration factor (appliances per household) [c]	Computed from number of existing appliances and number of households, or own assumptions on relative differences across MS
	Power per appliance and per new appliance (in average operating mode) [c]	Power per appliance: own estimate (section 3.2.3), based on number of new and replaced appliances and their power Power per new appliance: own estimate (section 3.2.3), based on (207) and own assumptions on relative differences across MS
	Installed electrical capacity	Computed based on number of existing appliances and their power
	Operating hours	Own estimate (section 3.2.3), based or partially based on (207) (depending on the appliance type) and on assumed relative differences across MS
	Total FEC; FEC by electrical appliance	Total FEC: statistics (206) or own estimate from appliance stock (depending on MS) FEC by electrical appliance: own estimate based on appliance stock

Notes

FEC: final energy consumption. MS: Member State.
Fuel code labels used in the JRC-IDEES-2021_Residential data files are mapped to Eurostat energy balance codes in Annex, Table 11.

a Also reported per capita and per household

b Also reported per square metre and per household, and independently for new and renovated households

c Reported based on a representative appliance and its equivalent power (section 3.2.3)

Source: JRC analysis.

3.2.2 Decomposition and calibration of household types and thermal uses

The estimated household stock is first disaggregated into types of households based on their heating equipment. While space heating is linked to an individual end use in JRC-IDEES, other thermal end uses can be interrelated: installed space heating equipment can thus influence the choice of the water heating and cooling equipment. For instance, a combi-boiler used for space heating can also satisfy hot water needs, or be complemented by a solar-electric water heater. JRC-IDEES accounts for this dynamic by defining household types by their combination of space and water heating options. Table 5 outlines all household types considered in JRC-IDEES.

Splitting household types based on their heating equipment has several advantages. First, it provides further technical detail to characterise household energy use (and hence improves the accuracy of the decomposition); secondly, it enables a better assessment of the scope for policy action (e.g., minimum efficiency standards, or renewable heating incentives). For example, the potential for policy action on solar thermal water heating depends on the number of households in which solar thermal devices can still be installed, and on the specific energy contribution that each solar installation can make based on its technical properties and climate conditions.

The Eurostat dataset on disaggregated final energy consumption in households (206) provides final energy consumption (FEC) by fuel and by end use (i.e. space heating, water heating, space cooling, cooking, lighting and appliances, and other end uses). This dataset reports data for each MS and mostly for 2010-2021; extrapolation rules are used to estimate the remaining years of the time horizon. As a starting point for the JRC-IDEES decomposition, each fuel considered for thermal end uses in this dataset is associated to one of the heating equipment options reported in Table 5.

Table 5. Household types considered in JRC-IDEES based on space and water heating options.

Space heating	Water heating
Solids	Solids combo LPG LPG + solar Electric Electric + solar
LPG	LPG LPG + solar Electric Electric + solar
Diesel oil	Diesel oil combo Diesel oil combo + solar Electric Electric + solar
Natural gas	Natural gas combo Natural gas combo + solar Electric Electric + solar
Biomass	Biomass combo Biomass combo + solar LPG LPG + solar Electric Electric + solar
Geothermal	Geothermal combo Geothermal combo + solar Electric Electric + solar
Distributed heat	Distributed heat combo Distributed heat combo + solar Electric Electric + solar
Advanced electric heating	LPG LPG + solar Electric Electric + solar
Conventional electric heating	LPG LPG + solar Electric Electric + solar

Source: JRC analysis.

The energy efficiency of each heating equipment option is estimated from historical trends provided by the Ecodesign Impact Accounting Annual Report 2021 (207) for the EU. The total thermal energy service, or useful energy (Box 2), provided by each heating equipment option is calculated from this assumed energy efficiency and the FEC provided by (206). Total households are then split across the heating equipment options based on the share of each corresponding fuel type in total useful energy consumption. This implies that each average household has an equal useful energy requirement regardless of equipment type, an assumption that is maintained unless for a specific fuel it leads to an unrealistically high useful energy share for combo water heating compared to space heating, in which case the initial FEC is reallocated across thermal end uses. The number of households using advanced electric heating is calculated from ambient heat consumption (21) and a seasonal coefficient of performance assumed consistently with (207). Finally, data from EurObserv'ER (208) are also used to estimate the use of solar water heaters. This process disaggregates all households across the types described in Table 5.

This decomposition method implicitly assumes all households have space heating, water heating, and cooking equipment[6]. Conversely, space cooling equipment (i.e. air conditioning) adoption is calibrated to MS national statistics when available; it is otherwise estimated from household space cooling electricity FEC (206) and the average thermal service assumed to be supplied by each air conditioning appliance.

The decomposition process is carried out on a yearly basis, which sometimes yields large fluctuations in the number of households of a certain type. If this implies that a large number of heating installations would be replaced well before their lifetime, the number of households is corrected to have a more consistent evolution in the installed stock of each heating equipment option. These corrections assume that the operation of the installed stock is more likely to vary than the stock itself. As a result, the useful energy demand per household may deviate from the initial assumption of uniform demand across household types.

While the decomposition methodology used in JRC-IDEES-2021 is consistent with the previous JRC-IDEES-2015 version, the newly available disaggregated energy consumption statistics (206) have significantly enhanced the resulting decomposition of residential thermal end uses.

3.2.3 Decomposition and calibration of electrical appliances

As with thermal uses, electrical appliances are calibrated in each MS to match Eurostat's households' disaggregated final energy consumption dataset (206). However, unlike energy balances, this dataset is not taken as a hard constraint due to its incomplete coverage. This subsection describes the decomposition process that is first used to characterise each electrical appliance type based on its stock, power, and operating hours. This characterisation is then iterated and adjusted to match ref. (206), to the extent that required adjustments are reasonable with respect to the appliance type and the MS under calibration.

Electrical appliances are split into two types of end uses (Figure 6): white appliances, i.e. refrigerators and freezers, washing machines, clothes dryers, and dishwashers; and brown appliances, i.e. ICT equipment, TV and multimedia, lighting[7], and other appliances (covering e.g. vacuum cleaners, irons, and all remaining devices). A representative appliance is defined for each electrical end use so that its technical evolution and penetration rate can be compared across MS and over time. This representative appliance is defined by its electrical power. This power does not represent nominal power, but an "equivalent" power that yields the expected annual energy

[6] This is an approximation, e.g. space heating is absent in many Southern European households.

[7] For simplicity, brown appliances in JRC-IDEES also include lighting, which is not usually classified as such.

consumption based on annual operating hours[8]. Moreover, the size of this representative appliance is implicitly represented by its power, and is consistently accounted for in its stock. For ICT equipment and other appliances, which cover a wide range of different device types, the representative appliance represents an aggregated bundle of devices (e.g., for other appliances: one iron, one vacuum cleaner, etc.).

Historically, the size of electrical appliances has evolved substantially. For instance, the volume of the average refrigerator sold in the EU has progressively increased since the 1990s. At the same time, the energy consumption per unit of service delivered (e.g. litre refrigerated) has generally decreased (207). These trends both affect (often in opposite ways) the FEC by appliance and should be considered when decomposing energy use. For white appliances, the representative appliance describes in each year a realistically sized device, whose stock is obtained from national statistics describing either the stock or household ownership rate[9]. For brown appliances, the representative appliance instead has a fixed size for all years, e.g. a 1000 lm light bulb. Therefore, for brown appliances, historical variations in the average appliance size are absorbed in JRC-IDEES by variations in the stock[10]. The stock of each brown appliance is estimated based on the representative appliance characteristics and own assumptions on household penetration per MS.

For each appliance type, the number of replaced appliances in each year is estimated by combining the defined stock with a fixed assumed lifetime. The only exception is lighting, where replacements assume a different lifetime in each year and combine different Weibull survival functions to represent the increasing penetration of Light-Emitting Diode (LED) bulbs (having longer lifetime compared to traditional bulbs). The number of new appliances is then calculated in each year accordingly to the stock and replaced appliances. Data on appliance lifetimes are generally based on ref. (207). This report segments technologies in more detail than JRC-IDEES; these more granular technology segments are therefore weighted by their yearly sales to match the representative appliance defined in JRC-IDEES.

The power of new appliances assumed in each year is estimated from the equivalent power that results from annual energy consumption and operating hours reported by ref. (207)[11]. For white appliances, where the size of the JRC-IDEES representative appliance is based on a real device, the power of new representative appliances is directly estimated from (207), which already captures appliance size variations[12]. For lighting, where a 1000 lm representative bulb is assumed, the power of new bulbs is estimated for an equivalent fixed-size bulb calculated from (207), which accounts for changes in efficiency. For TV and multimedia, the power of new representative appliances is partially aligned to (207); for ICT equipment and other appliances, whose broad scope of products is difficult to meaningfully relate to technology segments provided by (207), the alignment is only qualitative. As ref. (207) only provides EU-level data, the power of new appliances is then fine-tuned for each MS based on own assumptions – e.g. an earlier penetration of more

[8] For instance, a washing machine can have a peak power consumption around 1500W, but most of its running time uses much less power. If annual energy consumption is 200 kWh for 400 operating hours, the equivalent power is 500W.

[9] This is a substantive methodological change compared to JRC-IDEES-2015, which used a fixed-size representative appliance.

[10] For instance, if the real average bulb size in the stock in a specific year is 2000 lm, this would be represented in JRC-IDEES as two 1000 lm bulbs.

[11] The alignment is carried out only for 2000, 2010, 2015 and 2020. Intermediate years are interpolated. Since Ref. (207) provides data for 1990 but not for 2000, 2020 is interpolated between 1990 and 2010.

[12] For clothes dryers the alignment to (207) is in terms of yearly energy consumption instead of equivalent power.

efficient technology in higher-income countries. Finally, the power of the average representative stock appliance in a given year is estimated from the number of new and replaced appliances across the entire historical period and their power.

The last characterisation step estimates operating hours[13] for each appliance type and each year, starting from ref. (207). First, EU-level operating hours are defined. For washing machines, laundry dryers, and dishwashers, operating hours are estimated from operational data (207), such as number of cycles per year, cycle duration, and weight load. Refrigerators and freezers are assumed to operate 8760 hours per year. For TV and multimedia and lighting, operating hours are directly aligned to (207); for ICT equipment and other appliances, they are estimated from own assumptions. Operating hours are then adjusted to be representative of each MS. For instance, Northern European countries are assumed to have more operating hours for lighting than Southern European countries.

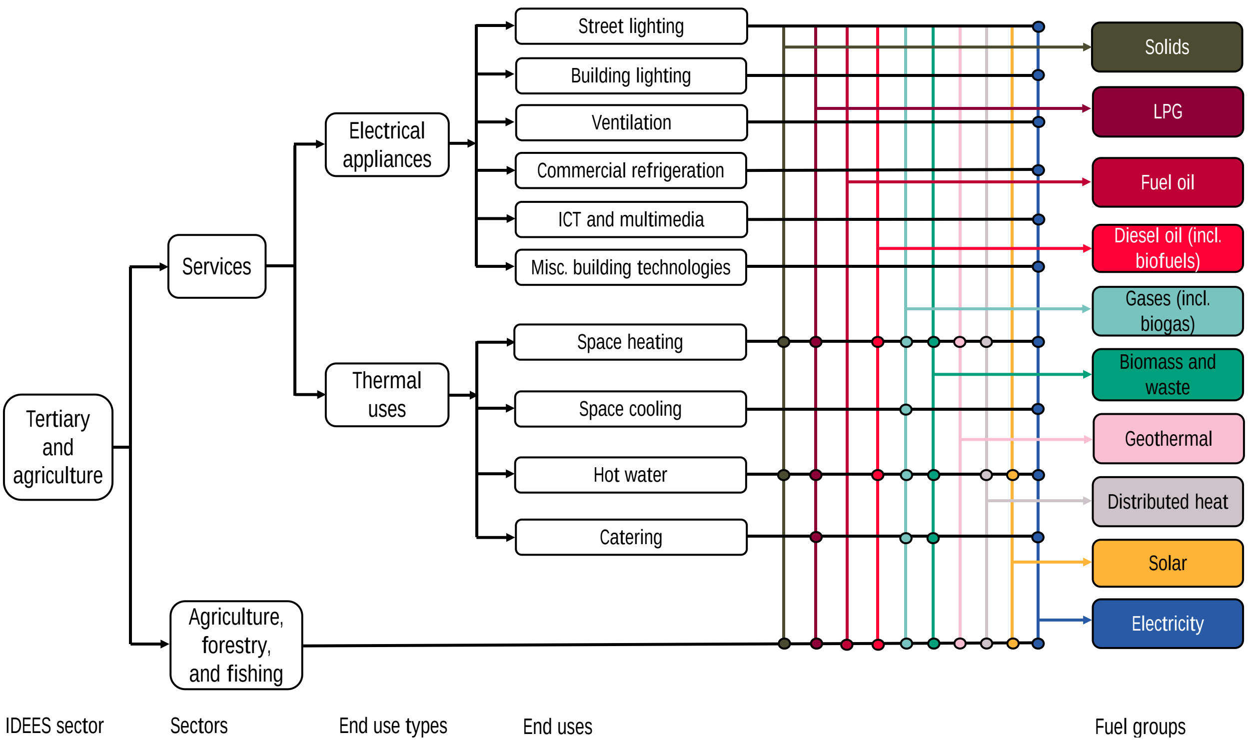
In parallel, a COVID-19 adjustment is introduced for operating hours, as ref. (206) reports that EU-level FEC for lighting and appliances progressively increased in 2020 and 2021. This increase is assumed to be related to the COVID-19 pandemic: in several MS, measures such as lock-downs and curfews led to increased time spent at home compared to previous years, and consequently to a greater use of specific appliance types – here assumed to be dishwashers, TV and multimedia, lighting, ICT equipment, and other appliances. 2020-2021 operating hours for these appliances are thus increased in each MS to match the EU-level FEC for lighting and appliances from ref. (206).

[13] Given the definition of equivalent power, operating hours are equivalent to full load hours.

3.3 Tertiary and agriculture sector

The tertiary and agriculture sector in JRC-IDEES combines the services sector with the agriculture, forestry, and fishing (AFF) sector. The services sector is primarily characterised using JRC reports on electricity consumption in the tertiary sector, and reports prepared for the European Commission on the eco-design of energy-using products (143–146,149–154,157,158,160,162,166,169–176,178–180,182,182–203). The services sector is disaggregated similarly as the residential sector (described in section 3.2), yielding two types of end uses: thermal uses and electrical appliances. The AFF sector is disaggregated into individual end uses and calibrated to Eurostat energy balances, similarly to the JRC-IDEES industry sector (described in section 3.1.3). These end uses are allocated across ten different fuel groups. The resulting decomposition (Figure 7) goes beyond the sector-level energy consumption data available from energy balances, and enables a more detailed characterisation of historical energy use in services and AFF. The following subsections detail the main assumptions used in this decomposition and calibration process for services and AFF, along with the main indicators reported by the JRC-IDEES tertiary data files.

Figure 7. Tertiary and agriculture structure in JRC-IDEES.



Notes
The decomposition of Agriculture, forestry, and fishing is reported in Annex, Table 13.

Source: JRC analysis.

3.3.1 Services

3.3.1.1 Overview and reporting structure

The JRC-IDEES services sector has the same general structure as the residential sector. However, unlike the residential sector, the surface area of a representative building in the services sector is assumed to be identical across all MS, and is calculated and reported for a representative *building cell* of 900 m^2. This value is derived from available information on the total useful surface area and estimated number of enterprises (31). The total useful surface area is aligned to the EU Building Observatory (BSO) (4), which provides data for all MS for 2020. The evolution of surface area in other years (and consequently the evolution of the stock of representative buildings) is then estimated from macro-economic data like population, GDP per capita, and number of employees.

To characterise in detail the energy use of the services building stock while matching Eurostat energy balances, the services sector is decomposed into thermal end uses and electrical appliances (Figure 7). Thermal uses include space heating, space cooling, hot water, and catering; electrical appliances include street lighting, building lighting, ventilation, commercial refrigeration, ICT and multimedia, and miscellaneous building technologies. Each end use is characterised by total stock, new and replaced installations, and technical specifications such as power, operating hours and efficiencies. This in turn allows the quantification of final energy consumption (FEC), useful energy consumption, and CO_2 emissions. These variables are calculated and reported at different levels, e.g. aggregated for all buildings, per representative 900 m^2 building cell, per square metre, or per capita.

Table 6 summarizes the main indicators correspondingly reported for services in the JRC-IDEES tertiary data files and their sources. The next two subsections present the decomposition process used to characterise thermal uses and electrical appliances while respecting aggregate statistical data sources for the services sector.

Table 6. Main reported indicators for the services sector and their source.

Level of reporting	Reported indicator	Source
Sector	Population	Statistics (32)
	Heating degree-days	Statistics (26)
	Gross domestic product [a]	Statistics (30)
	Value added [a, b]	Statistics (30)
	Employment data (employees)	Statistics (30)
	Number of existing, new and renovated buildings	Existing: computed from total surface area and assumed building size (900 m^2) New and renovated: own estimate (section 3.3.1.2) from building stock evolution
	Total useful surface area for existing [a, b, c], new and renovated buildings [c]	Existing: own estimate (section 3.3.1.2), based on (4) New and renovated: computed from number of new and renovated buildings and the assumed building size (900 m^2)
	Building size (employees per building)	Computed from number of employees and number of buildings
	Total FEC by fuel	Statistics (21)
	Total energy-related CO_2 emissions by fuel	Computed from total FEC using fuel-specific emissions factors (27,28)
Thermal uses	Number of existing, new and renovated buildings by heating equipment installed	Own estimate (section 3.3.1.2)
	FEC by thermal use and by fuel [c, e, f]	Own estimate (section 3.3.1.2)
	Thermal energy service by thermal use and by fuel [c, e, f]	Own estimate (section 3.3.1.2), based on estimated FEC by thermal use and by fuel, and own assumptions on heating equipment efficiency (based on (207))
	Energy-related CO2 emissions by thermal use and by fuel [c, e, f]	Computed from FEC using fuel-specific emissions factors (27,28)

Electrical appliances	Number of existing, new and replaced appliances [d]	Existing: own estimate (section 3.3.1.3), based on penetration of appliances per buildings/capita New and replaced: own estimate (section 3.3.1.3), based on stock evolution and assumed lifetime (partially based on (207))
	Penetration factor (appliances per building/capita) [d]	Own estimate, based on assumed relative differences across MS
	Power per appliance and per new appliance (in average operating mode) [d]	Power per appliance: own estimate, based on the number of new and replaced appliances and their power Power per new appliance: own estimate (section 3.3.1.3), partially based on (207) and assumed relative differences across MS
	Installed electrical capacity	Computed from number of existing appliances and their power
	Operating hours	Own estimate, based on assumed relative differences across MS
	FEC by electrical appliance	Own estimate based on the defined stock. Contribution of data centres to FEC in ICT and multimedia is based on (209)

Notes

FEC: final energy consumption. MS: Member State.
Building-level indicators consider a representative building cell size of 900 m^2.
Fuel code labels used in the JRC-IDEES-2021_Tertiary data files are mapped to Eurostat energy balance codes in Annex, Table 11.

a Also reported per capita
b Also reported per employee
c Also reported per building
d Reported based on a representative appliance and its equivalent power (section 3.3.1.3)
e Also reported independently for new and renovated buildings
f Also reported per square metre

Source: JRC analysis.

3.3.1.2 Decomposition and calibration of thermal uses

Unlike in the residential sector, statistics on disaggregated FEC across end uses are not available for the services sector. Therefore, the contribution of each end use to the total FEC in Eurostat energy balances (21) is estimated from assumed demand and equipment efficiency. Different drivers for energy demand are considered: space heating and cooling requirements relate to the useful surface area, while hot water and catering service needs are linked to population and income per capita. The energy efficiency of each heating equipment option is estimated from EU-level historical trends provided by the Ecodesign Impact Accounting Annual Report 2021 (207). This estimated energy efficiency enables the quantification of the useful energy demand (Box 2). The contribution of each end use to sectoral FEC is iterated to reach reasonable energy services intensities, e.g. for hot water or catering useful energy demand per capita.

Following the concept of household types in the residential sector (section 3.2.2), different services building types are defined by the main technology-fuel options used for space heating. However, unlike in the residential sector, this definition does not further detail space and water heating combinations. For each space heating type, the number of square meters served is identified, taking into account the technical efficiencies of space heating equipment, and differences in service levels/standards. In particular, total buildings are split across the space heating equipment options based on the share of each corresponding fuel type in total useful energy consumption. This assumes that buildings have an equal requirement for useful energy regardless of the fuel used. The number of buildings using advanced electric heating is calculated from ambient heat consumption (21) and a seasonal coefficient of performance assumed consistently with (207).

Requirements for space heating, hot water services, and catering are assumed to be met in all buildings, so that the entire surface area (i.e. all representative buildings) is allocated across fuel types. However, space cooling equipment (i.e. air conditioning) is assumed not to have reached complete adoption. Air conditioning adoption is calibrated to MS national statistics when available and otherwise based on assumed relative differences across MS.

The decomposition process is carried out on a yearly basis, which sometimes yields large fluctuations in the number of buildings of a given type. If this implies that a large number of heating installations would be replaced well before their lifetime, the number of buildings is corrected to have a more logical evolution in the installed stock of each heating equipment option. These corrections assume that the operation of the installed stock is more likely to vary than the stock itself. As a result, the useful energy demand per building may deviate from the initial assumption of uniform demand across building types.

3.3.1.3 Decomposition and calibration of electrical appliances

Contrary to households, no disaggregated Eurostat statistics on lighting and appliance electricity FEC are available in services. Therefore, besides the modelling decomposition described below, no further calibration is carried out. However, the total electricity FEC resulting from the decomposition of thermal uses and electrical appliances is constrained to match the energy balances (21).

The specific electrical end uses are disaggregated by taking into account JRC reports on electricity consumption in the tertiary sector, and reports prepared for the European Commission on the eco-design of energy-using products. Each electrical end use demand is assumed to be linked to specific drivers. Building lighting, ventilation and building technologies are assumed to be driven by the surface area, with ventilation also being linked to insulation levels. Street lighting is linked to population, population density, and GDP. Commercial refrigeration is primarily linked to population, and ICT and multimedia is primarily linked to the number of employees.

As in the residential sector, a representative appliance is defined for each electrical end use. For miscellaneous building technologies, the appliance represents an aggregated portfolio of devices (professional vacuum cleaner, washing machine, dryer, elevator, escalator, etc.) Representative appliances in services are always characterised by a fixed size (e.g. 2400 lm for building lighting, or 1 m^2 serviced for ventilation).[14] The stock of each electric appliance is estimated in each MS based on the mentioned drivers and on own assumptions, such as the appliance penetration by MS (e.g. number of bulbs per capita in the case of street lighting, or share of square metres serviced for ventilation). New and replaced appliances are estimated in each year based on the defined stock and assumed lifetimes. When possible, the assumed lifetimes are validated with ref. (207).

For the specific case of ICT and multimedia, this stock characterisation is further adapted to represent the increasing importance of data centres, which have been estimated to account for 2.7% of the 2018 electricity demand in the EU+UK on an increasing trend (209). The Energy-efficient Cloud Computing Technologies and Policies for an Eco-friendly Cloud Market report (209) estimates the yearly electricity consumption of data centres for 2010-2025, for selected MS and for different EU geographical aggregations (e.g. Northern, Eastern, Southern, and Western EU). This electricity consumption is first extrapolated backwards to 2000. For those MS not explicitly covered

[14] This implies that a variation in size of the real average appliance is absorbed in JRC-IDEES by the stock. For instance, if the average bulb size in a given year is 4800 lm, this would be represented in JRC-IDEES by two 2400-lm bulbs.

by (209) or by MS-specific sources (210), the regionally aggregated electricity FEC is allocated to each MS in proportion to its yearly services electricity FEC. Once the data centre electricity FEC is identified for all MS, an equivalent installed stock of appliances is computed from the representative appliance defined for ICT and multimedia. This equivalent stock – representing the FEC of data centres – is then added to the stock that was first estimated for ICT and multimedia.

The power of new appliances assumed in each year is to the extent possible aligned to the energy efficiency improvement trends reported by (207) for the part covered by this report.[15] Ref. (207) provides data for appliances regulated under Ecodesign, Energy Labelling and ENERGY STAR, although these regulations do not fully cover the set of appliances included in each electrical end use for services in JRC-IDEES. For appliances that are not regulated, efficiency improvements are assumed to be slower than those reported by (207). The power of new appliances for commercial refrigeration and ventilation is based on (207), while for ICT and multimedia and miscellaneous building technologies, the broad scope of products makes it difficult to directly match the technology segments provided by (207). Lastly, for street lighting and building lighting – which are the only entirely regulated end uses – the power of new appliances is generally aligned to (207) on the basis of annual energy consumption. Ref. (207) only provides EU-level data, so that the power of new appliances is then fine-tuned for each MS based on own assumptions: for instance, more efficient technology is assumed to be adopted earlier in higher-income countries. The power of the average representative stock appliance in a given year is then derived from the number of new and replaced appliances across the entire time frame and their power.

In a final step, the appliances are characterised by their operating hours. For commercial refrigeration and ventilation, 8760 operating hours are always assumed. For other electrical end uses, own assumptions are used to represent relative differences across MS and appliance types.

3.3.2 Agriculture, forestry, and fishing

The agriculture, forestry, and fishing sector is represented similarly to non-energy-intensive industry sectors. As such, energy requirements are split across two types of energy end uses:

- Process-related energy uses (Annex, Table 13), i.e., energy uses that are specific to the production processes of the subsector, covering farming machine drives, specific heat uses, pumping devices, and specific electricity uses; and
- non-process-related energy uses that involve cross-cutting technologies common to industrial sectors, covering lighting, low-enthalpy heat uses, ventilation, and motor drives.

Information related to energy end uses in the agriculture, forestry, and fishing sector is further reported in terms of their estimated FEC, useful energy consumption, and CO_2 emissions. The shares of these end uses in sectoral FEC, and the shares of technology/fuel options in each end use, are initially characterised using plausible technical features. For instance, farming machine drives are assumed to use a large share of all diesel oil and biodiesel consumed in the sector. This end use characterisation is then harmonised with sectoral energy balances using the matrix scaling approach described for industry in section 3.1.3. Similarly, data on physical output, installed capacity, and idle capacity are estimated with the same approach as for non-energy-intensive industry sectors, and reported in the JRC-IDEES data file for the tertiary and agriculture sector.

[15] The methodology is further detailed in the description of the residential sector (section 3.2.3). Possible differences in appliance size between JRC-IDEES and (207) are taken into account in the alignment.

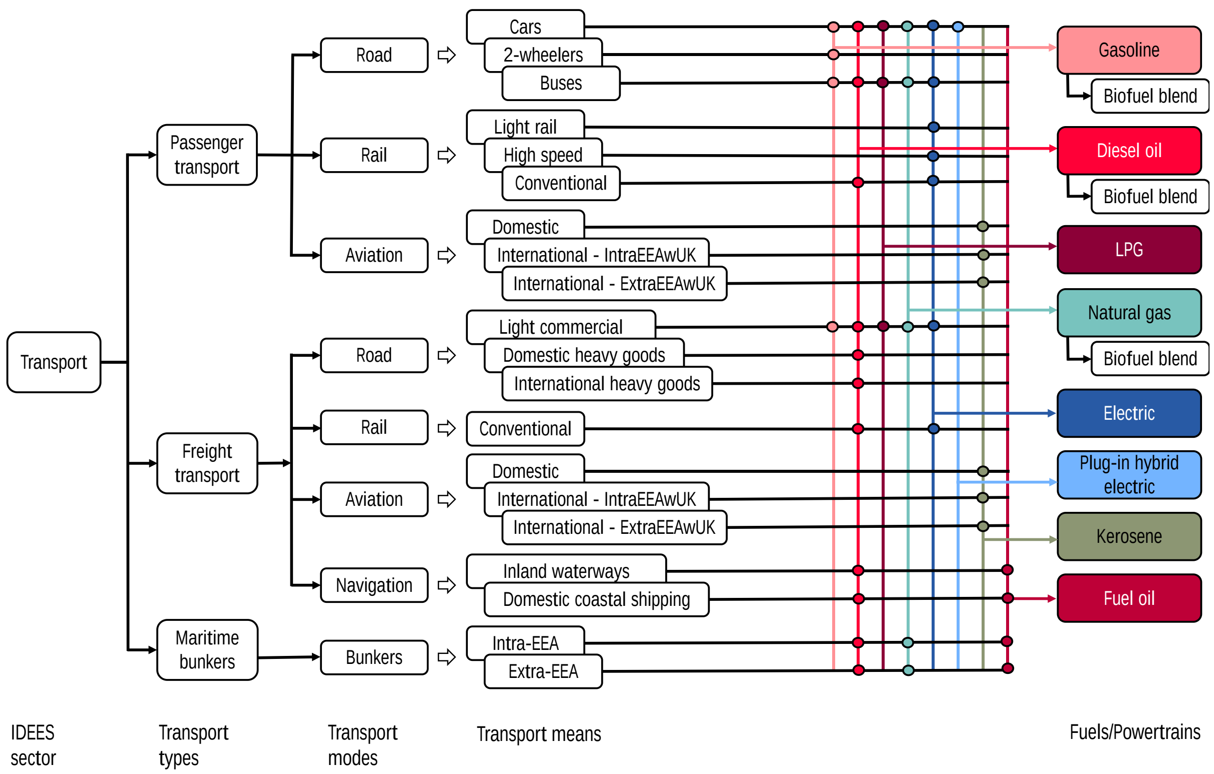
3.4 Transport sector

3.4.1 Overview and reporting structure

JRC-IDEES combines top-down statistics and bottom-up data to derive a consistent decomposition of the transport sector down to individual technologies. Top-down aggregate statistics on activity, final energy consumption, stock, and sales data are compiled from sources including Eurostat, the European Environment Agency, UNFCCC, and the EU Transport Pocketbook. From the bottom-up side, detailed technology-specific information is compiled from bodies such as TOSCA (Technology Opportunities and Strategies towards Climate Friendly Transport), ICCT (The International Council for Clean Transportation), and ACEA (European Automobile Manufacturers Association). The full list of transport-related sources is provided in the bibliography (211–233). JRC-IDEES harmonises these top-down and bottom-up sources through a decomposition approach (section 3.4.2) that yields a dataset matching high-level energy balances and activity statistics, while accounting for technical specifications and operating characteristics. Table 7 summarizes the main indicators accordingly reported by the JRC-IDEES transport data files.

The corresponding JRC-IDEES reporting structure (Figure 8) splits transport into three types: passenger transport, freight transport, and international maritime bunkers. Passenger transport is split into road, rail, and aviation modes, represented by nine total different means of transport. Freight transport is similarly split into road, rail, and aviation modes with the further addition of domestic navigation, and represented by another nine total means of transport. Beyond this disaggregation, individual end-use technologies are represented by eight fuel/powertrain types. The following subsections detail this decomposition and calibration approach for road transport, rail transport, aviation, and domestic and international navigation.

Figure 8. Transport structure in JRC-IDEES.



Source: JRC analysis.

Table 7. Main reported indicators for the transport sector and their source.

Level of reporting	Reported indicator	Source
Transport means	Activity (as passenger-km [pkm] or tonne-km [tkm])	For cars, buses, heavy goods vehicles, all rail means, inland waterways: Transport Pocketbook (215) Member State-level data; For powered two-wheelers, domestic and intra-EEAwUK aviation, domestic coastal shipping, and intra-EEA international maritime bunkers: Estimation from mileage and load factor while matching EU data reported in Transport Pocketbook (215) For light commercial vehicles, extra-EEAwUK aviation, extra-EEA international maritime bunkers: Own estimates
	Mileage	Processed statistics ((220) and national statistical sources for Italy, Malta, Netherlands, Slovenia); own estimates
	Load factor	Derived from activity and mileage or own estimates
	Stock of vehicles, new registration of vehicles	Processed statistics ((213–218,220,222) and national statistical sources for Cyprus, Finland, France, Hungary, Ireland, Italy, Malta, Netherlands, Portugal, Slovenia); own estimates
	Total FEC by fuel	Transport modes: Statistics (21) Transport means: Own estimates
	Total energy-related CO_2 emissions	Computed from total FEC using fuel-specific emissions factors (27,28)
	Number of flights in aviation	Statistics (220), own estimates for data gaps
	Volume carried (as passengers or tonnes) in aviation	Statistics (220), own estimates for data gaps
	Passenger aviation seats available	Statistics (220), own estimates for data gaps
Fuel/powertrain options for road, rail	Activity (as pkm or tkm)	Own estimate or derived from mileage and load factor
	Mileage	Own estimate
	Load factor	Derived from activity and mileage or own estimates
	Stock of vehicles, new registration of vehicles	Processed statistics and own estimates
	FEC	Own estimates
	Energy-related CO_2 emissions	Computed from total FEC using fuel-specific emissions factors (27,28)
	Test cycle efficiencies of new vehicles (only road)	Cars 2010-2021: Statistics (217) Light commercial vehicles 2012-2021: Statistics (218) Heavy goods vehicles 2019-2020: Statistics (216) Other means and years: own estimates
	Test cycle efficiencies of stock (only road)	Own estimate based on stock turnover and efficiencies of new vehicles

Notes

FEC: final energy consumption. EEAwUK: European Economic Area (EU Member States, Iceland, Liechtenstein, Norway) and United Kingdom.

Processed statistics used originate from primary statistics but are adjusted from the original source during calibration. Indicators derived from statistics are constrained to the original source, with minimal adjustments if needed to address clear data quality issues.

Fuel code labels used in the JRC-IDEES-2021_Transport data files are mapped to Eurostat energy balance codes in Annex, Table 11.

Source: JRC analysis.

3.4.2 Decomposition and calibration approach

3.4.2.1 Road transport

Road transport comprises passenger transport means (powered two-wheelers; motor coaches, buses and trolley buses; and private cars) and freight transport means (light commercial vehicles; heavy goods vehicles). For powered two-wheelers, only gasoline-powered vehicles are currently taken into account. Six powertrains are defined for private passenger cars based on the fuels used: gasoline, diesel, liquefied petroleum gas (LPG), natural gas, battery electric, and plug-in-hybrids. Five powertrains are defined for light commercial vehicles and motor coaches, buses and trolley buses (the same as for private cars, excluding plug-in hybrids). Heavy goods vehicles (i.e. vehicles with a gross vehicle weight greater than 3.5t) are assumed to use diesel powertrains only. Conventional internal combustion engine powertrains are assumed to account for the consumption of biofuel blends for gasoline, diesel, and natural gas.

Heavy goods vehicles are further split into domestic and international transport, based on the mode of operation[16]. As activity related to the international trade of goods is by definition cross-borders, JRC-IDEES assumes that the international truck fleet is technically homogenous across the EU. Common characteristics are thus assumed for unit fuel consumption, annual mileage, and average load of international transport trucks, and used to derive the fuel consumption and the stock of pass-through vehicles on national territory. For national haulage, the number of trucks registered nationally may not fully reflect the activity structure: some trucks may be operating outside a given country, and vice-versa. Therefore, the stock of trucks operating domestically is derived from reported mobility data, annual mileages, and load factors. Consequently, the stock of domestic and international trucks reported in JRC-IDEES for a Member State may deviate from data reported for the national stock of registered vehicles.

For each powertrain/fuel type associated with each transport means, the following transport-specific indicators are derived with a three-step decomposition process and reported in JRC-IDEES:

- vehicle stock and new registrations
- transport activity, as passenger-km (pkm) for passenger vehicles and tonne-km (tkm) for freight vehicles; mileage, as vehicle-km (vkm)
- load factors (passenger or tonnes per movement)
- vehicle efficiency (fuel use per hundred km)
- vehicle emissions intensity (CO_2 emissions per km).

The first step in this decomposition process is identifying the vehicle stock. For powered two-wheelers, vehicle stock is mostly derived from the Transport Pocketbook assuming all vehicles are gasoline-powered. National statistics or own estimations are used as complementary data sources to cross-check or adjust the Transport Pocketbook information. For private cars, light commercial vehicles (freight vehicles with a gross vehicle weight less than 3.5t) and motor coaches, buses and trolley buses, the availability of vehicle stock statistics varies considerably across countries. Where

[16] International transport is the international haulage performed within the territory of a country by any vehicle (independently of their registration).

possible, JRC-IDEES uses stock data from Eurostat, from the European Alternative Fuels Observatory, and from national statistics (Table 7). Remaining data gaps are filled with own assumptions combined with data on registration of new vehicles from the ICCT and the Transport Pocketbook. These own estimates build upon one or more years of stock data, and subsequently use a Gompertz survival function to estimate the evolution of the stock. This function is parameterized individually by Member State and assumes a maximum age of 30 years.

The total stock of heavy goods vehicles is estimated from the same general sources (Table 7) but without distinguishing fuels (i.e. the total stock is assigned to a representative diesel vehicle)[17]. This total stock is further split into domestic and international stock. The international stock is calculated by taking tonne-kilometres provided for international transport by the Transport Pocketbook, converting to vehicle-kilometres with a load factor, and dividing by an annual mileage of 85,000 km. The national stock is then calculated as the difference between the international stock and the estimated total stock.

The second step in the decomposition process is identifying the transport activity, in vehicle-km (vkm) as well as in passenger-km (pkm) or tonne-km (tkm). For powered two-wheelers, vehicle-km activity is generally based on Eurostat where available, and is otherwise scaled based on the evolution of the stock. Based on the resulting mileage, the total EU passenger activity (in pkm) reported by the Transport Pocketbook is split across the Member States. For private cars, motor coaches, buses and trolley buses, vehicle-km is either derived from Eurostat statistics, or estimated from the UNFCCC energy consumption split[18] and the vehicle fleet efficiency (described in the next decomposition step). The vkm figures may be revised to yield a consistent annual mileage per vehicle for the defined powertrains. Passenger-km activity is taken from the Transport Pocketbook, and combined with the vkm activity to define the load factor at the transport means level. Finally, the pkm activity is split across the powertrains based on the transport means-level vkm activity, and on assumed load factor alterations for specific powertrains.

Tonne-km freight activity for both international and domestic heavy duty freight is derived from the Transport Pocketbook, which itself draws from Eurostat, the International Transport Forum, national statistics, and own estimates. This information is converted into vehicle-kilometres using derived load factors or Eurostat information where possible. The load factor of international freight haulage is derived from the EU aggregate and is assumed to be homogeneous for all EU Member States (resulting around 14 tonnes per movement). Finally, the light commercial activity is estimated mainly based on Eurostat mileage (vkm), or the stock data with average mileage estimations and load factors (tonne per movement).

The final step of the decomposition is to derive fuel consumption and CO_2 emissions data based on the vehicle stock efficiency and activity levels. The vehicle efficiency for private cars, light commercial vehicles, and heavy goods vehicles is largely based on CO_2 emissions data reported by vehicle manufacturers for newly registered vehicles under Regulation (EC) No 443/2009, 510/2011 and 2018/956. The fuel-specific stoichiometric emission factor is then used to convert from gCO_2 to fuel efficiencies. JRC-IDEES reports new light-duty vehicle test cycle efficiencies based on the Worldwide harmonised Light vehicles Test Procedure (WLTP), and estimates those for earlier years that were reported based on the New European Driving Cycle (NEDC) test (2010-2018). A bridging

[17] Identifying different powertrains for heavy goods vehicles will be considered in future updates of JRC-IDEES.

[18] Using Table 1.A(a) Sectoral background data for energy from the UNFCCC submissions (29).

factor harmonises the WLTP and NEDC data; years before 2010 are estimated. The stock efficiency is then calculated based on the stock composition by vintage and the efficiency of the new registrations by year.

For powered two-wheelers and motor coaches, buses and trolley buses, efficiencies are derived from the UNFCCC energy consumption split where possible and otherwise estimated. To account for the discrepancy between energy balances and fuel consumption derived from test cycle efficiency, JRC-IDEES applies a correction factor that varies by country, year, and vehicle technology to represent discrepancies between test cycle and real efficiency, but also the effects of driving conditions and sustained patterns of "fuel tourism". As a result, the aggregated road transport energy consumption reported in JRC-IDEES matches by fuel the energy balances[19].

3.4.2.2 Rail transport

The passenger rail transport mode is split into 3 means – urban light rail (metro and tram), high speed passenger rail, and conventional passenger rail. The latter is assumed to use electricity or diesel, while the former two are exclusively driven by electricity. The rail freight mode only considers a conventional rail means, powered either by electricity or diesel. Rail transport reporting in JRC-IDEES is structured similarly to the case of road vehicles, including vehicle stock (of a representative vehicle), vehicle activity (in vkm, tkm and pkm), load factors (passenger or tonnes per movement), and vehicle efficiencies (as energy per vkm and emissions per vkm).

The rail transport efficiencies are estimated based on International Union of Railways (UIC) (233), on the Study on New Mobility Patterns in European Cities (3) and on TRACCS (5). The Transport Pocketbook reports rail activity in terms of passenger- and tonne-kilometres derived from national statistics, International Union of Public Transport, studies for DG Energy and Transport, and own estimates. Activity in vkm and load (in passengers or tonnes per movement) is derived from Eurostat statistics where available. JRC-IDEES otherwise estimates the load factors and/or the vehicle-kilometre data. The rolling stock figures are expressed for a representative vehicle, i.e., a common annual mileage is assumed for each means of rail transport (Table 8). The stock is calculated by dividing the total activity by this common assumed yearly mileage across all Member States, differentiating by rail transport means.

Table 8. Train characteristics.

End-use technology	Seats/Capacity	Annual mileage
Conventional Passenger Train	8 wagons, 40 seats per wagon	150 000 km
High Speed Rail	10 wagons, 56 seats per wagon	450 000 km
Metro, Tram and Urban Rail	5 wagons, 80 seats per wagon	110 000 km
Freight Train	30 wagons, 70t / 100m^3 capacity per wagon	200 000 km

Source: JRC analysis.

In a final step, the above estimations are combined, and fuel-specific vkm and load factors are re-estimated to ensure that energy balances are respected when combining with activity and efficiency data.

[19] The resulting efficiency incorporating the correction factor is called *effective vehicle efficiency* in JRC-IDEES data files.

3.4.2.3 Aviation

Aviation transport includes passenger and freight aviation modes. Each mode is further split in three geographical categories of flight origins/destinations: domestic, intra-EEA[20] + UK, and extra-EEA + UK. This split is of particular importance when considering the scope of aviation in the European Emissions Trading Scheme. For each category, JRC-IDEES reports the vehicle stock (expressed in terms of a representative plane), vehicle activity (in vkm, tkm and pkm, number of flights, number of passengers), load factors (passenger or tonnes per movement), capacity (seats available) and vehicle efficiencies (in terms of energy and emissions per vkm).

As an exception, the calibration period for aviation is 1990-2021 rather than 2000-2021 as other JRC-IDEES sectors[21]. Decomposing the 1990 energy consumption and CO_2 emissions data makes it possible to calculate reductions achieved for each geographical category. The *JRC-IDEES-2021_Transport* files report 2000-2021 data by MS, while the full 1990-2021 data is reported in *EU27/JRC-IDEES-2021_x1990_Aviation* files (with MS reported across sheets).

As MS-specific statistics are not available, the decomposition process for passenger transport splits the Transport Pocketbook (215) EU-level activity by first identifying for each MS and geographical category the total number of passengers and flights[22] from Eurostat, and deriving an average load factor (average passengers on board per flight). The average flight distance is then calculated for each MS and geographical category using EUROCONTROL (212), and combined with the number of flights and load factors to yield a first estimate of passenger transport activity. Finally, intra-EU activities are scaled to match aggregate Transport Pocketbook data. Freight activity is derived similarly, introducing a "representative flight" concept (with a common load factor) to account for freight volume carried by mixed passenger-freight flights.

As a next step in the decomposition, a technical fuel consumption is identified based on distance-dependent average aircraft efficiency from EUROCONTROL, which is applied to the country-specific ensemble of flights and routes. This average consumption accounts for different aircraft types/models serving the different distance bands (but not the specific routes). This estimated fuel consumption is revised by applying discrepancy factors derived from the difference to the reported fuel consumption for the specific routes, for the years in which data are available. Finally, these estimates are scaled to energy balances at total domestic and international level, while keeping as fixed the intra-EEA / extra-EEA fuel consumption ratios obtained from EUROCONTROL.

The stock of a representative plane in JRC-IDEES is derived from Eurostat, which provides information on the volume carried, the number of seats available, and the number of flights. A core assumption used in this calculation is the operation of stock, i.e. the average number of flights carried out each year by a single representative aircraft:

$$\text{Number of flights per aircraft per year } [flight/year] = \left(\frac{24\ [h/day] \cdot \text{daily use } [\%]}{\frac{\text{distance travelled per flight } [km/flight]}{\text{average speed } [km/h]} + \text{waiting time } [h/flight]} \right) \cdot \text{yearly use } [day/year]$$

Equation 1. Aviation stock operation.

[20] The European Economic Area (EEA) includes the EU Member States, Iceland, Liechtenstein, and Norway.

[21] Statistical data are very scarce prior to 1995, but energy balances are available. Energy-specific indicators are therefore used to estimate the past activity levels.

[22] By a departure-based logic using statistics related to departed flights.

The distance travelled per flight is a MS-specific result of the route distances and number of flights. Table 9 outlines other assumptions by means of air transport. The resulting number of flights per aircraft per year is combined with the total number of flights per year (derived from Eurostat) to yield the representative stock for each aviation means.

Table 9. Aviation stock characteristics.

	Domestic Passenger Flights	Intra-EEA+UK Passenger Flights	Extra-EEA+UK Passenger Flights	Domestic and intra-EEA+UK Freight Flights	Extra-EEA+UK Freight Flights
daily use (%)	60%	65%	80%	65%	90%
average speed (km/h)	600	625	750	550	700
waiting time (h/flight)	1.5	2	2.5	3	4
yearly use (day/year)	340	325	300	330	300

Source: JRC analysis.

3.4.2.4 Domestic and international navigation

JRC-IDEES also reports data for the freight navigation mode (split into means of domestic coastal shipping and inland waterways), and the maritime bunkers mode (considered in JRC-IDEES reporting as a type separate from passenger and freight, and split into intra-EEA and extra-EEA means).

Activity for inland waterways is determined in tkm from the Transport Pocketbook, and in vkm from Eurostat or load factor estimates. Activities in tkm for domestic coastal shipping and bunkers are estimated from the gross weight of goods transported between main ports[23] (scaled to match the Intra-EU Transport Pocketbook activities), while vkm activities are derived from load factor estimates. In domestic navigation, many MS have a single transport means (e.g. landlocked countries, or countries without inland waterways that nonetheless have domestic coastal shipping). Representative MS from this subset of countries are combined with TRACCS (5) to estimate efficiencies for the other countries. For international maritime, THETIS-MRV data were used to split the energy balances and derive fuel consumption and efficiencies (219). The stock follows a representative vessel concept assuming a common annual mileage: 70 000 km for inland waterways, 100 000 km for domestic navigation, and 115 000 km for maritime bunkers. The stock is then derived by dividing total vkm activity by the common annual mileage across all MS.

As in aviation, the calibration period is extended to 1990-2021, relying on activity estimates based mainly on the evolution of energy balances due to frequent data gaps before 1997. The extended period is reported in the EU27 folder in the following files[24]; for international maritime bunkers, these files also report both the Intra-EEA/Extra-EEA and Intra-EU/Extra-EU decompositions. This makes it possible to calculate reductions achieved compared to 1990 for both geographical splits.

— *JRC-IDEES-2021_x1990_Navigation_Domestic*: domestic navigation.

— *JRC-IDEES-2021_x1990_Navigation_International_EEA*: international maritime bunkers decomposed into Intra-EEA and Extra-EEA.

— *JRC-IDEES-2021_x1990_Navigation_International_EU*: international maritime bunkers decomposed into Intra-EU and Extra-EU.

[23] Using the typical route distances between main ports.

[24] Besides the extended period, the representative stock of vessels can also be found in these files.

3.5 Power & heat generation

3.5.1 Overview and reporting structure

The JRC-IDEES power & heat generation sector harmonises power plant-level data with aggregate data sources to represent installed generation capacities, operating characteristics, and planned investments and retirements for 260 individual power plant types in each MS. The majority of IDEES data are derived from the Electricity Production Information & Capacity (EPIC) database (234), a commercial detailed database that reports key characteristics for over 65,000 individual plants (each of which may be composed of multiple generation units, such as a wind farm with multiple turbines). EPIC also reports confirmed new investments in capacity until 2025 and retirements up to 2070, based on currently known planned retirements or expected power plant technical lifetimes. Additional power plant-level data on planned investments and retirements are sourced from the Joint Research Centre Open Power Plant Database (235) and Global Energy Monitor (236,237).

This plant-level dataset is cross-checked and calibrated (section 3.5.2) to ensure consistency at an aggregate level with information from Eurostat and EurObserv'ER (208). Eurostat is the main source of primary statistics for transformation inputs, own consumption, and electricity generation. For renewable energy, EurObserv'ER is used to check and complement Eurostat and EPIC. A general reference list for power & heat generation is available in the bibliography (234–242); these were complemented by country-specific data to address any data gaps and required cross-checks.

The JRC-IDEES reporting structure for power & heat generation aggregates the resulting plant-level dataset into three general types of generation plants – nuclear, conventional thermal, and renewables. Thermal power plants are grouped into ten fuel types[25], each of which is grouped into up to four distinct generation technologies. Renewable power plants are grouped into seven types of renewable energy, each of which has up to two corresponding generation technologies. Finally, each technology is grouped into up to four typical size classes[26]. In the case of thermal power plants, this resulting classification is applied separately for electricity-only plants and combined heat and power (CHP) plants. This yields a total of 260 individual power plant types.

Figure 9 summarizes the fuel / technology classification, and Annex, Table 16 shows the full disaggregation of plants by technology and size. For each individual plant type, the total number of generation units and their average size (which vary over time reflecting new and retired plants) are reported alongside explicit net and gross capacities. The JRC-IDEES power & heat generation data files thus report the following indicators and a general overview for each MS (detailed in Table 10), across sheets that distinguish electricity-only plants, CHP plants, and all plants:

— gross and net capacities of power plants,

— the number of power plants in use,

— the gross and net nominal capacity of new investments,

[25] Co-firing is explicitly represented for each conventional thermal plant.

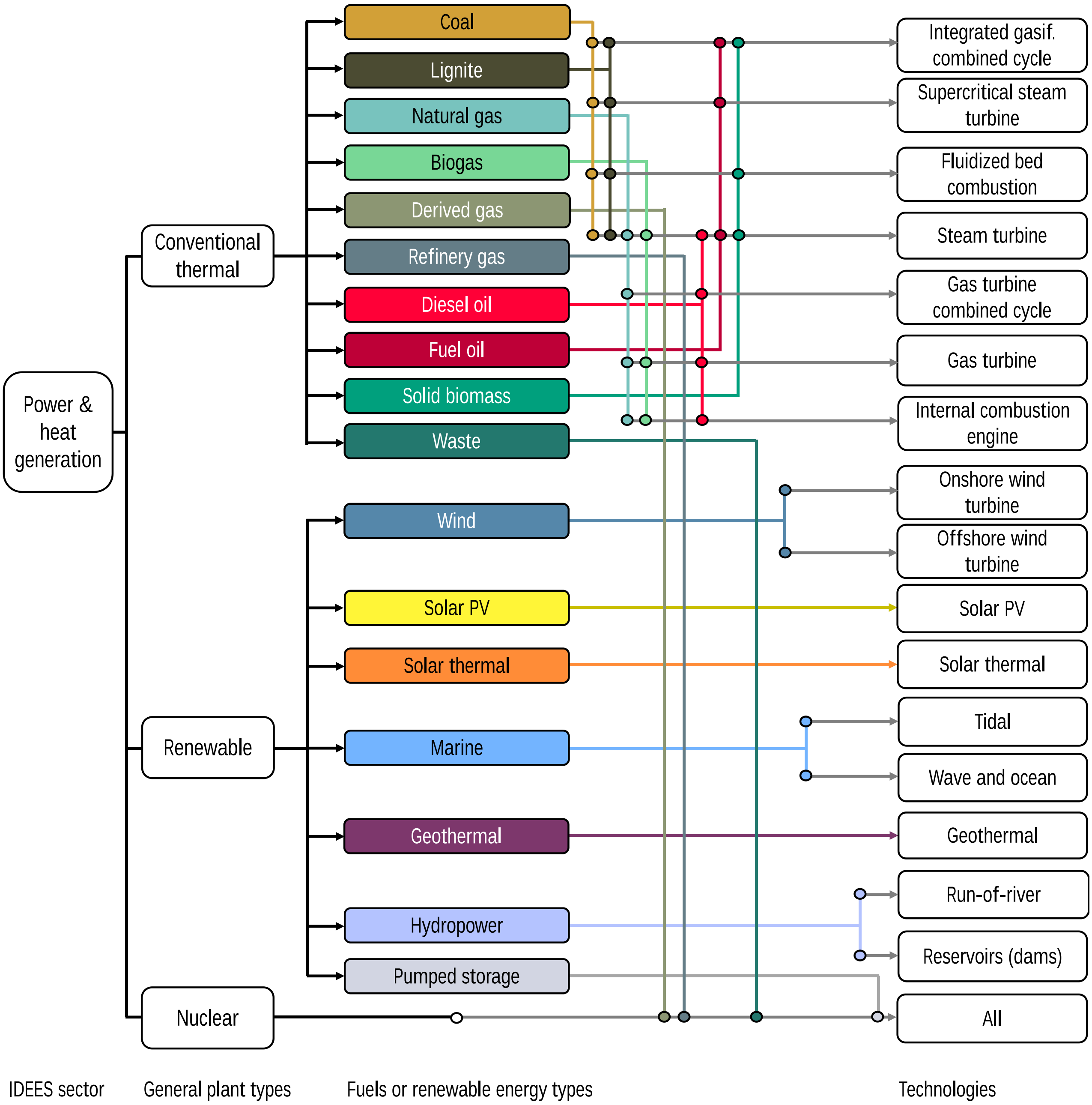
[26] Plants are assigned to a size class based on the average capacity of their individual generation units. Only two sizes are reported for nuclear plants, with only one size for tidal and wave power plants. Size class thresholds are presented in the JRC-IDEES-2021-PowerGen data files.

— the number of new investments,

— the gross and net nominal capacities of decommissioned units,

— the number of decommissioned units.

Figure 9. Power & heat generation structure in JRC-IDEES.



Notes

Plant size classes omitted for clarity and reported in Annex, Table 16.

Source: JRC analysis.

Table 10. Main reported indicators for the power & heat generation sector and their source.

Level of reporting	Reported indicator	Source
Individual power plant types by MS	Gross and net capacities (MW)	EPIC Database (234) further processed with country data and corrections. Eurostat processed statistics (241) for PV and wind generation capacity.
	Number of power plants in use (MW)	EPIC Database (234) further processed with country data and corrections
	Average gross capacity of power plants units (MW)	Own calculations based on EPIC Database (234)
	Gross and net nominal capacity of new investments (MW)	EPIC Database (234) further processed with country data and corrections
	Number of new investments (-)	EPIC Database (234) further processed with country data and corrections
	Average gross capacity of new investments (MW)	Own calculations based on EPIC Database (234)
	Gross and net nominal capacities of decommissioned units (MW)	EPIC Database (234) further processed with country data and corrections
	Number of decommissioned units (-)	EPIC Database (234) further processed with country data and corrections
	Average gross capacity of decommissioned units (MW)	Own calculations based on EPIC Database (234)
Overview by MS	Total gross and net electricity production (GWh)	Eurostat processed statistics (22)
	Total gross distributed heat production (GWh)	Eurostat processed statistics (22)
	Transformation input (toe)	Eurostat processed statistics (21)
	CO_2 emissions (kt CO2)	UNFCCC processed statistics (29)
	Rate of use	Own calculations based on EPIC Database (234) and Eurostat (22)
	Gross and net electric efficiencies	Own calculations based on Eurostat (22) and Eurostat (21)

Notes
Processed statistics originate from primary statistics but may be adjusted from the original source during calibration.

Fuel code labels used in the JRC-IDEES-2021_PowerGen data files are mapped to Eurostat energy balance codes in Annex, Table 11.

Source: JRC analysis.

3.5.2 Power plant data calibration

For all types of power plants considered, the reported gross and net nominal installed capacities, utilisation rates, transformation input, electricity generation, and electric efficiencies are obtained through an annual calibration process for 2000-2021. This process is applied in three steps for each MS individually. The first step covers the level of fuels used, where transformation input statistics are harmonised with gross electricity or heat production statistics. The goal of this step is to ensure that gross efficiencies of electricity or heat production are within technically plausible bounds. The next step harmonises the gross electricity production obtained from the first step, with the generation capacities reported in the EPIC-derived plant-level dataset. This is done by ensuring that utilisation rates are within technically plausible bounds. In this step, some further checks and calibration are applied to the co-firing of fuels in conventional thermal units. The last step computes total own consumption of the conventional thermal units and ensures that net and gross electricity generation are consistent with corresponding net and gross capacities.

In the case of onshore wind and solar PV power plants, the EPIC database reports a total of approximately 30,000 individual plants, making manual calibration impractical. These technologies are therefore automatically calibrated to match reference capacity time series for 2000-2021 in each MS. For total onshore wind capacity, these reference time series are directly taken from Eurostat (241) with minor adjustments following EurObserv'ER (208). For solar PV plants, reference capacity time series by MS are constructed for each size class individually. These time series follow total Eurostat PV capacity when available and are otherwise estimated from country-specific sources, in particular to address gaps in currently available Eurostat data for household-scale PV (<0.01 MW). For MS where Eurostat does not report an effective ratio for direct current-alternating current capacity, the different sources are harmonised using a generic ratio of 1.25 (238). The resulting reference onshore wind and PV capacity time series are then matched by shifting the commissioning or retirement date of individual EPIC plants by up to two years where needed. Plants that report multiple generation units (e.g. wind farms with multiple turbines) can similarly be disaggregated to represent staged construction and grid connection. In cases where the reference capacity time series still exceeds the resulting adjusted EPIC capacity by more than 1%, synthetic plants are imputed using the average unit size by MS reported in EPIC for each technology.

4 Conclusions

JRC-IDEES – the Joint Research Centre's Integrated Database of the European Energy System – compiles statistical data throughout all key sectors of the energy system (i.e., industry, residential, tertiary, transport, and the power sector), and complements this with processed data that further decompose energy consumption into sector-specific end uses. This approach quantifies the characteristics of energy equipment in use, identifies different drivers, and yields insights on their role by sector while respecting specific national structures. The result is a highly detailed, open-access analytical database that represents the EU at the level of individual Member States with annual data from 2000-2021. As such, JRC-IDEES has several key applications for energy system modelling, research, and policy analysis (Figure 10).

As a result, JRC-IDEES enables detailed insight into the factors behind the evolution of the energy system. In particular, it makes it possible to disentangle technology dynamics, behavioural patterns and structural changes, and can therefore also help assess the impact of related policies. The separate accounting of installed energy equipment and structural factors, together with the explicit tracking of the capacities and efficiencies of energy-using installations and power-generating assets, provides a basis to assess the scope for different policy actions – both as a self-standing analytical tool and as a comprehensive, detailed and internally consistent data source serving the parameterization needs of energy system models. Figure 10 shows examples of analytical applications in the scope of JRC-IDEES. However, the user must be mindful of the fact that JRC-IDEES, rather than a statistical database, is processed data: it is the product of a methodology to decompose aggregate primary statistics into a *plausible* more granular representation of the energy system. Expected updates to the underlying statistical data and decomposition assumptions will further enhance the quality of the database, and will be reflected in periodic updates to the JRC-IDEES-2021 release documented in this report.

Figure 10. Overview of JRC-IDEES applications.

To identify the drivers of past energy system evolution:

- Macro-economic/demographic/climatic conditions
- Technology dynamics
- Structural changes and behavioural patterns
- Impact of past policies
- Implicit monitoring of policies

To quantify the scope for future policy actions:

- Which are the key energy-consuming end uses?
- What is the margin for the technical improvement of energy equipment?
- What is the role of behavioural patterns and infrastructure improvements?

To set a common reference for future energy policy assessment within the European Union:

- Saving resources by avoiding redundant work on decomposing historical energy data
- Improving data quality through feedback from researchers and stakeholders
- Ensuring transparency
- Rendering modelling results comparable

Source: JRC analysis.

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Last update of data: 2022-11-14
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New registrations of motor coaches, buses and trolley buses by type of motor energy (code: road_eqr_busmot)
Last update of data: 2023-07-05
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List of abbreviations and definitions

Abbreviations	Definitions
ACEA	European Automobile Manufacturers Association
AFF	Agriculture, Forestry, and Fishing
BREF	Best Available Techniques Reference Document
BSO	Building Stock Observatory
CHP	Combined Heat and Power
EC	European Commission
EEA	European Economic Area
EPIC	Electricity Production Information & Capacity Database
EU	European Union
FEC	Final Energy Consumption
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GVA	Gross Value Added
ICCT	International Council for Clean Transportation
ICT	Information and Communication Technology
IDEES	Integrated Database of the European Energy System
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
LED	Light-Emitting Diode
LPG	Liquefied Petroleum Gas
MS	Member State
NEDC	New European Driving Cycle
NMM	Non-Metallic Minerals
TOSCA	Technology Opportunities and Strategies towards Climate-Friendly Transport
UIC	International Union of Railways
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
WLTP	Worldwide Harmonised Light Vehicles Test Procedure

List of units

Abbreviations	Definitions
g	Gram
GWh	Gigawatt-hour
km	Kilometre
kt	Kilotonne
ktoe	Kilotonne of oil equivalent
kWh	Kilowatt-hour
lm	Lumen
m^2	Square metre
MW	Megawatt
pkm	Passenger-kilometre
t	Tonne (metric)
tkm	Tonne-kilometre
toe	Tonne of oil equivalent
vkm	Vehicle-kilometre
W	Watt

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Annexes

Annex 1. Supplementary information.

Table 11. Fuel code correspondence between IDEES data files and Eurostat energy balance codes.

Sector	IDEES data file fuel label	IDEES data file fuel code	Energy balance fuel codes
Industry	Solids	SOLIDS	C0000X0350-0370, P1000, S2000
	Coke	COKE	C0311, C0312
	Non-coke solids	NONCOKE_SOLIDS	C0100, C0200, C0320, C0340, C0330, P1000, S2000
	Refinery gas	RFG	O4610, O4620
	LPG	LPG	O4630
	Diesel oil and liquid biofuels	DIESEL_LIQBIO	O4671XR5220B, R5210P, R5210B, R5220P, R5220B, R5230P, R5230B, R5290
	Fuel oil	RFO	O4680
	Other liquids	OTHER	O4100_TOT_4200-4500XBIO, O4652XR5210B, O4640 [a], O4651, O4653, O4661XR5230B, O4669, O4691, O4692, O4695, O4694, O4693, O4699
	Natural gas and biogas	NG_BIOGAS	G3000, R5300
	Derived gases	DERIVED	C0350-0370
	Biomass and waste	BIOMASS_WASTE	R5110-5150_W6000RI, R5160, W6210, W6100_6220
	Distributed steam	STEAM_DISTR	H8000
	Solar and geothermal	SOLAR_GEO	RA200, RA410
	Ambient heat	AMBIENT	RA600
	Electricity	ELEC	E7000
Residential and services	Solids	Solids	C0000X0350-0370; P1000; S2000
	LPG	LPG	O4630
	Diesel oil and liquid biofuels	Oil_LiqBio	O4100_TOT_4200-4500XBIO; O4610; O4620; O4652XR5210B; O4651; O4653; O4661XR5230B; O4669; O4640; O4671XR5220B; O4680; O4691; O4692; O4695; O4694; O4693; O4699; R5210P; R5210B; R5220P; R5220B; R5230P; R5230B; R5290
	Natural gas and biogas	NG_Biogas	G3000; C0350-0370; R5300
	Biomass and waste	Biomass_Waste	R5110-5150_W6000RI; R5160; W6210; W6100_6220
	Geothermal	Geo	RA200
	Distributed heat	Steam_Distr	H8000
	Solar	Solar	RA410
	Ambient heat	Ambient	RA600
	Electricity	Elec	E7000
Agriculture	Solids	SOLIDS	C0000X0350-0370; P1000; S2000
	LPG	LPG	O4630
	Diesel oil and liquid biofuels	DIESEL_LIQBIO	O4671XR5220B; R5210P; R5210B; R5220P; R5220B; R5230P; R5230B; R5290
	Fuel oil and other liquids	RFO	O4680; O4100_TOT_4200-4500XBIO; O4652XR5210B; O4651; O4653; O4661XR5230B; O4669; O4640; O4691; O4692; O4695; O4694; O4693; O4699
	Natural gas and biogas	NG_BIOGAS	G3000; C0350-0370; R5300
	Biomass and waste	BIOMASS_WASTE	R5110-5150_W6000RI, R5160, W6210, W6100_6220
	Solar and geothermal	SOLAR_GEO	RA200, RA410
	Ambient heat	AMBIENT	RA600
	Distributed heat	STEAM_DISTR	H8000
	Electricity	ELEC	E7000

Sector	IDEES data file fuel label	IDEES data file fuel code	Energy balance fuel codes
Road transport	Gasoline	Gasoline	O4652XR5210B; O4651; O4653; O4661XR5230B; O4669; O4640; O4691; R5210P; R5210B; R5230P; R5230B
	Diesel oil	Diesel	O4671XR5220B; O4680; O4692; O4695; O4694; O4693; O4699; R5220P; R5220B; R5290
	LPG	LPG	O4630
	Natural gas	NGas	G3000; R5300
	Electricity	Elec	E7000
Rail transport	Diesel oil excluding biofuels	Diesel	C0000X0350-0370; O4600XBIO
	Liquid biofuels	LiqBio	RA000; W6100_6220
	Electricity	Elec	E7000
Aviation	NA	NA	TOTAL
Navigation	NA	NA	TOTAL
Power & heat generation	Hard coal and derivatives	EFCoal	C0100; C0300
	Lignite, Peat and Derivates	EFLignite	C0200; P1000; S2000
	Refinery gas and ethane	EFRefineryGas	O4610; O4620
	Gas/Diesel oil	EFDiesel	O4100_TOT_4200-4500XBIO; O4630; O4652XR5210B; O4651; O4653; O4661XR5230B; O4669; O4640; O4671XR5220B
	Residual Fuel Oil	EFRFO	O4680
	Other Petroleum Products	EFOthPP	O4691; O4692; O4695; O4694; O4693; O4699
	Natural gas	EFNaturalGas	G3000
	Biogas	EFBiogas	R5300
	Derived Gases	EFDerivedGas	C0350-0370
	Solid biofuels (Wood & Wood Waste)	EFWood	R5110-5150_W6000RI
	Renewable municipal waste	EFMSWRen	W6210
	Liquid biofuels	EFBioLiquids	R5210P; R5210B; R5220P; R5220B; R5230P; R5230B; R5290
	Industrial wastes	EFWasteNRInd	W6100
	Non-renewable municipal waste	EFWasteNRMSW	W6220
	Wind	Wind	RA300
	Solar photovoltaics	SolarPV	RA420
	Solar thermal	SolarThermal	RA410
	Geothermal	Geothermal	RA200
	Tide, wave and ocean	Ocean	RA500
	Hydro	Hydro	RA100
	Electricity (Heat pumps, Electric Boilers)	HeatPump, ElectricBoiler	E7000

Source: JRC analysis.

Table 12. Industry: Energy-intensive sectors, subsectors, and processes.

Sector	Subsector	Process-related energy use
Iron and steel (ISI)	Integrated steelworks	Sinter/Pellet making
		Blast/Basic oxygen furnace
		Furnaces, refining and rolling
		Products finishing
	Electric arc	Smelters
		Electric arc
		Furnaces, refining and rolling
		Products finishing
Non-ferrous metals (NFM)	Alumina production	High enthalpy (steam) heat processing
		Refining
	Aluminium - primary	Aluminium electrolysis (smelting)
		Aluminium processing
		Aluminium finishing
	Aluminium - secondary	Secondary aluminium (incl. pre-treatment)
		Aluminium processing
		Aluminium finishing
	Other non-ferrous metals	Production
		Metal processing
		Metal finishing
Chemicals industry (CHI)	Basic chemicals	High enthalpy (steam) heat processing
		Furnaces
		Process cooling
		Generic electric process
	Other chemicals	High enthalpy (steam) heat processing
		Furnaces
		Process cooling
		Generic electric process
	Pharmaceutical products etc.	High enthalpy (steam) heat processing
		Furnaces
		Process cooling
		Generic electric process
Non-metallic mineral products (NMM)	Cement	Grinding, milling of raw material
		Pre-heating and pre-calcination
		Clinker production (kilns)
		Grinding, packaging and pre-casting
	Glass production	Forming
		Annealing
		Finishing processes
		Finishing processes
	Ceramics & other NMM	Mixing of raw material
		Drying and sintering of raw material
		Primary production process
		Product finishing
Pulp, paper and printing (PPA)	Pulp production	Wood preparation, grinding
		Pulping
		Cleaning
	Paper production	Stock preparation
		Paper machine
		Product finishing
	Printing and media reproduction	Printing and publishing

Source: JRC analysis.

Table 13. Industry: Non-energy-intensive sectors and processes.

Sector	Process-related energy use
Food, beverages and tobacco (FBT)	Oven (direct heat)
	Specific process heat
	Steam processing
	Drying
	Process cooling and refrigeration
	Electric machinery
Transport equipment (TRE)	Foundries
	Connection techniques
	Heat treatment
	Steam processing
	General machinery
	Product finishing (electric)
Machinery equipment (MAE)	Foundries
	Connection techniques
	Heat treatment
	Steam processing
	General machinery
	Product finishing (electric)
Textiles and leather (TEL)	Pre-treatment with steam
	Wet processing with steam
	Electric general machinery
	Drying
	Product finishing (electric)
Wood and wood products (WWP)	Specific processes with steam
	Electric mechanical processes
	Drying
	Product finishing (electric)
Other industrial sectors (OIS)	Steam processing
	Process heating
	Drying
	Process Cooling
	Diesel motors (incl. biofuels)
	Electric machinery
Agriculture (AGR)	Farming machine drives
	Specific heat uses
	Pumping devices (diesel and liq. biofuels)
	Pumping devices (electric)
	Specific electricity uses

Notes

Agriculture is reported in the tertiary and agriculture data file for each MS.

Source: JRC analysis.

Table 14. Industry: Correspondence between JRC-IDEES structure and Eurostat NACE reporting codes (1/2).

JRC-IDEES sector	NACE code	NACE description
	C24	Manufacture of basic metals
Iron and steel (ISI)		
Integrated steelworks		
Electric arc furnace		Value added is disaggregated to ISI subsectors during calibration
	C241	Manufacture of basic iron and steel and of ferro-alloys
	C242	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
	C243	Manufacture of other products of first processing of steel
	C2451	Casting of iron
	C2452	Casting of steel
Non-ferrous metals (NFM)		
Alumina production		
Aluminium production - primary		
Aluminium production - secondary		
Other non-ferrous metals		Value added is disaggregated to NFM subsectors during calibration
	C2442	Aluminium production
	C2453	Casting of light metals
	C2441	Precious metals production
	C2443	Lead, zinc and tin production
	C2444	Copper production
	C2445	Other non-ferrous metal production
	C2446	Processing of nuclear fuel
	C2454	Casting of other non-ferrous metals
Chemical industry (CHI)	C20, C21	Manufacture of chemicals and chemical products, Manufacture of basic pharm. products
Basic chemicals		
Other chemicals		Value added is disaggregated to CHI subsectors during calibration
	C2013	Manufacture of other inorganic basic chemicals
	C2014	Manufacture of other organic basic chemicals
	C2015	Manufacture of fertilisers and nitrogen compounds
	C2016	Manufacture of plastics in primary forms
	C2011	Manufacture of industrial gases
	C2012	Manufacture of dyes and pigments
	C202	Manufacture of pesticides and other agrochemical products
	C203	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
	C204	Manufacture of soap and detergents, cleaning and polishing preparations
	C205	Manufacture of other chemical products
	C206	Manufacture of man-made fibres
Pharmaceutical products etc.	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations

Source: JRC analysis.

Table 15. Industry: Correspondence between JRC-IDEES structure and Eurostat NACE reporting codes (2/2).

JRC-IDEES sector	NACE code	NACE description
Non-metallic mineral products (NMM)	C23	Manufacture of other non-metallic mineral products
Cement (incl. lime)	C235	Manufacture of cement, lime and plaster
	C236	Manufacture of articles of concrete, cement and plaster
Glass production	C231	Manufacture of glass and glass products
Ceramics & other NMM	C232	Manufacture of refractory products
	C233	Manufacture of clay building materials
	C234	Manufacture of other porcelain and ceramic products
	C237	Cutting, shaping and finishing of stone
	C239	Manufacture of abrasive products and non-metallic mineral products n.e.c.
Pulp, paper and printing (PPA)	C17, C18	Manufacture of paper and paper products, Printing and reproduction of recorded media
Pulp production	C1711	Manufacture of pulp
Paper production	C1712	Manufacture of paper and paperboard
	C172	Manufacture of articles of paper and paperboard
Printing and media reproduction	C18	Printing and reproduction of recorded media
Food, beverages and tobacco (FBT)	C10_C12	Manufacture of food products; beverages and tobacco products
Transport equipment (TRE)	C29_C30	Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment
Machinery equipment (MAE)	C25	Manufacture of fabricated metal products, except machinery and equipment
	C26	Manufacture of computer, electronic and optical products
	C27	Manufacture of electrical equipment
	C28	Manufacture of machinery and equipment n.e.c.
Textiles and leather (TEL)	C13_C15	Manufacture of textiles, wearing apparel, leather and related products
Wood and wood products (WWP)	C16	Manufacture of wood and of products of wood and cork, except furniture
Other industrial sectors (OIS)	B	Mining and quarrying
	F	Construction
	C22	Manufacture of rubber and plastic products
	C31_C32	Manufacture of furniture; other manufacturing

Source: JRC analysis.

Table 16. Power & heat generation: general plant types, fuels or energy types, technologies, and unit sizes.

General type	Fuel or energy type	Technology	Unit size
Nuclear	Nuclear power plants	All	L (>=750MW) M (<750MW)
Conventional thermal [a]	Coal power plants	Integrated gasification combined cycle Supercritical steam turbine Fluidized bed combustion Steam turbine	L (>=400MW) M (>=150MW and <400MW) S (>=7.5MW and <150MW) XS (<7.5MW)
	Lignite power plants	Integrated gasification combined cycle Supercritical steam turbine Fluidized bed combustion Steam turbine	L (>=400MW) M (>=150MW and <400MW) S (>=7MW and <150MW) XS (<7MW)
	Natural gas power plants	Gas turbine combined cycle Gas turbine Steam turbine Internal combustion engine	L (>=350MW) M (>=100MW and <350MW) S (>=9MW and <100MW) XS (<9MW)
	Biogas power plants	Gas turbine Steam turbine Internal combustion engine	L (>=350MW) M (>=100MW and <350MW) S (>=9MW and <100MW) XS (<9MW)
	Derived gas power plants	All	L (>=125MW) M (>=50MW and <125MW) S (>=7MW and <50MW) XS (<7MW)
	Refinery gas power plants	All	L (>=125MW) M (>=50MW and <125MW) S (>=7MW and <50MW) XS (<7MW)
	Diesel oil power plants	Gas turbine combined cycle Gas turbine Steam turbine Internal combustion engine	L (>=50MW) M (>=25MW and <50MW) S (>=7.5MW and <25MW) XS (<7.5MW)
	Fuel oil power plants	Supercritical steam turbine Integrated gasification combined cycle Steam turbine	L (>=250MW) M (>=75MW and <250MW) S (>=7MW and <75MW) XS (<7MW)
	Solid biomass power plants	Integrated gasification combined cycle Fluidized bed combustion Steam turbine	L (>=150MW) M (>=50MW and <150MW) S (>=7MW and <50MW) XS (<7MW)
	Waste power plants	All	L (>=150MW) M (>=50MW and <150MW) S (>=7MW and <50MW) XS (<7MW)
Renewable	Wind power plants - Onshore	All	L (>=4MW) M (>=2MW and <4MW) S (>=0.75MW and <2MW) XS (<0.75MW)
	Wind power plants - Offshore	All	L (>=6MW) M (>=3MW and <6MW) S (>=1.5MW and <3MW) XS (<1.5MW)
	Solar PV power plants	All	L (>=1MW) M (>=0.02MW and <1MW) S (>=0.01MW and <0.02MW) XS (<0.01MW)
	Solar thermal power plants	All	L (>=100MW) M (>=30MW and <100MW) S (>=5MW and <30MW) XS (<5MW)
	Geothermal power plants	All	L (>=40MW) M (>=10MW and <40MW) S (>=1MW and <10MW) XS (<1MW)
	Tidal, wave and ocean power plants	Tidal Wave and ocean	All

Hydro power plants - Run-of-river	All	L (>=30MW) M (>=10MW and <30MW) S (>=1MW and <10MW) XS (<1MW)
Hydro power plants - Reservoirs (dams)	All	L (>=75MW) M (>=10MW and <75MW) S (>=1MW and <10MW) XS (<1MW)
Pump storage	All	L (>=75MW) M (>=10MW and <75MW) S (>=1MW and <10MW) XS (<1MW)

Notes

For conventional thermal plants, this classification is separately reported for electric-only and combined heat and power (CHP) plants.

Source: JRC analysis.

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