# Guidance for standardized savings methodologies & indicative values for the public sector DRAFT

## Deliverable D2.3

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# Disclaimer

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# Content

# Summary

To achieve the reduction targets under the Energy Efficiency Directive (EED), a clear need arose for simplified, yet accurate, methodologies to calculate energy savings from energy efficiency actions being implemented by Member States. During streamSAVE+'s consultation (Winter 2024-2025) to identify the main challenges that Member States face when implementing Article 4, Article 5 and Article 8 of the EED, data collection procedures were stressed, as well as the lack of quality data. Moreover, the amendment of the revised Energy Efficiency Directive (EU/2023/1791) brings additional challenges to Member States, in particular regarding Article 8 and several requirements of its Annex V.

Next to a general guidance on energy savings calculations for both, Article 4 and 8 EED and information on how to assess costs and GHG emissions reduction related to the existing Priority Actions (streamSAVE), this guideline is focussing on Article 5 of the EED recast addressing the public sector and provides nine newly developed bottom-up calculation methodologies featuring indicative calculation values. The following methodologies have been prepared:

- Consumption reduction calculation for heat recovery from public institutions
- Consumption reduction calculation for building automation and control systems (BACS)
- Consumption reduction calculation for comfort cooling in public buildings
- Consumption reduction calculation for electric vehicle integration in public sector
- Consumption reduction calculation for public road lighting systems
- Consumption reduction calculation for replacement of electric motors
- Consumption reduction calculation for trainings related to energy efficiency for public sector employees
- Consumption reduction calculation for small-scale renewable heating technologies

A clear **guidance is included for each methodology**, so Member States can estimate the monitored or estimated final energy savings, based on EU-wide averages or can translate these into national specific savings. Next to this guidance, the methodologies can also be consulted via user-friendly excel templates per Priority Action. These templates will be integrated on the online Training module of the streamSAVE+ platform: https://streamsaveplus.eu/priority-actions.

# Introduction

## About streamSAVE+

With the ambitious recast of the Energy Efficiency Directive (EED - EU/2023/1791), there is increased pressure on the EU Member States (MS) to introduce new policy measures or enhance existing policies to increase significantly energy savings and reductions. Although a lot has been done to streamline the energy savings calculations (cf. H2020 streamSAVE) and to improve measurement and verification procedures (cf. H2020 ENSMOV), many Member States still need to further improve their approaches to successfully meet their EED targets.

The streamSAVE+ project aims to support Member States in their efforts to achieve their energy efficiency goals and provide highly scalable energy savings in accordance with Articles 4, 5, and 8 of the updated Energy Efficiency Directive (EED recast). The project's main goal is to streamline energy savings calculations. Particularly for actions - the so-called Priority Actions - that still offer substantial savings or for which energy savings can be difficult to evaluate. These actions can cover a variety of sectors, such as electrification in transport, integration of renewable energy sources (RES) for heating and cooling in buildings, and improvements in electric motors driven systems.

Four key activities are envisioned:

1. Development of a knowledge hub: Given the importance of deemed savings approaches in Member States' EED reporting streamSAVE+ focuses on streamlining bottom-up calculations methodologies of the Priority Actions. streamSAVE+ offers these savings methodologies in a transparent and streamlined way, to also show the comparability of savings.
2. Facilitation of dialogue among MSs to foster knowledge sharing and peer-to-peer cooperation. This involves nine participating countries (AT, BE, BG, CZ, EL, HR, LT, PT, SI), and a broader group of interested participants from six outreach countries (ES, FI, FR, IE, RO, SK).
3. Capacity building: Assistance to participating countries considering their requirements and needs. In-depth support will be given by technology experts, policy experts and country experts.
4. Analysing policies and future trends to establish the data framework and preparation of the policy packages of the participating countries.

More broadly, the project aims at fostering transnational knowledge and dialogue between public authorities, technology experts, and market actors. The key stakeholders will improve their energy savings calculation skills and ensure thus the sustainability and replicability of the streamSAVE+ results towards all European Member States.

## Tailoring standardized savings methodologies to the public sector

The aim of this guideline is to support Member States (MS) and public authorities of the European Union to implement Article 5, Public sector leading on energy efficiency. It is addressed primarily to the three groups of public authorities (federal, regional and municipal level) and subsequently also to the reporting body (the federal government).

This report describes the standardized calculation methodology for each of these new Priority Actions (PA), supporting the implementation of Article 5 of the EED. The basic bottom-up approach for calculating energy savings achieved by an action is (1) to consider all essential influences on the energy consumption of an appliance or system and (2) compare the baseline situation to the situation after the PA implementation. The savings methodologies are based on literature, statistical data, EED requirements as well as the expertise from streamSAVE's partners. This guidance contains the following information for each of the actions:

- Description of the action, including application area or scope of the standardized calculation methodology (e.g. subsector; limits of methodology);
- Calculation formula and parameter definition;
- Indicative values per parameter based on EU-wide data;
- Reference consumption or baseline and update;
- Correction for behavioural and/or regional effects.

# 1. Article 5 of the EED recast targeting public bodies

## 1.1. Overview and aim of this guidance

Public bodies must be role models in energy efficiency. Therefore Article 5 of the EED recast (EU/2023/1791) introduces a new obligation for public bodies to reduce their final energy consumption for all public institutions by at least 1.9 % each year (compared to 2021) until 2030.

During the transitional period until 11th of October 2027, the reduction target of at least 1.9 % each year is indicative (not mandatory), and it can be based on estimated final energy consumption data.

To achieve the reduction target of at least 1.9 % each year, public institutions must implement energy efficiency measures and verify the energy reductions at least annually by comparing the final energy consumption with a defined baseline.

Public bodies can estimate the impact of energy efficiency measures using various approaches. Where available, detailed methods may include tools that track and analyze energy use, water consumption, and $CO_2$ emissions at the level of individual public buildings (see chapters 1.5.1, 1.5.2, and 1.5.3). However, in the absence of comprehensive stock data, estimations can rely on streamlined deemed savings methodologies for Priority Actions developed under the H2020 streamSAVE project and this follow-up streamSAVE+ LIFE initiative.

Article 5 of the recast Energy Efficiency Directive (EED) is closely linked to Article 6, which sets renovation targets for public buildings, and Article 7, which mandates energy-efficient public procurement, as outlined in the EED Directive (EU) 2023/1791. The measures implemented under these articles should also deliver energy savings and contribute to achieving the overall 1.9 % annual reduction target.

Regarding the implementation of EED Articles 5, 6 and 7, the European Commission published a guidance document "EU Commission recommendation 2024/1716" for interpretation. This streamSAVE+ report is focusing on the calculation of energy savings for Priority Actions implemented by public bodies to achieve the reduction of final energy consumption under Article 5. It builds further on the former H2020 streamSAVE project (Guidance D2.2), as well as the recent EC guidance document EU 2024/1716.

## 1.2. Target Groups of Article 5 - Public bodies

Article 5 of the EED recast is targeted at all public bodies, which includes all national, regional, and local authorities and all entities directly financed and administered by public authorities (e.g. non-profit housing associations) with no industrial or commercial character. The criteria for those entities under Article 5 EED recast are:

- It is a legal entity under public and private law.
- It is financed predominantly (more than 50 %) by the public sector; Note: financing by charging fees does not meet the criterion of direct financing by public authorities.
- It does not participate in general business life on the relevant market in competition with private economic operators under the same conditions (i.e., according to the same economic rules) and does not bear the economic risk (including insolvency risk) of its actions, e.g. because a cost-bearing obligation of the state is provided for or it is very likely that losses will be borne by the state.
- It is managed by a majority by public authorities (more than half); Note: indirect appointment rights do not fulfill this criterion.

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EU Member States must identify all targeted public bodies and must ensure that they know their obligations under Article 5. More information is published in the European Commission a guidance document “EU Commission recommendation 2024/1716”.

## 1.3. Objective of Article 5 obligation – 1.9 % annually reduction of final energy consumption until 2030

The objective of Article 5 EED recast is to reduce the final energy consumption for all public institutions by at least 1.9 % each year until 2030. During a transitional period between the transposition date of EED recast and 11th October 2027, the target of the energy consumption reduction of at least 1.9 % each year is indicative (not mandatory), becoming obligatory after the transposition date.

The obligation for public bodies in local administrative units with a population of less than 50,000 respectively less than 5,000 starts later, but it is advisable to start implementing measures already at an earlier stage. Also, it is recommended that the reduction of the final energy consumption should come from all public bodies, also from local administrative units less than 50,000 respectively less than 5,000.

The obligation of Article 5 EED recast covers the total final energy consumption including public buildings, and all other sectors, e.g. healthcare, spatial planning, water management, wastewater treatment, sewage and water purification, waste management, public lighting, education, social services, and ICT. Member States can choose on a voluntary basis if they exclude public transport and/or the armed forces from the obligation but keeping in mind that armed forces as well as the public transport have attractive energy efficiency improvements. The energy consumption reduction of public transport and armed forces is indicative but can still count for fulfilling the obligation, even if it is excluded from the baseline.

*Table 1: Starting dates of Article 5 EED recast obligation*

| Obligation target: Reduction of final energy consumption by at least 1.9 % per year | Starting date of the obligation | Notes |
|---|---|---|
| For all public bodies except public bodies in local administrative units with a population of less than 50,000 | transposition date of EED recast | Targets are indicative until 11th of October 2027<br>The achievement of the target values must be demonstrated in the progress reports on the NECP, for the first time in March 2027. |
| For all public bodies with local administrative units with a population of less than 50,000 | 1st of January 2027 | Targets are indicative until 11th of October 2027 |
| For all public bodies with local administrative units with a population of less than 5,000 | 1st of January 2030 | - |

*Source: Article 5 of the EU Directive 2023/1791 (EED recast) and guidance document EU 2024/1716*

## 1.4. Article 5 obligation – Determining the baseline

To verify the energy reduction for all public institutions each year, the final energy consumption must be compared with a baseline. The baseline is defined as the final energy consumption of all public institutions in the year 2021. At the latest by 11th of October 2027, by the end of the transitional period, the baseline must be recalculated and adjusted but the baseline year remains the same (2021).

In the updates of the integrated national energy and climate reports (NECPs), the amount of the annual energy consumption reduction achieved by all public bodies and disaggregated by sector must be reported, including further measures to achieve those reductions. It is recommended to streamline the baseline determination of Article 5 EED recast with the data (dis)aggregation for the NECPs.

For public bodies with a population of less than 50,000, respectively less than 5,000, the baseline year is also 2021. It is recommended to start the data collection for the baseline determination before the obligation starts.

*Table 2: Obligation for the baseline determination related to Article 5 EED recast*

| Obligation: Determination of the final energy consumption baseline for the calendar year 2021 | Deadlines for determination of the baseline |
|---|---|
| For all public bodies with a population over 50,000<br>✛ For sector buildings<br>✛ For sector processes<br>✛ For sector transport (mobility services)* | Estimated baseline by transposition date.<br>Adjusted (final) baseline latest by 11 October 2027 |
| Armed forces* | Estimated baseline by transposition date.<br>Adjusted baseline latest by 11 October 2027 |
| For public bodies in local administrative units with a population of less than 50,000<br>✛ For sector buildings<br>✛ For sector processes<br>For sector transport (mobility services)* | Adjusted (final) baseline latest by 31st of December 2026 |
| For public bodies in local administrative units with a population of less than 5,000<br>✛ For sector buildings<br>✛ For sector processes<br>✛ For sector transport (mobility services)* | Adjusted (final) baseline latest by 31st of December 2029 |

*Only if it is not excluded

*Source: Article 5 of the EU Directive 2023/1791 (EED recast) and guidance document EU 2024/1716*

## 1.5. Bottom-up collection of final energy consumption data

For the data collection of final energy consumption, a comprehensive bottom-up methodology is needed. Public bodies should install a process for the collection of data related to sectors, subsectors, and energy sources. The transitional period of Article 5 EED recast gives public bodies additional time to set up the data collection process.

Also, for public bodies with a population of less than 50,000, respectively less than 5,000, it is recommended to start the data collection as soon as possible and not wait until the obligation starts.

It is not determined how the data collection should be done, e.g., using existing energy statistics, energy invoices, energy meter/smart meter data, data from accountancy, data from energy book-keeping or data from energy monitoring software. In the guidance document EU 2024/1716 a recommended bottom-up data collection sheet for public bodies is published.

It is recommended to collect and report the data on calendar year basis, because progress reporting under the Governance Regulation requires a reporting period of two calendar years (NECPRs). Also, it is recommended to streamline the data collection process with existing processes or use already existing procedures (accountancy, energy book-keeping, energy monitoring systems). Each year, starting with 2025, the public bodies must repeat the collection of final energy consumption data using the same methodology and data structure to collect the data for the baseline definition.

In the data collection process also GHG emission factors and GHG calculations can be considered, although not stipulated in Article 5. It is however of relevance in NECP design and reporting. A common approach to calculate GHG emissions of the energy consumption is by multiplying the energy consumption (e.g. electricity, natural gas) with the respective GHG emission factor(s), which can also be done also for the baseline energy consumption. GHG emission factors are quantifying how much GHG is emitted per unit of activity. There are different sources of GHG emission factors which can be used, one source is Annex VI of the Greenhouse Gas Directive (2018/2066/EU). But also, other emission factor sources (e.g. energy invoices) can be used. When selecting the GHG emission factors, the national circumstances should be considered.

See enclosed good practices of data collection processes in Flanders/Belgium, Croatia and Luxembourg.

### 1.5.1 Good Practice from Flanders - Terra[1] tool

Terra is an energy management platform that is developed and operated by the Flemish Energy Company ("Vlaams Energiebedrijf" of VEB), a public entity dedicated to support energy efficiency measures in the Flemish public sector. Terra is designed to centralize and analyse energy data, provide actionable insights, and facilitate compliance with European Union's reporting requirements.

The primary aim of Terra is to provide public bodies with a comprehensive understanding of their energy consumption, enabling informed decision-making and effective energy management. The platform is tailored to meet the needs of the public sector, providing tools to map energy use across buildings and infrastructure, identify inefficiencies and plan for energy-saving measures. By doing so, Terra not only helps in reducing operational costs but also in realising national climate and energy targets for 2030 and 2050.

The platform draws data from multiple sources, ensuring accurate and comprehensive insights. By integrating energy data with patrimony information, Terra helps to identify inefficiencies and opportunities for improvement through data-driven decision-making. Terra incorporates historical data from the Flemish distribution system operator (DSO), Fluvius, capturing up to three years of electricity and gas consumption. In the start of each year the DSO provides VEB with real consumption data for electricity and gas from 2 years prior. Terra integrates energy data from varies types of meters, including (if available) automatic (AMR), monthly (MMR), and yearly (YMR) readings and allows for manual input of additional consumption data by the public bodies. Terra accommodates a wide range of energy carriers, including electricity, natural gas, wood, heating oil, pellets, water and district heating. Terra connects with other tools and databases to expand its functionality. It links to the Energy Performance Certificate (EPC) database and building passport ("Gebouwenpas") for building performance insights and connects with a photovoltaics (PV) planning tool developed by Brussels University (VUB) and the Association of Flemish Cities and Municipalities (VVSG). The latter enables the evaluation of potential

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[1] Based on: interview by Vito with Tom Capiau – VEB (7/11/2024); https://www.veb.be/energiebeheer; Webinar: Terra haal meer uit je data (28/11/2024).

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PV installations, electrical vehicle (EV) charging stations, and energy-sharing systems, supporting renewable energy adoption and planning.

The functionalities of Terra address various aspects of energy management, reporting, and planning. Public organizations can use Terra to monitor energy consumption across their entire patrimony, from individual buildings to larger infrastructures. This includes mapping and categorizing energy carriers, as well as identifying inefficiencies in usage. Through the platform, public organizations can initiate energy audits, where consultants evaluate potential energy-saving measures and upload findings directly into Terra. These findings are associated with estimated costs, energy-saving potential, and $CO_2$ reduction, offering actionable insights for decision-makers.

The platform generates detailed dashboards and reports, showing energy consumption trends over time, comparing the performance of different buildings, and highlighting inefficiencies. Users can access visualizations such as heatmaps to identify peak consumption periods or detect anomalies in energy use. The reporting system also allows for benchmarking energy performance across buildings within the same organization, helping to prioritize energy-savings measures.

Terra also supports strategic planning by generating tailored Masterplans for Energy based on energy audit data. These plans outline specific measures for improving energy efficiency, including cost estimates, return-on-investment calculations, and $CO_2$ reduction potential. For organizations without detailed audit data, Terra can recommend generic energy savings measures based on building characteristics such as size and age of the building. Furthermore, the platform simplifies the process of applying for subsidies, streamlining access to financial support for energy-efficiency measures.

Terra supports open data initiatives by providing access to datasets through a public application programming interface (API). The platform also allows differentiated access tailored to the specific needs of municipalities, healthcare institutions, and other public bodies, ensuring flexibility in managing data while maintaining compliance with privacy regulations.

The platform prioritizes data protection and privacy. For example, energy consumption data for residential buildings is included only when the public organization pays the energy bills. If the properties are occupied and the public organization does not cover the energy costs, the data is excluded to safeguard privacy.

The Flemish government has selected the Terra platform to fulfil the reporting requirements under Article 5 of the Energy Efficiency Directive. Currently, the platform is being used by about 260 local administrations. However, the tool is intended for the entire public sector, not only public entities, such as hospitals and schools. Terra serves as a tool for monitoring energy consumption and identifying energy savings in public buildings. It will be used for mandatory reporting, helping to establish energy baselines and assess potential improvement measures along with the resulting final energy savings. To ensure it is not perceived as a burden by public organizations, the platform is designed to deliver added value to its users. It aims to function as a comprehensive tool that enables public entities to analyse their energy use and strategically plan their energy transition efforts.[2]

Figure 1 contains two bar charts that illustrate the annual energy consumption of a building as reported by the Terra platform. The charts separately present the usage of electricity (top chart) and natural gas (bottom chart) from the year 2018 through 2025. Both charts use kWh (kilowatt-hours) as the unit of measurement and provide year-over-year comparisons including percentage changes.

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[2] Meeting report of streamSAVE+ Dialogue Meeting #04: Local energy savings in national monitoring: can standardised methods help? (9/04/2025).

*Figure 1: Example of information provided in building energy reports Terra platform (annual consumption of electricity and natural gas)*

*Source: presentation Terra platform (Tom Capiau) - streamSAVE+ Dialogue Meeting #04: Local energy savings in national monitoring: can standardised methods help? (9/04/2025).*

### 1.5.2 Good Practice from Croatia - EMIS[3] tool

The Energy Management Information System (EMIS) is a web-based platform developed and operated by the Croatian Real Estate Agency (APN), aimed at supporting sustainable energy and water management across **public sector buildings** in Croatia. The system provides centralized oversight of consumption data and serves as a key tool for implementing systematic energy management strategies in the public sector.

EMIS enables public authorities—including cities, counties, and national institutions—to monitor, analyse, and manage energy and water use across their facilities. The platform is accessible from any internet-connected device and requires user authentication via a unique username and password. EMIS collects and processes both static data (e.g. building characteristics) and dynamic data (e.g. monthly utility consumption from suppliers).

Data is collected through two main channels: manual entry based on monthly utility bills, and automated data integration from suppliers whose billing send data to the EMIS database. This dual

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[3] Based on: Information provided by the Croatian Real Estate Agency (APN) (4/4/2025)

approach reduces errors and ensures data reliability. In addition, EMIS supports daily and weekly data input from on-site meters and allows for real-time data collection from over 3,800 remotely connected measuring devices. The system accepts hourly readings and integrates both offline and real-time data sources.

By leveraging this data, EMIS enables comprehensive energy and water analysis, benchmarking, and performance tracking across buildings. Automated alerts notify users of irregularities or consumption spikes, allowing for rapid response and cost control. Also, based on the information obtained through the conducted analysis, experts responsible for energy management identify and implement the necessary measures to increase energy efficiency, ultimately resulting in energy and monetary savings.

Key functionalities include:

- Collection and management of technical and consumption data for public buildings.
- Monitoring of public lighting energy use.
- Entry of energy audits, certificates, and efficiency measures.
- Module for monitoring the Government's program for energy renovation of public sector buildings.
- Generation of reports, dashboards, and visualizations.
- Real-time consumption monitoring and anomaly detection.
- User-specific interfaces, advanced filtering, and customizable access rights.
- Integration of energy data with smart meters, mobile apps (mISGE), and sensors.
- Tools for managing accounts, communication, documentation, and internal alerts.

In recent years, EMIS has expanded its capabilities. It now includes modules for fleet energy consumption monitoring and the integration of indoor environmental quality sensors. These features enhance the system’s ability to support public institutions in achieving other energy efficiency goals.

EMIS today (April 2025):

- 46,000+ energy consumption centres (including ca. 24,000 for public lighting).
- 67,000+ metering points, of which over 3,800 support remote readings.
- 112 million+ total readings, including nearly 109 million remote readings.
- 3,500+ sensors and over 185 million sensor readings.
- Over 15,700 monthly utility bills processed.
- Implementation of indoor air quality monitoring and vehicle fleet tracking modules.

EMIS continues to evolve as a central tool for the public sector in collecting data on final energy consumption, providing detailed insights into energy use in order to systematically manage energy, control consumption, and plan measures for improving energy efficiency. The data collected through the EMIS system will serve as a basis for establishing the consumption baseline of public sector entities. EMIS is planned to be used as the primary tool for entering and updating consumption data in the coming years and is currently being revised to be compliant with the EED Article 5 and 6 requirements and specific national requirements.

EMIS database statistics (17.10.2024.)

| ECC type | Number of objects | Number of metering points | Automatic Meters Count | Energy bill count | Number of readings | Number of automatic readings | Sensors count | Number of sensor readings |
|---|---|---|---|---|---|---|---|---|
| Complex | 1.085 | 3.117 (29) | 449 (3) | 631.273 | 23.374.328 | 22.991.645 | 0 | 0 |
| Building in complex | 4.566 | 5.238 (21) | 1.644 (5) | 797.063 | 25.396.589 | 24.797.171 | 54 | 2.059.496 |
| Free-standing building | 11.731 | 27.654 (434) | 1.328 (8) | 5.776.852 | 36.654.309 | 34.529.031 | 843 | 27.322.482 |
| Part | 4.295 | 7.515 (22) | 419 | 1.385.256 | 14.239.814 | 13.975.811 | 2.585 | 119.876.983 |
| **Sum - Building stock** | **21.677 (16.297)** | **43.524 (506)** | **3.840 (16)** | **8.590.444** | **99.665.040** | **96.293.658** | **3.482** | **149.258.961** |
| Public lighting | 24.279 | 23.370 | 2 | 6.379.672 | 1.165 | 0 | 0 | 0 |
| **Sum** | **45.956** | **66.894 (506)** | **3.842 (16)** | **14.970.116** | **99.666.205** | **96.293.658** | **3.482** | **149.258.961** |

Criteria for the inclusion of objects in the statistics: must have an EMIS code, must be existing (date of end of existence of the object must be empty), must not belong to the DEMO or TEST projects, object type must have the checkbox "Physical object" checked.

*Figure 2: Example of information provided in EMIS statistics*

*Source: presentation Energy Management Information System (EMIS) (Valentina Madžarević, Vanja Hartman) - streamSAVE+ Dialogue Meeting #01: Assessing energy savings from deep retrofit programmes (22/10/2024).*

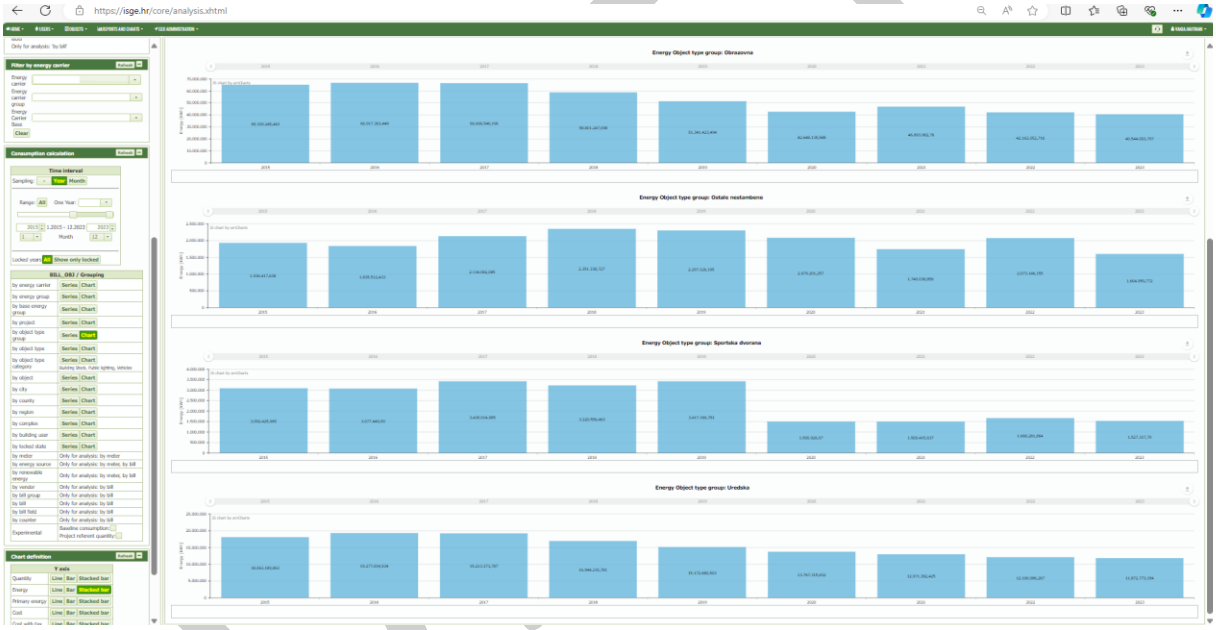

*Figure 3: Example of information provided in EMIS Analytics module*

*Source: presentation Energy Management Information System (EMIS) (Valentina Madžarević, Vanja Hartman) - streamSAVE+ Dialogue Meeting #01: Assessing energy savings from deep retrofit programmes (22/10/2024).*

## 1.5.3 Good Practice from Luxembourg – EnerCoach[4] [5] tool

EnerCoach is a comprehensive monitoring tool designed to track the energy consumption of public buildings, street lighting, and municipal transport. It plays a pivotal role in Luxembourg's KlimaPakt (Climate Pact), a voluntary agreement between the national government and municipalities. This pact incentivizes and rewards local efforts aimed at achieving ambitious environmental and energy objectives, in line with national and European directives (https://pacteclimat.lu).

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[4] Based on: https://www.ca-eed.eu/ia-document/enercoach-energy-monitoring-tool-luxembourg/

[5] More information available at: EnerCoach: energy accounting software | Klima-Agence

The platform is provided by SIGI (Syndicat Intercommunal de Gestion Informatique) and developed in close collaboration with Klima-Agence, Luxembourg's national energy and climate agency. Offered free of charge to all municipalities, EnerCoach allows for efficient energy accounting by enabling the recording, reporting, and analysis of electricity and heating use, water consumption, and $CO_2$ emissions in municipal buildings and public infrastructure, including public lighting and municipal fleet. EnerCoach provides detailed input and analysis at the level of individual meters, buildings, and time intervals. It includes visualization tools that help track historical consumption trends and compare energy performance across facilities.

EnerCoach enables the assessment of energy efficiency based on actual consumption data rather than estimates, offering a more accurate and objective view on energy performance. This is particularly important for meeting the assessment requirements under the KlimaPakt, where the allocation of subsidies is directly linked to demonstrated performance improvements. The tool also facilitates the identification of buildings with poor energy performance, helping municipalities prioritize actions where they are most needed. Prior to the implementation of EnerCoach, there was no systematic annual monitoring of energy consumption across all municipalities. The introduction of this tool has been an eye-opener, revealing the importance of structured and consistent energy monitoring and management. EnerCoach is currently being revised to be compliant with the EED Article 5 and 6 requirements and specific national requirements.

Figure 4 illustrates the EnerCoach monitoring tool used in Luxembourg. It provides a visual comparison of actual energy consumption (heat, electricity and water) against predefined targets, reference benchmarks, and legal or operational limits.

Catégorie d'objets : Toutes · Année : 2022 · Type : Tous

Nombre d'objets concernés
52 objets (dont 1 non comptabilisés)

Période
2013 - 2022

*Figure 4: Assessment and reports EnerCoach: consumption, targets, references and limits.*

Source: ca-eed.eu/ia-document/enercoach-energy-monitoring-tool-luxembourg/

## 1.6. Corrections for climate effects, service level and behavioural effects

Article 5 EED recast allows public bodies to consider influencing factors on the final energy consumption but are not obliged to consider climatic effects or other effects like the service level and/or the behavior of people.

By considering climate effects, service levels and behavioural effects as influencing factors on the final energy consumption the energy consumption data could be more comparable. Adjustments methodologies for the final energy consumption are described in the standards ISO 17742 "Energy efficiency and savings calculation for countries, regions and cities" and ISO 50049 "Calculation methods for energy efficiency and energy consumption variations at country, region and city levels". Important is that adjustment methodologies should not be changed and should be consistent across all consumption sectors. Any change should be described and justified (EU recommendation 2024/1716).

### Climatic effects

Considering climate effects should be done especially for comparing the final energy consumption of buildings with heating and cooling systems. Possible data sources for heating and cooling degree days include Eurostat[6] and the Website „Degree Days – Wheater Data for Energy Savings[7].

For example, the heating energy consumption should be correlated with the heating degree days to normalize it. As general calculation methodology the formula could be applied for calculating the normalized final energy consumption (NFEC):

$$\mathrm{NFEC} = \frac{\text{measured or estimated current energy consumption } * \text{ average heating degree days of the last 30 years}}{\text{heating degree days of the current season}}$$

The heating degree days of the current heating season should be related to the heating degree days of the last 30 or 50 years, for example.

### Service level

Adjustments related to the service level should be done e.g. when public bodies are added or removed and the total square meter ($m^2$) of the building's changes or the number of the staff. These adjustments could be considered and calculated with regression analysis.

### Behavioural effects

Energy savings actions can trigger changes in behaviour of final energy consumers, this can lead to both increased and decreased savings. Behavioural effects are hard to evaluate and should be based on empirical data (e.g. survey, studies on how behaviour is affected). Although not explicitly mentioned in the EED recast and in the EU recommendation 2024/1716, rebound effects should be estimated and considered by Member States within their savings methodologies to produce sufficiently accurate estimates of the generated energy savings (Labanca & Bertoldi, 2016).

## 1.7. Mitigation of Energy Poverty

Mitigation of energy poverty is an important goal, so it must be ensured that the interests of people affected by energy poverty, people living in low-income households and vulnerable groups are considered when energy efficiency measures (including energy reductions and costs) are planned and implemented. So, it is an important step that public authorities check if energy poverty is sufficient addressed and negative impacts are avoided when setting and implementing measures.

## 1.8. Estimation of energy savings

For Article 5 of the EED recast, the energy saving calculation is always based on two values, the final energy consumption of the baseline (before the implementation of an energy efficiency measures) and the final energy consumption after the implementation of the energy efficiency measure.

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[6] [nrg_chdd_a] Cooling and heating degree days by country - annual data

[7] Heating & Cooling Degree Days – Free Worldwide Data Calculation

If no measured or individual energy consumption data for the implemented energy efficiency measures is available, the standardized bottom-up methods and formulas of this project with default values can be used to estimate the energy savings. Each individual energy efficiency measure can be extrapolated. But it is always more accurate to calculate with individual values, and not using standardized methodologies for calculating the savings.

Energy savings which are gained through final energy consumption reduction within Article 5 can contribute to the reduction targets of Member States set within Article 4 EED recast and published in the NECPs.

### 1.8.1 Lifecycle GHG emissions

Related to Article 5 EED recast, public bodies are not obliged but should consider life cycle carbon emissions (GHG emissions, $CO2_{eq}$) when investing e.g. in public buildings or heating systems.

As example, for buildings, the lifecycle carbon emissions should be considered in all steps in line with the cradle-to-cradle principle:

- Raw material extraction;
- Production of the building materials;
- Construction of the building;
- Utilisation of the building;
- Dismantling of the building;
- Reuse and recycling of materials.

$CO_2$ emissions in the life cycle should be recorded as $CO_2$ equivalents to take all the different greenhouse gases into account. $CO_2$ equivalents are the unit of the climate impact of greenhouse gases, the so-called Global Warming Potential (GWP). The higher the global warming potential, the more a particular greenhouse gas warms the earth compared to $CO_2$.

Calculating the GHG emissions as mentioned in chapter 1.5, only a part of the GHG emissions is considered. Emissions for example from the production of building materials and emissions from refrigerants are not considered.

There is also a strong Connex to Article VII (public procurement) of the EED recast. In Article VII EED recast it is mentioned that the lifecycle of carbon emissions related to buildings should be considered: It enables contracting authorities to require that tenderers disclose information on the life cycle global warming potential, the use of low carbon materials and the circularity of materials used for new buildings and buildings to be renovated, in particular buildings above 2,000 square meters.

## 1.9. Wider benefits

In Article 5 it is mentioned that Member States shall encourage public bodies to consider also wider benefits. In addition to energy reductions, energy efficiency measures can bring wider benefits, e.g. economic and social benefits like

- Better indoor climate, more comfort;
- Increase occupational health and safety;
- Health-promoting;
- Reducing energy poverty;
- Reduction of maintenance costs.

See enclosed the description of an open-source tool considering also wider benefits, the MICATool. MICATool – Multiple Impacts Calculation Tool[8] is a free, user-friendly online platform designed to scientifically quantify the multiple impacts of energy efficiency measures. Developed as part of the MICAT project, which was financed by the Horizon 2020 programme, this open-source tool provides comprehensive documentation that guides users clearly through the workflow, functionalities, methodologies, and indicators employed in the analysis. Its online wizard allows cities, regions, and ministries to upload their own data or use default data, run the built-in algorithms, and obtain quantified (and, where possible, monetised) results for a harmonised set of multiple-impact indicators. Interactive dashboards and direct export functions make the findings easy to integrate into climate strategies and plans.

The table below provides a clear overview of how each Priority Action corresponds to specific subsectors and improvement actions implemented or planned in the latest version of the MICATool. For the tool to function correctly, measures, policies, and scenarios must be broken down into combinations of (sub-)sectors and improvement actions. This is because impact factors and default values can vary significantly across different combinations.

*Table 3: Mapping the Priority Actions to MICAT energy efficiency Improvement Actions*

| | **StreamSAVE** | **MICATool** | |
|---|---|---|---|
| **No.** | **Priority Action** | **Subsector** | **Improvement Action** |
| 1 | Heat recovery | Not implemented | |
| 2 | Building automation & control systems | Average tertiary | Behavioural changes |
| 3 | Cooling in public buildings | Average tertiary | Cross-cutting technologies |
| 4 | Electric vehicles (public fleets) | Road transport | Fuel switch |
| 5 | Public road lighting | Average tertiary | Electric appliances |
| 6 | Replacement of electric motors | Average industry (or other relevant) | Cross-cutting technologies |
| 7 | Trainings in Public Sector | Average residential/ tertiary/transport | Behavioural changes |
| 8 | Small-scale renewable central heating | Not implemented | |
| 9 | Actions to alleviate energy poverty | Average residential (co-benefit] | Building envelope / Heating fuel switch / Energy-efficient heating |

Currently, the multiple impacts of the two Priority Actions “Heat recovery (district heating)” and “Small-scale renewable central heating” cannot be evaluated using the MICATool. However, the SEED MICAT project is working to expand the multiple impacts framework to include renewable energy sources. This will allow to assess impacts of the Heat recovery Priority Action as well as the comparison of different policy pathways toward climate neutrality.

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[8] https://micatool.eu/seed-micat-project-en/index.php

After inputting the subsector and improvement action for Priority Action, MICATool quantifies the multiple impacts of energy-efficiency actions across three dimensions—social, economic, and environmental—by calculating a set of dedicated indicators. The current version of the tool evaluates the indicators listed in the table below for each impact category.

*Table 4: Social, economic and environmental indicators evaluated by MICATool*

| | |
|---|---|
| **Social indicators** | Health effects linked to reduced air pollution |
| | Avoided lost working days due to air pollution |
| | Alleviation of energy poverty (measured by M/2 and 2M metrics) |
| | Health impacts due to improved indoor climate (avoided asthma) |
| | Reduction in excess cold weather mortality |
| **Economic indicators** | Impact on energy intensity |
| | Impact on import dependence |
| | Impact on gross domestic product |
| | Additional employments |
| | Added asset value of buildings |
| | Turnover of energy efficiency goods |
| | Reduction of additionally needed generation capacity |
| **Environmental indicators** | Primary energy savings by energy carrier |
| | Reduction in air pollution |
| | Reduction in greenhouse gas emissions |
| | Contribution to renewable energy targets |

## 1.10. Bibliography

DIRECTIVE (EU) 2023/1791 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast) EED Directive (EU) 2023/1791, EED Recast

COMMISSION RECOMMENDATION (EU) 2024/1716 of 19 June 2024 setting out guidelines for the interpretation of Articles 5, 6 and 7 of Directive (EU) 2023/1791 of the European Parliament and of the Council as regards energy consumption in the public sector, renovation of public buildings and public procurement EU Commission recommendation 2024/1716

# 2. Consumption reduction calculation for heat recovery from public institutions

For the priority action on heat recovery the following public institutions, where heat recovery might be an option to save energy according to Article 5 of the EED III could be identified as follows:

- Public office buildings;
- Public schools;
- Public retirement or nursing homes;
- Prisons;
- Military barracks;
- Public hospitals;
- Public health resorts;
- Public indoor and outdoor swimming pools;
- Wastewater treatment plants;
- Publicly owned data centres;
- Etc.

Not in every above-mentioned public institution all the sources described under Section 7.2 are available. For example, in hospitals compressed air systems might be in place, in public office buildings or schools definitely not.

## 2.1. Sources for heat recovery in public institutions

There are different possibilities to recover heat in public institutions. Under this priority action the following sources for heat recovery are discussed.

### 2.1.1 Heat recovery from a cooling machine

When chillers are installed in a public institution, there is a possibility to recover heat. Normally the heat on the condenser side is discharged on rooftop often without being used.

By installing a heat recovery system in the secondary circuit of the chiller, the cooling capacity plus the electrical power used for the chiller's compressor can be recovered in form of heat. But the temperature level of the recovered heat depends on the condensation temperature of the chiller and is around 40 to 45 °C.

As the Coefficient of Performance (COP) decreases with a higher condensation temperature the usable temperature level is limited to be able to run a chiller efficiently.

A basic requirement for the usefulness and economic feasibility of heat recovery is a steady heat demand elsewhere in the public institution.

It is also possible to recover heat from the compressor of the chiller. In this case, the achievable temperature level is over 60°C and can therefore also be used to heat domestic hot water. However, as only about 10 – 15 % of the cooling capacity can be used at this temperature level, it is often not economically viable. As a result, recovery of superheating in chillers is rarely used.

If an even higher temperature level is required, the recovered energy can also be raised to a higher temperature level using heat pumps.

### 2.1.2 Heat recovery from a compressed air-system

Screw compressors, boosters and blowers convert almost 100% of the electrical drive energy into thermal energy. Approximately 96 percent is available for heat recovery, two percent remains as heat in the compressed air itself and two percent is emitted as radiant heat.

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Modern screw compressors, boosters and blowers are ideally suited as complete systems for heat recovery. In particular, the direct utilisation of waste heat via an exhaust air duct system opens the high recycling potential of 96% of the energy used.

This applies regardless of whether the compressor is a liquid-injection, a dry-compressing a screw, a booster, or a blower. Screw compressors can be equipped with exhaust air ducts. The ducts are installed on site. The heated air can be used to heat rooms. There are also other possible applications like drying processes,

Hot heating and domestic hot water up to +70 °C, or up to +85 °C if required, can be generated from compressor waste heat using heat exchanger systems.

Plate heat exchanger systems are designed for heating and domestic hot water. This is the standard application for waste heat recovery. Wherever the waste heat from screw compressors is used to heat hot domestic and/or process water or to generate process heat, high-quality stainless steel plate heat exchangers are the first choice.

Specially protected heat exchangers are used where there is no other water circuit in between and where the purity of the water to be heated is of the utmost importance, e.g. cleaning water in the food industry.

Up to 76 per cent of the electrical power supplied to a compressor can be used in hot water heating systems and domestic hot water systems. This significantly reduces the primary energy requirement for heating.

It goes without saying that heating is needed in winter. However, more or less heating energy is also needed during other months, for example to provide hot water. This means that an approximate heating energy requirement of 4,000 hours per year can be achieved at its best.

### 2.1.3 Heat recovery from wastewater

Wastewater also can be used for generating heat in combination with the use of heat pumps. In the following section different ways of applications are shortly described.

#### In-house applications

In-house systems for example can be used to preheat fresh water. In this case, heat exchangers are installed in the building before entering the public sewer.

General requirements for in-house systems are: A continuously available volume of waste water with a flow rate of at least 5 $m^3$/day (e.g. kitchens of 200 meals/day (all day)). The temperature level should be higher than 30 °C, there should be sufficient space available, and the heat exchanger should be located close to the hot water tank. The useable grey water must be collected separately from faeces pipe.

By such an application fresh cold water can preheated from an initial temperature of around 10 °C to around 26 °C and fed into the hot water boiler, where it is heated to a final temperature of around 60 °C.

Connection possibility:

Ideally, the heat exchanger should be located **after** the confluence of all sewer lines and **before** they enter the public sewer, or in the basement before leaving the building, or on the property before entering the public sewer.

Technology:

Wastewater pre-treatment is required (depending on wastewater quality) to remove coarse material, feces, etc. Either plate or tube heat exchangers can be used as heat exchangers. It is important that automatic cleaning of the heat exchangers is provided.

Application:

In-house systems can be operated with or without a heat pump. They can be used either to preheat fresh water or to feed it into the heating system. Potential users are operators of hospitals, spas, swimming pools, leisure parks, canteen kitchens, retirement homes, with correspondingly high volumes of hot wastewater. In-house systems are not suitable for purely residential and office buildings.

### Wastewater energy utilisation systems

Wastewater contains thermal energy from bathing water, cooking, washing up and also from production processes. The temperature of wastewater varies between 10 °C and 20 °C throughout the year. Compared to other heat sources (outside air, soil, groundwater), wastewater usually has higher temperatures and is therefore an ideal heat source for the **efficient operation** of **heat pumps**. To utilize wastewater energy as efficiently as possible, it is important to define energy consumers that can cope with the lowest possible temperature (e.g. low-temperature heating system) and extract heat energy throughout the year.

This is because the lower the temperature difference between the source (wastewater) and the sink (use of heated water), the more efficiently the heat pump works. Every degree less temperature difference improves the efficiency of the heat pump by 2 to 3 %. The year-round heat consumption also makes wastewater energy utilisation more economical, as the required investment costs can be allocated to a larger amount of useable energy.

At the heart of a wastewater energy utilisation system are a heat exchanger, which extracts energy from the wastewater and a heat pump, which uses the thermal energy to heat or cool buildings.

Thermal utilisation of wastewater can take place at various locations within the wastewater infrastructure by extracting heat from untreated (upstream of the wastewater treatment plant) or treated wastewater (downstream of the wastewater treatment plant).

### Heat Exchanger located in the sewer

Sewer heat exchangers are used to utilise wastewater energy in the sewer. These are special heat exchanger elements adapted to the sewer cross-section that are installed directly in the sewer pipe.

An alternative is a bypass, in which a partial flow of wastewater is channelled into a shaft, flows through a heat exchanger, and is then returned to the sewer. In this case, there is less intervention in the sewer and the system is more accessible, but more space is required outside the sewer.

What criteria must be met?

A sufficiently large sewer (at least DN 400 even better DN 800) is required. The available wastewater flow should be greater than **10 l/s**. The wastewater temperature should be at least **8 – 10 °C**. The consumer of the recovered heat must be located close to the sewer. The distance from the sewer pipe to the consumer should not be more than 300 meters. The heat demand should be at least 50 kW.

For smaller systems with a capacity of 50 to approx. 500 kW, special heat exchangers are installed directly in the sewer, the pipes lead to the technical centre where the heat pump is located, which is connected to the heating and cooling systems in the building.

In large systems with an output of 500 kW to 10 MW, the sewer wastewater is channelled via a shaft into a technic room, where innovative heat exchanger bundles in combination with heat pumps use the waste heat to heat buildings in winter and cool them in summer.

If wastewater energy utilisation takes place in the sewer (upstream), the wastewater may generally be cooled by a **maximum of 2 °C** so as not to negatively affect the purification performance of the wastewater treatment plant. Thus, an agreement of the sewer and treatment plant operator must be obtained.

### Wastewater heat recovery in wastewater treatment plant effluent:

There is usually a large volume of cleaned wastewater downstream of a treatment plant. However, this can only be used if there are sufficient energy consumers in the vicinity of the treatment plant or the wastewater treatment plant itself has a high heat demand e.g. for drying of sewage sludge or sewage sludge preheating and digestion tank heating, respectively.

The cooling of the treated wastewater is generally irrelevant and may even be desirable from a water protection point of view. Thus, if the wastewater energy utilization takes place in the wastewater treatment plant outlet (downstream), the treated wastewater can be cooled **down up to 5°Celsius**. This means that 2.5 times more heat can be utilized than in the sewer if using the same flow.

## 2.2. Heat recovery for on-site use in public institutions

Savings calculation methodologies covered by this Priority Action focus on heat recovery from public institutions as described above for on-site use. There is a wide spectrum of heat consuming applications in public institutions (see also section 7.1 above) that are suitable for heat recovery actions. Therefore, it is not feasible to define one representative application.

Hence, the methodology elaborated within this chapter:

- Heat recovery for on-site use in public institutions - use of excess heat for on-site applications (e.g. at WWTPs for heating or drying of sewage sludge, for heating in office buildings or hospitals)

In addition to saving energy, heat recovery systems lead to the reduction of waste heat into the ambient air (cooling machines) or into rivers (treated wastewater), which puts less strain on nearby ecosystems. The lower fuel input can also reduce air pollutant emissions.

This methodology refers to the use of excess heat from processes in public institutions on-site (see also section 7.1 and 7.2 above). As energy saving action under Article 5 of the EED recast, a heat consuming or producing (compressed air-system) or cooling process is retrofitted with a heat recovery system. The recovered heat serves as a heat source for **another** application on the site (e.g. space heating system, preheating another process, drying process, etc.). Therefore, it causes a reduction of the input of the main energy carrier in the other application within the public institution.

If the temperature of the recovered heat is lower than the temperature of the heat needed for another process, the temperature of the recovered heat can also be raised with a heat pump (see the figure below).

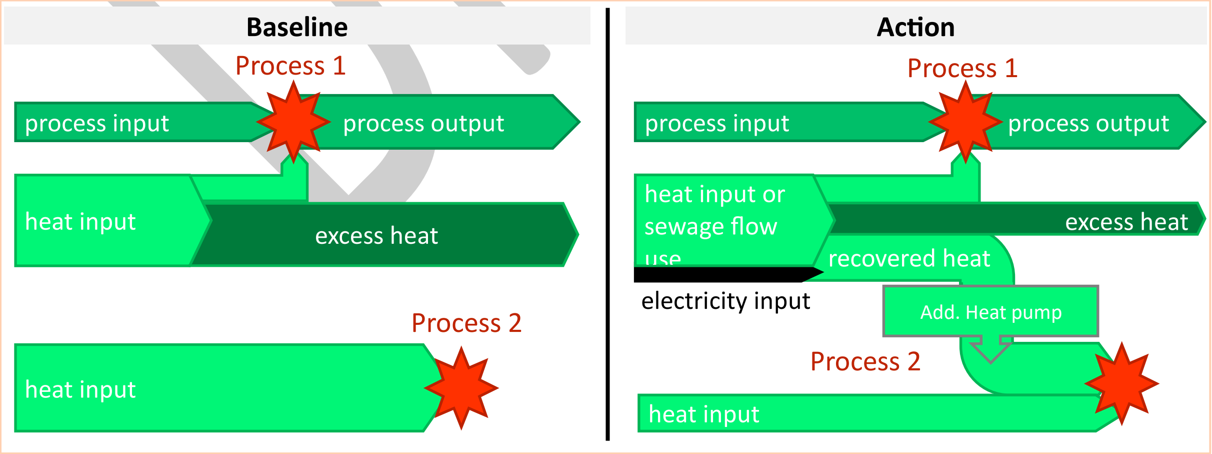

*Figure 5: Schematic illustration of on-site use of excess heat for other applications*

The methodology is applicable regardless of the energy carrier and the heat recovery technology. Recovered heat from buildings (heating, ventilation and air conditioning) cannot be evaluated with this methodology.

Processes with a potential for excess heat recovery are heterogeneous regarding their functions, dimensions, capacities etc. and are usually custom-made. Hence, it is impracticable to evaluate heat recovery measures with standardised values. Instead of providing indicative calculation values, this methodology focuses on guidelines for the acquisition of appropriate data.

## 2.3. Calculation of final energy savings (Article 5)

The final energy savings can be calculated with the following equation:

$$TFES = Q_{rec} \cdot \frac{1}{eff_{mhs}} \cdot f_{BEH}$$

| | |
|---|---|
| TFES | Total final energy savings [kWh/a] |
| $Q_{rec}$ | Recovered heat of the application or used environmental heat (heat source) via a heat pump [kWh/a] |
| $eff_{mhs}$ | Conversion efficiency of the main heating system of the relevant application [dmnl] |
| $f_{BEH}$ | Factor for correction of behavioural effects [dmnl] |

Indicative calculation values for this methodology are only prepared for the lifetime of savings due to the wide range of applications.

*Table 5: Indicative calculation value for use of excess heat for on-site applications*

| Lifetime of savings | [a] |
|---|---|
| Heat recovery in public institutions | 10 |

### 2.3.1 Methodological aspects

The calculation formula considers the amount of recovered heat which is used in another application of the public institution and thus (partly) substitutes the energy source for the main heating system of the application. To take heat generation losses into account, the efficiency of the main heating system of the other application is taken into consideration in the equation.

Behavioural, rebound effects may arise because the recovered waste heat is inexpensive compared to any other energy carrier. For example, the use of waste heat for space heating can trigger increased comfort requirements (higher room temperature, increased heated floor area).

### 2.3.2 Data sources for indicative calculation values

Due to the large variety of processes and the wide scope of this methodology, indicative calculation values are considered impracticable. Instead, this methodology provides a guidance for the evaluation of savings based on measured values.

The methodology is intended to be applied by implementing parties themselves. As there are no indicative calculation values for the recovered heat from processes and efficiencies of heat consuming applications in public institutions, data must be generated individually.

The **Recovered heat consumption of the application** (**$Q_{rec}$**) should be measured by a heat meter and, if applicable, converted into kWh. For monitoring reasons, it is suggested to use measuring protocols including the installation layout, measurement setup and period.

If a relevant part of the energy consumption of the process depends on the weather, the weather-related consumption must be normalized. Normalization with heating or cooling degree days is recommended:

$$Q_{rec,norm} = Q_{rec,measured} \cdot \frac{DD_{norm}}{DD_{mp}}$$

| | |
|---|---|
| $Q_{rec,norm}$ | Normalized final energy consumption [kWh/a] |
| $Q_{rec,measured}$ | Measured final energy consumption [kWh] |
| $DD_{norm}$ | Average annual heating or cooling degree days [Kd/a] |
| $DD_{mp}$ | Average heating or cooling degree days during the measuring period [Kd] |

The average heating or cooling degree days must be calculated from weather related measurement records. To determine degree days, each recording period (e.g. hours, days) must be multiplied with the temperature difference between the required process temperature and the average outdoor temperature. To obtain the normalised (**$DD_{norm}$**) degree days, it is advisable to average over several years.

If a heat pump is used to raise the temperature of the recovered heat (e.g. of a sewage flow), the following equation for the useable heat can be used:

$$Q_{rec} = Q_{rec,heatpump} = c_p \times \dot{m} \times \Delta T \times FLH$$

| | |
|---|---|
| $Q_{rec,heatpump}$ | Used environmental heat from a (sewage) flow [kWh/a] |
| $c_p$ | Specific heat capacity of water [4.176 kJ/l x K] |
| $M_{dot}$ | (Sewage) flow [l/s] |
| $\Delta T$ | Usable temperature of the flow [°K] |
| FLH | Full load hours [h/a] |

The equation shows the energy, which can be taken from the sewage flow. To raise the temperature additional electricity is needed for the compressor of the heat pump under the project situation. As already explained under Section 7.3.1 the usable heat energy generated via the heat pump would be $Q_{rec,heatpump}$ plus the electrical energy of the compressor. But since electric energy must be brought into the system additionally, it must be deducted from the useable heat again in order to calculate energy savings under this priority action. Thus, the accounted energy saving is exactly as of the equation above.

For the **Conversion efficiency of the main heating system of the application** (**$eff_{mhs}$**), application-specific information is to be used preferably. In some cases, the conversion efficiency is provided by the manufacturer of the application (e.g. on the eco-label). If specific values are unavailable, average efficiencies (e.g. from National Standards, literature) may be considered.

If the recovered heat is used for space heating and application-specific information is not available EU-wide indicative values can be applied for the main heating system.

The conversion efficiencies of space heating are taken from the latest year (2021) of the tables SER_hh_eff of the Integrated Database of the European Energy System of the Joint Research Center (Rozsai et al, 2024).

Table 6: Ratio of energy service to energy consumption [$kWh_{th}$/kWh]

| Heating system | Services |
|---|---|
| Solids | 0,682 |
| Liquified petroleum gas (LPG) | 0,668 |
| Gas/Diesel oil incl. biofuels (GDO) | 0,659 |
| Gas heat pumps | 2,834 |
| Gases incl. biogas | 0,761 |
| Biomass and wastes | 0,698 |
| Geothermal energy | 0,862 |
| Distributed heat | 0,867 |
| Advanced electric heating | 3,267 |
| Conventional electric heating | 0,816 |
| Electricity in circulation | 1,000 |

The conversion efficiencies per energy carrier were weighted by the final consumption (2021) of the services sector which were extracted from the tables SER_hh_fec of the Integrated Database of the European Energy System of the Joint Research Center (Rozsai et al, 2024).

Table 7: Final energy consumption [ktoe] of the heating systems

| Heating system | Services |
|---|---|
| Solids | 765,9 |
| Liquified petroleum gas (LPG) | 222,5 |
| Gas/Diesel oil incl. biofuels (GDO) | 8.969,3 |
| Gas heat pumps | 145,9 |
| Gases incl. biogas | 27.035,9 |
| Biomass and wastes | 3.524,1 |
| Geothermal energy | 247,3 |
| Distributed heat | 8.848,1 |
| Advanced electric heating | 2.021,4 |
| Conventional electric heating | 9.612,4 |
| Electricity in circulation | 479,5 |

If more than one application is fed by the recovered heat, energy consumption and efficiency must be considered separately for each application.

## 2.4. Bibliography for heat recovery

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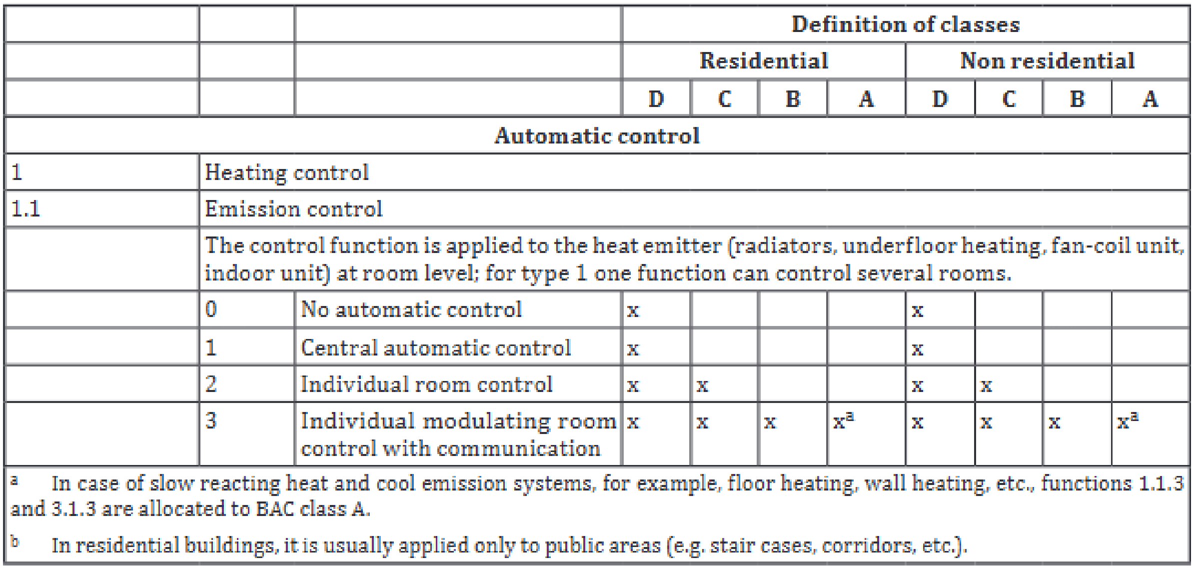
# 3. Consumption reduction calculation for building automation and control systems (BACS)

According to ISO 52120-1:2022 (ISO, 2022) BACS or Building Automation and Control Systems comprise all products, software and engineering services for automatic controls (including interlocks), monitoring, optimization for operation, human intervention and management to achieve energy-efficient, economical and safe operation of building services. Additionally, the use of the word ‘control’ does not imply that the system/device is restricted to control functions. Processing of data and information is possible. BACS is also referred to as BMS or building management system. The building energy management system comprises data collection, logging, alarming, reporting, and analysis of energy usage, etc. The system is designed to reduce the energy consumption, improve the utilization, increase the reliability, and predict the performance of the technical building systems, as well as optimize energy usage and reducing its cost.

Methods to assess the impact of BACS on the energy performance of buildings, have been developed in ISO 52120-1:2022. The standard defines 4 BAC energy efficiency classes, ranging from A, the most performant, to D, the least energy efficient. Additionally, ISO 52120-1:2022 assigns all processing functions to one of these classes for both residential and non-residential buildings. Following figure shows an example for automatic heating control, more specifically, the function emission control of thermal energy. Several processing functions are listed, such as ‘no automatic control’, or ‘individual room control with communication’ and subsequently assigned to a class for both residential and non-residential buildings.



| | | | Definition of classes | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Residential | | | | Non residential | | | |
| | | | D | C | B | A | D | C | B | A |
| Automatic control | | | | | | | | | | |
| 1 | Heating control | | | | | | | | | |
| 1.1 | Emission control | | | | | | | | | |
| | The control function is applied to the heat emitter (radiators, underfloor heating, fan-coil unit, indoor unit) at room level; for type 1 one function can control several rooms. | | | | | | | | | |
| | 0 | No automatic control | x | | | | x | | | |
| | 1 | Central automatic control | x | | | | x | | | |
| | 2 | Individual room control | x | x | | | x | x | | |
| | 3 | Individual modulating room control with communication | x | x | x | x[a] | x | x | x | x[a] |

[a] In case of slow reacting heat and cool emission systems, for example, floor heating, wall heating, etc., functions 1.1.3 and 3.1.3 are allocated to BAC class A.

[b] In residential buildings, it is usually applied only to public areas (e.g. stair cases, corridors, etc.).

*Figure 6: Example of requirements of the processing function 'emission control of thermal energy' in different BAC energy classes*

streamSAVE+ has developed a methodology to calculate the effect on final energy consumption of public buildings (owned or rented), that occurs from installing or upgrading BACS. However, in addition to reduction of final energy consumption and the related carbon savings, the use of BACS also generates benefits beyond energy efficiency. Examples are maintenance and fault prediction, increased comfort, convenience and wellbeing and health, as well as information provision to occupants of the buildings (Verbeke et al., 2020).

## 3.1. Calculation of energy consumption reduction (Article 5)

The methodology described herein can be used for calculating the impact of installing or upgrading BACS on the final energy consumption of a public building (owned or rented). Determining the impact of an upgrade is possible by using the energy efficiency classes from ISO 52120-1:2022, where 4 classes are defined, ranging from the least efficient (D) to the most efficient (A).

Further, ISO 52120-1:2022 defines over 40 BAC functions that have an impact on the energy performance of buildings, covering different sources of heating and cooling, and different types of ventilation and air conditioning systems. Calculating the impact of BACS on the final energy consumption can either be done in a detailed way, i.e. per BAC function, or by making use of the more generalized BAC energy efficiency factor. The calculation methodology described below, is based on the BAC factor method and can be used for calculating energy reductions buildings owned or occupied by public bodies, for five types of end-use (heating, cooling, domestic hot water, ventilation and lighting) and for the three European climate regions.

### 3.1.1 Calculation formula

The final energy consumption reductions can be calculated with the following equation:

$$REC_x = (FEC_{before,x} - FEC_{after,x}) \cdot cf_x$$

$$FEC_{before,x} = FEC_{floor,before,x} \cdot A$$

$$FEC_{after,x} = \frac{BAC_{after,x}}{BAC_{before,x}} \cdot FEC_{floor,before,x} \cdot A$$

| | |
|---|---|
| $REC_x$ | Total energy consumption reduction for end-use type x [kWh/a] |
| $FEC_{before,x}$ | Final energy consumption for end-use x, before implementation of the action [kWh/a] |
| $FEC_{after,x}$ | Final energy consumption for end-use x after implementation of the action [kWh/a] |
| $cf_x$ | Regional or climate factor for end-use type x [dmnl] |
| $FEC_{floor,before,x}$ | Specific final energy consumption for end-use type x, *before* implementation of the action, per unit floor area [kWh/m²/a] |
| A | Total floor area of building [m²] |
| $BAC_{after,x}$ | BAC energy efficiency factor *after* BACS upgrade for end-use type x [%], based on ISO 52120-1:2022 |
| $BAC_{before,x}$ | BAC energy efficiency factor *before* BACS upgrade for end-use type x [%], based on ISO 52120-1:2022 |

### 3.1.2 Indicative values

Indicative calculation values for this methodology have been prepared in the following tables. Please keep in mind that these values are based on EU-wide data and will need to be adjusted to national circumstances. Concerning the average BAC factor (before upgrade), the Ecodesign study (Van Tichelen et al., 2020) presents indicative values for the distribution of BAC factors per end use, per climate region for the EU. These values are considered representative for the reference year 2021. The average factors per end use and building type in the different climate regions are taken over below. Following non-residential building types are considered relevant for buildings owned or occupied by public bodies: offices, education, hospitals/healthcare and other.

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*Table 8: Estimated average stock of BAC factors by end-use and building type, for each climate region – $BAC_{before,x}$*

| North Region | Offices | Education | Hospitals/ Healthcare | Other |
|---|---|---|---|---|
| Space heating | 1.195 | 1.128 | 1.000 | 1.109 |
| Hot water | 1.019 | 1.030 | 0.992 | 1.030 |
| Cooling | 1.082 | 0.805 | 0.617 | 1.200 |
| Ventilation | 1.138 | 0.966 | 1.000 | 1.154 |
| Lighting | 0.989 | 0.991 | 1.000 | 1.000 |
| Space heating pumps | 1.121 | 1.072 | 1.038 | 1.073 |
| Hot water pumps | 1.018 | 1.029 | 0.991 | 1.029 |

| West Region | Offices | Education | Hospitals/ Healthcare | Other |
|---|---|---|---|---|
| Space heating | 1.189 | 1.128 | 0.978 | 1.109 |
| Hot water | 1.019 | 1.030 | 0.992 | 1.030 |
| Cooling | 1.082 | 0.805 | 0.617 | 1.200 |
| Ventilation | 1.135 | 0.966 | 0.978 | 1.154 |
| Lighting | 0.989 | 0.991 | 1.000 | 1.000 |
| Space heating pumps | 1.118 | 1.072 | 1.030 | 1.073 |
| Hot water pumps | 1.018 | 1.029 | 0.991 | 1.029 |

| South Region | Offices | Education | Hospitals/ Healthcare | Other |
|---|---|---|---|---|
| Space heating | 1.341 | 1.128 | 1.063 | 1.109 |
| Hot water | 1.036 | 1.030 | 1.019 | 1.030 |
| Cooling | 1.205 | 0.816 | 0.656 | 1.200 |
| Ventilation | 1.273 | 0.972 | 1.063 | 1.154 |
| Lighting | 0.989 | 0.991 | 1.000 | 1.000 |
| Space heating pumps | 1.182 | 1.072 | 1.067 | 1.073 |
| Hot water pumps | 1.035 | 1.029 | 1.018 | 1.029 |

**Note:** European (climate) regions: North (Czech Republic, Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Slovakia, Sweden), West (Austria, Belgium, France, Germany, Ireland, Luxemburg, Netherlands) and South (Bulgaria, Croatia, Cyprus, Greece, Hungary, Italy, Malta, Portugal, Romania, Slovenia, Spain).

**Source**: based on (Van Tichelen et al., 2020)

Next to the average stock of BAC factors, the final energy consumption before upgrade ($FEC_{before}$) needs to be established as well. Making use of the JRC-IDEES-2021 database (JRC, 2024), indicative values at EU-level have been developed for the average FEC of non-residential buildings (services), per end-use and for the three European climate regions.

*Table 9: Indicative values for final energy consumption and regional correction factor, per end use type*

| **$FEC_{before,x}$** | | **[kWh/m² useful floor area /a]** | | |
|---|---|---|---|---|
| Non-Residential<br>(services) | Space heating | 159.85 | | |
| | Space cooling | 9.09 | | |
| | Water heating | 25.61 | | |
| | Lighting | 16.06 | | |
| | Ventilation | 4.83 | | |
| **$cf_x$** | | **North** | **West** | **South** |
| Non-Residential<br>(services) | Space heating | 1.00 | 1 | 0.66 |
| | Space cooling | 0.85 | 1 | 1.50 |
| | Water heating | 0.93 | 1 | 1.07 |
| | Lighting | 1.03 | 1 | 1.05 |
| | Ventilation | 1.08 | 1 | 1.13 |

**Note:** European (climate) regions: North (Czech Republic, Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Slovakia, Sweden), West (Austria, Belgium, France, Germany, Ireland, Luxemburg, Netherlands) and South (Bulgaria, Croatia, Cyprus, Greece, Hungary, Italy, Malta, Portugal, Romania, Slovenia, Spain).

**Source:** (JRC, 2024)

### 3.1.3 Methodological aspects

The methodology is based on the BAC factor method as stipulated in ISO 52120-1:2022, allowing to estimate the consumption at national/regional level, without the need to collect the details for each BAC function at the building level. Hence, it can be applied to calculate energy reductions on the national/regional scale; however, if details on the BAC factors and final energy consumption per end-use type are available at the building level, the methodology can also be applied for a specific building.

The energy reductions formula takes into account the difference between the final energy consumption before and after the upgrade in BACS class. The formula also foresees the possibility to reflect the climate region.

The **final energy consumption before** $FEC_{before,x}$ is calculated by multiplying the final energy consumption for the considered end-use, before implementation of the action, per unit floor area, with the total floor area of buildings. Several data sources exist to calculate $FEC_{before,x}$. As buildings owned or occupied by public bodies are required to issue an Energy Performance Certificate (EPC), it is possible to work on the basis of building specific FEC per end-use based on the EPC score. This would be the case where detailed information per building is available. In case such information is not available for the individual building(s), it is also possible to work on the basis of regional or national averages. In that case, data from EPC scores per climate region can be used to calculate the average energy consumption of the building stock per end use and building type. However, the applicability of EPCs to estimate the baseline of a building is dependent on their quality to reflect actual energy consumption. Multiple sources indicate that EPCs tend to overestimate energy consumption of a building, as the first objective of EPCs is energy labelling (Amirkhani et al., 2021). Instead of EPC, information from the national or regional energy statistics per end use and building type can be used to calculate the average energy consumption of the building stock. The indicative values developed for $FEC_{before}$ in Table 9, follow the latter method and are based on the JRC-IDEES-2021 database (JRC, 2024), providing 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. The indicative values for the consumption can be adjusted for external conditions by means of a **regional or climate factor** $cf_x$ , and reflects the difference of final energy consumption of Northern and Southern countries in comparison to Member States in the West.

The **final energy consumption after the BACS improvement** $FEC_{after,x}$ is calculated by multiplying the specific energy demand for a type of-end use in the 'old' efficiency class ($FEC_{floor,before}$) by the total floor area A and the ratio of the new BAC factor to the old BAC factor. As the BAC factors are reported in the ISO 52120-1:2022 for each BACS class, it is only necessary to know the specific final energy consumption for the type of end-use before the improvement in BAC efficiency class and the total floor area of the building. This formula can be used for each end-use, as BACS factors are available for heating, cooling, domestic hot water, ventilation and lighting or on the more general level of thermal and electrical energy. An important side note in this respect consists of the expected impact from the revised Europeans Energy Performance of Buildings Directive (EPBD) (EU/2024/1275) which introduced new requirements for the implementation of BACS. Non-residential buildings with an effective rated output exceeding 290 kW must comply with the directive by 31 December 2024. For buildings with a rated output exceeding 70 kW, the compliance deadline is extended to 31 December 2029. These thresholds apply to all heating, air-conditioning, and ventilation systems in the building, including those controlled by landlords and tenants, while excluding process-related heating and cooling. For practical application, achieving Class B functionality under EN ISO 52120 is suggested by the European Building Automation Controls association for all non-residential buildings within the scope of the directive.

With respect to the reference year 2021, it will be necessary to map the **distribution of BACS classes in the building stock** $BAC_{before,x}$. The Ecodesign preparatory study (Van Tichelen et al., 2020) has developed indicative values on the EU-level, which have been taken up in **Chyba! Nenalezen zdroj odkazů.** and are considered representative for the reference year 2021.

### 3.1.4 Data sources for indicative calculation values

**BAC factors per BACS class** are stipulated in the standard ISO 52120-1:2022. BAC factors, which are the result of reference calculations on the level of building types, exist on an aggregated level of end-use (thermal energy or electrical energy) and on a more detailed level of end-use, for heating, cooling, domestic hot water, ventilation and lighting. They are provided for non-residential building types, comprising offices, wholesale and retail, education, hospitals and healthcare, hotels, restaurants and other. The BAC factors for aggregated and detailed types of end-use are included in section 3.3. In the context of buildings owned or occupied by public bodies, focus is on BAC factors for offices, education, hospitals and healthcare, and other.

The estimated, average stock $BAC_{before,x}$ of BAC factors for 2020 by end-use and building type, for each climate region have been developed by the Ecodesign preparatory study (Van Tichelen et al., 2020). These values are considered representative for the reference year 2021. They are provided for non-residential building types, comprising offices, wholesale and retail, education, hospitals and healthcare, hotels, restaurants and other. In the context of buildings owned or occupied by public bodies, focus is on BAC factors for offices, education, hospitals and healthcare, and other.

The $FEC_{before,x}$ of the final energy consumption for end-use, before implementation of the action, per unit floor area [kWh/m²/a] is based on the JRC-IDEES-2021 database (JRC, 2024). In the Integrated Database of the European Energy Sector, JRC brings together all statistical information related to the energy sector and complements this with processed data that further decomposes energy consumption. The complete output of JRC-IDEES-2021 is accessible to the general public and is revised periodically (Rózsai et al., 2024). In the context of buildings owned or occupied by public bodies, focus is on the services sector.

- The **total Final Energy Consumption** corresponds to the Eurostat energy balances for 2000-2021 of each Member State. 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 is estimated from assumed demand and equipment efficiency
- The **useful surface area** of a representative building in the services sector is assumed to be identical across all Member States and is calculated and reported for a representative building cell of 900 m². This value is derived from available information on the total useful surface area and estimated number of enterprises. The total useful surface area is aligned to the EU Building Observatory, which provides data for all Member States 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 normalize for **yearly (e.g., weather) fluctuations**, the indicative values for heating, cooling, hot water, lighting and ventilation are based on values averaged for the period 2010-2021.

The indicative values can be **adjusted for external conditions** by means of the regional or climate factor. The three regions in EU-27, as also used in (Van Tichelen et al., 2020), comprise the following countries: North (Czech Republic, Denmark, Estonia, Finland, Latvia, Lithuania, Poland, Slovakia, Sweden), West (Austria, Belgium, France, Germany, Ireland, Luxemburg, Netherlands) and South (Bulgaria, Croatia, Cyprus, Greece, Hungary, Italy, Malta, Portugal, Romania, Slovenia, Spain). The climate factor $cf_x$ is determined from the JRC-IDEES-2021 database, reflecting the average deviation of final energy consumption $FEC_{before,x}$ in all Northern and Southern countries in comparison to the Member States in the West, between 2010-2021.

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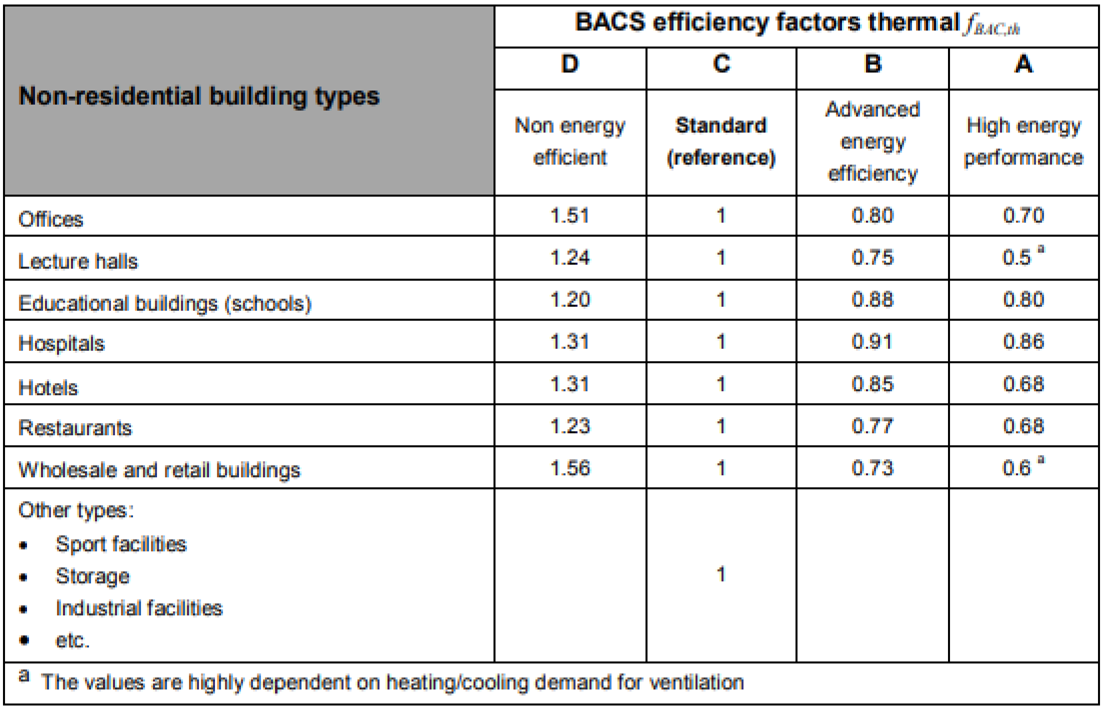
## 3.3. BAC Efficiency Factors

In this section, you can find the BAC efficiency factors, taken from the standard ISO 52120:2022 (ISO, 2024).

### 3.3.1 Aggregated level

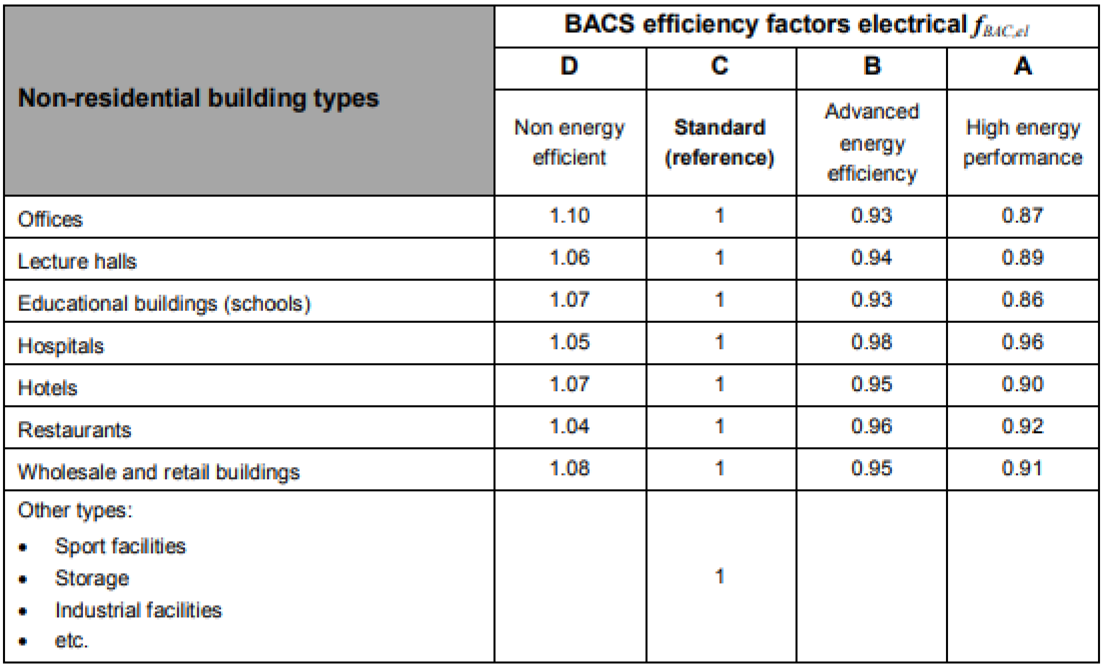
*Factors for thermal energy ($f_{BAC,th}$) – Non-residential*



| **Non-residential building types** | **BACS efficiency factors thermal $f_{BAC,th}$** | | | |
|---|---|---|---|---|
| | **D** | **C** | **B** | **A** |
| | Non energy efficient | **Standard (reference)** | Advanced energy efficiency | High energy performance |
| Offices | 1.51 | 1 | 0.80 | 0.70 |
| Lecture halls | 1.24 | 1 | 0.75 | 0.5 [a] |
| Educational buildings (schools) | 1.20 | 1 | 0.88 | 0.80 |
| Hospitals | 1.31 | 1 | 0.91 | 0.86 |
| Hotels | 1.31 | 1 | 0.85 | 0.68 |
| Restaurants | 1.23 | 1 | 0.77 | 0.68 |
| Wholesale and retail buildings | 1.56 | 1 | 0.73 | 0.6 [a] |
| Other types:<br>• Sport facilities<br>• Storage<br>• Industrial facilities<br>• etc. | | 1 | | |
| [a] The values are highly dependent on heating/cooling demand for ventilation | | | | |

Source: ISO, 2022

*Factors for electrical energy (fBAC,el) – Non-residential*

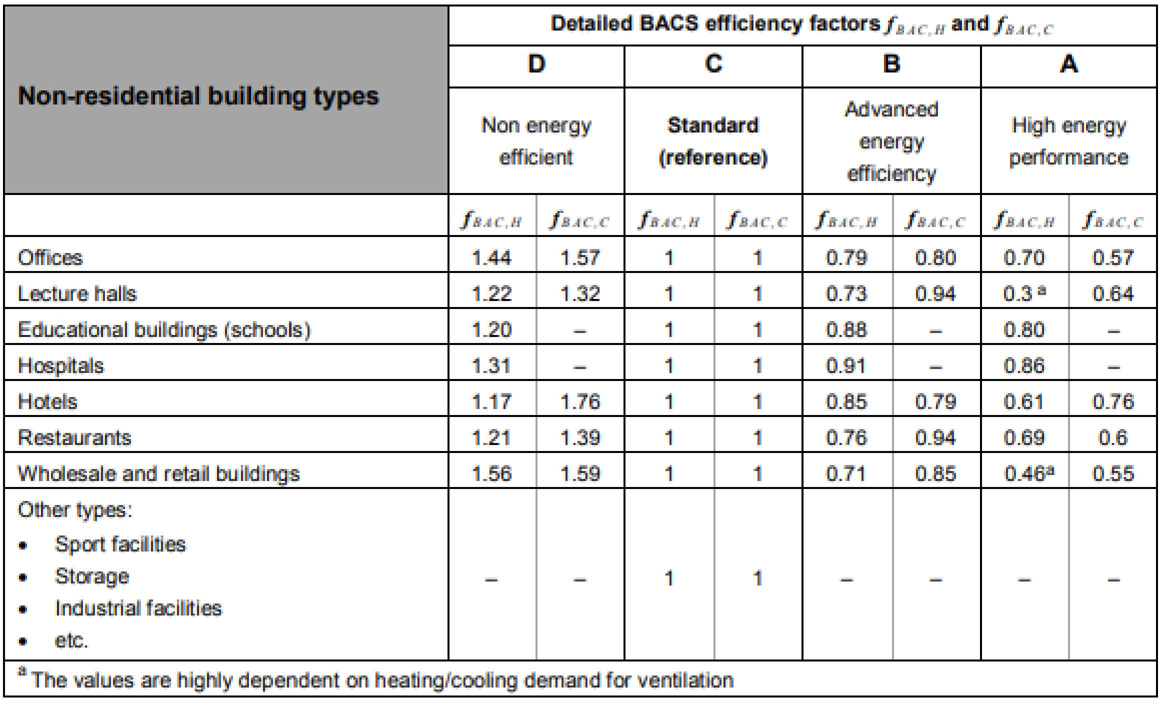


| **Non-residential building types** | **BACS efficiency factors electrical $f_{BAC,el}$** | | | |
|---|---|---|---|---|
| | **D** | **C** | **B** | **A** |
| | Non energy efficient | **Standard (reference)** | Advanced energy efficiency | High energy performance |
| Offices | 1.10 | 1 | 0.93 | 0.87 |
| Lecture halls | 1.06 | 1 | 0.94 | 0.89 |
| Educational buildings (schools) | 1.07 | 1 | 0.93 | 0.86 |
| Hospitals | 1.05 | 1 | 0.98 | 0.96 |
| Hotels | 1.07 | 1 | 0.95 | 0.90 |
| Restaurants | 1.04 | 1 | 0.96 | 0.92 |
| Wholesale and retail buildings | 1.08 | 1 | 0.95 | 0.91 |
| Other types:<br>• Sport facilities<br>• Storage<br>• Industrial facilities<br>• etc. | | 1 | | |

Source: ISO, 2022

### 3.3.2 Detailed level

*Factors for heating (fBAC,H) – Non-residential*

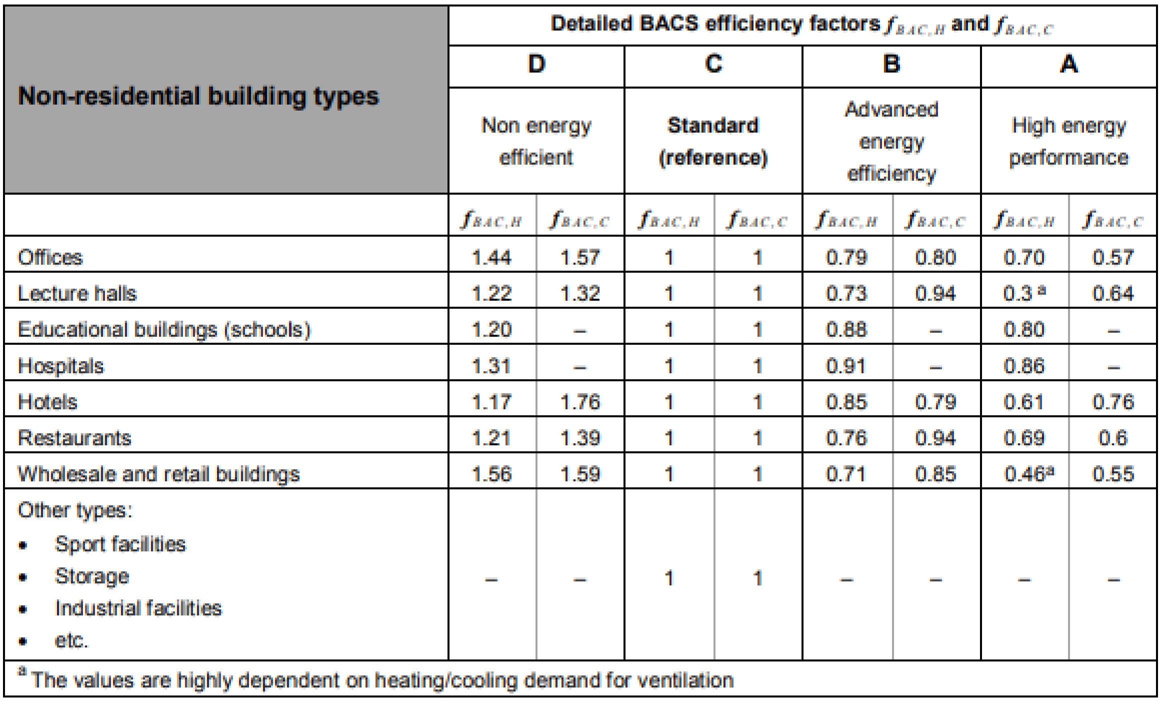


| **Non-residential building types** | **Detailed BACS efficiency factors $f_{BAC,H}$ and $f_{BAC,C}$** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **D** | | **C** | | **B** | | **A** | |
| | Non energy efficient | | **Standard (reference)** | | Advanced energy efficiency | | High energy performance | |
| | $f_{BAC,H}$ | $f_{BAC,C}$ | $f_{BAC,H}$ | $f_{BAC,C}$ | $f_{BAC,H}$ | $f_{BAC,C}$ | $f_{BAC,H}$ | $f_{BAC,C}$ |
| Offices | 1.44 | 1.57 | 1 | 1 | 0.79 | 0.80 | 0.70 | 0.57 |
| Lecture halls | 1.22 | 1.32 | 1 | 1 | 0.73 | 0.94 | 0.3 [a] | 0.64 |
| Educational buildings (schools) | 1.20 | – | 1 | 1 | 0.88 | – | 0.80 | – |
| Hospitals | 1.31 | – | 1 | 1 | 0.91 | – | 0.86 | – |
| Hotels | 1.17 | 1.76 | 1 | 1 | 0.85 | 0.79 | 0.61 | 0.76 |
| Restaurants | 1.21 | 1.39 | 1 | 1 | 0.76 | 0.94 | 0.69 | 0.6 |
| Wholesale and retail buildings | 1.56 | 1.59 | 1 | 1 | 0.71 | 0.85 | 0.46[a] | 0.55 |
| Other types:<br>• Sport facilities<br>• Storage<br>• Industrial facilities<br>• etc. | – | – | 1 | 1 | – | – | – | – |

[a] The values are highly dependent on heating/cooling demand for ventilation

Source: ISO, 2022

### *Factors for cooling (fBAC,C) – Non-residential*



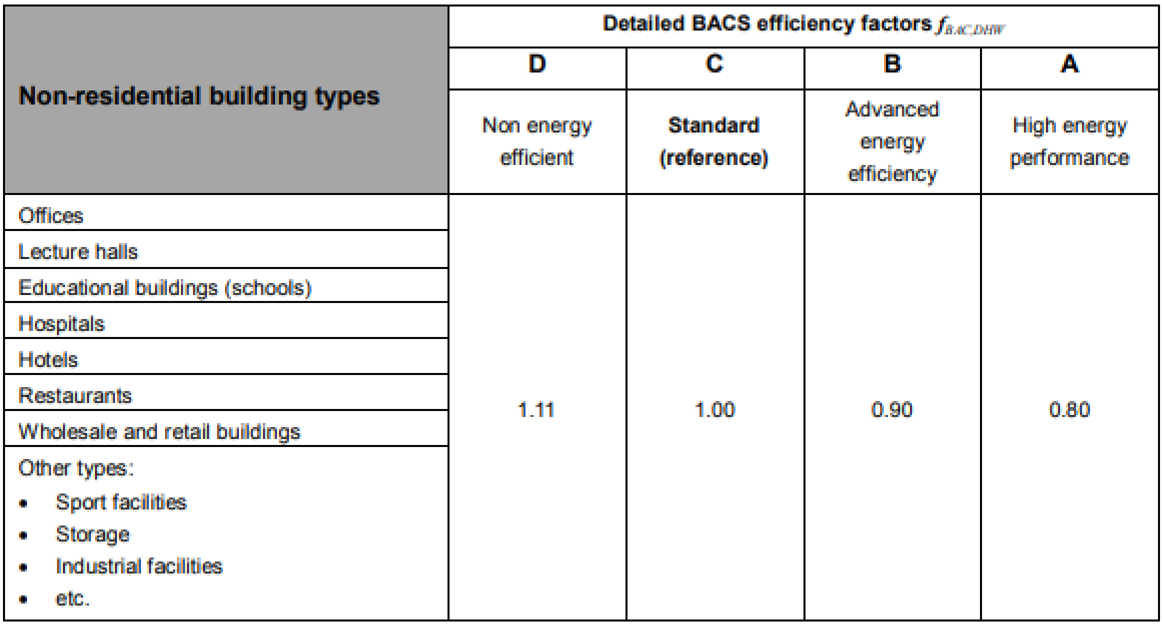
| **Non-residential building types** | **Detailed BACS efficiency factors $f_{BAC,H}$ and $f_{BAC,C}$** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **D** | | **C** | | **B** | | **A** | |
| | Non energy efficient | | **Standard (reference)** | | Advanced energy efficiency | | High energy performance | |
| | $f_{BAC,H}$ | $f_{BAC,C}$ | $f_{BAC,H}$ | $f_{BAC,C}$ | $f_{BAC,H}$ | $f_{BAC,C}$ | $f_{BAC,H}$ | $f_{BAC,C}$ |
| Offices | 1.44 | 1.57 | 1 | 1 | 0.79 | 0.80 | 0.70 | 0.57 |
| Lecture halls | 1.22 | 1.32 | 1 | 1 | 0.73 | 0.94 | 0.3 [a] | 0.64 |
| Educational buildings (schools) | 1.20 | – | 1 | 1 | 0.88 | – | 0.80 | – |
| Hospitals | 1.31 | – | 1 | 1 | 0.91 | – | 0.86 | – |
| Hotels | 1.17 | 1.76 | 1 | 1 | 0.85 | 0.79 | 0.61 | 0.76 |
| Restaurants | 1.21 | 1.39 | 1 | 1 | 0.76 | 0.94 | 0.69 | 0.6 |
| Wholesale and retail buildings | 1.56 | 1.59 | 1 | 1 | 0.71 | 0.85 | 0.46[a] | 0.55 |
| Other types:<br>• Sport facilities<br>• Storage<br>• Industrial facilities<br>• etc. | – | – | 1 | 1 | – | – | – | – |

[a] The values are highly dependent on heating/cooling demand for ventilation

Note: No values have been provided for the building types “educational buildings” and “hospitals” in the non-residential sector. For education buildings, the factors for cooling from the building type “lecture hall” have been used ($f_{BAC,C}$); for the hospitals, the BAC factors for aggregated thermal energy in hospitals have been used ($f_{BAC,th}$).

Source: ISO, 2022

### *Factors for Domestic Hot Water (fBAC,DHW) – Non-residential*

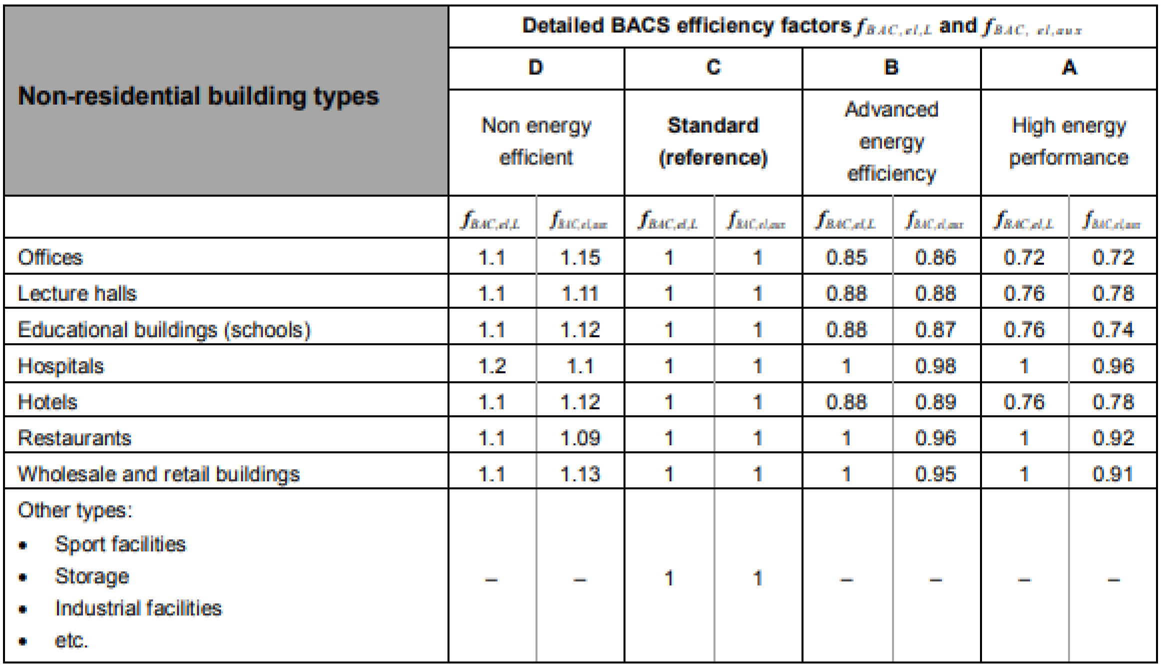


| Non-residential building types | Detailed BACS efficiency factors $f_{BAC,DHW}$ | | | |
|---|---|---|---|---|
| | D | C | B | A |
| | Non energy efficient | **Standard (reference)** | Advanced energy efficiency | High energy performance |
| Offices | 1.11 | 1.00 | 0.90 | 0.80 |
| Lecture halls | | | | |
| Educational buildings (schools) | | | | |
| Hospitals | | | | |
| Hotels | | | | |
| Restaurants | | | | |
| Wholesale and retail buildings | | | | |
| Other types:<br>• Sport facilities<br>• Storage<br>• Industrial facilities<br>• etc. | | | | |

Source: ISO, 2022

### *Factors for ventilation (fBAC,el,aux) – Non-residential*

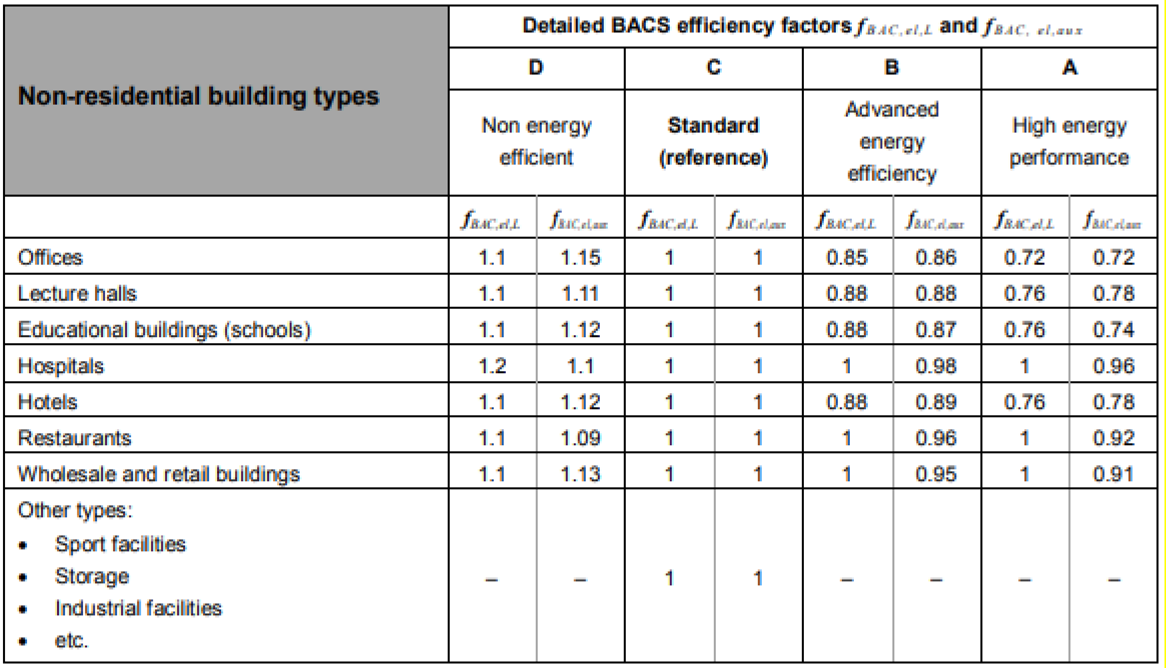
For non-residential ventilation, the detailed values for auxiliary energy $f_{BAC,el,aux}$ can be used.



| Non-residential building types | Detailed BACS efficiency factors $f_{BAC,el,L}$ and $f_{BAC,el,aux}$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | D | | C | | B | | A | |
| | Non energy efficient | | **Standard (reference)** | | Advanced energy efficiency | | High energy performance | |
| | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ |
| Offices | 1.1 | 1.15 | 1 | 1 | 0.85 | 0.86 | 0.72 | 0.72 |
| Lecture halls | 1.1 | 1.11 | 1 | 1 | 0.88 | 0.88 | 0.76 | 0.78 |
| Educational buildings (schools) | 1.1 | 1.12 | 1 | 1 | 0.88 | 0.87 | 0.76 | 0.74 |
| Hospitals | 1.2 | 1.1 | 1 | 1 | 1 | 0.98 | 1 | 0.96 |
| Hotels | 1.1 | 1.12 | 1 | 1 | 0.88 | 0.89 | 0.76 | 0.78 |
| Restaurants | 1.1 | 1.09 | 1 | 1 | 1 | 0.96 | 1 | 0.92 |
| Wholesale and retail buildings | 1.1 | 1.13 | 1 | 1 | 1 | 0.95 | 1 | 0.91 |
| Other types:<br>• Sport facilities<br>• Storage<br>• Industrial facilities<br>• etc. | – | – | 1 | 1 | – | – | – | – |

Source: ISO, 2022

### *Factors for lighting ($f_{BAC,el,L}$) – Non-residential*



| Non-residential building types | Detailed BACS efficiency factors $f_{BAC,el,L}$ and $f_{BAC,el,aux}$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | D | | C | | B | | A | |
| | Non energy efficient | | **Standard (reference)** | | Advanced energy efficiency | | High energy performance | |
| | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ | $f_{BAC,el,L}$ | $f_{BAC,el,aux}$ |
| Offices | 1.1 | 1.15 | 1 | 1 | 0.85 | 0.86 | 0.72 | 0.72 |
| Lecture halls | 1.1 | 1.11 | 1 | 1 | 0.88 | 0.88 | 0.76 | 0.78 |
| Educational buildings (schools) | 1.1 | 1.12 | 1 | 1 | 0.88 | 0.87 | 0.76 | 0.74 |
| Hospitals | 1.2 | 1.1 | 1 | 1 | 1 | 0.98 | 1 | 0.96 |
| Hotels | 1.1 | 1.12 | 1 | 1 | 0.88 | 0.89 | 0.76 | 0.78 |
| Restaurants | 1.1 | 1.09 | 1 | 1 | 1 | 0.96 | 1 | 0.92 |
| Wholesale and retail buildings | 1.1 | 1.13 | 1 | 1 | 1 | 0.95 | 1 | 0.91 |
| Other types:<br>• Sport facilities<br>• Storage<br>• Industrial facilities<br>• etc. | – | – | 1 | 1 | – | – | – | – |

Source: ISO, 2022

# 4. Consumption reduction calculation for comfort cooling in public buildings

This priority action focusses on comfort cooling in public buildings and covers major technologies to cool indoor space of buildings. These air conditioning (AC) applications ensure comfortable temperatures inside. The tackled technologies are basically heat pumps with cooling function and sometimes with both cooling and heating functions. There are two major groups:

1. Split and multi-split systems (air-to-air ACs) - Common type of air conditioning with at least two units: inside and outside (therefore it is called „split“) which cool down inside air using refrigerant (divided to 2 sub-categories below and above 12 kW);
2. Air-to-water chillers as production of cold water - Centralised units for cold water production and subsequently used for AC in the buildings.

The European standard EN 14825:2022 is key for both main groups. This standard defines seasonal energy efficiency (SEER) for cooling and other parameters which are used in other regulatory documents, such as Ecodesign or labelling regulations.

The Ecodesign regulations set minimum efficiency requirements. The minimum efficiency requirements means that only AC units with declared efficiency or higher could be introduced on European market. The existing current AC units are not affected.

**1. Split and multi-split systems (air-to-air ACs)** use refrigerant to bring out the inside heat to the outside environment. The system uses typically vapour-compression refrigeration cycle with electric compressor. The split systems are usually located in every cooled room. Multi-split system uses more inside units and at least one outside unit (or more outside units). Multi-split systems could be centralized or could be used only for a part of the building.

There are two sub-categories defined according to the rated cooling capacity:

- Sub-category 1A: Rated capacity ≤ 12 kW: is subject to energy labelling regulation 626/2011, Ecodesing regulation 206/2012 and are registered in European Product Registry for Energy Labelling[9] (EPREL). These systems are usually "small" or "medium" systems.
- Sub-category 1B: Rated capacity > 12 kW: this type is subject to Ecodesign regulation 2016/2281. These systems are "large" air-to-air AC systems.

### Sub-category 1A: Splits and multi-split ≤ 12 kW

The Ecodesign regulation 206/2012 has set minimum efficiency requirements defined in SEER. The minimum values are presented in the following table. These Ecodesign minimum requirements represent the current market minimum efficiency, not the highest available efficiency.

*Table 10: The SEER minimum values for split systems according to the Ecodesign according to the Ecodesing regulation 206/2012*.

| | | Minimum SEER | |
|---|---|---|---|
| **Rated capacity** | **Refrigerant GWP[10]** | **From 1.1.2013** | **From 1.1.2014** |
| < 6 kW | GWP > 150 | 3.6 (class D) | 4.6 (class B) |
| | GWP ≤ 150 | 3.24 | 4.14 |
| 6 - 12 kW | GWP > 150 | 3.6 (class D) | 4.3 |
| | GWP ≤ 150 | 3.24 | 3.87 |

### 1B: Air-to-air > 12 kW

The Ecodesign regulation 2016/2281 covers the large AC systems and chillers. The minimal values are expressed in seasonal space cooling energy efficiency ($\eta_{s,c}$). The standard EN 14825:2022 defines the formula for relation between $\eta_{s,c}$ and SEER:

$$\eta_{s,c} = 1/CC \times SEER - \sum F_i$$

where

CC is electricity conversion coefficient;

$F_1$ and $F_2$ are fixed coefficient, for air-to-air ACs $F_1$ is always equal to 3% and $F_2$ is equal to 0.

Minimal seasonal space cooling energy efficiency values and calculated minimal SEER values for electric energy (conversion coefficient CC = 2,28) are in the following table.

*Table 11: The minimum seasonal space cooling energy efficiency (ηs,c) and calculated SEER values for electricity conversion factor for large ACs air-to-air above 12 kW according to the Ecodesign regulation (2016/2281).*

| | **Minimum efficiency $\eta_{s,c}$ and calculated SEER for electricity conversion factor** | | | |
|---|---|---|---|---|
| Type | From 1.1.2018 | | From 1.1.2021 | |
| | $\eta_{s,c}$ (%) | SEER (-) | $\eta_{s,c}$ (%) | SEER (-) |
| Air-to-air (except rooftop ACs and splits < 12 kW) | 181 | 4.20 | 189 | 4.38 |

**2. Air-to-water chillers, or liquid chilling packages**, are centralised units for cold water production. The units could be used for cooling as part of the ventilation system (water to air heat exchanger with ventilation air as the ultimate heat transfer medium) or chilled water distribution for space cooling via hydronic system. The free-cooling function uses outside cold temperatures but it is not concerned for

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[9] https://eprel.ec.europa.eu/screen/product/airconditioners

[10] Global Warming Potential index

the calculation as chillers could incorporate free-cooling in various ways. Similarly, the heat recovery is not calculated in the overall calculation. Two types of air-to-water chillers are defined for the calculations: 1. cooling tower, 2. dry cooler. Cooling towers cool down water from condensation side of the refrigeration cycle by splashing water into outside units (towers) usually located on the roof. There could be water loop for heat reuse. Dry coolers cool down water indirectly via the outside air through forced convection by fans.

*Table 12: The minimum seasonal space cooling energy efficiency ($\eta_{s,c}$) and calculated SEER values for electricity conversion factor according to the Ecodesign regulation (2016/2281).*

| | Minimum efficiency $\eta_{s,c}$ and calculated SEER for electricity conversion factor | | | |
|---|---|---|---|---|
| Type | From 1.1.2018 | | From 1.1.2021 | |
| | $\eta_{s,c}$ (%) | SEER (-) | $\eta_{s,c}$ (%) | SEER (-) |
| Air-to-water chillers < 400 kW | 149 | 3.47 | 161 | 3.74 |
| Air-to-water chillers ≥ 400 kW | 161 | 3.74 | 179 | 4.15 |

## 4.1. Calculation of energy consumption reduction (Article 5)

The total energy savings from changing to a new cooling system can be calculated using the calculation below. This formula compares the final energy consumption of a newly installed cooling system with that of a reference cooling system used for the space cooling of the building. In particular, the floor area of a typically cooled building is multiplied by the specific cooling energy demand for cooling, as well as the seasonal energy efficiency of the old air conditioner ($SEER_{baseline}$) and new air conditioner installed ($SEER_{ef}$). Additionally, the final energy consumption is multiplied by a climate correction factor for the different climate conditions under which the actions are implemented, as well as a factor that takes into account behavioural aspects related to changes in energy consumption after the new cooling system is implemented.

### 4.1.1 Calculation formula

$$TFES = A \times SCD \times (1/SEER_{baseline} - 1/SEER_{ef}) \times f_{BEH} \times cf_x$$

| | |
|---|---|
| TFES | Total final energy savings [kWh/a] |
| A | Cooled floor area of the building [$m^2$] |
| SCD | Annual area specific cooling demand of the building [$kWh/m^2a$] |
| $SEER_{baseline}$ | Conversion efficiency of a baseline cooling system (seasonal energy efficiency ratio) [dmnl] |
| $SEER_{ef}$ | Conversion efficiency of a new cooling system (seasonal energy efficiency ratio) [dmnl] |
| $f_{BEH}$ | Factor for correction of behavioural effects [dmnl] |
| $cf_x$ | Climate correction factor [dmnl] |

### 4.1.2 Indicative values

Indicative calculation values for this methodology have been developed. Cooling demand is based on EU averages taking into consideration the climatic zone and SEER values are determined for the different capacity of cooling system.

*Table 13: Indicative values for the calculation of the total energy savings resulting from changing the cooling source.*

| Climatic zone | SCD [kWh/m²a] | $cf_x$ |
|---|---|---|
| West | 9.09 | 1 |
| North | 7.75 | 0.85 |
| South | 13.67 | 1.50 |
| **Conversion efficiency according to the AC capacity** | **$SEER_{baseline}$** | **$SEER_{ef}$** |
| single splits ≤ 4kW | 4.60 | 8.5 (A+++) |
| single splits and multi-splits > 4kW and ≤ 12 kW | 4.60 | 6.1 (A++) |
| multi-split (air-to-air ACs) >12 kW | 4.38 | 6.57 |
| liquid chilling package, cooling tower | 3.74 | 7.48 |
| liquid chilling package, dry cooler | 3.74 | 5.98 |

The suggested numbers are based on EU-wide data and should be adjusted to national circumstances when available.

### 4.1.3 Methodological aspects

Both main types (mentioned above: splits and chillers) are subject to the European standard EN 14825:2022[11]. This standard defines calculation method of seasonal energy efficiency SEER for cooling. The advantage of SEER is that it reflects efficiency of a set of boundary conditions representing a typical cooling season and not only the efficiency determined at fixed boundary conditions. The SEER is also used to determine the energy label class thresholds, could be used for greater capacities than 12 kW and for chillers as well. Thus, the SEER values are main efficiency methodology to determine the baseline and efficient cooling systems.

This methodology evaluates the energy savings of a new installation of an efficient cooling system replacing a non-efficient one of the same type and it only applies to refrigeration systems with electric compressors used for comfort cooling in buildings. The methodology does not address other cooling systems, such as gas-powered compressor systems, thermoelectric refrigeration, industrial chillers, application-specific chillers, and so on. It should also be noted that the adoption of this action includes only the replacement of the AC and does not consider improvements in cooling media distribution.

### 4.1.4 Data sources for indicative calculation values

The values for the **specific cooling demand of the building** (**SHD**) per unit floor area [kWh/m²a] are based on the Integrated Database of the European Energy System (IDEES) (Rózsai at al, 2024). In the IDEES, JRC gathers essential statistical information relevant to the energy sector and complements it with processed data that further decomposes energy usage. The full JRC-IDEES output is available to the public, and it compiles energy system statistics from 2000 to 2021. For our estimation values, we selected datasets 2010-2021 to reflect the most recent data on the one hand, while also having a long enough average period of values to normalise for yearly changes in energy consumption.

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[11] Air conditioners, liquid chilling packages and heat pumps, with electrically driven compressors, for space heating and cooling, commercial and process cooling - Testing and rating at part load conditions and calculation of seasonal performance

The indicative values are averaged data from 2010 to 2021 of the final energy consumption for cooling per surface area (SER_hh_fecs) based on data from the service sector. The data are adjusted over three climatic zones divided as in Van Tichelen et al., 2020 and includes the following countries: North (CZ, DK, EE, FI, LT, LV, PL, SE, SK), South (BG, CY, EL, ES, HR, HU, IT, MT, PT, RO, SI), West (AT, BE, DE, FR, IE, LU, NL).

For the **conversion efficiency of the baseline cooling system** (**$SEER_{baseline}$**) it is preferable to use actual efficiencies. The indictive values of baseline efficiencies are attached to the current Ecodesign minimum efficiencies:

- type 1A: split systems baselines efficiencies use the highest SEER value of 2014 Ecodesign phase = 4.60;
- type 1B: the large air-to-air systems use the value of 2021 Ecodesign step = 4.38;
- type 2: air-to-water chillers use the value of 2021 Ecodesign step for < 400 kW = 3.74.

The indicative values used to define **conversion efficiency of the new cooling system,** (**$SEER_{ef}$**) were determined as widely available but very efficient cooling systems. We estimated these values as following:

- type 1A: The split and multi-split systems were divided into two more sub-groups according to the rated cooling capacity because the split systems ≤ 4kW are generally more efficient. The efficiency criteria values of the Topten Europe project are used[12]: splits ≤ 4kW = 8.50 (threshold of A+++ label), splits > 4kW and ≤ 12 kW = 6.10 (threshold of A++ label);
- type 1B: The efficient $SEER_{ef}$ value is set as above 50 % compared to Ecodesign minimum threshold value = 6.57 (Eurovent);
- type 2: The air-to-water chillers with cooling towers are slightly more effective. The efficient $SEER_{ef}$ value for chillers with cooling tower is set as above 100 % compared to Ecodesign minimum = 7.48. The $SEER_{ef}$ value for chillers with dry cooling is set as above 60 % compared to Ecodesign minimum = 5.98 (Eurovent).

Using the **climate factor** (**$C_{fx}$**), the formula can be adjusted when the average energy consumption value of the EU is utilised. The division into three regions (based on Van Tichelen et al., 2020), includes the following countries: North (CZ, DK, EE, FI, LT, LV, PL, SE, SK), South (BG, CY, EL, ES, HR, HU, IT, MT, PT, RO, SI), West (AT, BE, DE, FR, IE, LU, NL). The climate factor is determined from the JRC-IDEES database. The west region is used as a reference climatic zone (=1), and the factors for the north and south regions are calculated as the relative divergence from the west region. The factor is calculated from the values of energy consumption per square meter for cooling in service sector from the average values for the years 2010-2021.

Additionally, the formula allows for the use of **factor to account for behavioural effects** (**$f_{BEH}$**). It is highly improbable that the installation of the new cooling system will impact the behaviour of users of public buildings. They frequently don't even know the source of the building's cooling system. However, when correctly implemented, energy-saving policy initiatives or interventions might change user behaviour to lower energy consumption. It is highly probable that the new system will contain features to monitor energy usage or even demand control systems that can lower energy use in the building. See chapter 6 for measures on behavioural changes of public sector employees.

## 4.2. Bibliography for comfort cooling in public buildings

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# 5. Consumption reduction calculation for electric vehicle integration

Replacing conventional vehicles with electric vehicles (EVs) within the public sector represents a transformative opportunity to enhance operational efficiency, reduce environmental impact, and align with broader sustainability goals. EVs, which include a wide range of transportation modes such as two-wheelers, cars, buses, trucks, and trains, operate partially or fully using electric motors. These motors are powered through a network of public and private charging infrastructure, allowing them to function without reliance on fossil fuels.

In the context of public sector fleets—such as those used by municipal services, public transportation, and government agencies—electric vehicles offer several critical advantages over internal combustion engine (ICE) vehicles. Chief among these is their superior energy efficiency. This higher efficiency means that electric vehicles require less energy to perform the same work, resulting in lower operational energy costs.

Additionally, EVs have inherently lower maintenance requirements due to their simpler mechanical systems and fewer moving parts. This translates into reduced service downtime and long-term cost savings for public sector entities. Their quiet operation also contributes to the reduction of urban noise pollution, which is particularly valuable in densely populated areas. Furthermore, electric vehicles produce no local emissions, leading to improved air quality in cities and communities, which supports public health initiatives and regulatory compliance.

Beyond these technical advantages, transitioning public sector fleets to electric vehicles supports a broader shift in energy use from fossil fuels to electricity. As the electricity supply continues to decarbonize with the increased integration of renewable energy sources, the environmental benefits of EVs become even more pronounced. This transition results not only in reduced greenhouse gas emissions but also in lower primary energy consumption. Electric vehicles are uniquely suited to urban driving conditions, as their energy consumption is determined primarily by instantaneous power demands rather than maximum power output. Additionally, features like regenerative braking allow them to recapture energy that would otherwise be lost, further increasing efficiency.

Implementing this transition requires coordinated efforts to replace conventional vehicles in municipal services such as waste collection, and utility work with electric alternatives. It also involves electrifying public transport buses and replacing government staff cars with electric models. These changes should be supported by strategic investments in charging infrastructure, vehicle procurement policies, and integration with smart grid systems to optimize electricity usage and reduce peak demand.

The objective was to develop a uniform methodology to calculate the savings from electric vehicles (fuel switching), considering different types of vehicles (cars, vans, buses, trucks) and different fuel options (including hybrid options).

The developed methodology also addresses the following challenges:

- **Data collection:**
  It is suggested that Member States MS use the national values from monitoring of $CO_2$ of vehicles. However, indicative EU-wide values are provided with typical data for the main types of vehicles.
- **Definition of baseline:**
  The methodology suggests indicative values to streamline baseline calculations among all MS, based on the standards and monitored data for $CO_2$ emissions.
- **Approach to additionality:**
  The requirements of the EU regulations will be introduced into the specific final energy consumption of the reference vehicles to fulfill the criterion of additionality.
- **Prevention of double-counting of savings:**
  This methodology is designed specifically to calculate energy savings attributable to the replacement of conventional vehicles with electric vehicles (EVs). While supporting infrastructure such as charging stations plays a critical role in enabling EV adoption, it does not directly contribute to energy savings under this framework. Including infrastructure could risk double-counting savings, particularly in cases where infrastructure is accounted for under other policy measures or funding mechanisms. Therefore, in line with EU guidance on Article 8 and to maintain methodological integrity, savings from charging infrastructure are explicitly excluded. All reported savings must originate from the operational efficiency of electric vehicles themselves.
- **Assessment of behavioral aspects**:
  User behavior can significantly influence actual energy consumption—for instance, through driving style, charging habits, or vehicle utilization. These factors can create rebound effects (increased usage due to lower operational costs) or spill-over effects (broader behavioral changes due to technology adoption). Although these aspects are not directly evaluated in this methodology due to the variability and data intensity required (e.g., user surveys, longitudinal studies), a behavioral correction factor (%) is included in the core formula. This factor enables Member States to optionally account for empirical findings when available, ensuring flexibility without compromising consistency.

## 5.1. Calculation of impact on energy consumption (Article 5)

The methodology is applied to fuel switching between conventional and electric vehicles. The conventional options include vehicles using diesel, petrol and LNG, as well as hybrid options. The more efficient options include electric vehicles.

This methodology can be used both for **newly purchased vehicles as well as the replacement of another, “conventional” vehicle**. Even though the purchase of a new vehicle leads to increased energy consumption, it is assumed that otherwise, a “conventional” vehicle with even higher energy consumption would have been purchased.

The final energy consumption before the action is implemented (reference vehicle) and after the action is implemented (efficient vehicle) can be calculated with the following equations.

$$FEC_{ref} = sFEC_{ref} * \frac{DT}{100} * n * f_{BEH}$$

$$FEC_{eff} = sFEC_{eff} * \frac{DT}{100} * n * f_{BEH}$$

The final energy savings can be calculated with the following equation.

$$TFES = \left(sFEC_{ref} - sFEC_{eff}\right) * \frac{DT}{100} * n * f_{BEH}$$

| | |
|---|---|
| $TFES$ | Total final energy savings [kWh/a] |
| $FEC$ | Annual final energy consumption [kWh/a] |
| $sFEC_{ref}$ | Specific final energy consumption of the reference vehicle [kWh/100 km] |
| $sFEC_{eff}$ | Specific final energy consumption of the efficient vehicle [kWh/100 km] |
| $DT$ | Average yearly distance traveled with the vehicle [km/a] |
| $n$ | Number of efficient vehicles purchased [dmnl] |
| $f_{BEH}$ | Factor for correction of behavioral effects [%] |

The specific energy consumption considering different options of fuels can be calculated using the following equation.

$$sFEC = sFC * NCV * \left(1 - Share_{DT,E}\right) + sEC * Share_{DT,E}$$

| | |
|---|---|
| $sFEC$ | Specific final energy consumption of the vehicle [kWh/100 km] |
| $sFC$ | Specific fuel consumption of the vehicle [l/100 km] |
| $sEC$ | Specific electricity consumption of the vehicle [kWh/100 km] |
| $NCV$ | Net Calorific Value for the fuel used in the vehicle [kWh/l] |
| $Share_{DT,E}$ | Share of the distance traveled using electricity in the vehicle [%] |

Indicative calculation values for this methodology have been prepared in Table 14 to Table 17.

Table 14: Indicative values for specific energy consumption of the reference vehicle

| $sFEC_{ref}$ | [kWh/100 km] |
|---|---|
| Car – Petrol (2021) | 53.78 |
| Car – Diesel (2021) | 53.96 |
| Car – LPG (2021) | 44.05 |
| Car – LNG (2021) | 45.51 |
| Car – PHEV (2021) | 34.28 |
| Car – EU average (2021) | 48.06 |
| Van - Diesel (2021) | 77.22 |
| Truck or Bus - Diesel | 364.36 |

Table 15: Indicative values for specific energy consumption of the efficient vehicle

| $sFEC_{eff}$ | [kWh/100 km] |
|---|---|
| Car BEV | 16.75 |
| Car Hydrogen | 24.40 |
| Van BEV | 23.28 |
| Truck and Bus BEV | 125.32 |

Table 16: Share of the distance traveled using electricity for PHEVs

| $Share_{DT,E}$ | [%] |
|---|---|
| PHEV 2018-2021 | 46.6 |
| PHEV 2025+ | 84.6 |

Table 17: Indicative values for the distance traveled

| $DT$ | [km/a] |
|---|---|
| Car | 13,740 |
| Van | 17,480 |
| Bus | 55,570 |
| Truck | 77,800 |

Table 18: Indicative values for the Net Calorific Value of the used fuel

| $NCV$ | [kWh/l] |
|---|---|
| Petrol | 9.29 |
| Diesel | 10.09 |
| Liquefied petroleum gases | 7.23 |
| Natural gas liquids | 8.59 |
| Biofuels | 7.5 |

Please keep in mind that these values are based on EU-wide data and need to be adjusted to national circumstances: In order to be in line with EU regulations, the values depend on the year of implementation of the measure. There are also baseline values that depend on the used fuel, but also aggregated average values (EU average) considering the actual share per type of car sold, therefore allowing also the evaluation of alternative measures considering the replacement of different options of vehicles.

### 5.1.1 Methodological aspects:

The methodology is based on the difference between the specific final energy consumption of the reference versus the more efficient vehicle. The specific energy consumption is given in kWh/100 km, being, therefore, the consumption multiplied by the average distance traveled with the vehicle. The methodology also has the option to include the impact of behavioral factors, such as the rebound and spill-over.

The main formula was based on the formula developed by the multEE project (multEE, 2017) and used in the Austrian catalog (Anlage 1 BGB1. II, Nr. 172, 2016). In addition, the evaluation of the specific energy consumption was added, to allow for the estimation of savings for hybrid options and different types of vehicles. Therefore, the corresponding formula describes the specific energy consumption based on the consumption of fuel and electricity, the energy density of the used fuel as well as the share of the distance traveled using electricity or fuel. When evaluating non-hybrid options, the formula is simplified, using only the term associated with the fuel or electricity and without the need for including data about the share of distance traveled.

### 5.1.2 Data sources for indicative calculation values:

The **specific energy consumption of the reference vehicles** was calculated based on two datatsets, namely: *Monitoring of CO2 emissions from new passenger cars* and *Monitoring of CO2 emissions from new light commercial vehicles (vans)* available at: https://www.eea.europa.eu/en/datahub/datahubitem-view/9636827c-bd0c-40f5-814e-c4065c11c9a0. These datasets refer to the specific CO2 emissions for newly registered cars and vans in a given calendar year, in terms of grams of CO2 emissions per kilometre. According to the regulation, data on new registrations of passenger cars and vans, including their CO2 emissions, are to be collected each year by countries and submitted to the European Commission. Manufacturers can verify the data and notify the Commission of any errors identified in the dataset. The Commission/EEA assesses the manufacturers' corrections, and, where justified, takes them into account in calculating their average CO2 emissions and specific emission targets. The databases containe detailed data per registered vehicle. The specific energy consumption of the reference vehicles has been calculated from the fuel consumption (l/100 km) using the Net Calorific Values and corresponding fuel densities taking into account the number of specific transport technologies (also included in the database).

The values can be updated every considering the most recent data. The EU average values for cars in each year were assessed with a weighted average considering the percentage of cars in use by fuel type. For Plug-in Hybrid Electric Vehicle (PEHV) the share of energy consumption between fuel and electricity presented in Table 16 was used. For buses and trucks, the modified estimates were used taking into account the Techno-economic assumptions of the PRIMES-TREMOVE transport model for 2020 Reference scenario (E3-Modelling, 2021). Reference values can be adjusted to national circumstances using the average emissions in each country.

The values for **specific energy consumption of the efficient vehicles** were based on the typical electricity consumption of battery electric vehicles (BEV) from the following sources for cars and vans (datatsets: Monitoring of CO2 emissions from new passenger cars, (EEA, 2025a); and Monitoring of CO2 emissions from new light commercial vehicles (vans), (EEA, 2025b)), for trucks and bus (PRIMES-TREMOVE transport model, 2020).

The values for the **share of the distance traveled using electricity for PHEVs** were based on (JEC, 2020) and (Mandev et al, 2024).

The **distance traveled** was assessed considering the values that were proposed in streamSAVE project. For more accurate assessment values can also be adjusted to national circumstances using national statistics.

The **Net Calorific Values** of the used fuels are taken from Annex VI of the Regulation on the monitoring and reporting of greenhouse gas emissions (2018/2066/EU).

The formula includes the option to take into account **behavioral aspects**, despite not presenting an indicative value, since behavioral aspects are highly dependent on the specific technology, users, prices, etc, and need to be based on empirical data (e.g. surveys). However, and the main potential effects are described and typical numbers to the impact are presented.

## 5.2. Bibliography for electric vehicles and charging infrastructure

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# 6. Consumption reduction calculation for public road lighting systems

Different terms refer to lighting systems that light up outdoor environments. The most common terms are "public lighting", "outdoor lighting", "street lighting" and "road lighting". The methodology developed by streamSAVE+ follows the most recent EU GPP – European Green Public Procurement

Criteria for Road Lighting and traffic signals recommendations (European Commission. Joint Research Centre & VITO, 2019a) and uses the term “road lighting” that is also better aligned with EN 13201 (CEN, 2014) and CIE 115 (Commission Internationale de L’Eclairage, 2010).

This methodology deals with the replacement of existing road lighting systems to more energy efficient technologies. It provides two different formulas for the calculation of the energy consumption reduction that account not only for the replacement of existing light points, but also for the installation of lighting control technologies.

From a life cycle analysis perspective, the main environmental impacts of road lighting systems are related to their energy consumption during the use phase (European Commission. Joint Research Centre & VITO, 2019a). This impact can be reduced in several ways, by using luminaires and light sources combinations with a higher efficiency, by implementing light control systems to, for instance, dim during periods of low road use and by adequately developing the lighting project to prevent unnecessary over-lighting. The energy savings provided by the implemented measures will contribute to the reduction of electricity consumption and $CO_2$ emissions. The replacement of the old light source technologies by LED light sources also provides a longer lifetime for savings and a significant reduction of maintenance costs, decreasing the system’s life cycle cost.

Besides the efficiency of light sources and systems, other criteria such as lighting levels and quality of service should be considered. The presented methodology addresses the challenges strictly related to the calculation of energy consumption. To guarantee that all requirements are fulfilled, it is therefore recommended to follow the relevant European and national standards and procedures, namely the performance requirements on EN 13201-2 (CEN, 2016), when implementing the measures and developing projects for new road lighting systems.

The methodology can be applied in all Member States, following the provided indicative values and indications.

## 6.1. Calculation of energy consumption reduction (Article 5)

In the methodology developed, two different formulas can be used, depending on the availability of data. The **first formula** follows a ***“project-based approach”*** and the **second formula** a more ***“simplified approach”***.

### 6.1.1 Project-based approach (first formula)

The following formula can be used when the power of the existing and of the new light points are known, extended by the possibility to include savings provided by lighting control technologies, if their dimming levels operation is known.

$$REC = \left[\left(N_{ref} \cdot \sum_{i=0}^{n} \frac{\left(P_{ref} \cdot t_{ref\,i} \cdot D_{ref\,i}\right)}{1000}\right) - \left(N_{eff} \times \sum_{i=0}^{n} \frac{\left(P_{eff} \cdot t_{eff\,i} \cdot D_{eff\,i}\right)}{1000}\right)\right] \cdot f_{BEH}$$

| | |
|---|---|
| REC | Total energy consumption reduction [kWh/a] |
| $N_{ref}$ | Number of light points in the old/inefficient system [dmnl] |
| $N_{eff}$ | Number of light points in the new/efficient system [dmnl] |
| $P_{ref}$ | Power of each light point of the old/inefficient system, including lamp and other components on the luminaire (e.g. control gear and communication/control units) [W] |

| | |
|---|---|
| $P_{eff}$ | Power of each light point of the new/efficient system, including lamp and other components on the luminaire (e.g. control gear and communication/control units) [W] |
| $t_{ref\ i}$ | Annual operating time [h/a] of light points in the old/inefficient system in dimming level "i" ($D_{ref\ i}$) |
| $D_{ref\ i}$ | Percentage of working light points power [%], in the old/inefficient system, during the dimming level "i" |
| $t_{eff\ i}$ | Annual operating time [h/a] of light points in the new/efficient system in dimming level "i" ($D_{ref\ i}$) |
| $D_{eff\ i}$ | Percentage of working light points power [%], in the new/efficient system, during the dimming level "i" |
| $f_{BEH}$ | Factor for correction of behavioural effects [dmnl] |
| i | Dimming levels "i", being "0" the lighting full power mode |
| n | Total number of dimming levels |

Indicative calculation values for this formula have been prepared in the following table.

*Table 19: Indicative values for the energy consumption reduction of road lighting, first formula*

| **Total annual operating time** | **[h/a]** |
|---|---|
| Total annual operating hours of lighting system (sum of time with and without dimming, that must be equal to $\sum_{i=0}^{n} t_{ref\ i}$ and $\sum_{i=0}^{n} t_{eff\ i}$) | 4,015 |
| Factor for correction of behavioural effects | [dmnl] |
| Factor for correction of behavioural effects ($f_{BEH}$) | 1 |

For the calculation of the **power of each light point of the old/inefficient system ($P_{ref}$),** as well as for the high intensity discharge (HID) lamps, the following formula should be used to include the energy losses of the control gear:

$$P_{ref} = \left(\frac{P_{ls}}{\eta_{control\ gear}}\right)$$

| | |
|---|---|
| $P_{ref}$ | Power of each light point of the old/inefficient system, including lamp and other components on the luminaire (e.g. control gear and communication/control units) [W] |
| $P_{ls}$ | Power of the light source [W] |
| $\eta_{control\ gear}$ | Efficiency of the control gear at full load [%] |

The next table presents the indicative values for the control gear efficiency of high intensity discharge (HID) lamps, needed for the calculation of the baseline situation.

*Table 20: Indicative values for control gear efficiency of HID lamps*

| **Power of the light source ($P_{ls}$) [W]** | **Minimum control gear efficiency ($\eta_{control\ gear}$) [%]** |
|---|---|

| | |
|---|---|
| $P_{ls} \leq 30$ | 78 |
| $30 < P_{ls} \leq 75$ | 85 |
| $75 < P_{ls} \leq 105$ | 87 |
| $105 < P_{ls} \leq 405$ | 90 |
| $P_{ls} > 405$ | 92 |

### 6.1.2 Simplified approach (second formula)

A more simplified approach is presented in the next formula. It can be used in the case of lower data availability and when an equivalence between the power of the existing and the new light points needs to be assumed. The formula also offers the possibility to include savings provided by lighting control technologies, using predefined dimming strategies.

$$REC = \left[ \sum_{j=1}^{n} \left( N_j \cdot ECR_j \cdot LC_j \right) \right] \cdot f_{BEH}$$

| | |
|---|---|
| REC | Total energy consumption reduction [kWh/a] |
| $N_j$ | Number of light points in the lighting system “j” [dmnl] |
| $ECR_j$ | Indicative value for the Energy Consumption Reduction of each light point in the lighting system “j”, according to the table below [kWh/a] |
| $LC_j$ | Factor to account for the consumption reduction according to the lighting control strategy used in the lighting system “j”, according to the table below [dmnl]<br>In the absence of light control technologies, this factor is “1”. |
| $F_{BEH}$ | Factor for correction of behavioural effects [dmnl] |
| j | Lighting system “j” |
| n | Total number of lighting systems |

Indicative calculation values for this formula have been prepared in the next table, using a total operating time of 4,015 hours per year. The **Energy Consumption Reduction per light point (ECR$_j$)** are presented according to a conversion table between the old and new technology.

*Table 21: Indicative values for the energy consumption reduction of road lighting, second formula*

| **Old/inefficient light point** | | **New/efficient light point** | | **Energy consumption reduction (ECR$_j$) [kWh/a]** | **Value for the ratio (LC$_j$)** | |
|---|---|---|---|---|---|---|
| Technology | Lamp power (W) | Technology | Light point power (W) | | Dimming to 50% for 7 h/day | Dimming to 50% for 5 h/day |
| High-Pressure Sodium (HPS) | 400 | Light Emitting Diode (LED) with at least 120lm/W | 250 | 777.76 | 1.41 | 1.29 |
| | 250 | | 160 | 471.12 | 1.43 | 1.31 |
| | 200 | | 125 | 388.88 | 1.41 | 1.29 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 150 | | 95 | 286.68 | 1.42 | 1.30 |
| | 100 | | 60 | 219.76 | 1.35 | 1.25 |
| | 70 | | 40 | 169.40 | 1.3 | 1.22 |
| | 50 | | 30 | 115.28 | 1.33 | 1.24 |
| Metal-Halide (MH) | 400 | Light Emitting Diode (LED) with at least 120lm/W | 300 | 577.76 | 1.66 | 1.47 |
| | 250 | | 180 | 391.12 | 1.59 | 1.42 |
| | 175 | | 125 | 277.76 | 1.57 | 1.41 |
| | 150 | | 110 | 226.68 | 1.62 | 1.44 |
| | 70 | | 50 | 129.40 | 1.49 | 1.35 |
| Factor for correction of behavioural effects | | | | [dmnl] | | |
| Factor for correction of behavioural effects ($f_{BEH}$) | | | | 1 | | |

### 6.1.3 Methodological aspects

The **first formula** presented on this methodology is based on a ***"project approach"*** to calculate energy consumption of lighting systems, based on simple active power multiplied by the number of operating hours. The baseline is defined using the actual power of the light points of the old/inefficient lighting system. It is recommended that Member States, if not yet available, develop and maintain a database with the characteristics of the installed road lighting technologies and the replacements performed, to allow for an accurate baseline calculation and monitoring.

The formula also offers the possibility to account for the consumption reduction by using light dimming control technologies. If a light dimming control technology was installed on the old/inefficient system, it can also be accounted for in the baseline. If not, the equation term $\sum_{i=0}^{n}[P_{ref} \times t_{ref\,i} \times D_{ref\,i}]$ will be equal to $P_{ref} \times 4015\ h/a$. The same applies for the new and more efficient lighting system: if no control is used to perform the light dimming, then the term $\sum_{i=0}^{n}[P_{eff} \times t_{eff\,i} \times D_{eff\,i}]$ will be equal to $P_{eff} \times 4015\ h/a$.

The dimming levels are defined using the "percentage of working light points power" ($D_i$) and the "annual operating time" ($t_i$), that can be calculated based on the "average daily operating time" ($h_i$), multiplied by 365 days. For better understanding, the next figure shows how the dimming levels should be defined.

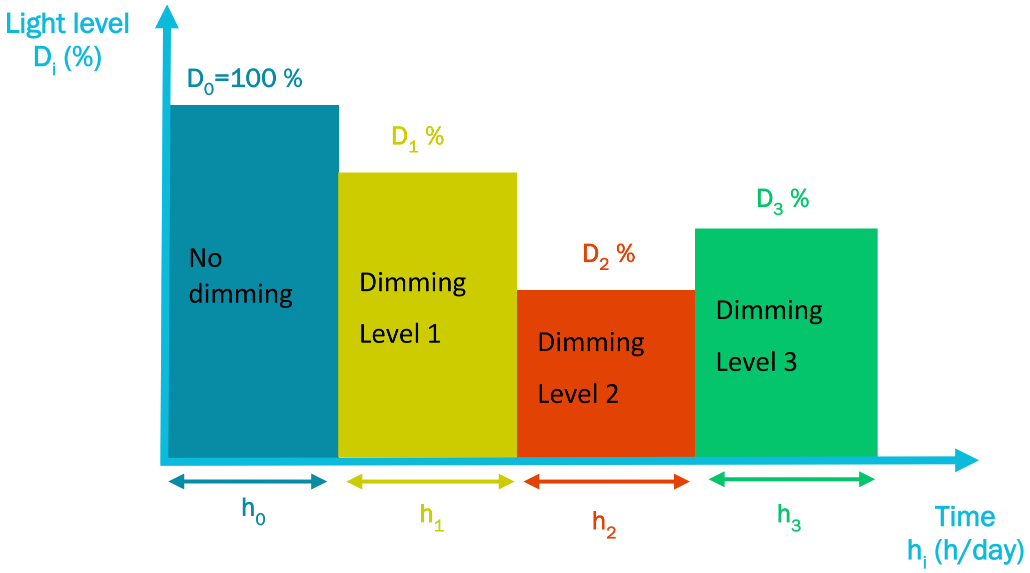

*Figure 7: Definition of dimming levels*

The different number of light points for the old/inefficient system and for the new/efficient systems is used to account for possible changes in lighting projects. Sometimes, to fulfil the requirements of a new lighting project, there can be the need to increase or decrease the number of lighting points of the system.

This way, the project-based approach can be optimally adapted to each national framework since it accounts for the use of different lighting control technologies (with different dimming strategies) and changes that may occur in newly implemented lighting projects.

The **second formula** presented is based on a more ***"simplified approach"*** when calculating savings provided by more energy efficient lighting systems. The indicative values were obtained considering the below mentioned assumptions and supporting publications.

The methodology does not directly evaluate behavioural aspects, but the formulas include the option to consider behavioural aspects.

### 6.1.4 Data sources for indicative calculation values

The **total annual operating hours**, which is equal to the sum of the terms in the formula $\sum_{i=0}^{n}[t_{ref\ i}]$ and $\sum_{i=0}^{n}[t_{eff\ i}]$, is based on the globally accepted value of 11 hours per day (4,015 hours per year). This is the value suggested by the most recent EU GPP (European Commission. Joint Research Centre & VITO, 2019a) and an analogous value (4,000 hours per year) has been used in all the European reference documents regarding road lighting systems, from the EuP Lot 9 (Van Tichelen et al., 2007), to the EuP Lot 37 (Van Tichelen et al., 2016) and the most recent EU GPP Criteria for Road Lighting and traffic signals (European Commission. Joint Research Centre & VITO, 2019b). As referred in EuP Lot 37 (Van Tichelen et al., 2016): *"Seasonal changes between winter and summer increase with distance from the equator. Nordic countries have daylight during almost the whole day in summer and are dark (almost) all day in winter. At equinox (21 March and 21 September), day and night periods are equal everywhere over the globe. As a consequence, 4,000 operating hours per year is the universal default value for Street Lighting."*

For calculation simplification reasons, due to the dimming levels definition (hours per day and consequently the total annual hours), and also following the most recent EU GPP, it was decided to use the 11 hours per day or 4,015 hours per year.

The indicative values for the **efficiency of the high intensity discharge (HID) lamps** are based on the requirements of Commission Regulation (EC) No 245/2009 (European Commission, 2009), which are also included in the new requirements of the Commission Regulation (EC) No 2019/2020 (European Commission, 2019a).

In the **first formula**, no indicative values (Table 19) are suggested for the **dimming levels** and individual annual operating time, so that specific control technology and project values can be used. Road lighting requirements are traditionally dominated by road traffic safety concerns and the perceived security feeling, especially in densely populated areas. Switching off completely the road lighting systems is rarely applied (Van Tichelen et al., 2016) and there are several arguments, although disputable, for not implementing this action (e.g. road security, criminality levels). When using lighting control technologies to perform dimming of the lighting systems, the light levels must comply with EN 13201 or similar national guidelines.

The **second formula** uses indicative values (Table 21) for **Energy Consumption Reduction ($ECR_j$)** per light point according to the old/inefficient technology type and lamp power and an equivalent LED lamp power. The power conversion factor between technologies was obtained by taking into account the indicative rated lamp efficacy of the old/inefficient technology, based on the Commission Regulation (EC) No 245/2009 (European Commission, 2009), and the threshold efficacy for LED light sources based on the new requirements of the Commission Regulation (EC) No 2019/2020 (European Commission, 2019a) (i.e. 120.0 lm/W). The lamp power of the old/inefficient technologies are based on market manufacturers research. Since those manufacturers present a wide variety of different values for the LED lamp power, the equivalent power was calculated based on a simple conversion of the required LED lumen output to be equal or surpass the output provided by the old/inefficient technology, rounded to an integer value within 5 W intervals. To simplify, it was assumed that within this calculated power, the efficiency for the control gear for LED light sources is included.

For the energy consumption of the old/inefficient technologies, the calculations take into account the minimum efficiency requirements for control gear for HID lamps, based on the Commission Regulation (EC) No 245/2009, which are included in the new requirements of the Commission Regulation (EC) No 2019/2020, and can be seen in the table for indicative values of the **first formula** (Table 20).

For the **second formula**, it is suggested to use indicative values for **the factor to account for the consumption reduction according to the lighting control strategy (LCj)** presented in Table 21. These values are based on calculations using the savings achieved by installing lighting control technologies on the new/efficient lighting systems, matching the referred control strategy (i.e. dimming percentage and hours per day), according to each proposed technology retrofit.

It is difficult to define indicative values for the dimming level strategies. These are usually defined at national or local level. The suggestions in the above table with the indicative values for the **second formula** are derived from streamSAVE project's analysis of the member states bottom-up methodologies collection across Europe (i.e. Austria, see D2.1); and from the indication on the EU GPP (European Commission, 2018) technical specification core criteria TS3 for minimum dimming performance. The latter suggests that light sources and luminaires shall be installed with fully functional dimming controls that are programmable to set *at least one pre-set level of dimming* down to at least 50 % of maximum light output.

The project **factors for correction of behavioural effects** are suggested to be included in the formula, since these values can be available for each specific project. No indicative values can be provided EU-wide, due to limitations in supporting publications and studies.

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# 7. Consumption reduction calculation for replacement of electric motors

Electric motors are very relevant consumer of electricity consumption in the tertiary sector, which includes services and the public sector. They are used ubiquitously to convert electrical power into mechanical power in many applications (e.g. ventilation, cooling systems, HVAC, elevators, escalators; pumps in water and waste water appliances). This means that even a small improvement in efficiency translates into very large absolute savings.

Electric motors have very long lifetimes, which means that their replacement rate is very slow. Recent field assessments (in Switzerland and the USA) have shown that the actual lifetime of motors largely exceeds their expected lifetimes, often largely exceeding the expected maximum of 20 years (Werle, 2015) (Rao, 2021). Although subject to minimum performance requirements under the Ecodesign Directive, the replacement rate of old inefficient motors is still slow and, therefore, their anticipated renovation driven by policy incentives is desirable.

The methodology presented in this document targets the replacement of existing old inefficient motors for more energy efficient technologies. The developed methodology also addresses the following challenges:

- **Data collection:**
  It is suggested that Member States (MS) develop and maintain a database with national values for the operating characteristics of electric motors (load factors, operating hours) collected from the efficiency measures carried out.
- **Definition of baseline:**
  The methodology suggests indicative values to streamline baseline calculations among all MS, based on global and European standards.

## 7.1. Calculation of energy consumption reduction (Article 5)

This methodology deals with the replacement of existing old motors with more efficient new motors, which can lead to savings in final energy consumption. It provides formulas for the calculation of energy reductions of the implemented measures that account not only for the replacement of existing motors in fixed speed applications, but also for the installation of Variable Speed Drives (VSDs) in applications where the motor speed and torque need to be adjusted based on the demand. In most applications, VSDs are recommended instead of fixed-speed drives due to their higher energy efficiency.

In accordance with Commission Regulation (EU) 2019/1781, electric motors placed on the EU market are required to meet at least the IE3 efficiency class. For 2- to 6-pole motors with a rated output between 75 kW and 200 kW, compliance with the IE4 efficiency class becomes mandatory as of July 1, 2023.

### 7.1.1 Calculation formula

The final energy consumption reductions can be calculated with the following equation:

$$TFES = n \cdot P_n \cdot h \cdot (\frac{1}{\eta_c} - \frac{1}{\eta_{he}}) \cdot LF \cdot 100$$

Additional savings in case of the installation of a variable speed drive:

$$TFES_{VSD} = n \cdot \frac{P_n}{\eta_{he}} \cdot 100 \cdot h \cdot f_{VSD}$$

| | |
|---|---|
| TFES | Total final energy savings [kWh/a] |
| n | Number of motors replaced [dmnl] |
| $P_n$ | Nominal power as indicated in the nameplate [kW] |
| h | Annual operating hours [h] |
| $\eta_c$ | Efficiency of old motor [%] |
| $\eta_{he}$ | Efficiency of more efficient motor [%] |
| LF | Load factor [dmnl] |
| $f_{VSD}$ | Factor to account for additional savings generated by the installation of a variable speed control (VSD) [dmnl] |

### 7.1.2 Indicative values

**If known, values specific to the project implemented should be used for the "annual operating hours", "efficiency of conventional motor", "efficiency of high-efficiency motor" and "load factor".**

When the exact number of operating hours and load factor cannot be determined approximation can be done by using indicative calculation values in Table 22 and Table 23. Table 23 can be used for approximation of the annual operating hours (**h**) and load factor (**LF)** when some of the characteristics of facility the motors are installed in are known and the power range is 0.75 up to 22 kW, otherwise it can be used data from Table 22.

*Table 22: Indicative values for average load factor and operating hours (tertiary sector)*

| Tertiary | [dmnl] |
|---|---|
| Annual operating hours [h] | 1,480 |
| Load factor LF [dmnl] | 0.60 |

*Table 23: Indicative values for load factor and the annual operating hours h by power range and device type*

| Power range | Device type | Services | |
|---|---|---|---|
| | | Working hours [h] | Load factor [%] |
| 0.75 to < 4 | Pumps | 3,800 | 0.55 |
| 4 to < 10 | | 3,050 | 0.60 |
| 10 to < 22 | | 3,000 | 0.60 |
| 0.75 to < 4 | Fans | 2,250 | 0.60 |
| 4 to < 10 | | 2,250 | 0.65 |
| 10 to < 22 | | 2,250 | 0.65 |
| 0.75 to < 4 | Air compressors | 1,030 | 0.40 |
| 4 to < 10 | | 1,000 | 0.45 |
| 10 to < 22 | | 980 | 0.45 |
| 0.75 to < 4 | Transporters | 621 | 0.61 |

| | | | |
|---|---|---|---|
| 4 to < 10 | | 916 | 0.53 |
| 10 to < 22 | | 725 | 0.49 |
| 0.75 to < 4 | Refrigerators | 4,200 | 0.70 |
| 4 to < 10 | | 4,170 | 0.70 |
| 10 to < 22 | | 4,050 | 0.75 |
| 0.75 to < 4 | Other | 500 | 0.30 |
| 4 to < 10 | | 530 | 0.30 |
| 10 to < 22 | | 570 | 0.30 |

Indicative values for the average default savings factor for different types of end-uses achieved by the installation of a VSD can be taken from Table 24.

*Table 24: Indicative values for the average default savings factor*

| End-Use | $f_{VSD}$ |
|---|---|
| Pumps | 0.28 |
| Fans | 0.28 |
| Air Compressors | 0.12 |
| Cooling compressors | 0.12 |
| Conveyors | 0.12 |
| Other Motors | 0.12 |

The detailed values for efficiency of the motors ŋ, depending on their power, can be found in Table 25, Table 26 and Table 27. Average values can be found in Table 28. **When the power of the motors is exactly known, it's recommended to base the savings estimations on the more granular values.**

Indicative values for the motor efficiency according to detailed classes on number of poles and powers are shown in the following tables. Efficiencies for IE1, IE2, IE3 and IE4 are based on the IEC 60034- 30-1 standard or Annex I of Commission Regulation EU 2019/1781 (Ecodesign Regulation) and IE5 on IEC 60034-30-2.

*Table 25: Indicative values for 2-Poles and 4-Poles motor efficiency (IE1, IE2, IE3 and IE4) (%)*

| | 2-Poles | | | | | 4-Poles | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Motor Power [kW] | IE1 | IE2 | IE1 - IE2 average | IE3 | IE4 | IE1 | IE2 | IE1 - IE2 average | IE3 | IE4 |
| 0.12 | 45.0 | 53.6 | 49.3 | 60.8 | 66.5 | 50.0 | 59.1 | 54.6 | 64.8 | 69.8 |
| 0.18 | 52.8 | 60.4 | 56.6 | 65.9 | 70.8 | 57.0 | 64.7 | 60.9 | 69.9 | 74.7 |
| 0.20 | 54.6 | 61.9 | 58.3 | 67.2 | 71.9 | 58.5 | 65.9 | 62.2 | 71.1 | 75.8 |
| 0.25 | 58.2 | 64.8 | 61.5 | 69.7 | 74.3 | 61.5 | 68.5 | 65.0 | 73.5 | 77.9 |
| 0.37 | 63.9 | 69.5 | 66.7 | 73.8 | 78.1 | 66.0 | 72.7 | 69.4 | 77.3 | 81.1 |
| 0.40 | 64.9 | 70.4 | 67.7 | 74.6 | 78.9 | 66.8 | 73.5 | 70.2 | 78.0 | 81.7 |
| 0.55 | 69.0 | 74.1 | 71.6 | 77.8 | 81.5 | 70.0 | 77.1 | 73.6 | 80.8 | 83.9 |
| 0.75 | 72.1 | 77.4 | 74.8 | 80.7 | 83.5 | 72.1 | 79.6 | 75.9 | 82.5 | 85.7 |
| 1.1 | 75.0 | 79.6 | 77.3 | 82.7 | 85.2 | 75.0 | 81.4 | 78.2 | 84.1 | 87.2 |
| 1.5 | 77.2 | 81.3 | 79.3 | 84.2 | 86.5 | 77.2 | 82.8 | 80.0 | 85.3 | 88.2 |
| 2.2 | 79.7 | 83.2 | 81.5 | 85.9 | 88.0 | 79.7 | 84.3 | 82.0 | 86.7 | 89.5 |
| 3 | 81.5 | 84.6 | 83.1 | 87.1 | 89.1 | 81.5 | 85.5 | 83.5 | 87.7 | 90.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 83.1 | 85.8 | 84.5 | 88.1 | 90.0 | 83.1 | 86.6 | 84.9 | 88.6 | 91.1 |
| 5.5 | 84.7 | 87.0 | 85.9 | 89.2 | 90.9 | 84.7 | 87.7 | 86.2 | 89.6 | 91.9 |
| 7.5 | 86.0 | 88.1 | 87.1 | 90.1 | 91.7 | 86.0 | 88.7 | 87.4 | 90.4 | 92.6 |
| 11 | 87.6 | 89.4 | 88.5 | 91.2 | 92.6 | 87.6 | 89.8 | 88.7 | 91.4 | 93.3 |
| 15 | 88.7 | 90.3 | 89.5 | 91.9 | 93.3 | 88.7 | 90.6 | 89.7 | 92.1 | 93.9 |
| 18.5 | 89.3 | 90.9 | 90.1 | 92.4 | 93.7 | 89.3 | 91.2 | 90.3 | 92.6 | 94.2 |
| 22 | 89.9 | 91.3 | 90.6 | 92.7 | 94.0 | 89.9 | 91.6 | 90.8 | 93.0 | 94.5 |
| 30 | 90.7 | 92.0 | 91.4 | 93.3 | 94.5 | 90.7 | 92.3 | 91.5 | 93.6 | 94.9 |
| 37 | 91.2 | 92.5 | 91.9 | 93.7 | 94.8 | 91.2 | 92.7 | 92.0 | 93.9 | 95.2 |
| 45 | 91.7 | 92.9 | 92.3 | 94.0 | 95.0 | 91.7 | 93.1 | 92.4 | 94.2 | 95.4 |
| 55 | 92.1 | 93.2 | 92.7 | 94.3 | 95.3 | 92.1 | 93.5 | 92.8 | 94,6 | 95.7 |
| 75 | 92.7 | 93.8 | 93.3 | 94.7 | 95.6 | 92.7 | 94.0 | 93.4 | 95.0 | 96.0 |
| 90 | 93.0 | 94.1 | 93.6 | 95.0 | 95.8 | 93.0 | 94.2 | 93.6 | 95.2 | 96.1 |
| 110 | 93.3 | 94.3 | 93.8 | 95.2 | 96.0 | 93.3 | 94.5 | 93.9 | 95.4 | 96.3 |
| 132 | 93.5 | 94.6 | 94.1 | 95.4 | 96.2 | 93.5 | 94.7 | 94.1 | 95.6 | 96.4 |
| 160 | 93.8 | 94.8 | 94.3 | 95.6 | 96.3 | 93.8 | 94.9 | 94.4 | 95.8 | 96.6 |
| 200 up to 249 | 94.0 | 95.0 | 94.5 | 95.8 | 96.5 | 94.0 | 95.1 | 94.6 | 96.0 | 96.7 |
| 250 up to 314 | 94.0 | 95.0 | 94.5 | 95.8 | 96.5 | 94.0 | 95.1 | 94.6 | 96.0 | 96.7 |
| 315 up to 1 000 | 94.0 | 95.0 | 94.5 | 95.8 | 96.5 | 94.0 | 95.1 | 94.6 | 96.0 | 96.7 |

*Table 26: Indicative values for 6-Poles and 8-Poles motor efficiency (IE1, IE2, IE3 and IE4) (%)*

| | 6-Poles | | | | | 8-Poles | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Motor Power [kW] | IE1 | IE2 | IE1 - IE2 average | IE3 | IE4 | IE1 | IE2 | IE1 - IE2 average | IE3 | IE4 |
| 0.12 | 38.3 | 50.6 | 44.5 | 57.7 | 64.9 | 31.0 | 39.8 | 35.4 | 50.7 | 62.3 |
| 0.18 | 45.5 | 56.6 | 51.1 | 63.9 | 70.1 | 38.0 | 45.9 | 42.0 | 58.7 | 67.2 |
| 0.20 | 47.6 | 58.2 | 52.9 | 65.4 | 71.4 | 39.7 | 47.4 | 43.6 | 60.6 | 68.4 |
| 0.25 | 52.1 | 61.6 | 56.9 | 68.6 | 74.1 | 43.4 | 50.6 | 47.0 | 64.1 | 70.8 |
| 0.37 | 59.7 | 67.6 | 63.7 | 73.5 | 78.0 | 49.7 | 56.1 | 52.9 | 69.3 | 74.3 |
| 0.40 | 61.1 | 68.8 | 65.0 | 74.4 | 78.7 | 50.9 | 57.2 | 54.1 | 70.1 | 74.9 |
| 0.55 | 65.8 | 73.1 | 69.5 | 77.2 | 80.9 | 56.1 | 61.7 | 58.9 | 73.0 | 77.0 |
| 0.75 | 70.0 | 75.9 | 73.0 | 78.9 | 82.7 | 61.2 | 66.2 | 63.7 | 75.0 | 78.4 |
| 1.1 | 72.9 | 78.1 | 75.5 | 81.0 | 84.5 | 66.5 | 70.8 | 68.7 | 77.7 | 80.8 |
| 1.5 | 75.2 | 79.8 | 77.5 | 82.5 | 85.9 | 70.2 | 74.1 | 72.2 | 79.7 | 82.6 |
| 2.2 | 77.7 | 81.8 | 79.8 | 84.3 | 87.4 | 74.2 | 77.6 | 75.9 | 81.9 | 84.5 |
| 3 | 79.7 | 83.3 | 81.5 | 85.6 | 88.6 | 77.0 | 80.0 | 78.5 | 83.5 | 85.9 |
| 4 | 81.4 | 84.6 | 83.0 | 86.8 | 89.5 | 79.2 | 81.9 | 80.6 | 84.8 | 87.1 |
| 5.5 | 83.1 | 86.0 | 84.6 | 88.0 | 90.5 | 81.4 | 83.8 | 82.6 | 86.2 | 88.3 |
| 7.5 | 84.7 | 87.2 | 86.0 | 89.1 | 91.3 | 83.1 | 85.3 | 84.2 | 87.3 | 89.3 |
| 11 | 86.4 | 88.7 | 87.6 | 90.3 | 92.3 | 85.0 | 86.9 | 86.0 | 88.6 | 90.4 |
| 15 | 87.7 | 89.7 | 88.7 | 91.2 | 92.9 | 86.2 | 88.0 | 87.1 | 89.6 | 91.2 |
| 18.5 | 88.6 | 90.4 | 89.5 | 91.7 | 93.4 | 86.9 | 88.6 | 87.8 | 90.1 | 91.7 |
| 22 | 89.2 | 90.9 | 90.1 | 92.2 | 93.7 | 87.4 | 89.1 | 88.3 | 90.6 | 92.1 |
| 30 | 90.2 | 91.7 | 91.0 | 92.9 | 94.2 | 88.3 | 89.8 | 89.1 | 91.3 | 92.7 |
| 37 | 90.8 | 92.2 | 91.5 | 93.3 | 94.5 | 88.8 | 90.3 | 89.6 | 91.8 | 93.1 |
| 45 | 91.4 | 92.7 | 92.1 | 93.7 | 94.8 | 89.2 | 90.7 | 90.0 | 92.2 | 93.4 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 55 | 91.9 | 93.1 | 92.5 | 94.1 | 95.1 | 89.7 | 91.0 | 90.4 | 92.5 | 93.7 |
| 75 | 92.6 | 93.7 | 93.2 | 94.6 | 95.4 | 90.3 | 91.6 | 91.0 | 93.1 | 94.2 |
| 90 | 92.9 | 94.0 | 93.5 | 94.9 | 95.6 | 90.7 | 91.9 | 91.3 | 93.4 | 94.4 |
| 110 | 93.3 | 94.3 | 93.8 | 95.1 | 95.8 | 91.1 | 92.3 | 91.7 | 93.7 | 94.7 |
| 132 | 93.5 | 94.6 | 94.1 | 95.4 | 96.0 | 91.5 | 92.6 | 92.1 | 94.0 | 94.9 |
| 160 | 93.8 | 94.8 | 94.3 | 95.6 | 96.2 | 91.9 | 93.0 | 92.5 | 94.3 | 95.1 |
| 200 up to 249 | 94.0 | 95.0 | 94.5 | 95.8 | 96.3 | 92.5 | 93.5 | 93.0 | 94.6 | 95.4 |
| 250 up to 314 | 94.0 | 95.0 | 94.5 | 95.8 | 96.5 | 92.5 | 93.5 | 93.0 | 94.6 | 95.4 |
| 315 up to 1 000 | 94.0 | 95.0 | 94.5 | 95.8 | 96.6 | 92.5 | 93.5 | 93.0 | 94.6 | 95.4 |

*Table 27: Indicative values for 2-Poles, 4-Poles, 6-Poles and 8-Poles motor efficiency (IE5) (%)*

| Motor Power [kW] | IE5 | | | |
|---|---|---|---|---|
| | 2-Poles | 4-Poles | 6-Poles | 8-Poles |
| 0.12 | 71.4 | 74.3 | 69.8 | 67.4 |
| 0.18 | 75.2 | 78.7 | 74.6 | 71.9 |
| 0.20 | 76.2 | 79.6 | 75.7 | 73.0 |
| 0.25 | 78.3 | 81.5 | 78.1 | 75.2 |
| 0.37 | 81.7 | 84.3 | 81.6 | 78.4 |
| 0.40 | 82.3 | 84.8 | 82.2 | 78.9 |
| 0.55 | 84.6 | 86.7 | 84.2 | 80.6 |
| 0.75 | 86.3 | 88.2 | 85.7 | 82.0 |
| 1.1 | 87.8 | 89.5 | 87.2 | 84 |
| 1.5 | 88.9 | 90.4 | 88.4 | 85.5 |
| 2.2 | 90.2 | 91.4 | 89.7 | 87.2 |
| 3 | 91.1 | 92.1 | 90.6 | 88.4 |
| 4 | 91.8 | 92.8 | 91.4 | 89.4 |
| 5.5 | 92.6 | 93.4 | 92.2 | 90.4 |
| 7.5 | 93.3 | 94.0 | 92.9 | 91.3 |
| 11 | 94.0 | 94.6 | 93.7 | 92.2 |
| 15 | 94.5 | 95.1 | 94.3 | 92.9 |
| 18.5 | 94.9 | 95.3 | 94.6 | 93.3 |
| 22 | 95.1 | 95.5 | 94.9 | 93.6 |
| 30 | 95.5 | 95.9 | 95.3 | 94.1 |
| 37 | 95.8 | 96.1 | 95.6 | 94.4 |
| 45 | 96.0 | 96.3 | 95.8 | 94.7 |
| 55 | 96.2 | 96.5 | 96.0 | 94.9 |
| 75 | 96.5 | 96.7 | 96.3 | 95.3 |
| 90 | 96.6 | 96.9 | 96.5 | 95.5 |
| 110 | 96.8 | 97.0 | 96.6 | 95.7 |
| 132 | 96.9 | 97.1 | 96.8 | 95.9 |
| 160 | 97.0 | 97.2 | 96.9 | 96.1 |
| 200 up to 1 000 | 97.2 | 97.4 | 97.0 | 96.3 |

*Table 28: Average indicative values for motor efficiency (%)*

| Power range [kW] | Avg. Power | IE1-IE2 Avg | IE3 | IE4 |
|---|---|---|---|---|
| 0.75 - 7.5 | 3.2 | 81.9 | 86.5 | 89.1 |

| | | | | |
|---|---|---|---|---|
| 7.5 - 75 | 34.3 | 91.2 | 93.3 | 94.6 |
| 75 - 375 | 201.5 | 94.3 | 95.7 | 96.4 |
| 375 - 1000 | 587.5 | 94.5 | 95.9 | 96.6 |

### 7.1.3 Methodological aspects

This methodology allows calculating energy savings resulting from replacing old electric motors with more energy efficient ones. The energy consumption of an electric motor results from its nominal output power, the operating hours, the average load and its efficiency. The final energy savings results from the improvement in efficiency. The formula gives yearly energy savings.

**The calculations should be based, whenever possible, on the real characteristics of the installation before and after the action. It is recommended that Member States, if not yet available, develop and maintain a database with the installed motor characteristics and the replacements performed, for baseline calculation and monitoring the evolution.**

In case a VSD is installed at the time of the motor renovation, the additional savings (**$TFES_{VSD}$)** can be estimated by using the formula above. These savings are added to the TFES for motor renovation (**TFES**).

**Because of the high variation in savings possible when installing a VSD, which are very dependent of the characteristics of the system, it is recommended that an engineering analysis is carried out to evaluate these savings for the specific measure. The formula presented here only gives a rough estimate of the energy savings.**

### 7.1.4 Data sources for indicative calculation values

The indicative values for **average load factor** (**LF**) of 0.60 in Table 22 is assumed on the study which collected data on the EU-15 motor stock (de Almeida, 2000).

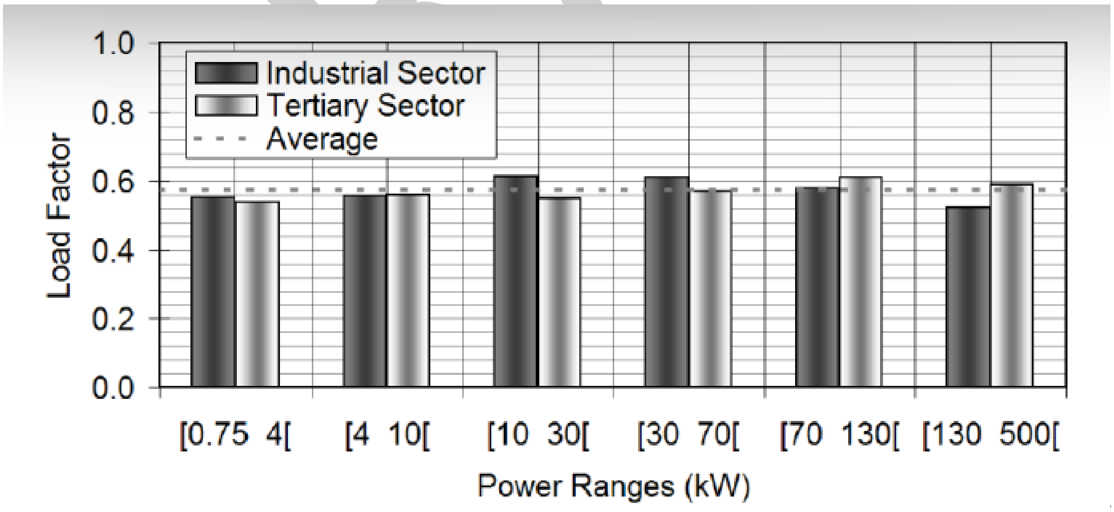

*Figure 8: EU-15 Motor average load factor - industry and tertiary sectors (de Almeida, 2000)*

The calculation of **number of average annual operating hours (h)** presented in Table 22 is taken from the savings catalogue of Luxembourg (Luxembourg, 2015).

Detailed indicative values for **annual operating hours (h)** and **load factor (LF)** shown in Table 23 were taken from the Croatian Rulebook on system for monitoring, measurement and verification of energy savings (2022) for the services sector. Data was taken from European project, EMEEES project, Metod 12. The same factors for load factor are also provided in the Slovenian regulation, but the working hours are not specified. Values can be used for approximation if the power is in range 0.75 up to 22 kW.

The values for the **VSD average default savings factor** (**$f_{VSD}$**) are taken from (de Almeida, 2000) and (de Almeida, 2001).

When the **real efficiency** (**$\eta_c$** and **$\eta_{he}$**)) of the motor being replaced is not known, an average value of the minimum efficiency for the efficiency levels IE1 and IE2 according to the IEC 60034-30-1 standard or Annex I of Commission Regulation EU 2019/1781 (Ecodesign Regulation), for the relevant power class should be used. Likewise, the nameplate efficiency of the replacing motor should be used or, alternatively, the minimum efficiency of its power class (IE3 or IE4) as defined in the IEC 60034-30-1 standard. Efficiency levels for electric motors are standardised globally through IEC 60034-30-1, and these levels are used when establishing national or regional Minimum Energy Performance Standards (MEPS). The standard defines efficiency classes IE1 to IE4, where IE1 is the least efficient and IE4 is the most efficient motor efficiency class. Indicative values in Table 25 and Table 26 are based on the IEC 60034- 30-1 standard or Annex I of Commission Regulation EU 2019/1781 (Ecodesign Regulation) and in Table 27 is based on IEC 60034-30-2. Indicative values for efficiency given in Table 28 are the average efficiency limits, within the relevant power range.

## 7.2. Bibliography for replacement of electric motors

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IEC (2016) IEC 60034-30-2:2016 Rotating electrical machines - Part 30-2: Efficiency classes of variable speed AC motors (IE-code); International Electrotechnical Commission: Geneva, Switzerland

Luxembourg (2015) Règlement grand-ducal du 7 août 2015 relatif au fonctionnement du mécanisme d'obligations en matière d'efficacité énergétique. Journal Official du GrandDuché de Luxembourg, https://legilux.public.lu/filestore/eli/etat/leg/memorial/2015/a170/fr/pdf/eli-etat-leg-memorial-2015-a170-fr-pdf.pdf

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# 8. Consumption reduction calculation for trainings related to energy efficiency for public sector employees

As Europe accelerates its transition to a low-carbon economy, the public sector is increasingly recognized as a catalyst for driving sustainable energy use and climate resilience.

In this context, capacity building through targeted training programs has emerged as a strategic lever for embedding energy efficiency into public operations. These programs equip civil servants, municipal planners, procurement officers, facility managers, and policy makers with the technical skills and strategic insight necessary to meet the rising demands of EU climate legislation, including national contributions under the National Energy and Climate Plans (NECPs).

Training programs serve as a strategic tool to instil knowledge, reshape habits, and foster a culture of responsibility around energy use within public institutions. Through structured learning, simulations, and hands-on engagement, public employees gain not only technical skills but also a deeper awareness of the environmental and economic impacts of their daily decisions. Trainings can prompt simple yet effective behavioural shifts—such as optimizing lighting and heating schedules, proactively maintaining energy systems, and advocating for sustainable procurement—which collectively yield significant savings.

Studies and EU-funded initiatives suggest that behavioural measures alone can contribute to significant (3 % - 15 %) reduction in energy consumption in public buildings, depending on the baseline conditions and institutional engagement. When combined with strategic energy management and low-cost operational adjustments, this potential rises substantially. Beyond direct energy and cost savings, behavioural change also improves interdepartmental coordination, compliance with EU energy directives, and public credibility, reinforcing the public sector's role as a model for sustainability. In this context, investing in training is not merely a compliance measure—it is a transformational opportunity that empowers staff, optimizes operations, and accelerates the path to decarbonization.

## 8.1. Best practices from EU countries

This chapter presents a comparative overview of prominent public sector energy training initiatives in five European settings: Slovenia, Ireland, Luxembourg, Lithuania, and a Pan-European framework. Each program reflects a tailored approach to local capacity development while contributing to the broader EU objective of systemic, verifiable energy savings in the public domain.

### 8.1.1 LIFE IP CARE4CLIMATE Training Program

**Country:** Slovenia

The LIFE IP CARE4CLIMATE project is Slovenia's flagship integrated climate action program, led by the Ministry of the Environment, Climate and Energy and co-funded by the European Union's LIFE Programme and the Climate Change Fund. Launched in 2019 and running through 2026, the project aims to support the implementation of Slovenia's National Energy and Climate Plan (NECP) by providing education, training, and capacity building tailored also to the public sector among others.

The training program addresses various levels of public administration, including procurement officers, municipal planners, facility managers, and policy makers. It is structured around the development of both technical competencies and strategic awareness, ensuring that participants understand the practical tools available for reducing greenhouse gas emissions and increasing the energy efficiency of public infrastructure.

Among the core topics covered are Green Public Procurement (GPP), where public employees learn how to include environmental and energy performance criteria into tendering processes. Another key module focuses on Energy Performance Contracting (EPC), educating participants on structuring and managing public-private energy efficiency investments based on performance outcomes. Additional modules focus on sustainable renovation of public buildings, use of Building Information Modeling (BIM) for energy planning, and the development of municipal energy strategies aligned with EU directives.

Training is delivered through a blended model, combining on-site workshops, online courses, pilot projects, and hands-on digital tools. Participants are equipped to act as change agents within their institutions, ensuring that climate commitments translate into measurable results at the local and national levels.

**Reference:**
CARE4CLIMATE. (2025). Project CARE4CLIMATE. Retrieved on 10.5.2025 from https://www.care4climate.si/en

### 8.1.2 Public Sector Energy Programme – SEAI

**Country: Ireland**

The Public Sector Energy Programme, developed and delivered by the Sustainable Energy Authority of Ireland (SEAI), is a flagship national initiative aimed at building energy efficiency capacity across Ireland's public sector. It provides structured support to public bodies in meeting Ireland's legally binding target of a 50% improvement in energy efficiency by 2030, in line with EU directives and national climate action policies.

The program offers an integrated approach that combines technical assistance, institutional mentoring, and strategic planning. At its core is a comprehensive education and training framework for public employees—particularly energy managers, procurement officers, and senior decision-makers—designed to embed energy management practices throughout public institutions.

Training modules are based on best-in-class methodologies, including the Energy MAP framework and ISO 50001 standards, and focus on areas such as strategic energy planning, energy-efficient procurement, project implementation, and data reporting. Participating organizations are supported through mentorship, workshops, and on-site energy assessments, ensuring that knowledge translates into actionable improvements.

The program also emphasizes peer learning and collaboration, facilitating networking among public bodies through knowledge-sharing platforms and annual performance reports. This has helped normalize energy efficiency as a cross-functional responsibility in the public sector, rather than a siloed technical task.

Measured outcomes from the initiative have shown that institutions engaging in SEAI's training and advisory services achieve **up to 20%** energy savings through behavioural change, operational upgrades, and strategic investment. The program has become a cornerstone in Ireland's broader decarbonization efforts and a model for public sector engagement in energy transition.

**Reference:**
**Sustainable Energy Authority of Ireland. (2025.). Public Sector Energy Programme. Retrieved on 11.5.2025 from** https://www.seai.ie/plan-your-energy-journey/public-sector/public-sector-energy-programme

### 8.1.3 Energy Efficiency Buildings – ESF+ Training Programme

**Country: Luxembourg**

The Energy Efficiency Buildings project, co-financed by the European Social Fund Plus (ESF+), is a targeted initiative in Luxembourg aimed at enhancing the energy efficiency skills of individuals responsible for managing buildings—particularly within the public sector. The program focuses on equipping technical staff and facility managers with advanced competencies in monitoring, optimizing, and reducing energy use in buildings that are owned or operated by public institutions and cooperatives.

Designed in alignment with Luxembourg's national climate and energy targets, the training addresses both theoretical and hands-on aspects of building energy performance. Participants—ranging from municipal employees and technical managers to representatives of building management associations—are trained in how to assess energy consumption patterns, use digital tools for performance tracking, and implement cost-effective energy-saving measures. The curriculum also covers regulatory compliance, energy reporting, and strategic planning for retrofits or equipment upgrades.

A key feature of the program is its practical orientation: trainees engage directly with building systems and data, allowing them to contextualize what they learn and apply it immediately within their own institutional settings. By developing in-house expertise, the initiative reduces dependency on external consultants and fosters a culture of proactive, informed energy stewardship in the public sector.

This program is seen as a cornerstone of Luxembourg's capacity-building strategy to meet the European Green Deal's goals, especially as public buildings are expected to set the standard for sustainable construction and operation.

**Reference:**

**Fonds européens. (2025). Energy Efficiency Buildings. Retrieved on 11.5.2025 from** https://fonds-europeens.public.lu/fr/projets/fse/2021-2027/2047.html

### 8.1.4 LIFE IP EnerLIT and Urban Redevelopment Manager Training

**Country: Lithuania**

Lithuania has launched multiple targeted training initiatives to support public sector employees in advancing national energy efficiency goals. Two notable efforts—the LIFE Integrated Project "Improving Energy Efficiency in Lithuania" (LIFE IP EnerLIT) and the Training of Managers for Urban Redevelopment—focus explicitly on capacity building within public institutions and municipalities.

The LIFE IP EnerLIT project, coordinated by the Lithuanian Environmental Projects Management Agency (APVA) and co-financed by the EU LIFE Programme, aims to support the implementation of Lithuania's National Energy and Climate Plan. One of its core components is the strategic education of public sector stakeholders, including ministry personnel, local government representatives, and other institutional actors. Training activities under EnerLIT address themes such as integrated energy planning, implementation of energy-saving projects in public buildings, regulatory compliance, and monitoring and reporting of energy performance indicators. These sessions are supplemented by guidance documents and inter-agency workshops to facilitate knowledge exchange.

Complementing this, the Training of Managers for Urban Redevelopment project—developed in collaboration with the European Climate Initiative (EUKI)—was created to strengthen the capacity of employees from local and national administrations. The program delivered in-depth instruction on urban energy planning, building renovation strategies, and sustainable land-use development.

Participants worked collaboratively to develop energy-efficient urban redevelopment concepts, which were later evaluated and presented as part of national planning strategies.

Together, these programs not only improve the technical competencies of public sector employees in energy efficiency but also support institutional learning, strategic alignment with EU directives, and long-term planning capacity within Lithuanian municipalities and ministries.

**References:**

**Environmental Projects Management Agency (APVA). (n.d.). LIFE Integrated Project "Improving Energy Efficiency in Lithuania" (LIFE IP EnerLIT). Retrieved on 10.5.2025 from** https://apva.lrv.lt/en/project-implementation/national-projects/life-integrated-project-improving-energy-efficiency-in-lithuania-life-ip-enerlit/

**European Climate Initiative. (2017). Training of Managers for Urban Redevelopment in Lithuania. Retrieved on 10.5.2025 from** https://www.euki.de/en/euki-projects/training-of-managers-for-urban-redevelopment-in-lithuania/

### 8.1.5 EUREM – European Energy Manager Training Program

**Countries: Pan-European (implemented in over 30 countries, including Germany, Austria, Czech Republic, and Slovenia)**

The European Energy Manager (EUREM) training is an internationally recognized program that certifies professionals in energy management across various sectors. While not designed exclusively for the public sector, it is increasingly attended by public sector employees—particularly those responsible for managing energy use in municipalities, public buildings, hospitals, and utilities.

EUREM is structured as a modular, practice-oriented training program, typically lasting several months and combining theoretical coursework with the development of a real-world energy efficiency project. Participants gain competencies in energy auditing, performance analysis, energy accounting, renewable integration, and economic evaluation of energy-saving measures. The training covers cross-cutting technologies such as HVAC, lighting, building envelopes, and automation, making it highly applicable to the diverse infrastructure operated by public institutions.

For public sector employees, the EUREM training offers several strategic benefits. It builds internal capacity for identifying, planning, and implementing energy efficiency projects without relying solely on external consultants. Moreover, it strengthens cross-departmental communication by introducing standardized terminology and reporting formats for energy performance. Public institutions that enrol staff in EUREM often see long-term gains in operational savings, improved compliance with EU directives (e.g., EPBD and EED), and enhanced credibility when applying for energy-related funding or grants.

Given the structured format, EU-wide certification, and proven impact, EUREM remains one of the most valuable energy management training options for public sector professionals aiming to implement robust and accountable energy-saving programs.

**Reference:**

**EUREM – European EnergyManager. (2023). About EUREM. Retrieved from** https://www.eurem.net

As these programs mature, a growing need emerges to quantitatively evaluate their contribution to actual energy savings and greenhouse gas reductions. While qualitative feedback and case-based outcomes are commonly reported, systematic methodologies for estimating and verifying the energy savings attributable to training programs remain underdeveloped.

## 8.2. Trainings related to Energy Efficiency in Public sector for Public Sector employees

The following chapter addresses this gap by proposing a structured methodology for energy savings estimation. This approach aims to establish a robust framework that links capacity-building efforts with measurable performance improvements, enabling policymakers and program managers to assess effectiveness, justify investments, and optimize future interventions.

The reviewed training programs across Europe share a common focus on equipping public sector employees with the skills and tools necessary to advance energy efficiency and climate objectives. While each initiative is tailored to national priorities, several core topics emerge consistently.

The table below summarizes the key training areas covered, along with brief descriptions of their objectives and relevance to public sector practice.

*Table 29: Overview of Training Topics in Public Sector Energy Efficiency Programs*

| Topics of trainings | Short description |
|---|---|
| Green Public Procurement (GPP) | Training for public procurement officers on integrating environmental and energy efficiency criteria into tendering processes, promoting sustainable purchasing. |
| Energy Performance Contracting (EPC) | Modules focused on structuring, managing, and monitoring performance-based energy efficiency investments in collaboration with private sector partners. |
| Strategic Energy and Climate Planning | Instruction for municipal planners and policy makers on aligning local strategies with National Energy and Climate Plans (NECPs) and EU directives. |
| Building Energy Management and Optimization | Practical training for facility managers and technical staff on monitoring, analysing, and reducing energy consumption in public buildings. |
| Digital Tools for Energy Planning | Use of advanced platforms such as Building Information Modelling (BIM) and energy accounting software for scenario analysis and planning. |
| Energy Auditing and Reporting | Certification-based training in conducting energy audits, evaluating technical solutions, and reporting in line with ISO 50001 and Energy MAP frameworks. |
| Sustainable Renovation Techniques | Guidance on implementing low-carbon and energy-efficient renovation measures in public buildings, including envelope upgrades and system retrofits. |
| Urban Redevelopment and Land-Use Planning | Training on integrated urban planning strategies that enhance energy efficiency through compact, sustainable land development. |
| Behavioral and Institutional Change | Capacity-building for driving organizational change, fostering energy-saving behaviour, and establishing cross-functional energy responsibility. |
| Peer Learning and Knowledge Exchange | Facilitated networking and mentorship components to promote collaborative learning and institutional knowledge-sharing within and across public bodies. |

The methodology developed by streamSAVE+ focus on trainings targeting the public sector and dealing with behaviour changes related to using energy. Behaviour changes related to investment decisions (e.g., adopting a new technology) are out of the scope of this methodology. streamSAVE+ therefore presents a BU methodology with indicative values that will try to overcome the difficulties of reporting energy savings due to behavioural change actions.

This methodology can be applied by all Member States, following the provided indicative values and guidance, to estimate the savings of trainings related to energy efficiency in public sector for public sector employees.

## 8.3. Calculation of final energy savings (Article 7)

*dc*

Where:

| TFES | Total final energy savings [kWh/a] |
|---|---|
| N | Number of participants [dmnl] |
| UFEC | Unitary Final Energy Consumption per tertiary sector unit (electricity or other fuels) [kWh/a] |
| | Surface area (number of square meters) [m$^2$] |
| S | Energy saving factor [%] |
| dc | Double-counting factor [%] |

Indicative calculation values for this methodology have been prepared in the following tables. Please keep in mind that these values are based on EU-wide data for tertiary sector (explicit data for public sector was not available) and will need to be adjusted to national circumstances. Indicative values are taking into account also the degree days for each represented country.

*Table 30: Indicative values for Unitary Final Energy Consumption per sqm in tertiary sector (2010-2021 average) for the target final uses*

| EU region | UFEC Energy use for space heating per sqm in tertiary sector (1) [kWh/sqm] (JRC IDEES, 2021) | UFEC Energy use for space cooling per sqm in tertiary sector (2) [kWh/sqm] (JRC IDEES, 2021) | UFEC Energy use for hot water prep. per sqm in tertiary sector (3) [kWh/sqm] (JRC IDEES, 2021) | UFEC Energy use for lighting per sqm in tertiary sector unit (4) [kWh/sqm] (JRC IDEES, 2021) | UFEC Energy use for ventilation per sqm in tertiary sector unit (5) [kWh/sqm] (JRC IDEES, 2021) |
|---|---|---|---|---|---|
| **North** (6) | 159.33 | 7.75 | 23.80 | 16.57 | 5.20 |
| **South** (7) | 159.85 | 9.09 | 25.61 | 16.06 | 4.83 |
| **West** (8) | 105.18 | 13.67 | 27.51 | 16.84 | 5.47 |

Notes:
(1) Values including energy use for space heating per sqm in tertiary sector (services and public sector);

(2) Values including energy use for space cooling per sqm in tertiary sector (services and public sector);
(3) Values including energy use for hot water preparation per sqm in tertiary sector (services and public sector);
(4) Values including energy use for lighting per sqm in tertiary sector (services and public sector);
(5) Values including energy use for ventilation per sqm in tertiary sector (services and public sector).
(6) North: Czech Republic, Denmark, Estonia, Finland, Lithuania, Latvia, Poland, Sweden, Slovakia;
(7) South: Bulgaria, Cyprus, Greece, Spain, Croatia, Hungary, Italy, Malta, Portugal, Romania, Slovenia;
(8) West: Austria, Belgium, Germany, France, Ireland, Luxembourg, Netherlands.

*Table 31: Indicative values for the Energy Savings factor (S)*

| Final use | Type of measure | Energy Savings factor (S) [%] |
|---|---|---|
| Electricity (lighting, ventilation) | Trainings related to Energy Efficiency in Public sector | 3.5% |
| Electricity and other fuels for space heating | Trainings related to Energy Efficiency in Public sector | 3.30% |
| Electricity and other fuels for cooling | Trainings related to Energy Efficiency in Public sector | 3.30% |
| Electricity and other fuels for hot water preparation | Trainings related to Energy Efficiency in Public sector | 3.30% |

*Table 32: Indicative values for the lifetime of savings in feedback and tailored advice in the residential sector*

| Lifetime of savings | [a] |
|---|---|
| Lifetime of savings | Time between two implementations |

### 8.3.1 Methodological aspects:

This methodology only accounts for savings resulting from behaviour changes related to using energy. Behaviour changes related to investment decisions (e.g., adopting a new technology) are out of the scope of this methodology. Their impact on final energy savings is reflected by the Energy saving factor (**S**). Indicative values for Energy Savings factor reflect the values used in streamSAVE project for savings related to tailored advice for citizens with feedback from energy experts. In that case the Energy Savings factor (S) amounted to 3.5% of **Unitary Final Energy Consumption** per household for measures related to electricity use (3.0% for electrical heating) and 3.6% for the use of non-electricity technologies. Hence, we propose the same estimation for indicative values for public sector. For electricity use (lighting, ventilation) 3.5% is estimated and for other uses (electricity and other fuels) 3.30% is estimated.

A set of indicative values are suggested, and their calculation and data sources are explained on the next paragraphs.

The **Unitary Final Energy Consumption per square meter in tertiary sector (UFEC)** indicators in the table represent different types of useful final energy consumption per square meter in the tertiary sector, as disaggregated in the (JRC, 2021) database. Tertiary sector includes services and public buildings such as offices, schools, hospitals, and government facilities.

The first **UFEC** indicator, **energy use for space heating**, measures the average energy consumed per square meter to heat indoor spaces. This reflects the demand for thermal comfort during colder months and depends on factors such as outdoor temperature, building insulation, and heating system efficiency.

The second **UFEC** indicator, **energy use for space cooling**, refers to the average energy consumption per square meter required for cooling indoor spaces. It includes systems such as air conditioning and reflects the energy needed to maintain comfort during warmer periods.

The third **UFEC** indicator, **energy use for hot water preparation**, captures the average energy demand per square meter used to heat water for sanitary purposes, such as washing and cleaning. An average estimation was used since this demand varies depending on the function of the building for example, healthcare facilities may have higher needs than standard offices.

The fourth **UFEC** indicator focuses on **energy use for lighting**, measuring how much energy is consumed per square meter for artificial lighting. This is influenced by building design, availability of natural daylight, occupancy patterns, and the efficiency of lighting systems such as LED or fluorescent fixtures.

The fifth and final **UFEC** indicator concerns **energy use for ventilation**. It measures the energy consumed per square meter to operate mechanical ventilation systems, which ensure indoor air quality by exchanging or filtering air. This consumption tends to be more constant in buildings with stringent air quality requirements, like hospitals or large office complexes.

The UFEC indicators in the table are presented according to three EU regional groupings, namely North, South, and West. These regions categorize countries with similar climatic and geographic characteristics to provide a clearer comparison of energy consumption patterns in the tertiary sector.

The North region includes Czech Republic, Denmark, Estonia, Finland, Lithuania, Latvia, Poland, Sweden, and Slovakia.

The South region comprises Bulgaria, Cyprus, Greece, Spain, Croatia, Hungary, Italy, Malta, Portugal, Romania, and Slovenia.

The West region consists of Austria, Belgium, Germany, France, Ireland, Luxembourg, and the Netherlands.

There is no indicative value for the **Double-counting factor (dc)** since it can be disregarded when a measure implies direct monitoring of the participants (e.g., a training scheme), which is able to detect directly who has already been targeted.

It is difficult to suggest an indicative value of the **Lifetime of savings** on measures targeting behavioural changes. The existing scientific literature is unable to provide a solid suggestion for it. Member States may also use other values, but in any case, must describe in their integrated NECP the lifetimes applied per type of measure and how they are calculated or what they are based on.

### 8.3.2 Data sources for indicative calculation values:

The source of the indicative values for the **Unitary Final Energy Consumption (UFEC)** was the JRC IDEES database (JRC, 2024). The final energy consumption per sqm in tertiary sector (2010-2021 average) for the target final uses (space heating, space cooling, hot water preparation, lighting and ventilation) was collected from the IDEES dataset.

The indicative values for the **Energy Savings factor (S)** are aligned with the feedback studies that were analyzed in the scope of streamSAVE project (https://streamsave.eu/).

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# 9. Consumption reduction calculation for small-scale renewable heating technologies

This priority action focusses on small systems for central heating and hot water preparation from renewable energy produced on-site. The proposed calculating approach focusses on the energy savings that can be achieved by changing the heat source and installing electricity heat pump or biomass boilers in public buildings. There are two main types of heat pumps widely used: air source heat pumps and ground source heat pumps. These systems capture heat from the air or ground outside the building and concentrate it for use indoors. Small-scale biomass-based boilers are typically powered by firewood or pellets.

The developed methodology for calculating energy savings is applicable to both of these technologies and focusses primarily on small-scale sources (e.g. under 70 kW according to Labeling Scope and EPREL database or under 400 kW according to Ecodesign scope), which are commonly used for thermal comfort and the production of domestic hot water in public buildings such as administrative buildings, civil buildings, schools, hospitals, etc.

Depending on the size of the public building being heated, these can be a single source of heat or a series of units connected in cascade cascade, especially in the case of heat pumps. These can add up to a quite substantial energy output. As a consequence, it is important to mention as a side note that according to the revised EU Energy Performance of Buildings Directive (EPBD) (EU/2024/1275), non-residential buildings with an effective rated output exceeding 290 kW in heating, air-conditioning, and ventilation systems must be equipped with building automation and control systems (BACS) by the end of 2024, and with a rated output exceeding 70 kW by the end of 2029.

To ensure a decarbonised heating and cooling sector, it is critical to encourage the replacement of old and inefficient heating installations with highly efficient heating units. The EU's Ecodesign and Energy Labelling Act aims to improve environmental performance while also establishing minimum necessary requirements for product energy efficiency. It is worth noting that compared to the minimum requirements under Ecodesign, efficiency, especially for heat pumps, has advanced significantly.

## 9.1. Calculation of energy consumption reduction (Article 5)

The formula below can be used to calculate the total energy savings resulting from changing the heating source to a new electric heat pump or biomass boiler. This formula compares a reference heating system's final energy consumption (calculated as energy demand divided by energy system efficiency) for space heating and domestic hot water to a newly installed small-scale renewable energy system (RES). In particular, the floor area of a typically heated building or dwelling is multiplied by the final energy demand for space heating (SHD) and hot water preparation (HWD), as well as the heating system's conversion efficiency before ($\mathrm{eff}_{\mathrm{baseline}}$) and after ($\mathrm{eff}_{\mathrm{action}}$) the action is implemented. Furthermore, the final energy consumption is multiplied by a factor that accounts for behavioural aspects ($\mathrm{f}_{\mathrm{BEH}}$) associated with increases in energy consumption following the implementation of the new heat source, as well as a climate correction factor ($\mathrm{c}_{\mathrm{fx}}$) for the various climate conditions under which the actions are implemented.

### 9.1.1 Calculation formula

The final energy consumption reductions can be calculated with the following equation:

$$\begin{aligned} TFES = A \times \Bigg[ & SHD \times \left(\frac{1}{eff_{SHDbaseline}} - \frac{1}{eff_{SHDaction}}\right) \\ & + HWD \times \left(\frac{1}{eff_{HWDbaseline}} - \frac{1}{eff_{HWDaction}}\right)\Bigg] \times f_{BEH} \end{aligned}$$

### 9.1.2 Indicative values

Based on averages across EU Member States, indicative calculation values for this methodology have been developed, taking into account the type and size of components for a typical installation. However, there are several limits to this approach. This technology is only applicable to heating and hot water preparation using electrically driven heat pumps or biomass boiler. This methodology cannot quantify savings from the usage of reversible heat pumps, which are frequently used for cooling.

The proposed numbers are based on EU-wide data and need to be adjusted to national circumstances when available.

It should also be pointed out that the adoption of this action does not reduce space heating and hot water demand because improvements to the building envelope as well as changes in hot water usage are not considered.

The inidicative values for the **energy demand for the space heating** (SHD) as well as the **hot water demand** (HWD) per unit floor area [kWh/m²a] are based on the Integrated Database of the European Energy System (IDEES) database (Rózsai at al, 2024). In the IDEES, JRC gathers essential statistical information relevant to the energy sector and complements it with processed data that further decomposes energy usage. The full JRC-IDEES output is available to the public, and it compiles energy system statistics from 2000 to 2021. For our estimation values, we selected datasets 2010-2021 to reflect the most recent data on the one hand, while also having a long enough average period of values to normalise for yearly changes in energy consumption.  These values are best to use in combination with efficiencies presented in Table 34: Conversion efficiencies of baseline heating systems.

Table below provides calculated average of data from 2010 to 2021 of the energy demand per surface area based on data from the service dataset (SER_hh_tess) . The data are averaged over three climatic zones devide as in Van Tichelen et al., 2020 and includes the following countries: North (CZ, DK, EE, FI, LT, LV, PL, SE, SK), South (BG, CY, EL, ES, HR, HU, IT, MT, PT, RO, SI), West (AT, BE, DE, FR, IE, LU, NL).

*Table 33: Energy demand per surface area for heating and hot water*

| Climatic zone | SHD [kWh/m²a] | HWD [kWh/m²a] |
|---|---|---|
| West | 119.87 | 18.82 |
| North | 116.25 | 17.14 |
| South | 83.82 | 17.99 |

For the **conversion efficiencies of reference heating systems** (**$eff_{baseline}$**) is preferable to use actual efficiencies. These are available in the energy certification of the building. If certification hasn't been completed yet, the option to look up the baseline technology's yearly consumption of energy in the EPREL database (https://eprel.ec.europa.eu/screen/product/spaceheaters).  The heat distribution system's efficiency should also be taken into account, however, efficiencies at nominal load of the heating unit can be used as a good estimate if seasonal efficiencies are not known. The energy consumption of the technologies that were in use before to the action's adoption should be weighed against the (seasonal) efficiencies.  Additionally, the average efficiency of all units should be used when multiple units are used to heat the building. The age of the baseline heating source will also affect its efficiency. However, we can presume that the focus will be primarily to older (lower efficiency) sources.

When the heat source is unknown, the user can use average indicative values of the efficiencies weighted over the energy consumption of the technologies used. These values are based on an average of heating and hot water system efficiencies taken from the IDEES database (JRC, 2024) from “SER_hh_eff” datasets for each Member state. Otherwise, the efficiency for each individual heating system is indicated.  The conversion efficiencies of the baseline space heating are taken from the IDEES database, referring to the average EU27 System efficiency indicator of total stock for the services (SER_hh_eff) in 2021 over all EU member states as it is the baseline year for the savings calculation under the Art 5 of EED.

*Table 34: Conversion efficiencies of baseline heating systems*

| Heat source | Conversion factor ($eff_{baseline}$) |
|---|---|
| Solids | 0.679 |
| Liquified petroleum gas (LPG) | 0.721 |
| Gas/Diesel oil incl. biofuels (GDO) | 0.651 |
| Gases incl. biogas | 0.729 |
| Biomass and wastes | 0.558 |
| Geothermal energy | 0.854 |
| Conventional electric heating | 0.801 |
| Advanced electric heating | 3.207 |
| Weighted value for heating ($eff_{SHDbaseline}$) | 0.901 |
| Weighted value for hot water ($eff_{HWDbaseline}$) | 0.773 |

The following indicative values can be used to define **conversion efficiency of the new source of heat** (**$eff_{action}$**). For heat pumps, the indicative weighted values of efficiencies for space heating are calculated in a similar way as values "baseline" but using "SER_hh_eff_in" datasets (JRC, 2024) with data for new and renovated buildings. Values for 2021 are used as the most up-to-date values that will be closest to current requirements and trends. The value for water demand in case of electrically driven heat pumps is derived from the Techno-economic assumptions of the PRIMES model (E3-Model, 2024).

The conversion efficiency of biomass boilers is the efficiency of the best technology available on the market. It was obtained from the ANNEX X of the Commission Recommendation on transposing the energy savings obligations under the Energy Efficiency Directive (European Commission, 2019).

In the case of a biomass boiler, it is possible to use one efficiency for both heating and water heating, but in the case of a heat pump it is necessary to take the efficiencies separately for heating and hot water preparation, or to use the aggregated seasonal efficiency for the whole system (heat pumps can be often combined with a bivalent source) .

*Table 35: Conversion efficiency factors for newly installed heat sources*

| **Conversion efficiency of Heat pumps** | |
|---|---|
| Heat pump for space heating | 3.56 |
| Heat pump for hot water | 2.4 |
| **Conversion efficiency of Biomass boilers** | 0.920 |

The formula also includes the possibility of using a **factor to account for behavioural effects** (**$f_{BEH}$**). However, it is quite unlikely that the behaviour of public building users will change with installation of the new heating source. Most of the time, users are even unaware of the building's heat source. On the other hand, when implemented properly energy-saving policy measures or interventions, they can change users' behaviour to reduce energy use. It is highly probable that the new source will contain features to monitor energy usage or even demand control systems that can lower energy use in the building.

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# List of figures

# List of tables

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