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Background report

# Update of the life cycle inventories for the electricity production from natural gas


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(Natural gas power plants at night, photo in the public domain)

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# Abbreviations

CENTREL *Central European Electricity Network*
CHP *Combined Heat and Power*
ENTSO-E *European Network of Transmission System Operators for Electricity*
ERCOT *Electric Reliability Council of Texas, Electric Reliability Council of Texas*
FRCC *Florida Reliability Coordinating Council*
LCA *Life cycle assessment*
LCI *Life Cycle Inventory*
MRO *Midwest Reliability Organization*
NORDEL *NORDEL was a body for co-operation between the Scandinavian and Northern European transmission system operators in Finland, Norway, Sweden, the eastern regions of Denmark (Zealand, Lolland and Falster)*
NPCC *Northeast Power Coordinating Council*
RFC *ReliabilityFirst Corporation*
SERC SERC Reliability Corporation
SPP *Southwest Power Pool*
UCTE *Union for the Co-ordination of Transmission of Electricity*
WECC *Western Electricity Coordinating Council*

# 1 Introduction

Life cycle assessment (LCA) has been an important tool to assess the environmental performance of products, materials or entrepreneurial activities for decades. LCAs are based on knowledge of, among other things, material properties and physical or chemical processes, which have been curated by the LCA community in large background databases. To keep these databases up-to-date, reviewing existing processes is an important undertaking, especially for processes that feed into many product systems. Electricity production processes are among the most relevant in the LCA ecosystem.

Within the energy sector, especially natural gas power generation, is of high importance for LCA studies as part of transition technology that can lower emissions and environmental impacts in comparison to coal power generation but may still contribute to a wide range of environmental impact categories. The underlying Life Cycle Inventory (LCI) data of the supply chain for electricity generation from natural gas in the UVEK:2018 database (KBOB et al., 2018) was largely based on raw data from the year 2007 and before. For example, some of the key emission data was based on reports from the 1980s and 1990s (Faist-Emmenegger et al., 2007), while the data on the natural gas supply mixes has been updated in recent years (ESU Services, 2022) but lacked integration with natural gas power generation. Data on the co-generation of heat and power was missing for many regions of the world despite its prevalence. Efficiencies in natural gas-based power generation have improved drastically due to the widespread use of combined cycle power plants that can reach electrical efficiencies of more than 60 %. Airborne pollutant emissions from natural gas are inconsistent between regions. Various countries have emerged as main user of natural gas in their respective power sectors. Newer data on various aspects related to gas-based electricity production would be readily available.

The situation described above influences the environmental impact assessment results within the BAFU database directly from electricity generation from natural gas but also for many processes that use gas-based electricity or heat, because:

- The natural gas supply mix can have a higher contribution especially to climate change impacts than previously estimated as new data suggests regionally higher methane leakage in extraction and transport.
- The emission profile of the natural gas combustion process (directly based on the mass of pollutants that can be emitted during natural gas combustion) has changed, thus also changing the corresponding impact assessment results.
- The efficiency of power plants and, correspondingly, the quantity of fuel burned to produce 1 kWh of electricity, and thus its relative emissions, have changed over time.
- The energy-efficient co-generation of heat and power was largely missing in the UVEK database, thus making the emissions per kWh of electricity appear too high.

Since the development of inventories in 2007, environmental regulation in most countries has become substantially stricter, and novel technologies have been introduced to abate emissions (e.g. low NOx burners or selective catalytic reduction). The LCI models for natural gas power generation therefore needed to be updated to reflect the developments since then.
The Federal Office for the Environment (FOEN) commissioned an update of the inventory data for the production of electricity from natural gas and their process chains in the UVEK:2023 database. This update provides the upcoming version of the UVEK:2024 database with updated inventories for these types of electricity productions. Natural gas power generation and heat supply is modelled for more than 20 different countries and regions. Other emissions and inputs like the natural gas power plant construction,

auxiliary materials for the operation of the power plants and others remain unchanged as described in Faist Emmenegger et al. (2007). The scope and structure of the update is visualized in Figure 1.

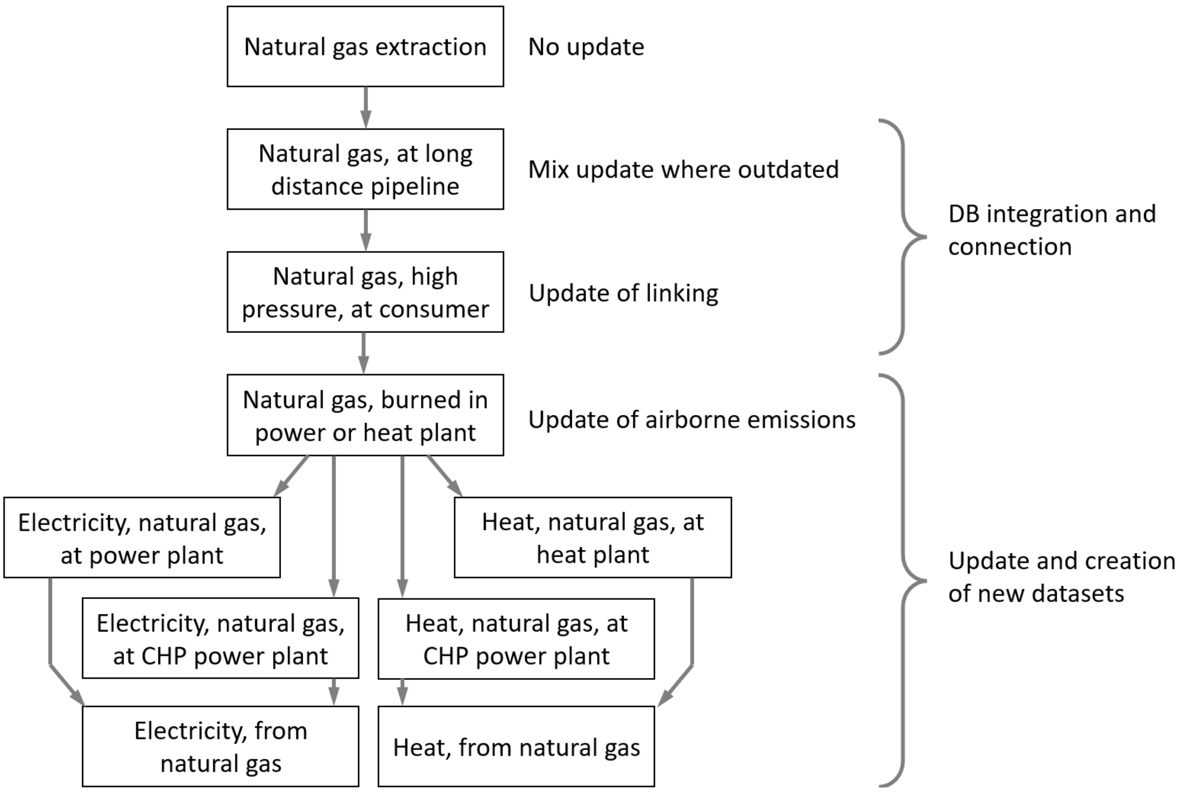


**Figure 1: General structure of the natural gas energy supply in the BAFU database after the update.**

The LCIs for the electricity generation from natural gas are made freely accessible to anyone (open access) with a Creative Commons License attributional.

The update follows the most recent finalized version of the UVEK guidelines for LCI data quality (R. Frischknecht et al., 2007). In the UVEK:2023 LCI database, the different electricity generation technologies are modelled as well as regional electricity market mixes. Gas-fired power generation is currently modelled for many individual countries (e.g. within Europe) and for specific regions (e.g. the NERC regions within the US), split into datasets for heat from fuel combustion (e.g. "Natural gas, burned in power plant") and electricity supply from heat (e.g. "Electricity, natural gas, at power plant"). Additional datasets for specific gas-fired power plants and power plant types also exist within the database (e.g. for the "Jakobsberg" gas power plant) but are largely unused by other datasets in the database and are also not integrated into electricity mixes.

The basic modelling principles of the existing data have been described in an ecoinvent report (Faist-Emmenegger et al., 2007). The data basis at that time was from the 1990s and the early 2000s. Since then, several modelling principles have evolved in the field of LCA, rendering old approaches like the missing allocation of emissions and fuel inputs for gas-based energy supply outdated. New data has become available (e.g. on emission intensities for natural gas combustion) and the data priorities in the BAFU database have changed in comparison to when the datasets were created (e.g. by making no specific datasets for the sub-regions in the US necessary). In addition, gas-based power supply may have changed in importance in several regions, making some of the existing datasets obsolete while others may be missing.

# 2 Goal and Scope

## 2.1 Validation process

All inventories were validated by the external reviewer René Itten (ZHAW Zürcher Hochschule für Angewandte Wissenschaften) according to the BAFU DQRv2 (Rolf Frischknecht, 2023). The following criteria were reviewed:

- Completeness of the documentation: All investigated datasets should be described in the report, and all necessary meta information and flow data should be available for each dataset.
- Consistency with the quality guidelines: It is checked whether the unit processes have been modelled according to the ecoinvent quality guidelines (R. Frischknecht et al., 2007). The quality guidelines cover for example the estimation of transport distances or the calculation of energy demands in the inventory.
- Plausibility check of the LCI data: Selected input and output flows are controlled for plausibility.
- Completeness of inputs and outputs: The completeness of flows is based on the environmental and technical knowledge of the reviewing person. Reviewers are not necessarily technical experts of the processes reviewed. If necessary, they were supported by the person responsible for the report.
- Mathematical correctness of calculations: Selected inputs and outputs are controlled in view of mathematical correctness.

This review procedure is not comparable to the peer review specified in the ISO standards. The validation report is attached in the annex.

## 2.2 Updated and New Datasets

This section provides an overview of all LCI datasets updated within this revision. Section 3.1 lists all the updated LCI datasets for natural gas combustion. Section 3.2 list all the LCI data for electricity generation and heat supply from natural gas. A comprehensive list of replacement and obsolete datasets is also shown in chapter 3.3. Furthermore, the annex contains meta data tables. There is also a digital version of the data tables available as ODS file (OASIS Open Document Format table).
On behalf of the FOEN, the LCIs of gas-fired energy supply within the BAFU:2024 LCI database were updated. Naturally, this was not possible for all processes, either because of lack of new data or budget limitations. This report provides an overview of the updates and additions to the data involved. Thus, the reader should have a full overview about the datasets as they are now provided for the current BAFU database.

The following list shows the work packages of the project:

1. Update of emissions for gas-based energy supply
2. Update of efficiencies for gas-based energy supply
3. Connection to recently updated gas supply chain data

4. Revision of basic modelling principles (allocation, structure)
5. Revision of coverage (based on current relevance)
6. Update of uncertainty data and documentation
7. Integration, testing and final review of datasets

This update aims at creating high-quality LCI datasets that improve the reliability of LCAs based on the BAFU LCI database.

Basic Life Cycle Inventories:
LCIs will be updated or newly created for the following countries/regions (Total 37):

- Each of the EU-27 countries[1]
- Switzerland
- Russia
- China
- India
- Japan
- Malaysia
- Taiwan
- South Korea
- Middle East
- USA
- ENTSO-E (ENTSO-E, 2024)

## 2.3 System boundaries

### 2.3.1 Allocation of by-products

The allocation procedure for electricity and heat generation is based on exergy as described in detail in (Heck, 2007) and assumes an exergy content of 30 % for the co-generated heat, which roughly corresponds to exported low pressure steam at around 140 - 150 °C. This temperature level is the same as in the coal update, despite possible differences in the steam conditions coming from these different types of power plants. It is meant to reflect a compromise between exported heat for domestic heating purposes (frequently in the temperature range of 80 – 130 °C, but in some countries like Russia also much higher) and industrial steam requirements (typically in the range of 150 – 400 °C). This compromise is necessary, as more specific exported heat data is not available.

### 2.3.2 Natural gas supply chain

The renewal of the inventories for natural gas production was not part of this study. Therefore, the inventory “Natural gas, high pressure, at consumer {} U” from the database was used for the respective countries. If the inventory of a specific country was not available in the database, an approximation had to be made with another country or region. The following chapter documents which approximations were used.

[1] Cyprus could not be included, as the country was lacking current data.

#### 2.3.2.1 Europe

Table 1 shows a list of European countries. It is noted in the table whether an inventory of a specific country was available or whether the country had to be approximated with the inventory "Natural gas, high pressure, at consumer {RER} U".

**Table 1: Overview of the availability of the inventories of the specific countries.**

| Country | Inventory of the land was available | Approximated via RER |
|---|---|---|
| Austria | X | |
| Belgium | X | |
| Bulgaria | | X |
| Croatia | | X |
| Czech Republic | X | |
| Denmark | X | |
| Estonia | | X |
| Finland | X | |
| France | X | |
| Germany | X | |
| Greece | X | |
| Hungary | X | |
| Ireland | X | |
| Italy | X | |
| Latvia | | X |
| Lithuania | | X |
| Luxembourg | | X |
| Malta | | X |
| Netherlands | X | |
| Poland | | X |
| Portugal | | X |
| Romania | | X |
| Slovakia | X | |
| Slovenia | | X |
| Spain | X | |
| Sweden | X | |
| United Kingdom | X | |
| Switzerland | X | |
| ENTSO-E | | X |

### 2.3.2.2 Asia

For the Asia region, only Japan was available as an inventory in the database and there was no regional average. There are three different types of natural gas supply in the countries of the Asian region:

- Domestic production
- Import via pipelines
- Import in the form of liquefied natural gas (LNG)

Table 2 shows the countries for which the composition of the three natural gas supplies was assumed (International Energy Agency IEA, 2021). The inventory "Natural gas, high pressure, at consumer {JP} U" was used for imports in the form of liquefied natural gas, as Japan ensures almost 100 % of its natural gas supply with liquefied natural gas. The inventory "Natural gas, high pressure, at consumer {RER} U" was used as an approximation for domestic production and import via pipelines.

The countries in the Middle East region, such as Iran, Qatar and Saudi Arabia, are all natural gas exporting countries. They produce more natural gas than is needed in their own country. Therefore, 100 % domestic production is assumed for the Middle East region.

**Table 2: Overview of the share of natural gas supply for countries in the Asia region.**

| Country | Share domestic production | Share import pipeline | Share import LNG |
|---|---|---|---|
| Russia | 100 % | | |
| China | 57 % | 18 % | 25 % |
| India | 50 % | | 50 % |
| Japan | | | 100 % |
| Malaysia | 81 % | | 19 % |
| Taiwan | | | 100 % |
| South Korea | | | 100 % |
| Region Middle East (RME) | 100 % | | |

#### 2.3.2.3 USA

The inventory "Natural gas, at consumer {US} U" was available for the USA region, but not as "high pressure" at consumer, compared to the European countries, where high pressure inventories were available.

## 2.4 Data collection and representativeness

The data collection in this natural gas generation update project prioritizes different types of data for the different parameters that are being updated. Overall, regionally specific data sources are preferred over generic ones, thus creating a hierarchy of available data. Key data sources are the country-level statistics of the European Union (European Commission EC, 2023) and the International Energy (International Energy Agency IEA, 2023a, 2023b). These data sources are primarily used to calculate production volumes, which are needed for electricity and heat generation from power plants (for production volumes and allocation between co-products), as well as the necessary fuel inputs (to calculate fuel efficiencies per technology type).

For OECD countries, these data sources are assumed to be of good quality as they are aligned with the national data collection procedures of the national statistical offices and hence the data is not subject to major data transformation or interpretation problems. More problems have been documented with non-OECD countries and especially some main economies in Asia. For example, the Chinese statistical offices also collect data on fossil power generation, but the classification of data does not follow the same approach as in OECD countries and hence, all types of combustion data is reported in aggregated form. For this country, and similar cases around the world, the data quality may be lower as the IEA had to make supplementary assumptions in order to disaggregate fuel types. Using the national statistics of such countries directly would not have allowed to prevent such issues, but instead would have forced to make own assumptions. For consistency reasons, it was therefore assumed that the direct use of elsewhere reported disaggregated data delivered the best possible outcome.

Overall, this type of national data is generally subject to an extensive amount of consistency checks and is furthermore widely used and tested in numerous application scenarios, so there is a rather high trust in the data representativeness. At the same time, there are no alternative data sources of similar coverage and level of detail.

Bottom-up measurements are the preferred data source for emission intensities of most airborne pollutants. In case of carbon dioxide, methane or carbon monoxide emission intensities, the standardized average emission factors of IPCC (IPCC, 2021) are used, which are based on measurements and carbon balances per fuel type. For key air pollutants like $SO_2$, $NO_x$, PM (including $PM_{>10}$, $PM_{10-2.5}$, and $PM_{2.5}$), there are plant-level measurements of the major installations per country. And finally, other airborne pollutants for natural gas power and heat plants are based on the recommended average emission factors of the European Union (EMEP/EEA, 2023)(EMEP/EEA, 2019), which have also been derived from several bottom-up emission measurement campaigns.

The recent plant-specific bottom-up emission measurements are most specific in terms of regional and temporal appropriateness for the intended scope of this update project, but typically only cover a part of the major installations in each country. Not all of the pollutants are necessarily included, and especially smaller sites or emission amounts below individual national reporting thresholds may be somewhat under-represented. Furthermore, differences in substance nomenclature or measurement techniques can also present challenges in terms of comparability. Implicit extrapolations fill data gaps.

Emission factor approaches, on the other hand, may lead to more robust results, especially when only few measurements are available, or the pollutant emissions largely result from material balances. At the same time, they are generally not available at the same temporal and spatial resolution of the more detailed bottom-up measurements per plant. As the trace elements are used from the most recent version of EMEP/EEA guidebooks, it is assumed that they can still be considered appropriate for the current updates where comprehensive recent measurements are lacking. To some extent, individual plants may report some trace elements (for example in the European Union), but these are assumed to be too scattered and hence their representativeness is unclear (e.g. do only major emitters report?), so these have not been selected as data source for robustness reasons. The previous approach of the natural gas power datasets in the UVEK datasets was based on theoretical considerations, mass balances and weak assumptions instead of emission measurements, so we assume that the current approach leads to more reliable results despite less differentiation between emitting regions.

Several aspects of the BAFU natural gas power and heat datasets are taken over from previous versions of the UVEK database as their update is outside the scope of the current project. Data quality and representativeness of such data is reported in detail in the old documentation (Faist-Emmenegger et al., 2007), but some inconsistencies are created in the current update due its incremental nature.

The general approach closely resembles the one for the recent coal power update of the BAFU database.

## 2.5 LCI process data

The data used for this update of the electricity production processes was collected from the respective plants. All data is provided as unit process raw data in the EcoSpold v1 format (unit process in SimaPro) as well as openLCA JSON format.

## 2.6 Uncertainties and meta data

Uncertainties have been added on a per-flow resolution. For efficiency-related dataset (fuel input per heat or electricity output), the previously existing datasets have been adapted. For heat and supply mixes, the uncertainty was set to zero to avoid double counting of uncertainties in comparison to earlier database versions. For environmental exchanges, the data source quality has been evaluated in relation to the best possible quality for the intended use. Thus, with the help of the existing pedigree uncertainty classification approach, a classification of available data quality could be made, which then subsequently allowed to calculated flow-specific uncertainties. This follows the approach that has been used in the BAFU database in the past and is compliant with the latest data quality requirements.
Meta data of all the datasets has been updated or added in line with the existing datasets but reflects their most recent changes. Key meta data is listed in tables A1 to A7 in the appendix of this document.

# 3 Life cycle inventories

## 3.1 “burned in” datasets

The datasets called "natural gas, burned in power plant or heat plant" contain primarily the direct emissions of the combustion process into the environment per amount of fuel consumed as well as some infrastructure-related technosphere exchanges. Only the direct emissions were updated, while the other exchanges we kept as they were. As a result, only the emission data update is described in the following paragraphs. As the infrastructure-related data is generic rather than region specific within the UVEK database, the existing values could even be taken over for newly created natural gas combustion datasets.

For the direct emissions, a tiered approach was followed. Emission of greenhouse gases $CO_2$, $CH_4$ and $N_2O$ was adapted from the IPCC guidelines (IPCC, 2021), thus leading to harmonization across combustion datasets. That is considered a reasonable choice as emission uncertainty ranges are rather low according to the IPCC, whereas upstream emissions (during extraction, processing and transportation) as well as the efficiencies differ strongly per region, and thus are assumed to represent the main drivers of differences in climate change impacts.

For emission of nitrogen oxides ($NO_x$), sulphur dioxide ($SO_2$) and particulate matter ($PM_{>10}$, $PM_{10\text{-}2.5}$, and $PM_{2.5}$) it was attempted to retrieve recent measured or reported data per region as these are considered to be key air pollutants coming from natural gas combustion that cause human health impacts. Such data reports were available for European countries from European Commission (International Energy Agency IEA, 2023a, 2023b) and EEA (EMEP/EEA, 2023), while such data was available for the US from EPA (EMEP/EEA, 2023).

For each region covered by these data sources, total reported emissions from natural gas combustion were divided by fuel input to derive emission factors per fuel input that could then be directly implemented in the respective datasets. Instead of the different size classes of PM, the European data reported total "dust" emissions. However, it is clear from data sources such as EMEP/EEA (2023) that this corresponds to PM2.5 emissions within Europe, while other size classes are zero. This has been the disaggregation principle that was applied to dust emissions.

These emission factors were calculated as fuel input-weighted averages to reflect the different size classes and utilization levels of the plants that reported such emissions. Within Europe, such data covers all large combustion installations, while smaller units are not covered and may introduce a certain bias in the data. The US data, in contrast, has reported emissions even for much smaller units, but with a simpler approach (emission estimates instead of measurements) and without covering combustion boilers for heat plants. Thus, the bias in the US data may deviate from the bias in the European data.

As numerous power- or heat plants co-combust different types of fuel, several units with major shares of other fuels had to neglected. That is because especially the combustion of solid fuels (like coal, waste or biomass) as well as liquid fuels (like oil) have substantially different emission profiles due to different combustion profiles, technologies in use and material compositions.

For the countries outside Europe, it was also attempted to retrieve reported emission intensity data of these key pollutants. For Russia, for example, different kinds of older company reporting documents were found that also revealed emission intensities of these key pollutants, but the plausibility of these results seemed doubtful in comparison to the other measured emissions that were known. A possible cause might be co-combustion of heavy or residual fuel oil at these plants, that could not be distinguished in detail but may have increased the emission intensities beyond levels typically found at natural gas power plants.

For the Middle East, only very few plants reported their emission levels, and these were rather low as these corresponded to very new installations. Satellite imagery for example for $NO_x$ emission suggest, though, that $NO_x$ emissions are rather high in the area, especially in countries such as Iran, where no emission intensity data seemed to be available. In order to not substantially underestimate emissions in this region, the rather low emission factors were not used.

Japan has rather detailed records of many types of pollutant releases within its Pollutant Release and Transfer Register (PRTR), but $NO_x$, $SO_2$ and PM are not among them. Some individual, older data points for NOx emissions from natural gas combustion in Japan exist in scientific literature, but their representativeness was unclear, especially in light of the modern gas power plants existing in Japan. Thus, guidance from Japanese LCI experts was sought, but it became clear that even in the Japanese IDEA LCI database, generic estimates for such emission intensities had to be used. Thus, the few available data points related to Japanese $NO_x$ combustion in natural gas power plants were also not used.

For all other countries, representative emission intensity data also appeared to be unavailable. For such cases, as well as other air pollutants, in addition to data gaps, a regional, technology-specific approach was used. To that end, the combustion type was calculated by assuming that natural gas combustion for pure heat supply was coming from boilers, while the combustion in power plants was disaggregated by the national technology shares in terms of generating capacity for the three technology types boilers, gas turbines, and internal combustion engines. Tier 2 technology-specific emission factors for these technologies were available from EEA (2023), while the installed and operational capacity for these technologies was available from S&P Global (2024). As the latter data source did not cover Russian capacity data, additionally S&P Global (2023) had to be used for this specific case. Where there was a gap for tier 2 emission factor data, tier 1 emission factors were used instead.

After calculating the ratios of these technologies per country, the emission factors were calculated as linear combinations of the EEA (2023) values. The resulting emission factors for $NO_x$, $SO_2$ and $PM_{2.5}$, together with the measured or reported data where available, are shown in Figure 2 to Figure 4.

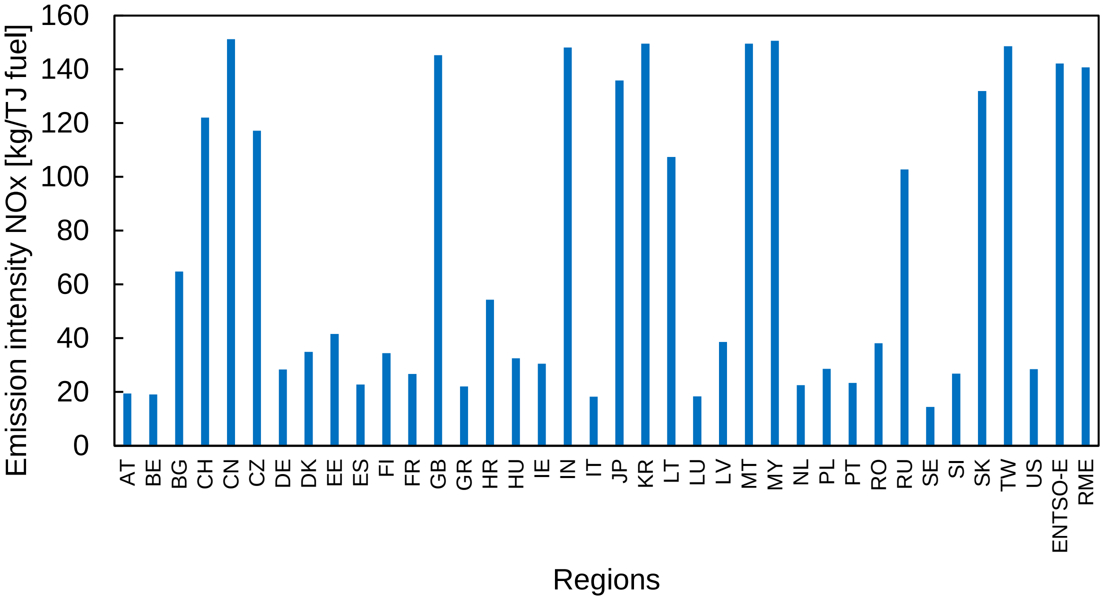


**Figure 2: Emission intensities of $NO_x$ per MJ fuel in "natural gas, burned in heat or power plant" dataset per region.**

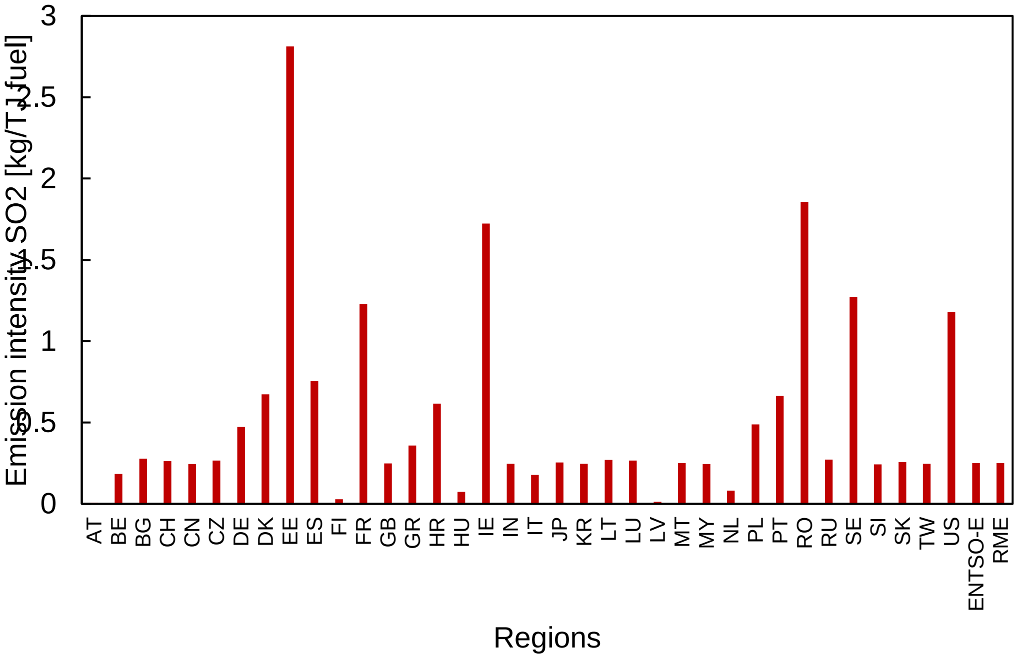


**Figure 3: Emission intensities of $SO_2$ per MJ fuel in "natural gas, burned in heat or power plant" dataset per region.**

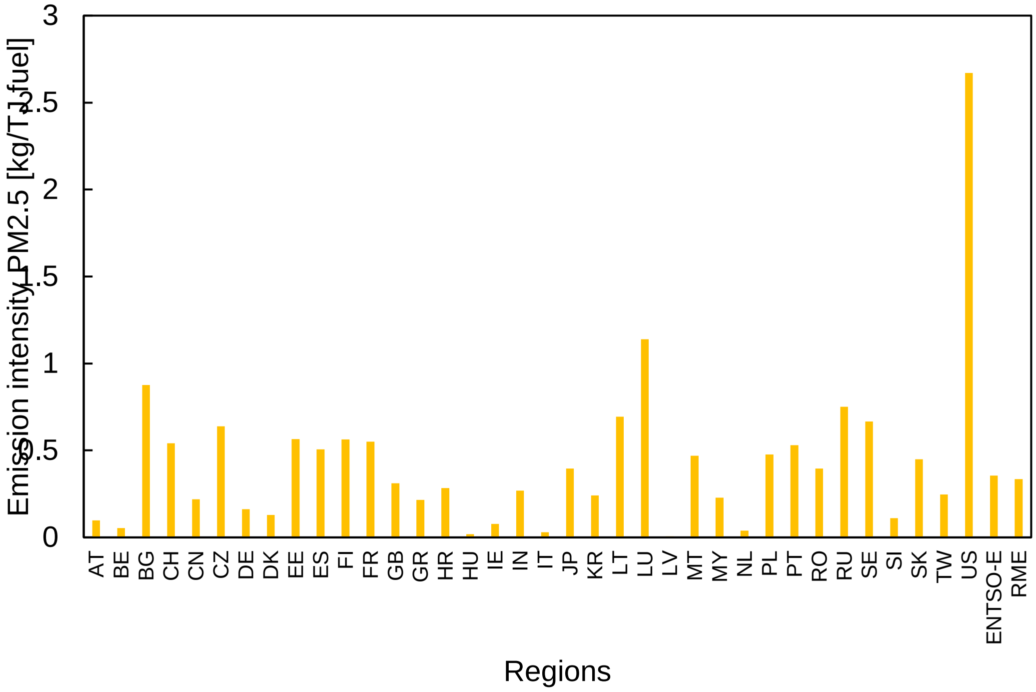


**Figure 4: Emission intensities of $PM_{2.5}$ per MJ fuel in "natural gas, burned in heat or power plant" dataset per region.**

#### 3.1.1.1 Natural gas combustion coverage

The update for natural gas combustion datasets includes a total of 37 datasets as shown in Table 3.

**Table 3: Natural gas combustion datasets covered by this update.**

| Natural gas combustion dataset |
|---|
| Natural gas, burned in power plant or heat plant/AT U |
| Natural gas, burned in power plant or heat plant/BE U |
| Natural gas, burned in power plant or heat plant/BG U |
| Natural gas, burned in power plant or heat plant/CH U |
| Natural gas, burned in power plant or heat plant/CN U |
| Natural gas, burned in power plant or heat plant/CZ U |
| Natural gas, burned in power plant or heat plant/DE U |
| Natural gas, burned in power plant or heat plant/DK U |
| Natural gas, burned in power plant or heat plant/EE U |
| Natural gas, burned in power plant or heat plant/ENTSO-E U |
| Natural gas, burned in power plant or heat plant/ES U |
| Natural gas, burned in power plant or heat plant/FI U |
| Natural gas, burned in power plant or heat plant/FR U |
| Natural gas, burned in power plant or heat plant/GB U |
| Natural gas, burned in power plant or heat plant/GR U |
| Natural gas, burned in power plant or heat plant/HR U |
| Natural gas, burned in power plant or heat plant/HU U |
| Natural gas, burned in power plant or heat plant/IE U |
| Natural gas, burned in power plant or heat plant/IN U |
| Natural gas, burned in power plant or heat plant/IT U |
| Natural gas, burned in power plant or heat plant/JP U |
| Natural gas, burned in power plant or heat plant/KR U |
| Natural gas, burned in power plant or heat plant/LT U |
| Natural gas, burned in power plant or heat plant/LU U |
| Natural gas, burned in power plant or heat plant/LV U |
| Natural gas, burned in power plant or heat plant/MT U |
| Natural gas, burned in power plant or heat plant/MY U |
| Natural gas, burned in power plant or heat plant/NL U |
| Natural gas, burned in power plant or heat plant/PL U |
| Natural gas, burned in power plant or heat plant/PT U |
| Natural gas, burned in power plant or heat plant/RME U |
| Natural gas, burned in power plant or heat plant/RO U |
| Natural gas, burned in power plant or heat plant/SE U |
| Natural gas, burned in power plant or heat plant/SI U |
| Natural gas, burned in power plant or heat plant/SK U |
| Natural gas, burned in power plant or heat plant/TW U |
| Natural gas, burned in power plant or heat plant/US U |

## 3.2 Electricity and heat generation

Electricity and heat generation datasets are named “Electricity, [...] at power plant”, “Electricity, [...] at CHP power plant”, “Heat, [...] at CHP power plant” or “Heat, [...] at heat plant” for the different regions. For all these datasets, energy balances are calculated based on the annual fuel input and electricity output per fuel (as reported in IEA (2023a). The target year of the update was set to 2022.

The natural gas fuel consumption per electricity output was calculated by dividing the one by the other and directly implemented in the respective datasets. For being able to perform these calculations, only data on natural gas in the stricter sense (including liquefied natural gas LNG), but excluding other types of similar gases such as coke oven gas, refinery gas, biogas, etc. was used.

For electricity outputs, the statistics provide only gross electricity generation data, while the somewhat lower net electricity generation data is available for consumption. To convert net electricity generation data into gross electricity generation data, the national ratios for the corresponding technologies were used.

Uncertainties were directly adapted over from the original UVEK:2023 datasets as the general methodology behind the data has not changed substantially. These uncertainties were also applied to hat plants in the same way.

Co-generation Combined Heat and Power (CHP) power plants have been considered as in the latest coal power generation update (Itten et al., 2023). Thus, co-generation data is included by allocating the fuel inputs required by heat supply and electricity supply and taking only the electricity part into account for the calculation of the total fuel demands per region. The underlying calculation is:

$$f_{specific} = \frac{m_{fuel,non-cogen} + m_{fuel,cogen,allocated}}{e_{non-cogen} + e_{cogen,allocated}}$$

With:

$f_{specific}$: Specific fuel demand [MJ/kWh]
$m_{fuel,non-cogen}$: Fuel input (non-cogeneration plants) [MJ/a]
$m_{fuel,cogen,allocated}$: Fuel input (cogeneration plants, allocated) [MJ/a]
$e_{non-cogen}$: Electricity generation (non-cogeneration plants) [kWh/a]
$e_{cogen,allocated}$: Electricity generation (cogeneration plants, allocated) [kWh/a]

Some European CHP power plants lacked data on their heat output (United Kingdom GB, Ireland IE, Spain ES). For these types of power plants, the ENTSO-E average energy balances were assumed, thus allowing to estimate the heat output in relation to the electricity output. Overall allocated efficiencies (as fuel input per either electricity or heat output) were then re-calculated based on this data.

The natural gas electricity generation per region as well as the natural gas heat supply was then calculated as a mix of the corresponding CHP and non-CHP production volumes. Again, for electricity, net electricity generation data was used to this end. The ratios were then connected within the dataset types "Electricity, from natural gas" or "Heat, from natural gas". For the cases where CHP power generation data had gaps in terms of heat output (GB, IE, ES), the CHP heat generation data was excluded from the regional heat supply mixes. In case such data becomes available in the future, or a more reliable approach for estimating the electricity to heat ratios can be used, it would be preferable to add these technologies to the respective heat supply mix datasets.

Swiss data at the electricity supply mix level showed only contributions from natural-gas-based CHP power generation, whereas it is known that several gas-based electricity-only power plants exist in Switzerland. Thus, a cross-check was conducted with the national reporting of the Federal Office for Energy (Bundesamt für Energie BFE, 2023). Their report in CHP power generation showed that despite the large capacity of electricity-only power plants in Switzerland, these have been only operated to a very small extent. Hence, the Swiss data electricity generation data was considered reasonable.

Future updates of the Swiss natural gas electricity generation mixes might become relevant once data on the utilization of the emergency gas turbines, that have been newly installed and commissioned in 2023, becomes available. Data on the emission rates of this plant as well as expected efficiencies has been collected, but not yet integrated into the database. This data is available on request.

An overview of the resulting fuel consumption intensities per amount of electricity and heat supply (expressed as efficiencies) is shown Figure 5 and Figure 6, respectively. The ratios of electricity-only and CHP power generation per country are shown in Figure 7 and the corresponding ratios for heat in Figure 8.

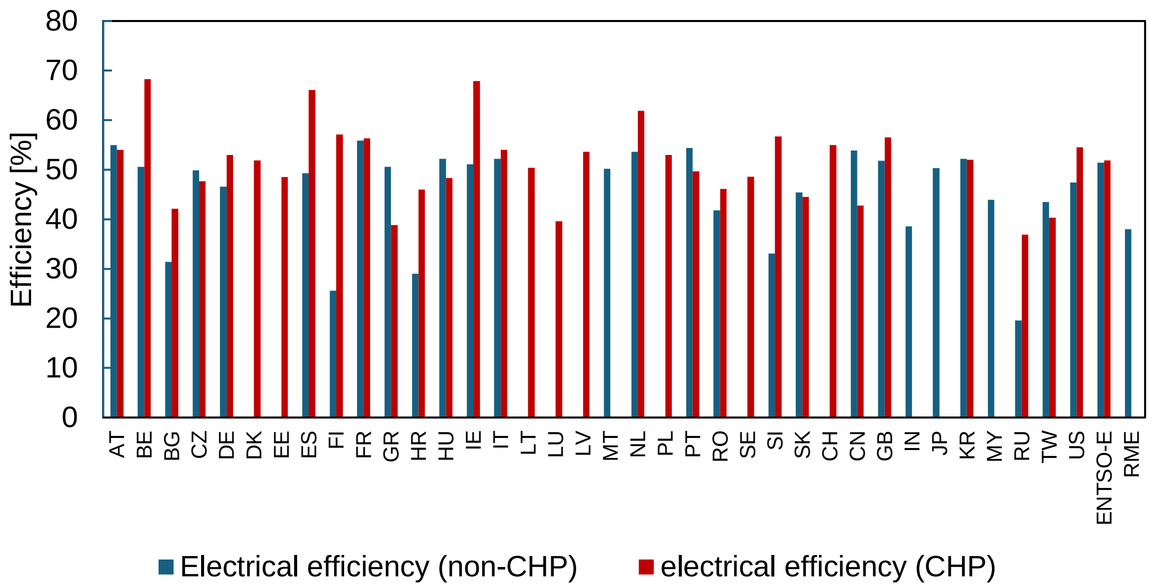


**Figure 5: Net electrical efficiencies of natural gas power plants in different regions as implemented with this update.**

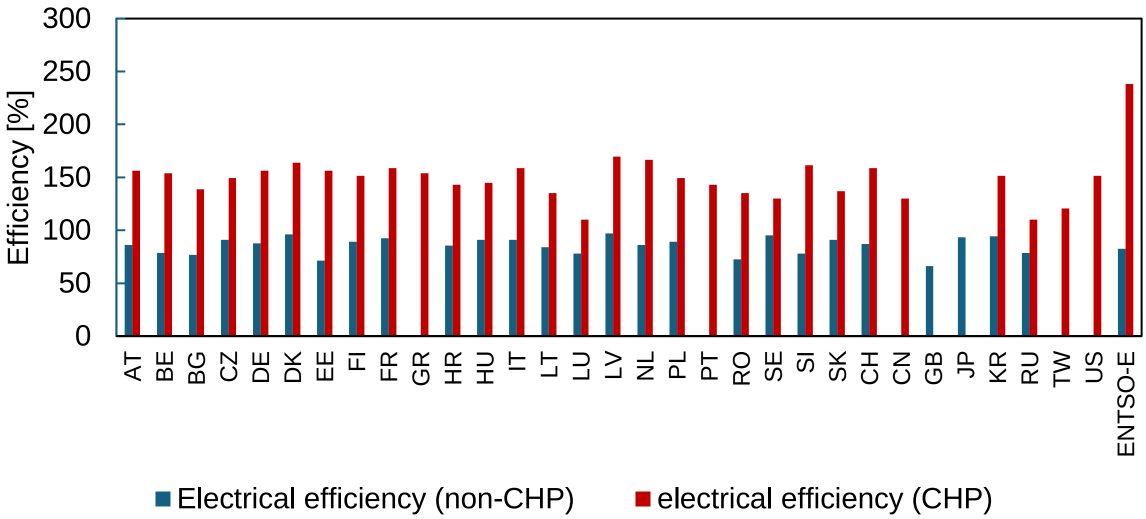


**Figure 6: Heat efficiencies of natural gas power plants in different regions as implemented with this update.**
Please note: Due to waste heat use and allocation procedure, CHP power plants can have higher efficiencies than 100 %, meaning that the burden is in part carried by the electricity generation

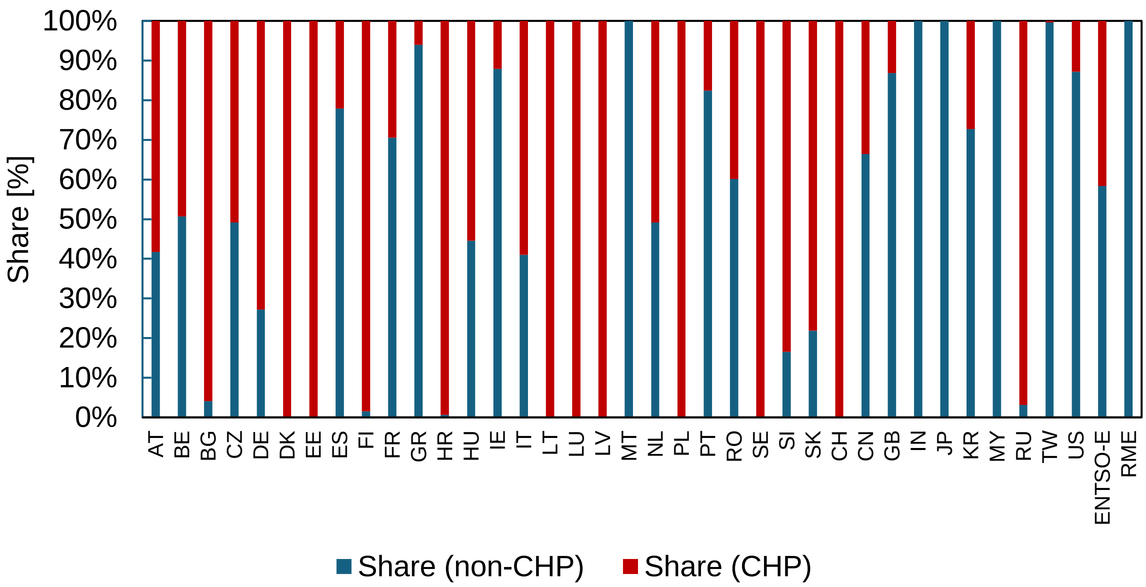


**Figure 7: Share of electricity-only and CHP electricity in different regions as implemented with this update.**

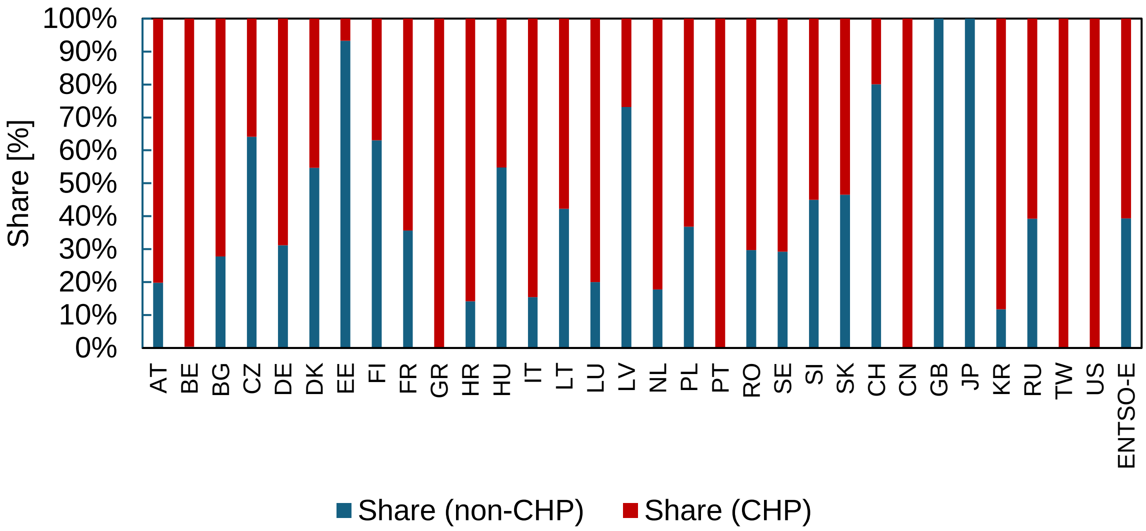


**Figure 8: Share of heat-only and CHP heat in different regions as implemented with this update.**

#### 3.2.1.1 Electricity and heat generation from natural gas coverage

The update for the electricity generation datasets from natural gas includes a total of 63 datasets as shown in Table 4. The corresponding 60 updated heat supply datasets are shown in Table 5.

**Table 4: Updated electricity generation datasets.**

| Electricity-only power plants | CHP power plants |
|---|---|
| Electricity, natural gas, at power plant/AT U | Electricity, natural gas, at CHP power plant/AT U |
| Electricity, natural gas, at power plant/BE U | Electricity, natural gas, at CHP power plant/BE U |
| Electricity, natural gas, at power plant/BG U | Electricity, natural gas, at CHP power plant/BG U |
| Electricity, natural gas, at power plant/CZ U | Electricity, natural gas, at CHP power plant/CZ U |
| Electricity, natural gas, at power plant/DE U | Electricity, natural gas, at CHP power plant/DE U |
| | Electricity, natural gas, at CHP power plant/DK U |
| | Electricity, natural gas, at CHP power plant/EE U |
| Electricity, natural gas, at power plant/ES U | Electricity, natural gas, at CHP power plant/ES U |
| Electricity, natural gas, at power plant/FI U | Electricity, natural gas, at CHP power plant/FI U |
| Electricity, natural gas, at power plant/FR U | Electricity, natural gas, at CHP power plant/FR U |
| Electricity, natural gas, at power plant/GR U | Electricity, natural gas, at CHP power plant/GR U |
| Electricity, natural gas, at power plant/HR U | Electricity, natural gas, at CHP power plant/HR U |
| Electricity, natural gas, at power plant/HU U | Electricity, natural gas, at CHP power plant/HU U |
| Electricity, natural gas, at power plant/IE U | Electricity, natural gas, at CHP power plant/IE U |
| Electricity, natural gas, at power plant/IT U | Electricity, natural gas, at CHP power plant/IT U |
| | Electricity, natural gas, at CHP power plant/LT U |
| | Electricity, natural gas, at CHP power plant/LU U |
| | Electricity, natural gas, at CHP power plant/LV U |
| Electricity, natural gas, at power plant/MT U | |
| Electricity, natural gas, at power plant/NL U | Electricity, natural gas, at CHP power plant/NL U |
| | Electricity, natural gas, at CHP power plant/PL U |
| Electricity, natural gas, at power plant/PT U | Electricity, natural gas, at CHP power plant/PT U |
| Electricity, natural gas, at power plant/RO U | Electricity, natural gas, at CHP power plant/RO U |
| | Electricity, natural gas, at CHP power plant/SE U |
| Electricity, natural gas, at power plant/SI U | Electricity, natural gas, at CHP power plant/SI U |
| Electricity, natural gas, at power plant/SK U | Electricity, natural gas, at CHP power plant/SK U |
| | Electricity, natural gas, at CHP power plant/CH U |
| Electricity, natural gas, at power plant/CN U | Electricity, natural gas, at CHP power plant/CN U |
| Electricity, natural gas, at power plant/GB U | Electricity, natural gas, at CHP power plant/GB U |
| Electricity, natural gas, at power plant/IN U | |
| Electricity, natural gas, at power plant/JP U | |
| Electricity, natural gas, at power plant/KR U | Electricity, natural gas, at CHP power plant/KR U |
| Electricity, natural gas, at power plant/MY U | |
| Electricity, natural gas, at power plant/RU U | Electricity, natural gas, at CHP power plant/RU U |
| Electricity, natural gas, at power plant/TW U | Electricity, natural gas, at CHP power plant/TW U |
| Electricity, natural gas, at power plant/US U | Electricity, natural gas, at CHP power plant/US U |
| Electricity, natural gas, at power plant/ENTSO-E U | |
| Electricity, natural gas, at power plant/RME U | |

**Table 5: Updated heat supply datasets.**

| Heat from CHP power plants | Heat from heat plants |
|---|---|
| Heat, natural gas, at CHP power plant/AT U | Heat, natural gas, at heat plant/AT U |
| Heat, natural gas, at CHP power plant/BE U | Heat, natural gas, at heat plant/BE U |
| Heat, natural gas, at CHP power plant/BG U | Heat, natural gas, at heat plant/BG U |
| Heat, natural gas, at CHP power plant/CZ U | Heat, natural gas, at heat plant/CZ U |
| Heat, natural gas, at CHP power plant/DE U | Heat, natural gas, at heat plant/DE U |
| Heat, natural gas, at CHP power plant/DK U | Heat, natural gas, at heat plant/DK U |
| Heat, natural gas, at CHP power plant/EE U | Heat, natural gas, at heat plant/EE U |
| Heat, natural gas, at CHP power plant/ES U | |
| Heat, natural gas, at CHP power plant/FI U | Heat, natural gas, at heat plant/FI U |
| Heat, natural gas, at CHP power plant/FR U | Heat, natural gas, at heat plant/FR U |
| Heat, natural gas, at CHP power plant/GR U | |
| Heat, natural gas, at CHP power plant/HR U | Heat, natural gas, at heat plant/HR U |
| Heat, natural gas, at CHP power plant/HU U | Heat, natural gas, at heat plant/HU U |
| Heat, natural gas, at CHP power plant/IE U | |
| Heat, natural gas, at CHP power plant/IT U | Heat, natural gas, at heat plant/IT U |
| Heat, natural gas, at CHP power plant/LT U | Heat, natural gas, at heat plant/LT U |
| Heat, natural gas, at CHP power plant/LU U | Heat, natural gas, at heat plant/LU U |
| Heat, natural gas, at CHP power plant/LV U | Heat, natural gas, at heat plant/LV U |
| Heat, natural gas, at CHP power plant/NL U | Heat, natural gas, at heat plant/NL U |
| Heat, natural gas, at CHP power plant/PL U | Heat, natural gas, at heat plant/PL U |
| Heat, natural gas, at CHP power plant/PT U | |
| Heat, natural gas, at CHP power plant/RO U | Heat, natural gas, at heat plant/RO U |
| Heat, natural gas, at CHP power plant/SE U | Heat, natural gas, at heat plant/SE U |
| Heat, natural gas, at CHP power plant/SI U | Heat, natural gas, at heat plant/SI U |
| Heat, natural gas, at CHP power plant/SK U | Heat, natural gas, at heat plant/SK U |
| Heat, natural gas, at CHP power plant/CH U | Heat, natural gas, at heat plant/CH U |
| Heat, natural gas, at CHP power plant/CN U | |
| Heat, natural gas, at CHP power plant/GB U | Heat, natural gas, at heat plant/GB U |
| | Heat, natural gas, at heat plant/JP U |
| Heat, natural gas, at CHP power plant/KR U | Heat, natural gas, at heat plant/KR U |
| Heat, natural gas, at CHP power plant/RU U | Heat, natural gas, at heat plant/RU U |
| Heat, natural gas, at CHP power plant/TW U | |
| Heat, natural gas, at CHP power plant/US U | |
| Heat, natural gas, at CHP power plant/ENTSO-E U | Heat, natural gas, at heat plant/ENTSO-E U |

A part of the electricity-only power plants has existed in the BAFU database before, but CHP power plants as well as heat plants have been missing so far and thus have been newly added.

### 3.2.2 Electricity and heat supply mixes for natural gas

The regional coverage of these datasets is visualized for convenience reasons in Figure 9, while the general members of the ENTSO-E region are shown in Figure 10. This region thus replaces the former UCTE, NORDEL and CENTREL regions, as the latter have been unified with the formation of the European ENTSO-E electricity grid operation. The UK is considered part of the ENTSO-E due to a lack of regionally disaggregated data, even though it only partially is (Northern Ireland). The merging of US electricity grid regions replaces the former sub-national US electricity grid regions NPCC, ERCOT, FRCC, MRO, RFC, SERC, SPP and WECC. Yugoslavia (CS) is not covered anymore with this update, but datasets for Serbia (RS), Montenegro (ME) or Kosovo (XK) are created where needed. This information is summarised in Table 6.

As there are numerous definitions on the extent of the "Middle East" without clear consensus, the present update followed the coverage of previous UVEK updates as visualized in Figure 11. Thus, the regional extent of the Middle East comprises Iran (IR), Iraq (IQ), Saudi Arabia (SA), United Arab Emirates (AE), Kuwait (KW) and Qatar (QA).

**Figure 9: Geographical coverage of the update.**

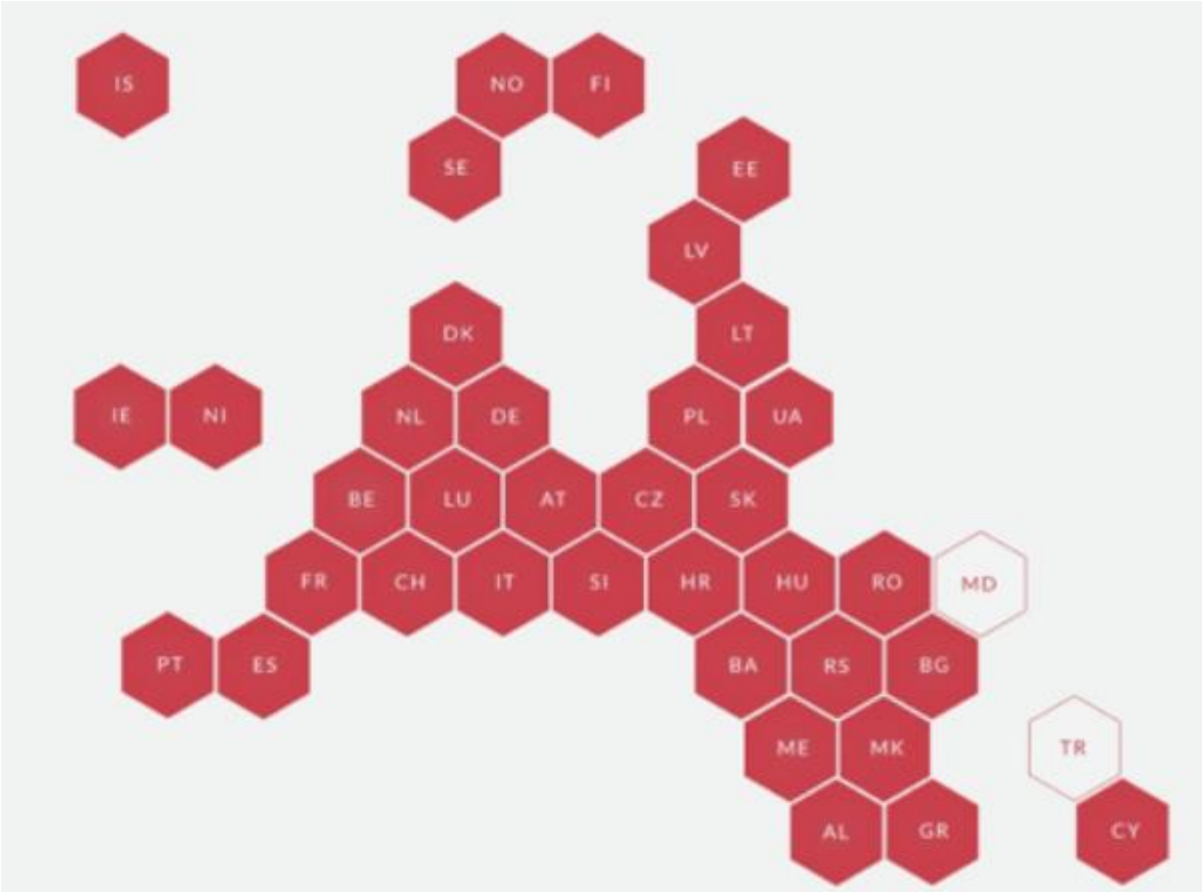


**Figure 10: ENTSO-E electricity grid members with abbreviations representing their country ISO 2 code abbreviations.** Source: ENTSO-E (2024). Only those countries with substantial electricity power generation from natural gas have been added.

**Table 6: Regional grouping and changes between BAFU database versions.**

<table>
<tr><th>Region UVEK:2023</th><th>Region UVEK:2024</th></tr>
<tr><td>CENTREL</td><td rowspan="3">ENTSO-E</td></tr>
<tr><td>NORDEL</td></tr>
<tr><td>UCTE</td></tr>
<tr><td>ERCOT</td><td rowspan="8">US</td></tr>
<tr><td>FRCC</td></tr>
<tr><td>MRO</td></tr>
<tr><td>NPCC</td></tr>
<tr><td>RFC</td></tr>
<tr><td>SERC</td></tr>
<tr><td>SPP</td></tr>
<tr><td>WECC</td></tr>
<tr><td rowspan="3">CS</td><td>RS</td></tr>
<tr><td>ME</td></tr>
<tr><td>XK</td></tr>
</table>

**Figure 11: Coverage of Middle Eastern countries within the RME region in this update.**

The integration of electricity generation from electricity-only power plants and combined heat and power plants, along with heat supply from CHP plants and heat plants, into electricity supply and heat supply mix datasets is intended to support users of the BAFU database who do not know or are not concerned with the specific origin of the electricity or heat. This consolidation makes it easier for them to access and utilize the data without having to select the specific supply technologies. By providing unified datasets, the structure of the recent coal power generation data update of the BAFU database is followed and completed (Itten et al., 2023). The 38 electricity and 34 heat supply mixes from natural gas that have been created within this update are listed in Table 7.

**Table 7: Electricity and heat supply mixes for natural gas.**

| Electricity supply datasets | Heat supply datasets |
|---|---|
| Electricity, from natural gas/AT U | Heat, from natural gas/AT U |
| Electricity, from natural gas/BE U | Heat, from natural gas/BE U |
| Electricity, from natural gas/BG U | Heat, from natural gas/BG U |
| Electricity, from natural gas/CZ U | Heat, from natural gas/CZ U |
| Electricity, from natural gas/DE U | Heat, from natural gas/DE U |
| | Heat, from natural gas/DK U |
| | Heat, from natural gas/EE U |
| Electricity, from natural gas/ES U | Heat, from natural gas/ES U |
| Electricity, from natural gas/FI U | Heat, from natural gas/FI U |
| Electricity, from natural gas/FR U | Heat, from natural gas/FR U |
| Electricity, from natural gas/GR U | Heat, from natural gas/GR U |
| Electricity, from natural gas/HR U | Heat, from natural gas/HR U |
| Electricity, from natural gas/HU U | Heat, from natural gas/HU U |
| Electricity, from natural gas/IE U | Heat, from natural gas/IE U |
| Electricity, from natural gas/IT U | Heat, from natural gas/IT U |
| | Heat, from natural gas/LT U |
| | Heat, from natural gas/LU U |
| | Heat, from natural gas/LV U |
| Electricity, from natural gas/MT U | |
| Electricity, from natural gas/NL U | Heat, from natural gas/NL U |
| | Heat, from natural gas/PL U |
| Electricity, from natural gas/PT U | Heat, from natural gas/PT U |
| Electricity, from natural gas/RO U | Heat, from natural gas/RO U |
| | Heat, from natural gas/SE U |
| Electricity, from natural gas/SI U | Heat, from natural gas/SI U |
| Electricity, from natural gas/SK U | Heat, from natural gas/SK U |
| | Heat, from natural gas/CH U |
| Electricity, from natural gas/CN U | Heat, from natural gas/CN U |
| Electricity, from natural gas/GB U | Heat, from natural gas/GB U |
| Electricity, from natural gas/IN U | |
| Electricity, from natural gas/JP U | |
| Electricity, from natural gas/KR U | Heat, from natural gas/KR U |
| Electricity, from natural gas/MY U | |
| Electricity, from natural gas/RU U | Heat, from natural gas/RU U |
| Electricity, from natural gas/TW U | Heat, from natural gas/TW U |
| Electricity, from natural gas/US U | Heat, from natural gas/US U |
| Electricity, from natural gas/ENTSO-E U | Heat, from natural gas/ENTSO-E U |
| | Heat, from natural gas/JP U |

| Electricity supply datasets | Heat supply datasets |
| --- | --- |
| Electricity, from natural gas/RME U | |
| Electricity, from natural gas/DK U | |
| Electricity, from natural gas/EE U | |
| Electricity, from natural gas/LT U | |
| Electricity, from natural gas/LU U | |
| | |
| Electricity, from natural gas/LV U | |
| Electricity, from natural gas/PL U | |
| Electricity, from natural gas/SE U | |
| Electricity, from natural gas/CH U | |

## 3.3 Obsolete Processes

As mentioned in chapter 3.2.2, several processes have been superseded by their corresponding aggregation of the geography:

- NORDEL and CENTREL included in ENTSO-E
- NPCC, ERCOT, FRCC, MRO, RFC: replaced with US

Additionally, all processes for the cogen process "Jakobsberg" are deemed obsolete and should be removed from the database (26 processes):

- Heat, at cogen 160kWe Jakobsberg, allocation price {CH} U
- Heat, at cogen 160kWe Jakobsberg, allocation heat {CH} U
- Electricity, at cogen 160kWe Jakobsberg, allocation electricity {CH} U
- Heat, at module cogen 160kWe Jakobsberg, allocation energy {CH} U
- Heat, at system cogen 160kWe Jakobsberg, allocation electricity {CH} U
- Electricity, at cogen 160kWe Jakobsberg, allocation heat {CH} U
- Electricity, at cogen 160kWe Jakobsberg, allocation energy {CH} U
- Heat, at cogen 160kWe Jakobsberg, allocation exergy {CH} U
- Heat, at module cogen 160kWe Jakobsberg, allocation exergy {CH} U
- Electricity, at cogen 160kWe Jakobsberg, allocation exergy {CH} U
- Heat, at system cogen 160kWe Jakobsberg, allocation energy {CH} U
- Heat, at system cogen 160kWe Jakobsberg, allocation price {CH} U
- Heat, at cogen 160kWe Jakobsberg, allocation electricity {CH} U
- Heat, at module cogen 160kWe Jakobsberg, allocation price {CH} U
- Electricity, at cogen 160kWe Jakobsberg, allocation price {CH} U
- Heat, at cogen 160kWe Jakobsberg, allocation energy {CH} U
- Heat, at module cogen 160kWe Jakobsberg, allocation heat {CH} U
- Heat, at system cogen 160kWe Jakobsberg, allocation heat {CH} U

- Heat, at system cogen 160kWe Jakobsberg, allocation exergy {CH} U
- Heat, at module cogen 160kWe Jakobsberg, allocation electricity {CH} U
- xx heat, at local distribution cogen 160kWe Jakobsberg, allocation price {CH} U
- xx natural gas, burned in cogen 160kWe Jakobsberg {CH} U
- xx heat, at local distribution cogen 160kWe Jakobsberg, allocation energy {CH} U
- xx heat, at local distribution cogen 160kWe Jakobsberg, allocation exergy {CH} U
- xx heat, at local distribution cogen 160kWe Jakobsberg, allocation electricity {CH} U
- xx heat, at local distribution cogen 160kWe Jakobsberg, allocation heat {CH} U

The same applies to all exergy processes with a prefix of "xx", these should also be removed during this update of the database:

- xx electricity, biogas, allocation exergy, at PEM fuel cell 2kWe, future {CH} U
- xx heat, biogas, allocation exergy, at SOFC fuel cell 125kWe, future {CH} U
- xx heat, biogas, allocation exergy, at micro gas turbine 100kWe {CH} U
- xx electricity, biogas, allocation exergy, at SOFC fuel cell 125kWe, future {CH} U
- xx electricity, pellets, allocation exergy, at stirling cogen unit 3kWe, future {CH} U
- xx electricity, at cogen 160kWe lambda=1, allocation exergy {CH} U
- xx heat, biogas, allocation exergy, at PEM fuel cell 2kWe, future {CH} U
- xx heat, biogas, allocation exergy, at SOFC-GT fuel cell 180kWe, future {CH} U
- xx heat, natural gas, allocation exergy, at SOFC-GT fuel cell 180kWe, future {CH} U
- xx electricity, biogas, allocation exergy, at micro gas turbine 100kWe {CH} U
- xx heat, pellets, allocation exergy, at stirling cogen unit 3kWe, future {CH} U
- xx heat, at cogen, biogas agricultural mix, allocation exergy {CH} U
- xx electricity, biogas, allocation exergy, at SOFC-GT fuel cell 180kWe, future {CH} U
- xx electricity, at cogen, biogas agricultural mix, allocation exergy {CH} U
- xxx Heat, at cogen 500kWe lean burn, allocation exergy {CH} U
- xx heat, at cogen ORC 1400kWth, wood, allocation exergy {CH} U
- xx electricity, natural gas, allocation exergy, at SOFC fuel cell 125kWe, future {CH} U
- xx heat, at cogen ORC 1400kWth, wood, emission control, allocation exergy {CH} U
- xx electricity, natural gas, allocation exergy, at PEM fuel cell 2kWe, future {CH} U
- xxx Heat, at cogen 6400kWth, wood, allocation exergy {CH} U
- xx heat, natural gas, allocation exergy, at micro gas turbine 100kWe {CH} U
- xx electricity, at cogen ORC 1400kWth, wood, emission control, allocation exergy {CH} U
- xxx Heat, at cogen 6400kWth, wood, emission control, allocation exergy {CH} U
- xx heat, natural gas, allocation exergy, at SOFC fuel cell 125kWe, future {CH} U
- xx electricity, natural gas, allocation exergy, at SOFC-GT fuel cell 180kWe, future {CH} U
- xxx Electricity, at cogen 500kWe lean burn, allocation exergy {CH} U
- xx electricity, natural gas, allocation exergy, at micro gas turbine 100kWe {CH} U
- xxx Electricity, at cogen 6400kWth, wood, allocation exergy {CH} U

# 4 Life cycle impact assessment

The following tables summarise the life cycle impact assessments for the indicators Ecological Scarcity 2021, GWP 2021 and Cumulative Energy Demand.
The first results presented are the calculations for the burning processes, followed by the two electricity generation processes "at power plant" and "at CHP power plant". These two processes are then aggregated for the specific countries and according to the corresponding statistics, leading to "Electricity, natural gas" country production mix processes.
The compilation for the heat generation processes follows the same structure and is presented afterwards.

A comparison with the former life cycle inventories from UVEK:2018 is also provided.

## 4.1 Summary LCIA results

### 4.1.1 Natural gas burning processes

**Table 8: LCIA results of natural gas burning processes**

| **Inventory name/unit** | **Ecological Scarcity 2021** | **IPCC 2021, GWP 100a** | **Cumulated Energy Demand** | **Ecological Scarcity UVEK:2018** | **IPCC, GWP 100a UVEK:2018** | | |
|---|---|---|---|---|---|---|---|
| Natural gas, burned in power plant or heat plant / MJ | UBP | kg $CO_2$-eq | MJ | UBP | kg $CO_2$-eq | UBP ratio | kg $CO_2$-eq ratio |
| Austria | 91.980 | 0.076 | 0.500 | 85.124 | 0.071 | 8.1% | 6.9% |
| Belgium | 82.225 | 0.067 | 1.089 | 82.620 | 0.068 | -0.5% | -1.0% |
| Bulgaria | 91.249 | 0.074 | 1.101 | - | - | - | - |
| Croatia | 90.733 | 0.074 | 1.101 | - | - | - | - |
| Cyprus | - | - | - | - | - | - | - |
| Czechia | 93.511 | 0.075 | 1.080 | - | - | - | - |
| Denmark | 72.931 | 0.060 | 0.995 | - | - | - | - |
| Estonia | 90.515 | 0.074 | 1.101 | - | - | - | - |
| Finland | 98.564 | 0.081 | 1.155 | - | - | - | - |
| France | 91.009 | 0.074 | 1.095 | 83.206 | 0.069 | 9.4% | 7.9% |
| Germany | 85.331 | 0.071 | 1.046 | 78.967 | 0.066 | 8.1% | 7.3% |
| Great Britain | 82.019 | 0.065 | 1.008 | - | - | - | - |
| Greece | 99.051 | 0.081 | 1.152 | - | - | - | - |
| Hungary | 98.676 | 0.080 | 1.199 | - | - | - | - |
| Ireland | 77.855 | 0.064 | 1.010 | - | - | - | - |
| Italy | 97.325 | 0.080 | 1.085 | 85.750 | 0.071 | 13.5% | 12.6% |
| Latvia | 90.207 | 0.074 | 1.101 | - | - | - | - |
| Lithuania | 76.307 | 0.065 | 0.551 | - | - | - | - |
| Luxembourg | 90.210 | 0.074 | 1.101 | 82.416 | 0.068 | 9.5% | 8.0% |
| Malta | 94.055 | 0.074 | 1.101 | - | - | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Netherlands | 77.378 | 0.064 | 1.055 | 73.387 | 0.061 | 5.4% | 5.6% |
| Poland | 93.667 | 0.074 | 1.101 | - | - | - | - |
| Portugal | 89.784 | 0.074 | 1.101 | - | - | - | - |
| Romania | 90.284 | 0.074 | 1.101 | - | - | - | - |
| Slovakia | 101.865 | 0.081 | 1.155 | - | - | - | - |
| Slovenia | 89.920 | 0.074 | 1.101 | - | - | - | - |
| Spain | 97.152 | 0.079 | 1.133 | 93.590 | 0.077 | 3.8% | 2.2% |
| Sweden | 71.959 | 0.060 | 0.995 | - | - | - | - |
| | | | | | | | |
| Switzerland | 91.425 | 0.073 | 1.085 | - | - | - | - |
| Russia | 92.452 | 0.074 | 1.101 | - | - | - | - |
| China | 99.866 | 0.078 | 1.146 | - | - | - | - |
| India | 105.744 | 0.082 | 1.191 | - | - | - | - |
| Japan | 117.283 | 0.091 | 1.282 | 103.175 | 0.083 | 13.7% | 9.0% |
| Malaysia | 98.418 | 0.077 | 1.136 | - | - | - | - |
| Taiwan | 117.659 | 0.091 | 1.282 | - | - | - | - |
| South Korea | 89.495 | 0.074 | 0.641 | - | - | - | - |
| Middle East | 93.592 | 0.074 | 1.101 | - | - | - | - |
| USA | 90.540 | 0.073 | 1.034 | 89.127 | 0.067 | 1.6% | 9.8% |
| Europe (ENTSO-E) | 93.667 | 0.074 | 1.101 | 82.416 | 0.068 | 13.7% | 8.0% |

### 4.1.2 Electricity generation processes

**Table 9: LCIA results of electricity, natural gas, at power plant**

| **Inventory name/unit** | **Ecological Scarcity 2021** | **IPCC 2021, GWP 100a** | **Cumulated Energy Demand** | **Ecological Scarcity UVEK:2018** | **IPCC, GWP 100a UVEK:2018** | | |
|---|---|---|---|---|---|---|---|
| Electricity, natural gas, at power plant / kWh | UBP | kg $CO_2$-eq | MJ | UBP | kg $CO_2$-eq | UBP ratio | kg $CO_2$-eq ratio |
| Austria | 602.467 | 0.498 | 7.222 | 885.288 | 0.739 | -31.9% | -32.7% |
| Belgium | 585.441 | 0.479 | 7.753 | 724.575 | 0.596 | -19.2% | -19.7% |
| Bulgaria | 1'045.712 | 0.844 | 12.623 | - | - | - | - |
| Croatia | 1'126.000 | 0.914 | 13.669 | - | - | - | - |
| Cyprus | - | - | - | - | - | - | - |
| Czechia | 674.215 | 0.538 | 7.787 | - | - | - | - |
| Denmark | - | - | - | - | - | - | - |
| Estonia | - | - | - | - | - | - | - |
| Finland | 1'386.789 | 1.134 | 16.244 | - | - | - | - |
| France | 586.097 | 0.480 | 7.049 | 591.597 | 0.491 | -0.9% | -2.3% |
| Germany | 658.756 | 0.546 | 8.073 | 649.901 | 0.542 | 1.4% | 0.7% |
| Great Britain | 570.033 | 0.448 | 7.002 | - | - | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Greece | 704.252 | 0.577 | 8.192 | - | - | - | - |
| Hungary | 680.866 | 0.554 | 8.271 | - | - | - | - |
| Ireland | 548.098 | 0.452 | 7.109 | - | - | - | - |
| Italy | 670.567 | 0.552 | 7.476 | 823.202 | 0.683 | -18.5% | -19.2% |
| Latvia | - | - | - | - | - | - | - |
| Lithuania | - | - | - | - | - | - | - |
| Luxembourg | - | - | - | 1211.515 | 1.002 | - | - |
| Malta | 674.374 | 0.528 | 7.897 | - | - | - | - |
| Netherlands | 519.980 | 0.431 | 7.089 | 723.592 | 0.599 | -28.1% | -28.0% |
| Poland | - | - | - | - | - | - | - |
| Portuga | 594.368 | 0.488 | 7.292 | - | - | - | - |
| Romania | 778.247 | 0.635 | 9.494 | - | - | - | - |
| Slovakia | 807.793 | 0.640 | 9.161 | - | - | - | - |
| Slovenia | 976.534 | 0.800 | 11.962 | - | - | - | - |
| Spain | 709.210 | 0.577 | 8.271 | 723.454 | 0.598 | -2.0% | -3.5% |
| Sweden | - | - | - | - | - | - | - |
| | | | | | | | |
| Switzerland | - | - | - | - | - | - | - |
| Russia | 1'698.349 | 1.353 | 20.233 | - | - | - | - |
| China | 667.106 | 0.521 | 7.658 | - | - | - | - |
| India | 986.593 | 0.768 | 11.117 | - | - | - | - |
| Japan | 839.747 | 0.651 | 9.176 | 953.340 | 0.771 | -11.9% | -15.6% |
| Malaysia | 807.031 | 0.631 | 9.312 | - | - | - | - |
| Taiwan | 973.036 | 0.752 | 10.598 | - | - | - | - |
| South Korea | 616.621 | 0.507 | 4.416 | - | - | - | - |
| Middle East | 886.317 | 0.698 | 10.431 | - | - | - | - |
| USA | 688.102 | 0.556 | 7.855 | 935.833 | 0.700 | -26.5% | -20.5% |
| Europe (ENTSO-E) | 656.609 | 0.516 | 7.721 | 781.304 | 0.646 | -16.0% | -20.1% |

**Table 10: LCIA results of electricity, natural gas, at CHP power plant**

| Inventory name/unit | Ecological Scarcity 2021 | IPCC 2021, GWP 100a | Cumulated Energy Demand |
|---|---|---|---|
| Electricity, natural gas, at CHP power plant / kWh | UBP | kg $CO_2$-eq | MJ |
| Austria | 613.504 | 0.507 | 7.354 |
| Belgium | 433.325 | 0.354 | 5.739 |
| Bulgaria | 781.091 | 0.631 | 9.428 |
| Croatia | 710.441 | 0.577 | 8.624 |
| Cyprus | - | - | - |
| Czechia | 705.074 | 0.563 | 8.143 |
| Denmark | 506.143 | 0.419 | 6.908 |
| Estonia | 671.625 | 0.547 | 8.173 |

| | | | |
|---|---|---|---|
| Finland | 620.950 | 0.508 | 7.273 |
| France | 581.547 | 0.476 | 6.995 |
| Germany | 579.398 | 0.480 | 7.100 |
| Great Britain | 568.393 | 0.447 | 6.982 |
| Greece | 920.183 | 0.753 | 10.704 |
| Hungary | 735.137 | 0.598 | 8.930 |
| Ireland | 539.534 | 0.445 | 6.998 |
| Italy | 649.155 | 0.534 | 7.238 |
| Latvia | 606.194 | 0.495 | 7.402 |
| Lithuania | 544.829 | 0.464 | 3.934 |
| Luxembourg | 820.910 | 0.670 | 10.023 |
| Malta | - | - | - |
| Netherlands | 450.340 | 0.373 | 6.140 |
| Poland | 636.002 | 0.500 | 7.479 |
| Portuga | 650.931 | 0.534 | 7.985 |
| Romania | 705.117 | 0.575 | 8.602 |
| Slovakia | 824.091 | | |
| Slovenia | 570.994 | 0.468 | 6.994 |
| Spain | 673.264 | 0.547 | 7.852 |
| Sweden | 533.216 | | 7.371 |
| | | | |
| Switzerland | 598.831 | 0.476 | 7.109 |
| Russia | 901.410 | 0.718 | 10.739 |
| China | 839.874 | 0.656 | 9.642 |
| India | - | - | - |
| Japan | - | - | - |
| Malaysia | - | - | - |
| Taiwan | 1'050.690 | 0.812 | 11.444 |
| South Korea | 619.306 | 0.509 | 4.436 |
| Middle East | - | - | - |
| USA | 598.467 | 0.484 | 6.831 |
| Europe (ENTSO-E) | 649.116 | 0.510 | 7.633 |

**Table 11: LCIA results of electricity, natural gas (production mix)**

| **Inventory name/unit** | **Ecological Scarcity 2021** | **IPCC 2021, GWP 100a** | **Cumulated Energy Demand** |
|---|---|---|---|
| Electricity, natural gas, at power plant / kWh | UBP | kg $CO_2$-eq | MJ |
| Austria | 608.896 | 0.503 | 7.299 |
| Belgium | 510.400 | 0.417 | 6.760 |
| Bulgaria | 791.931 | 0.639 | 9.559 |
| Croatia | 713.184 | 0.579 | 8.658 |

| | | | |
|---|---|---|---|
| Cyprus | - | - | - |
| Czechia | 689.915 | 0.551 | 7.968 |
| Denmark | 506.143 | 0.419 | 6.908 |
| Estonia | 671.625 | 0.547 | 8.173 |
| Finland | 689.468 | 0.564 | 8.076 |
| France | 584.755 | 0.479 | 7.033 |
| Germany | 600.994 | 0.498 | 7.365 |
| Great Britain | 717.345 | 0.587 | 8.345 |
| Greece | 569.817 | 0.448 | 7.000 |
| Hungary | 710.940 | 0.578 | 8.637 |
| Ireland | 547.063 | 0.451 | 7.096 |
| Italy | 657.941 | 0.541 | 7.336 |
| Latvia | 606.194 | 0.495 | 7.402 |
| Lithuania | 544.829 | 0.464 | 3.934 |
| Luxembourg | 820.910 | 0.670 | 10.023 |
| Malta | 674.374 | 0.528 | 7.897 |
| Netherlands | 484.580 | 0.402 | 6.607 |
| Poland | 636.002 | 0.500 | 7.479 |
| Portuga | 604.328 | 0.496 | 7.414 |
| Romania | 749.097 | 0.611 | 9.139 |
| Slovakia | 820.524 | 0.650 | 9.305 |
| Slovenia | 638.066 | 0.523 | 7.816 |
| Spain | 701.275 | 0.570 | 8.179 |
| Sweden | 533.216 | 0.447 | 7.371 |
| | | | |
| Switzerland | 598.831 | 0.476 | 7.109 |
| Russia | 926.479 | 0.738 | 11.038 |
| China | 725.167 | 0.566 | 8.325 |
| India | 986.593 | 0.768 | 11.117 |
| Japan | 839.747 | 0.651 | 9.176 |
| Malaysia | 807.031 | 0.631 | 9.312 |
| Taiwan | 973.339 | 0.752 | 10.602 |
| South Korea | 617.353 | 0.508 | 4.422 |
| Middle East | 886.317 | 0.698 | 10.431 |
| USA | 676.639 | 0.547 | 7.724 |
| Europe (ENTSO-E) | 653.488 | 0.514 | 7.684 |

## 4.1.3 Heat generation processes

**Table 12: LCIA results of heat, natural gas, at plant**

| Inventory name/unit | Ecological Scarcity 2021 | IPCC 2021, GWP 100a | Cumulated Energy Demand |
|---|---|---|---|
| Heat, natural gas, at plant / MJ | UBP | kg $CO_2$-eq | MJ |
| Austria | 106.696 | 0.088 | 1.279 |
| Belgium | 104.426 | 0.085 | 1.383 |
| Bulgaria | 118.624 | 0.096 | 1.432 |
| Croatia | 106.158 | 0.086 | 1.289 |
| Cyprus | - | - | - |
| Czechia | 102.862 | 0.082 | 1.188 |
| Denmark | 75.849 | 0.063 | 1.035 |
| Estonia | 126.722 | 0.103 | 1.542 |
| Finland | 110.391 | 0.090 | 1.293 |
| France | 98.290 | 0.080 | 1.182 |
| Germany | 97.277 | 0.081 | 1.192 |
| Greece | - | - | - |
| Great Britain | 123.849 | 0.097 | 1.521 |
| Hungary | 108.544 | 0.088 | 1.319 |
| Ireland | - | - | - |
| Italy | 107.057 | 0.088 | 1.194 |
| Latvia | 92.914 | 0.076 | 1.134 |
| Lithuania | 90.805 | 0.077 | 0.656 |
| Luxembourg | 115.469 | 0.094 | 1.410 |
| Malta | - | - | - |
| Netherlands | 89.758 | 0.074 | 1.224 |
| Poland | 104.908 | 0.082 | 1.234 |
| Portuga | - | - | - |
| Romania | 124.592 | 0.102 | 1.520 |
| Slovakia | 112.052 | 0.089 | 1.271 |
| Slovenia | 115.098 | 0.094 | 1.410 |
| Spain | - | - | - |
| Sweden | 75.557 | 0.063 | 1.044 |
| | | | |
| Switzerland | 105.138 | 0.084 | 1.248 |
| Russia | 117.414 | 0.094 | 1.399 |
| China | - | - | - |
| India | - | - | - |
| Japan | 125.493 | 0.097 | 1.371 |
| Malaysia | - | - | - |

| | | | |
|---|---|---|---|
| Taiwan | - | - | - |
| South Korea | 94.865 | 0.078 | 0.679 |
| Middle East | - | - | - |
| USA | - | - | - |
| Europe | 113.338 | 0.089 | 1.333 |

**Table 13: LCIA results of heat, natural gas, at CHP power plant**

| **Inventory name/unit** | **Ecological Scarcity 2021** | **IPCC 2021, GWP 100a** | **Cumulated Energy Demand** | **Ecological Scarcity UVEK:2018** | **IPCC, GWP 100a UVEK:2018** | | |
|---|---|---|---|---|---|---|---|
| Heat, natural gas, at CHP power plant / MJ | UBP | kg $CO_2$-eq | MJ | UBP | kg $CO_2$-eq | UBP ratio | kg $CO_2$-eq ratio |
| Austria | 58.867 | 0.049 | 0.706 | - | - | - | - |
| Belgium | 53.446 | 0.044 | 0.708 | - | - | - | - |
| Bulgaria | 65.699 | 0.053 | 0.793 | - | - | - | - |
| Croatia | 63.513 | 0.052 | 0.771 | - | - | - | - |
| Cyprus | - | - | - | - | - | - | - |
| Czechia | 62.652 | 0.050 | 0.724 | - | - | - | - |
| Denmark | 44.488 | 0.037 | 0.607 | - | - | - | - |
| Estonia | 57.930 | 0.047 | 0.705 | - | - | - | - |
| Finland | 65.052 | 0.053 | 0.762 | - | - | - | - |
| France | 57.336 | 0.047 | 0.690 | - | - | - | - |
| Germany | 54.612 | 0.045 | 0.669 | - | - | - | - |
| Great Britain | 34.448 | 0.027 | 0.423 | | | | |
| Greece | 64.383 | 0.053 | 0.749 | - | - | - | - |
| Hungary | 68.087 | 0.055 | 0.827 | - | - | - | - |
| Ireland | 32.699 | 0.027 | 0.424 | - | - | - | - |
| Italy | 61.315 | 0.050 | 0.684 | - | - | - | - |
| Latvia | 53.222 | 0.043 | 0.650 | - | - | - | - |
| Lithuania | 56.467 | 0.048 | 0.408 | - | - | - | - |
| Luxembourg | 82.091 | 0.067 | 1.002 | - | - | - | - |
| Malta | - | - | - | - | - | - | - |
| Netherlands | 46.427 | 0.038 | 0.633 | - | - | - | - |
| Poland | 62.757 | 0.049 | 0.738 | - | - | - | - |
| Portugal | 62.849 | 0.052 | 0.771 | - | - | - | - |
| Romania | 66.810 | 0.055 | 0.815 | - | - | - | - |
| Slovakia | 74.362 | 0.059 | 0.843 | - | - | - | - |
| Slovenia | 55.751 | 0.046 | 0.683 | - | - | - | - |
| Spain | 40.804 | 0.033 | 0.476 | - | - | - | - |
| Sweden | 55.408 | 0.046 | 0.766 | - | - | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Switzerland | 57.598 | 0.046 | 0.684 | 38.45 | 0.032 | 49.8% | 43.1% |
| Russia | 84.132 | 0.067 | 1.002 | - | - | - | - |
| China | 76.897 | 0.060 | 0.883 | - | - | - | - |
| India | - | - | - | - | - | - | - |
| Japan | 117.283 | 0.091 | 1.282 | - | - | - | - |
| Malaysia | - | - | - | - | - | - | - |
| Taiwan | 97.657 | 0.075 | 1.064 | - | - | - | - |
| South Korea | 59.067 | 0.049 | 0.423 | - | - | - | - |
| Middle East | - | - | - | - | - | - | - |
| USA | 59.756 | 0.048 | 0.682 | - | - | - | - |
| Europe | 59.385 | 0.047 | 0.698 | 87.61 | 0.072 | -32.2% | -35.0% |

**Table 14: LCIA results of heat, natural gas (production mix)**

| Inventory name/unit | Ecological Scarcity 2021 | IPCC 2021, GWP 100a | Cumulated Energy Demand |
|---|---|---|---|
| Heat, natural gas / MJ | UBP | kg $CO_2$-eq | MJ |
| | | | |
| Austria | 68.34 | 0.056 | 0.82 |
| Belgium | 53.62 | 0.044 | 0.71 |
| Bulgaria | 80.41 | 0.065 | 0.97 |
| Croatia | 69.55 | 0.056 | 0.84 |
| Cyprus | - | - | - |
| Czechia | 88.43 | 0.071 | 1.02 |
| Denmark | 61.65 | 0.051 | 0.84 |
| Estonia | 122.12 | 0.099 | 1.49 |
| Finland | 93.62 | 0.077 | 1.10 |
| France | 71.93 | 0.059 | 0.87 |
| Germany | 67.94 | 0.056 | 0.83 |
| Great Britain | 64.38 | 0.053 | 0.75 |
| Greece | 123.85 | 0.097 | 1.52 |
| Hungary | 90.25 | 0.073 | 1.10 |
| Ireland | 32.70 | 0.027 | 0.42 |
| Italy | 68.40 | 0.056 | 0.76 |
| Latvia | 82.25 | 0.067 | 1.00 |
| Lithuania | 70.98 | 0.060 | 0.51 |
| Luxembourg | 82.09 | 0.067 | 1.00 |
| Malta | - | - | - |
| Netherlands | 54.11 | 0.045 | 0.74 |
| Poland | 78.28 | 0.062 | 0.92 |
| Portugal | 62.85 | 0.052 | 0.77 |
| Romania | 83.96 | 0.068 | 1.02 |

| | | | |
|---|---|---|---|
| Slovakia | 91.90 | 0.073 | 1.04 |
| Slovenia | 82.42 | 0.068 | 1.01 |
| Spain | 40.80 | 0.033 | 0.48 |
| Sweden | 61.29 | 0.051 | 0.85 |
| | | | |
| Switzerland | 95.68 | 0.076 | 1.14 |
| Russia | 97.19 | 0.077 | 1.16 |
| China | 76.90 | 0.060 | 0.88 |
| India | - | - | - |
| Japan | 125.49 | 0.097 | 1.37 |
| Malaysia | - | - | - |
| Taiwan | 97.66 | 0.075 | 1.06 |
| South Korea | 63.28 | 0.052 | 0.45 |
| Middle East | - | - | - |
| USA | 59.76 | 0.048 | 0.68 |
| Europe | 80.60 | 0.063 | 0.95 |

# 5 Discussion and Outlook

Compared to former UVEK:2018 database, the new processes show higher numbers for global warming potential as well as for the impact assessment with the method of ecological scarcity 2021. As there have been numerous changes between the two databases, these changes are not easily tracked down. One known significant change would be the update supply chain for natural gas though. The more detailed and thorough consideration of venting and flaring as well as the losses along the bigger pipelines have a significant impact on all of the results.

The main benefit of the new processes is the largely expanded scope of covered countries, enabling more precise energy processes for different regions in the future.

The most important next step would be the integration of the new processes in the corresponding country supply mixes for electricity and heat, therefore enabling users and practitioners to use the updated data in their LCA models.

# 6 Literature


Bundesamt für Energie BFE. (2023). Thermische Stromproduktion inklusive Wärmekraftkopplung (WKK) in der Schweiz (Ausgabe 2022). Retrieved from https://www.bfe.admin.ch/bfe/de/home/versorgung/energieeffizienz/waerme-kraft-kopplung-wkk.html

EMEP/EEA. (2019). EMEP/EEA air pollutant emission inventory guidebook 2019. EEA Report No 13/2019. ISSN 1977-8449. Retrieved from https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

EMEP/EEA. (2023). EMEP/EEA air pollutant emission inventory guidebook 2023 - Technical guidance to prepare national emission inventories. EEA Report 06/2023. Retrieved from https://www.eea.europa.eu/publications/emep-eea-guidebook-2023

ENTSO-E. (2024). ENTSO-E Member Companies. Retrieved from https://www.entsoe.eu/about/inside-entsoe/members/

ESU Services. (2022). Life cycle inventories for long-distance transport and distribution of natural gas. Retrieved from https://esu-services.ch/fileadmin/download/publicLCI/bussa-2022-LCI%20for%20the%20gas%20distribution.pdf

European Commission EC. (2023). Eurostat database. Retrieved from https://ec.europa.eu/eurostat/de/home.

European Environment Agency EEA. (2023). Reported information on large combustion plants under the Energy Community Treaty. Retrieved from https://www.eea.europa.eu/en/datahub/datahubitem-view/b37addc8-b60e-4304-ae49-eba5828a9163

Faist-Emmenegger, M., Heck, T., & Tuchschmid, M. (2007). Erdgas. In: Dones, R. (Ed.) et al., Sachbilanzen von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Ökobilanzen für die Schweiz. Final report ecoinvent No. 6-V, Paul Scherrer Institut Villigen, Swiss Centre for Life Cycle Inventories, Dübendorf, CH. Online: www.ecoinvent.ch.

Frischknecht, R., Jungbluth, N., Althaus, H. J., Doka, G., Dones, R., Heck, T., et al. (2007). *Overview and Methodology. ecoinvent report No. 1, v2.0.* Swiss Centre for Life Cycle Inventories, Dübendorf, CH.

Frischknecht, Rolf. (2023). *Database protocol – FOEN LCI data DQRv2.* Uster.

Heck, T. (2007). Wärme-Kraft-Kopplung. In: Dones, R., Bauer, C., Bolliger, R., Burger, B., Faist Emmenegger, M., Frischknecht, R., Heck, T., Jungbluth, N. and Röder, A., Eds., Sachbilanzen von Energiesystemen: Grundlagen für den ökologischen Vergleich von Energiesystemen und den Einbezug von Energiesystemen in Őkobilanzen für die Schweiz.

International Energy Agency IEA. (2021). Natural gas supply – Asia Pacific. Retrieved from https://www.iea.org/regions/asia-pacific/natural-gas

International Energy Agency IEA. (2023a). IEA Extended World Energy Balances. Retrieved from https://www.oecd-ilibrary.org/energy/data/iea-world-energy-statistics-and-balances/extended-world-energy-balances-edition-2023_8624f431-en

International Energy Agency IEA. (2023b). IEA World Energy Statistics. Retrieved from https://www.oecd-ilibrary.org/energy/data/iea-world-energy-statistics-and-balances/world-energy-statistics-edition-2023_da332b95-en

IPCC. (2021). *Climate Change 2021, The Physical Science Basis - Summary for Policymakers.* Retrieved from https://www.ipcc.ch/report/ar6/wg1/

Itten, R., Oberschelp, C., Kröhnert, H., & Stucki, M. (2023). Life Cycle Inventories of solid fossil fuels: updates for electricity generation from hard coal, lignite and peat. Retrieved from https://digitalcollection.zhaw.ch/items/b04cbc51-0d93-41ab-b36f-f98e40c877ef

KBOB, eco-bau, & IPB. (2018). KBOB-Ökobilanzdatenbestand 2016 und UVEK-Ökobilanzdatenbestand 2018.

S&P Global. (2023). Platts World Electric Power Plant (WEPP) database. Retrieved from https://www.spglobal.com/commodityinsights/en/products-services/electric-power/market-data-power

S&P Global. (2024). S&P Capital IQ Pro. Retrieved from https://www.capitaliq.spglobal.com/

# Appendix

## A1 Life Cycle Inventory Metadata

**Table A1: Key meta data for natural gas power generation from electricity-only power plants.**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Electricity, natural gas, at power plant/AT U | Electricity, natural gas, at power plant/BE U | Electricity, natural gas, at power plant/BG U | Electricity, natural gas, at power plant/CZ U | Electricity, natural gas, at power plant/DE U | Electricity, natural gas, at power plant/ES U | Electricity, natural gas, at power plant/FI U | Electricity, natural gas, at power plant/FR U | Electricity, natural gas, at power plant/GR U | Electricity, natural gas, at power plant/HR U | Electricity, natural gas, at power plant/HU U | Electricity, natural gas, at power plant/IE U | Electricity, natural gas, at power plant/IT U | Electricity, natural gas, at power plant/MT U | Electricity, natural gas, at power plant/NL U | Electricity, natural gas, at power plant/PT U | Electricity, natural gas, at power plant/RO U | Electricity, natural gas, at power plant/SI U | Electricity, natural gas, at power plant/SK U | Electricity, natural gas, at power plant/CN U | Electricity, natural gas, at power plant/GB U | Electricity, natural gas, at power plant/IN U | Electricity, natural gas, at power plant/JP U | Electricity, natural gas, at power plant/KR U | Electricity, natural gas, at power plant/MY U | Electricity, natural gas, at power plant/RU U |
| Geography | 662 | Location | AT | BE | BG | CZ | DE | ES | FI | FR | GR | HR | HU | IE | IT | MT | NL | PT | RO | SI | SK | CN | GB | IN | JP | KR | MY | RU |
| ReferenceFunction | 403 | Unit | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh |
| DataSetInformation | 201 | Type | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 492 | GeneralComment | The average net electrical efficiency is about 55 %. The electricity generation of this technology in the region is at about 4400 GWh based on international energy statistics. | The average net electrical efficiency is about 50.6 %. The electricity generation of this technology in the region is at about 10000 GWh based on international energy statistics. | The average net electrical efficiency is about 31.4 %. The electricity generation of this technology in the region is at about 70 GWh based on international energy statistics. | The average net electrical efficiency is about 49.9 %. The electricity generation of this technology in the region is at about 1900 GWh based on international energy statistics. | The average net electrical efficiency is about 46.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. | The average net electrical efficiency is about 49.3 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 25.6 %. The electricity generation of this technology in the region is at about 10 GWh based on international energy statistics. | The average net electrical efficiency is about 55.9 %. The electricity generation of this technology in the region is at about 30000 GWh based on international energy statistics. | The average net electrical efficiency is about 50.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. | The average net electrical efficiency is about 29 %. The electricity generation of this technology in the region is at about 20 GWh based on international energy statistics. | The average net electrical efficiency is about 52.2 %. The electricity generation of this technology in the region is at about 3700 GWh based on international energy statistics. | The average net electrical efficiency is about 51.1 %. The electricity generation of this technology in the region is at about 10000 GWh based on international energy statistics. | The average net electrical efficiency is about 52.2 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 50.2 %. The electricity generation of this technology in the region is at about 1900 GWh based on international energy statistics. | The average net electrical efficiency is about 53.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. | The average net electrical efficiency is about 54.4 %. The electricity generation of this technology in the region is at about 10000 GWh based on international energy statistics. | The average net electrical efficiency is about 41.8 %. The electricity generation of this technology in the region is at about 4900 GWh based on international energy statistics. | The average net electrical efficiency is about 33.1 %. The electricity generation of this technology in the region is at about 80 GWh based on international energy statistics. | The average net electrical efficiency is about 45.4 %. The electricity generation of this technology in the region is at about 420 GWh based on international energy statistics. | The average net electrical efficiency is about 53.9 %. The electricity generation of this technology in the region is at about 170000 GWh based on international energy statistics. | The average net electrical efficiency is about 51.8 %. The electricity generation of this technology in the region is at about 110000 GWh based on international energy statistics. | The average net electrical efficiency is about 38.6 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 50.3 %. The electricity generation of this technology in the region is at about 330000 GWh based on international energy statistics. | The average net electrical efficiency is about 52.2 %. The electricity generation of this technology in the region is at about 120000 GWh based on international energy statistics. | The average net electrical efficiency is about 43.9 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 19.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2020 | 2020 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2022 | 2022 |
| Geography | 663 | Text | AT in 2022 | BE in 2022 | BG in 2022 | CZ in 2022 | DE in 2022 | ES in 2022 | FI in 2022 | FR in 2022 | GR in 2022 | HR in 2022 | HU in 2022 | IE in 2022 | IT in 2022 | MT in 2022 | NL in 2022 | PT in 2022 | RO in 2022 | SI in 2022 | SK in 2022 | CN in 2022 | GB in 2022 | IN in 2022 | JP in 2022 | KR in 2022 | MY in 2021 | RU in 2021 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | ProductionVolume | 4400 GWh | 10000 GWh | 70 GWh | 1900 GWh | 20000 GWh | 60000 GWh | 10 GWh | 30000 GWh | 20000 GWh | 20 GWh | 3700 GWh | 10000 GWh | 60000 GWh | 1900 GWh | 20000 GWh | 10000 GWh | 4900 GWh | 80 GWh | 420 GWh | 170000 GWh | 110000 GWh | 60000 GWh | 330000 GWh | 120000 GWh | 60000 GWh | 20000 GWh |

**Table A2: Key meta data for natural gas power generation from CHP power plants.**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Electricity, natural gas, at CHP power plant/AT U | Electricity, natural gas, at CHP power plant/BE U | Electricity, natural gas, at CHP power plant/BG U | Electricity, natural gas, at CHP power plant/CZ U | Electricity, natural gas, at CHP power plant/DE U | Electricity, natural gas, at CHP power plant/DK U | Electricity, natural gas, at CHP power plant/EE U | Electricity, natural gas, at CHP power plant/ES U | Electricity, natural gas, at CHP power plant/FI U | Electricity, natural gas, at CHP power plant/FR U | Electricity, natural gas, at CHP power plant/GR U | Electricity, natural gas, at CHP power plant/HR U | Electricity, natural gas, at CHP power plant/HU U | Electricity, natural gas, at CHP power plant/IE U |
| Geography | 662 | Location | AT | BE | BG | CZ | DE | DK | EE | ES | FI | FR | GR | HR | HU | IE |
| ReferenceFunction | 403 | Unit | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh |
| DataSetInformation | 201 | Type | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 492 | GeneralComment | The average allocated net electrical efficiency is about 54 %. The electricity generation of this technology in the region is at about 6100 | The average allocated net electrical efficiency is about 68.3 %. The electricity generation of this technology in the region is at about 10000 | The average allocated net electrical efficiency is about 42.1 %. The electricity generation of this technology in the region is at about 1700 | The average allocated net electrical efficiency is about 47.7 %. The electricity generation of this technology in the region is at about 2000 | The average allocated net electrical efficiency is about 53 %. The electricity generation of this technology in the region is at about 60000 | The average allocated net electrical efficiency is about 51.9 %. The electricity generation of this technology in the region is at about 940 | The average allocated net electrical efficiency is about 48.5 %. The electricity generation of this technology in the region is at about 50 GWh | The average allocated net electrical efficiency is about 51.9 % (ENTSO-E average). The electricity generation of this technology in the region | The average allocated net electrical efficiency is about 57.1 %. The electricity generation of this technology in the region is at about 880 | The average allocated net electrical efficiency is about 56.3 %. The electricity generation of this technology in the region is at about 10000 | The average allocated net electrical efficiency is about 38.8 %. The electricity generation of this technology in the region is at about 1100 | The average allocated net electrical efficiency is about 46 %. The electricity generation of this technology in the region is at about 3300 | The average allocated net electrical efficiency is about 48.3 %. The electricity generation of this technology in the region is at about 4600 | The average allocated net electrical efficiency is about 51.9 % (ENTSO-E average). The electricity generation of this technology in the region |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | AT in 2022 | BE in 2022 | BG in 2022 | CZ in 2022 | DE in 2022 | DK in 2022 | EE in 2022 | ES in 2022 | FI in 2022 | FR in 2022 | GR in 2022 | HR in 2022 | HU in 2022 | IE in 2022 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | ProductionVolume | 6100 GWh | 10000 GWh | 1700 GWh | 2000 GWh | 60000 GWh | 940 GWh | 50 GWh | 20000 GWh | 880 GWh | 10000 GWh | 1100 GWh | 3300 GWh | 4600 GWh | 1900 GWh |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Electricity, natural gas, at CHP power plant/IT U | Electricity, natural gas, at CHP power plant/LT U | Electricity, natural gas, at CHP power plant/LU U | Electricity, natural gas, at CHP power plant/LV U | Electricity, natural gas, at CHP power plant/NL U | Electricity, natural gas, at CHP power plant/PL U | Electricity, natural gas, at CHP power plant/PT U | Electricity, natural gas, at CHP power plant/RO U | Electricity, natural gas, at CHP power plant/SE U | Electricity, natural gas, at CHP power plant/SI U | Electricity, natural gas, at CHP power plant/SK U | Electricity, natural gas, at CHP power plant/CH U | Electricity, natural gas, at CHP power plant/CN U | Electricity, natural gas, at CHP power plant/GB U | Ele ty, na ga CH po pla R |
| Geography | 662 | Location | IT | LT | LU | LV | NL | PL | PT | RO | SE | SI | SK | CH | CN | GB | KR |
| ReferenceFunction | 403 | Unit | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kW |
| DataSetInformation | 201 | Type | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | 492 | GeneralComment | The average allocated net electrical efficiency is about 54 %. The electricity generation of this technology in the region is at about 80000 | The average allocated net electrical efficiency is about 50.4 %. The electricity generation of this technology in the region is at about 470 | The average allocated net electrical efficiency is about 39.6 %. The electricity generation of this technology in the region is at about 100 | The average allocated net electrical efficiency is about 53.6 %. The electricity generation of this technology in the region is at about 1100 | The average allocated net electrical efficiency is about 61.9 %. The electricity generation of this technology in the region is at about 20000 | The average allocated net electrical efficiency is about 53 %. The electricity generation of this technology in the region is at about 10000 | The average allocated net electrical efficiency is about 49.7 %. The electricity generation of this technology in the region is at about 3000 | The average allocated net electrical efficiency is about 46.1 %. The electricity generation of this technology in the region is at about 3300 | The average allocated net electrical efficiency is about 48.6 %. The electricity generation of this technology in the region is at about 140 | The average allocated net electrical efficiency is about 56.7 %. The electricity generation of this technology in the region is at about 380 | The average allocated net electrical efficiency is about 44.5 %. The electricity generation of this technology in the region is at about 1500 | The average allocated net electrical efficiency is about 55 %. The electricity generation of this technology in the region is at about 360 | The average allocated net electrical efficiency is about 42.8 %. The electricity generation of this technology in the region is at about 90000 | The average allocated net electrical efficiency is about 51.9 % (ENTSO-E average). The electricity generation of this technology in the region | Th av all d r ele al eff cy ab 52 Th ele ty ge on thi tec og the reg is ab 40 |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 20 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 20 |
| Geography | 663 | Text | IT in 2022 | LT in 2022 | LU in 2022 | LV in 2022 | NL in 2022 | PL in 2022 | PT in 2022 | RO in 2022 | SE in 2022 | SI in 2022 | SK in 2022 | CH in 2022 | CN in 2022 | GB in 2022 | KF 20 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | ProductionVolume | 80000 GWh | 470 GWh | 100 GWh | 1100 GWh | 20000 GWh | 10000 GWh | 3000 GWh | 3300 GWh | 140 GWh | 380 GWh | 1500 GWh | 360 GWh | 90000 GWh | 20000 GWh | 40 GV |

## Table A3: Key meta data for heat supply from CHP power plants.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, natural gas, at CHP power plant/ATU | Heat, natural gas, at CHP power plant/BEU | Heat, natural gas, at CHP power plant/BGU | Heat, natural gas, at CHP power plant/CZU | Heat, natural gas, at CHP power plant/DEU | Heat, natural gas, at CHP power plant/DKU | Heat, natural gas, at CHP power plant/EEU |
| Geography | 662 | Location | AT | BE | BG | CZ | DE | DK | EE |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | IncludedProcesses | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the ENTSO E region adjusted for co-generation (using allocation based on exergy content) since data for the specific region was not plausible. | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the ENTSO E region adjusted for co-generation (using allocation based on exergy content) since data for the specific region was not plausible. | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). |
| | 492 | GeneralComment | The average allocated fuel consumption is about 0.64 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 20000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.65 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 10000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.72 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 20000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.67 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 10000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.64 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 130000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.61 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 4000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.64 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 220 TJ based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | AT in 2022 | BE in 2022 | BG in 2022 | CZ in 2022 | DE in 2022 | DK in 2022 | EE in 2022 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | ProductionVolume | 20000 TJ | 10000 TJ | 20000 TJ | 10000 TJ | 130000 TJ | 4000 TJ | 220 TJ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, natural gas, at CHP power plant/ESU | Heat, natural gas, at CHP power plant/FIU | Heat, natural gas, at CHP power plant/FRU | Heat, natural gas, at CHP power plant/GRU | Heat, natural gas, at CHP power plant/HRU | Heat, natural gas, at CHP power plant/HUU | Heat, natural gas, at CHP power plant/IEU |
| Geography | 662 | Location | ES | FI | FR | GR | HR | HU | IE |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | IncludedProcesses | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). |
| | 492 | GeneralComment | The average allocated fuel consumption is assumed to be 0.42 MJ/MJ heat ouput (ENTSO-E average). The heat generation of this technology in the region is unknown. | The average allocated fuel consumption is about 0.66 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 2700 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.63 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 40000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.65 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 320 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.7 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 8300 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.69 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 10000 TJ based on international energy statistics. | The average allocated fuel consumption is assumed to be 0.42 MJ/MJ heat ouput (ENTSO-E average). The heat generation of this technology in the region is unknown. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | ES in 2022 | FI in 2022 | FR in 2022 | GR in 2022 | HR in 2022 | HU in 2022 | IE in 2022 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | ProductionVolume | unknown | 2700 TJ | 40000 TJ | 320 TJ | 8300 TJ | 10000 TJ | unknown |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, natural gas, at CHP power plant/ITU | Heat, natural gas, at CHP power plant/LTU | Heat, natural gas, at CHP power plant/LUU | Heat, natural gas, at CHP power plant/LVU | Heat, natural gas, at CHP power plant/NLU | Heat, natural gas, at CHP power plant/PLU | Heat, natural gas, at CHP power plant/PTU |
| Geography | 662 | Location | IT | LT | LU | LV | NL | PL | PT |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | IncludedProcesses | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). |
| | 492 | GeneralComment | The average allocated fuel consumption is about 0.63 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 50000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.74 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 2900 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.91 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 1000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.59 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 2500 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.6 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 40000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.67 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 20000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.7 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 10000 TJ based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | IT in 2022 | LT in 2022 | LU in 2022 | LV in 2022 | NL in 2022 | PL in 2022 | PT in 2022 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | ProductionVolume | 50000 TJ | 2900 TJ | 1000 TJ | 2500 TJ | 40000 TJ | 20000 TJ | 10000 TJ |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, natural gas, at CHP power plant/ROU | Heat, natural gas, at CHP power plant/SEU | Heat, natural gas, at CHP power plant/SIU | Heat, natural gas, at CHP power plant/SKU | Heat, natural gas, at CHP power plant/CHU | Heat, natural gas, at CHP power plant/CNU | Heat, natur… at CH… powe… plant… |
| Geography | 662 | Location | RO | SE | SI | SK | CH | CN | GB |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | IncludedProcesses | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat output at the plant gate. The dataset uses the average net efficiency of power plants in the region adjusted for co-generation (using allocation based on exergy content). | Heat… at th… gate… data… the av… net effici… powe… in th… adju… co-… gene… (usin… alloc… based… exerg… conte… |
| | 492 | GeneralComment | The average allocated fuel consumption is about 0.74 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 20000 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.77 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 1400 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.62 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 1300 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.73 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 8400 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.63 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 540 TJ based on international energy statistics. | The average allocated fuel consumption is about 0.77 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 800000 TJ based on international energy statistics. | The a… alloc… fuel consu… is assu… be 0.4… MJ/M… ouput (ENTS… avera… The h… gener… of thi… techn… in the… is unk… |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | RO in 2022 | SE in 2022 | SI in 2022 | SK in 2022 | CH in 2022 | CN in 2022 | GB in… |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | ProductionVolume | 20000 TJ | 1400 TJ | 1300 TJ | 8400 TJ | 540 TJ | 800000 TJ | unkn… |

**Table A4: Key meta data for heat supply from heat plants.**

| | | | AT | BE | BG | CZ | DE | DK | EE |
|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, natural gas, at heat plant/AT U | Heat, natural gas, at heat plant/BE U | Heat, natural gas, at heat plant/BG U | Heat, natural gas, at heat plant/CZ U | Heat, natural gas, at heat plant/DE U | Heat, natural gas, at heat plant/DK U | Heat, natural gas, at heat plant/EE U |
| Geography | 662 | Location | AT | BE | BG | CZ | DE | DK | EE |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | IncludedProcesses | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. |
| | 492 | GeneralComment | The average fuel consumption is about 1.16 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 5400 TJ based on international energy statistics. | The average fuel consumption is about 1.27 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 40 TJ based on international energy statistics. | The average fuel consumption is about 1.3 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 5800 TJ based on international energy statistics. | The average fuel consumption is about 1.1 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 20000 TJ based on international energy statistics. | The average fuel consumption is about 1.14 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 60000 TJ based on international energy statistics. | The average fuel consumption is about 1.04 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 4900 TJ based on international energy statistics. | The average fuel consumption is about 1.4 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 3000 TJ based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | AT in 2022 | BE in 2022 | BG in 2022 | CZ in 2022 | DE in 2022 | DK in 2022 | EE in 2022 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | Production Volume | 5400 TJ | 40 TJ | 5800 TJ | 20000 TJ | 60000 TJ | 4900 TJ | 3000 TJ |

| | | | FI | FR | HR | HU | IT | LT | LU |
|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, natural gas, at heat plant/FI U | Heat, natural gas, at heat plant/FR U | Heat, natural gas, at heat plant/HR U | Heat, natural gas, at heat plant/HU U | Heat, natural gas, at heat plant/IT U | Heat, natural gas, at heat plant/LT U | Heat, natural gas, at heat plant/LU U |
| Geography | 662 | Location | FI | FR | HR | HU | IT | LT | LU |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | IncludedProcesses | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. |
| | 492 | GeneralComment | The average fuel consumption is about 1.12 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 4600 TJ based on international energy statistics. | The average fuel consumption is about 1.08 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 20000 TJ based on international energy statistics. | The average fuel consumption is about 1.17 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 1400 TJ based on international energy statistics. | The average fuel consumption is about 1.1 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 20000 TJ based on international energy statistics. | The average fuel consumption is about 1.1 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 9700 TJ based on international energy statistics. | The average fuel consumption is about 1.19 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 2100 TJ based on international energy statistics. | The average fuel consumption is about 1.28 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 250 TJ based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | FI in 2022 | FR in 2022 | HR in 2022 | HU in 2022 | IT in 2022 | LT in 2022 | LU in 2022 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | Production Volume | 4600 TJ | 20000 TJ | 1400 TJ | 20000 TJ | 9700 TJ | 2100 TJ | 250 TJ |

| | | | LV | NL | PL | RO | SE | SI | SK |
|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, natural gas, at heat plant/LV U | Heat, natural gas, at heat plant/NL U | Heat, natural gas, at heat plant/PL U | Heat, natural gas, at heat plant/RO U | Heat, natural gas, at heat plant/SE U | Heat, natural gas, at heat plant/SI U | Heat, natural gas, at heat plant/SK U |
| Geography | 662 | Location | LV | NL | PL | RO | SE | SI | SK |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | IncludedProcesses | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. | Heat output at the plant gate. The dataset uses the average net efficiency of heat plants in the region. |
| | 492 | GeneralComment | The average fuel consumption is about 1.03 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 6700 TJ based on international energy statistics. | The average fuel consumption is about 1.16 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 8700 TJ based on international energy statistics. | The average fuel consumption is about 1.12 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 10000 TJ based on international energy statistics. | The average fuel consumption is about 1.38 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 10000 TJ based on international energy statistics. | The average fuel consumption is about 1.05 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 570 TJ based on international energy statistics. | The average fuel consumption is about 1.28 MJ/MJ heat ouput. The heat generation of this technology in the region is at about 1000 TJ based on international energy statistics. | The average fuel consumption is about [illegible] MJ/MJ heat ouput. The heat generation of this technology in the region is at about 7300 TJ based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | LV in 2022 | NL in 2022 | PL in 2022 | RO in 2022 | SE in 2022 | SI in 2022 | SK in 2022 |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | 724 | Production Volume | 6700 TJ | 8700 TJ | 10000 TJ | 10000 TJ | 570 TJ | 1000 TJ | 7300 TJ |

**Table A5: Key meta data for regional electricity supply mixes.**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Electricity, from natural gas/AT U | Electricity, from natural gas/BE U | Electricity, from natural gas/BG U | Electricity, from natural gas/CZ U | Electricity, from natural gas/DE U | Electricity, from natural gas/ES U | Electricity, from natural gas/FI U | Electricity, from natural gas/FR U | Electricity, from natural gas/GR U | Electricity, from natural gas/HR U |
| Geography | 662 | Location | AT | BE | BG | CZ | DE | ES | FI | FR | GR | HR |
| ReferenceFunction | 403 | Unit | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh |
| | 492 | General Comment | The mix of electricity generation technologies in the region is collected from international energy statistics. | The average net electrical efficiency is about 50.6 %. The electricity generation of this technology in the region is at about 10000 GWh based on international energy statistics. | The average net electrical efficiency is about 31.4 %. The electricity generation of this technology in the region is at about 70 GWh based on international energy statistics. | The average net electrical efficiency is about 49.9 %. The electricity generation of this technology in the region is at about 1900 GWh based on international energy statistics. | The average net electrical efficiency is about 46.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. | The average net electrical efficiency is about 49.3 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 25.6 %. The electricity generation of this technology in the region is at about 10 GWh based on international energy statistics. | The average net electrical efficiency is about 55.9 %. The electricity generation of this technology in the region is at about 30000 GWh based on international energy statistics. | The average net electrical efficiency is about 50.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. | The average net electrical efficiency is about 29 %. The electricity generation of this technology in the region is at about 20 GWh based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | AT in 2022 | BE in 2022 | BG in 2022 | CZ in 2022 | DE in 2022 | ES in 2022 | FI in 2022 | FR in 2022 | GR in 2022 | HR in 2022 |
| Representativeness | 722 | Percent | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Electricity, from natural gas/HU U | Electricity, from natural gas/IE U | Electricity, from natural gas/IT U | Electricity, from natural gas/MT U | Electricity, from natural gas/NL U | Electricity, from natural gas/PT U | Electricity, from natural gas/RO U | Electricity, from natural gas/SI U | Electricity, from natural gas/SK U |
| Geography | 662 | Location | HU | IE | IT | MT | NL | PT | RO | SI | SK |
| ReferenceFunction | 403 | Unit | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh |
| | 492 | General Comment | The average net electrical efficiency is about 52.2 %. The electricity generation of this technology in the region is at about 3700 GWh based on international energy statistics. | The average net electrical efficiency is about 51.1 %. The electricity generation of this technology in the region is at about 10000 GWh based on international energy statistics. | The average net electrical efficiency is about 52.2 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 50.2 %. The electricity generation of this technology in the region is at about 1900 GWh based on international energy statistics. | The average net electrical efficiency is about 53.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. | The average net electrical efficiency is about 54.4 %. The electricity generation of this technology in the region is at about 10000 GWh based on international energy statistics. | The average net electrical efficiency is about 41.8 %. The electricity generation of this technology in the region is at about 4900 GWh based on international energy statistics. | The average net electrical efficiency is about 33.1 %. The electricity generation of this technology in the region is at about 80 GWh based on international energy statistics. | The average net electrical efficiency is about 45.4 %. The electricity generation of this technology in the region is at about 420 GWh based on international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | HU in 2022 | IE in 2022 | IT in 2022 | MT in 2022 | NL in 2022 | PT in 2022 | RO in 2022 | SI in 2022 | SK in 2022 |
| Representativeness | 722 | Percent | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Electricity, from natural gas/CN U | Electricity, from natural gas/GB U | Electricity, from natural gas/IN U | Electricity, from natural gas/JP U | Electricity, from natural gas/KR U | Electricity, from natural gas/MY U | Electricity, from natural gas/RU U | Electricity, from natural gas/TW U | Electricity, from natural gas/US U | Electricity, from natural gas/ENTSO-E U | Electric y, from natural gas/RM E U |
| Geography | 662 | Location | CN | GB | IN | JP | KR | MY | RU | TW | US | ENTSO-E | RME |
| ReferenceFunction | 403 | Unit | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh | kWh |
| | 492 | General Comment | The average net electrical efficiency is about 53.9 %. The electricity generation of this technology in the region is at about 170000 GWh based on international energy statistics. | The average net electrical efficiency is about 51.8 %. The electricity generation of this technology in the region is at about 110000 GWh based on international energy statistics. | The average net electrical efficiency is about 38.6 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 50.3 %. The electricity generation of this technology in the region is at about 330000 GWh based on international energy statistics. | The average net electrical efficiency is about 52.2 %. The electricity generation of this technology in the region is at about 120000 GWh based on international energy statistics. | The average net electrical efficiency is about 43.9 %. The electricity generation of this technology in the region is at about 60000 GWh based on international energy statistics. | The average net electrical efficiency is about 19.6 %. The electricity generation of this technology in the region is at about 20000 GWh based on international energy statistics. | The average net electrical efficiency is about 43.5 %. The electricity generation of this technology in the region is at about 100000 GWh based on international energy statistics. | The average net electrical efficiency is about 47.4 %. The electricity generation of this technology in the region is at about 1440000 GWh based on international energy statistics. | The average net electrical efficiency is about 51.4 %. The electricity generation of this technology in the region is at about 370000 GWh based on international energy statistics. | The averag net electric efficien y is about 3 %. The electric y generat on of this technol gy in the region i at abou 770000 GWh based c internat onal energy statistic . |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2020 | 2020 | 2020 | 2021 | 2021 | 2020 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2022 | 2022 | 2022 | 2023 | 2023 | 2022 |
| Geography | 663 | Text | CN in 2022 | GB in 2022 | IN in 2022 | JP in 2022 | KR in 2022 | MY in 2021 | RU in 2021 | TW in 2021 | US in 2022 | ENTSO-E in 2022 | RME in 2021 |
| Representativeness | 722 | Percent | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

**Table A6: Key meta data for regional heat supply mixes.**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, from natural gas/AT U | Heat, from natural gas/BE U | Heat, from natural gas/BG U | Heat, from natural gas/CZ U | Heat, from natural gas/DE U | Heat, from natural gas/DK U | Heat, from natural gas/EE U | Heat, from natural gas/ES U | Heat, from natural gas/FI U | Heat, from natural gas/FR U | Heat, from natural gas/GR U | Heat, from natural gas/HR U | Heat, from natural gas/HU U |
| Geography | 662 | Location | AT | BE | BG | CZ | DE | DK | EE | ES | FI | FR | GR | HR | HU |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | Included Processes | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. |
| | 492 | General Comment | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | AT in 2022 | BE in 2022 | BG in 2022 | CZ in 2022 | DE in 2022 | DK in 2022 | EE in 2022 | ES in 2022 | FI in 2022 | FR in 2022 | GR in 2022 | HR in 2022 | HU in 2022 |
| Technology | 692 | Text | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Heat, from natural gas/IE U | Heat, from natural gas/IT U | Heat, from natural gas/LT U | Heat, from natural gas/LU U | Heat, from natural gas/LV U | Heat, from natural gas/NL U | Heat, from natural gas/PL U | Heat, from natural gas/PT U | Heat, from natural gas/RO U | Heat, from natural gas/SE U | Heat, from natural gas/SI U | Heat, from natural gas/SK U | Heat, from natural gas/CH U | Heat, from natura gas/C U |
| Geography | 662 | Location | IE | IT | LT | LU | LV | NL | PL | PT | RO | SE | SI | SK | CH | CN |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 402 | Included Processes | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat mix for the region. | Heat r for th regior |
| | 492 | General Comment | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The mix of heat supply technologies in the region is collected from international energy statistics. | The m of hea suppl techn gies ir the regior collec from interna onal energ statist |
| TimePeriod | 601 | StartDate | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 | 2021 |
| | 602 | EndDate | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 | 2023 |
| Geography | 663 | Text | IE in 2022 | IT in 2022 | LT in 2022 | LU in 2022 | LV in 2022 | NL in 2022 | PL in 2022 | PT in 2022 | RO in 2022 | SE in 2022 | SI in 2022 | SK in 2022 | CH in 2022 | CN in 2022 |
| Technology | 692 | Text | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Avera install techn gy. |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |

**Table A7: Key meta data for regional natural gas combustion datasets.**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ReferenceFunction | 401 | Name | Natural gas, burned in power plant or heatplant/ATU | Natural gas, burned in power plant or heatplant/BEU | Natural gas, burned in power plant or heatplant/BGU | Natural gas, burned in power plant or heatplant/CHU | Natural gas, burned in power plant or heatplant/CNU | Natural gas, burned in power plant or heatplant/CZU | Natural gas, burned in power plant or heatplant/DEU | Natural gas, burned in power plant or heatplant/DKU | Natural gas, burned in power plant or heatplant/EEU | Natural gas, burned in power plant or heatplant/ENTSO-EU | Natural gas, burned in power plant or heatplant/ESU | Natural gas, burned in power plant or heatplant/FIU | Natural gas, burned in power plant or heatplant/FRU | Natural gas, burned in power plant or heatplant/GBU | Natural gas, burned in power plant or heatplant/GRU | Natural gas, burned in power plant or heatplant/HRU | Natural gas, burned in power plant or heatplant/HUU | Natural gas, burned in power plant or heatplant/IEU | Natural gas, burned in power plant or heatplant/INU | Natural gas, burned in power plant or heatplant/ITU | Natural gas, burned in power plant or heatplant/JPU | Natural gas, burned in power plant or heatplant/KRU | Natural gas, burned in power plant or heatplant/LTU | Natural gas, burned in power plant or heatplant/LUU | Natural gas, burned in power plant or heatplant/LVU | Natural gas, burned in power plant or heatplant/MTU | Natural gas, burned in power plant or heatplant/MYU | Natural gas, burned in power plant or heatplant/NLU | Natural gas, burned in power plant or heatplant/PLU |
| Geography | 662 | Location | AT | BE | BG | CH | CN | CZ | DE | DK | EE | ENTSO-E | ES | FI | FR | GB | GR | HR | HU | IE | IN | IT | JP | KR | LT | LU | LV | MT | MY | NL | PL |
| ReferenceFunction | 403 | Unit | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ | MJ |
| | 492 | General Comment | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. For the assessment of main characteristics and criteria emissions (SOx, NOx, | The module describes the operation of an average plant in the region. The plant is used for middle load with 4000 hours of operation at full capacity per year. The plant is assumed to operate 150000 hours during its lifetime. 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| TimePeriod | 601 | StartDate | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 |
| | 602 | EndDate | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 | 2022 |
| Geography | 663 | Text | AT in 2021 | BE in 2021 | BG in 2021 | CH in 2021 | CN in 2021 | CZ in 2021 | DE in 2021 | DK in 2021 | EE in 2021 | ENTSO-E in 2021 | ES in 2021 | FI in 2021 | FR in 2021 | GB in 2021 | GR in 2021 | HR in 2021 | HU in 2021 | IE in 2021 | IN in 2021 | IT in 2021 | JP in 2021 | KR in 2021 | LT in 2021 | LU in 2021 | LV in 2021 | MT in 2021 | MY in 2021 | NL in 2021 | PL in 2021 |
| Technology | 692 | Text | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. | Average installed technology. |
| Representativeness | 722 | Percent | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |