European Commission

Support to Primary Energy Factors Review (PEF)

Final report

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Support to Primary Energy Factors Review (PEF)

Final Report

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Final Report

In association with:

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1 Introduction

The **aim of this study** is to provide technical support to the European Commission in studying all aspects related to the Primary Energy Factors (PEF) and updating their values. PEF are included in the Energy Efficiency Directive (EED, Directive (EU) 2012/27) the Energy Performance of Buildings Directive (EPBD, Directive (EU) 2010/31), as well as in the Commission's 2021 proposals for the recast of both Directives.

The EED contains a legal obligation to review the value of the **PEF for electricity** by 25 December 2022. This part of the study was timely finalised and the methodology and results were discussed in a workshop with stakeholders in October 2022 and submitted to DG ENER in November 2022. The description of the methodology and the results are included in chapter 7.4 of this report.

The proposal for the revision of the EED contains a provision, which foresees the possibility for **PEFs for other energy vectors** to be used if deemed appropriate and justified. Therefore, this study also has the specific objectives to:

- Assess, with the help of experts and stakeholders, the necessity to define and the possible utility of PEF values for other energy carriers;
- Examine if there are sound methodologies for the calculation of PEF values for (a selected set of) other energy carriers;
- If applicable, identify and gather the necessary information and data and calculate the PEF for other energy carriers.

Similarly to the role of PEFs under the EED, their role under the EPBD is analysed. In particular, the specific objectives related to **PEFs for buildings** are to:

- Explain the role of PEFs in the methodologies for the calculation of energy performance of buildings;
- Examine if there are sound methodologies for the calculation of PEFs and if EN 17423 is being considered;
- Assess the national, regional or local PEFs (distinguishing non-renewable, renewable and total) for different energy carriers;
- Explore the treatment of on-site and off-site renewable energy sources in the energy performance calculations.

This report is structured as follows:

Chapter 2 provides an overview on the regulatory framework for PEFs. It contains a brief description of the European regulation and gives an overview on European and International standards related to PEFs and the respective definitions and calculation methodologies.

In **chapter 3** the methodology for the calculation of PEFs is discussed along assessment criteria, including a sensitivity analysis of methodological decisions.

Chapter 4 summarises the calculation of the updated PEF for electricity and discusses methodological implications for PEFs for other energy carriers.

Chapter 5 describes and analyses the use of PEFs in buildings in the EU-27 Member States. Specific questions like the impact of on-site production of electricity and other methodological issues are discussed.

The final **chapter 6** summarises key findings and draws conclusions based on the review of the PEF methodology. Relevant further developments for the calculation of PEFs are outlined.

In the **annexes** the calculation of the PEF for electricity is presented and stakeholder and expert workshops are briefly summarised.

2 Regulatory framework for PEFs

2.1 Relevant EU regulation

European Green Deal

With the European Green Deal, the EU strives to become the first climate-neutral continent. By 2050, net emissions of greenhouse gases should be reduced to zero, with the intermediary goal of reducing net emissions by at least 55% by 2030. Main legislative areas for the decarbonisation of the energy system are:

- the Energy Efficiency Directive (EED),
- the Energy Performance of Buildings Directive (EPBD),
- the Ecodesign Directive, and
- the Renewable Energy Directive (RED),

focusing on higher shares of renewable energy and improved energy efficiency. According to the agreed text of the EED recast, final and primary energy consumption has to be reduced by 38% and 40,5% respectively by 2030, compared to the projections of the Reference Scenario 2007. With the European Green Deal the „Energy Efficiency First Principle" was further strengthened.

Energy Efficiency Directive (EED)

The amending EED (EU Directive 2018/2002) includes in its Annex IV the methodology and (default) value of the PEF for electricity to be used by Member States (emphasis added): *"Applicable when energy savings are calculated in primary energy terms using a bottom-up approach based on final energy consumption. For savings in kWh electricity, Member States shall apply a coefficient established through a transparent methodology on the basis of national circumstances affecting primary energy consumption, in order to ensure a precise calculation of real savings. Those circumstances shall be substantiated, verifiable and based on objective and non-discriminatory criteria. For savings in kWh electricity, Member States may apply a default coefficient of* ***2,1*** *or use the discretion to define a different coefficient, provided that they can justify it. When doing so, Member States shall take into account the energy mix included in their integrated national energy and climate plans to be notified to the Commission in accordance with Regulation (EU) 2018/1999. By 25 December 2022 and every four years thereafter, the Commission shall revise the default coefficient on the basis of observed data."*

The agreed recast EED includes some modifications to the text relating to PEFs. Moreover, the new legal text recognises the possibility for PEFs for other energy vectors to be used, if justified, as mentioned in Article 29(4)[1]: *"For savings in kWh of other energy carriers, Member States shall apply a coefficient in order to accurately calculate the resulting primary energy consumption savings."*

These various needs to update the value of the PEF for electricity and to consider whether PEFs for other energy vectors would be appropriate - as set out in the relevant legislation - are at the basis of this study.

Energy Performance of Buildings Directive (EPBD)

The EPBD (Directive (EU) 2018/844) requires that *"The calculation of primary energy shall be based on primary energy factors or weighting factors per energy carrier, which may be based on national, regional*

[1] Article numbering as in the agreed text in March 2023

or local annual, and possibly also seasonal or monthly, weighted averages or on more specific information made available for individual district system.
Primary energy factors or weighting factors shall be defined by Member States. In the application of those factors to the calculation of energy performance, Member States shall ensure that the optimal energy performance of the building envelope is pursued.
In the calculation of the primary energy factors for the purpose of calculating the energy performance of buildings, Member States may take into account renewable energy sources supplied through the energy carrier and renewable energy sources that are generated and used on-site, provided that it applies on a non-discriminatory basis".

The aim of these provisions was to improve the transparency and consistency of the different regional and national energy performance calculation methodologies used by EU Member States. Additionally, the provisions aimed to ensure that the Energy Efficiency First Principle and the equal treatment of on-site and off-site renewable energy sources are respected in the calculation of PEFs by Member States.

The performance indicators are used to set minimum requirements for new and renovated buildings and as the basis of informative Energy Performance Certificates (EPCs) that are required whenever a building is constructed, sold or let. The reduction in the use of primary energy for end-uses covered by the EPBD is an important policy goal, both through minimum performance requirements and for EPCs. From the perspective of building owners, managers and designers, primary energy is particularly important for meeting mandatory regulations for new and renovated buildings, but the related costs might carry more weight than primary energy when assessing possible improvements to existing buildings.

In its proposal for a recast of the EPBD, the Commission has proposed to make a distinction in the PEF calculations between the "non-renewable primary energy factor", "renewable primary energy factor" and "total primary energy factor", as mentioned in Article 1.14 and Annex I: *"The calculation of primary energy shall be based on primary energy factors, (distinguishing non-renewable, renewable and total) per energy carrier, which have to be recognised by the national authorities. Those primary energy factors may be based on national, regional or local information. Primary energy factors may be set on annual, seasonal, monthly, daily or hourly basis or on more specific information made available for individual district systems.*
Primary energy factors or weighting factors shall be defined by Member States. The choices made and data sources shall be reported according to EN 17423 or any superseding document. Member States may opt for an average EU primary energy factor for electricity instead of a primary energy factor reflecting the electricity mix in the country. [...]
In the calculation of the primary energy factors for the purpose of calculating the energy performance of buildings, Member States may take into account renewable energy sources supplied through the energy carrier and renewable energy sources that are generated and used on-site, provided that it applies on a non-discriminatory basis."

Eco-design and energy labelling

The PEF values also have an impact in the context of the approaches deriving from the Energy Labelling and Energy-related Products legislation, in particular Directive 2009/125/EC establishing a framework for the setting of eco-design requirements for energy-related products and Regulation (EU) 2017/1369 setting a framework for energy labelling. As a result of the changed default PEF for electricity in the EED (2.1 instead of 2.5), the minimum space heating values, the Eco-design lot1 revision and the energy labelling classes had to be adjusted in order to take into account the higher overall energy efficiency of the electricity system. In order to take this new PEF into account, the energy labelling classes for electric space heaters had to be adapted in the current scheme of 10 labelling classes, from A+++ to G. This new classification will be in place at least until 2025, as mentioned in the 2017 Energy labelling regulation.[2]

Renewable Energy Directive (RED)

The Renewable Energy Directive (2018/2001/EU) is part of the Clean Energy for all European package, set in force in 2018. Its target to increase the share of renewable energy sources in gross final energy consumption in the EU up to 32% in 2030 was further strengthened to 40% in 2021 and recently, in March 2023, the European Parliament and the Council reached a provisional agreement for the revision of the directive and set the renewable energy target to 42.5%, aiming for 45%.

2.2 European and International Standards

In this section, a non-exhaustive overview of the most relevant existing or upcoming international and European standards that are related to PEFs is provided. The identified standards provide extensive information on definitions, calculation methodologies, documentation and default values. However, they all provide possible methodological options rather than obligatory rules.

The most relevant ISO standards are:

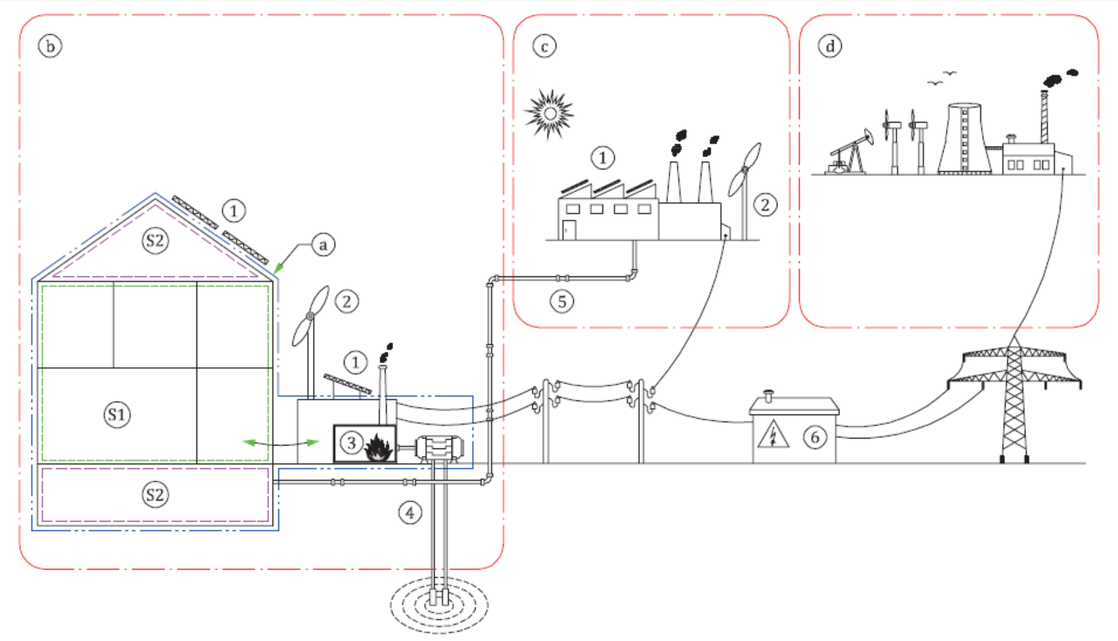
- ISO 52000-1:2017 **Energy performance of buildings — Overarching EPB assessment** — Part 1: General framework and procedures
- ISO/FDIS 52000-3 **Energy performance of buildings — Overarching EPB assessment** — Part 3: General principles for determination and reporting of Primary Energy Factors (PEF) and CO_2 emission coefficients [under development]
- ISO 52000-1:2017 on energy performance of buildings replaces EN 15603:2008. In this standard the following definitions are provided:
    - **Primary energy:** energy that has not been subjected to any conversion or transformation process (Note 1 to entry: Primary energy includes non-renewable energy and renewable energy. If both are taken into account it can be called total primary energy.) (3.4.29)
    - **Energy from non-renewable sources; non-renewable energy:** energy from a source which is depleted by extraction (3.4.10)
    - **Energy from renewable sources; renewable energy:** energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases (3.4.11)
    - **Renewable primary energy factor:** renewable primary energy for a given distant or nearby energy carrier, including the delivered energy and the considered energy overheads of delivery to the points of use, divided by the delivered energy (3.5.21)
    - **Non-renewable primary energy factor:** non-renewable primary energy for a given energy carrier, including the delivered energy and the considered energy overheads of delivery to the points of use, divided by the delivered energy (3.5.17)
    - **Numerical indicator of primary energy use:** primary energy use per unit of reference floor area (Note 1 to entry: Since primary energy use can be expressed in total primary energy, non-renewable primary energy can be specified in the numerical indicator (e.g., non-renewable primary energy use).) (3.5.18)

[2] Marcogaz (2021), PEF implications for ecodesign and energy labelling – a technical view.

- **Energy carrier:** substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes (3.4.9)
- **Energy source:** source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process (3.4.15)
- **Exported energy:** energy, expressed per energy carrier, supplied by the technical building systems through the assessment boundary (Note 1 to entry: It can be specified by generation types (e.g., combined heat and power, photovoltaic) in order to apply different weighting factors. Note 2 to entry: Exported energy can be calculated or it can be measured.) (3.4.20)
- **On-site:** premises and the parcel of land on which the building(s) is located and the building itself (3.4.27)
- **Assessment period:** period of time over which the energy performance is assessed (Note 1 to entry: The assessment) (3.6.1)
- **Calculation interval:** discrete time interval for the calculation of the energy performance (Example: one hour, one month, one heating and/or cooling season, one year, operating modes and bins[3].) (3.6.3)

In Figure 2-1 the concept of on-site, nearby and distant is illustrated schematically.

Figure 2-1: The concept of on-site, nearby and distant in ISO 52000-1:2017



Key

a	assessment boundary (use energy balance)	1	PV, solar
b	perimeter: on-site	2	wind
c	perimeter: nearby	3	boiler room
d	perimeter: distant	4	heat pump
S1	thermally conditioned space	5	district heating/cooling
S2	space outside thermal envelope	6	substation (low/medium voltage and possible storage)

[3] bin: statistical temperature class for the outdoor temperature (ISO 52000, 3.6.2)

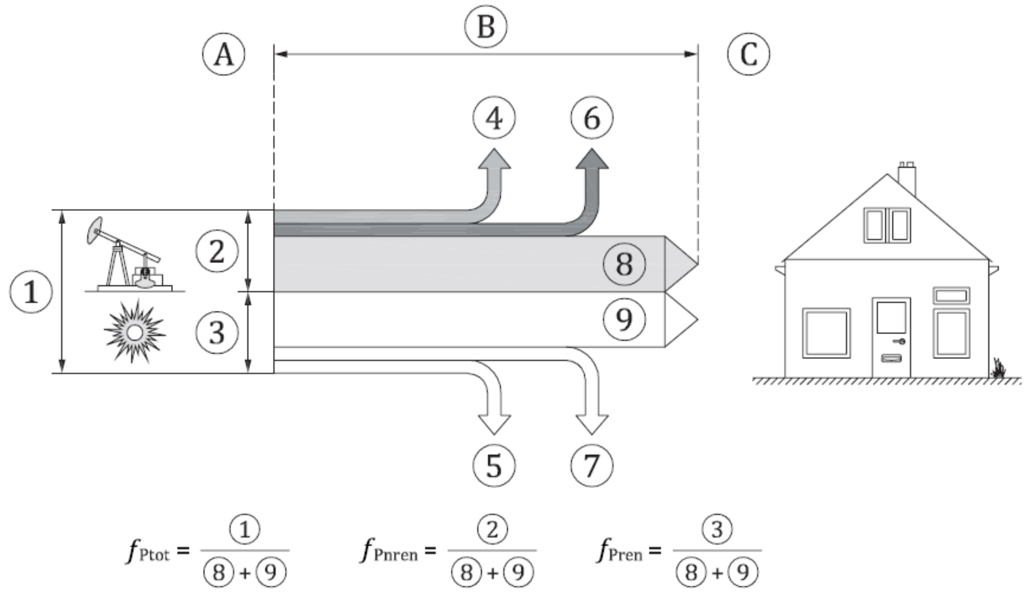
Informative annex H proposes to include renewable energy produced on-site or nearby in the calculation of renewable energy necessary to cover the required energy by a nearly Zero-Energy Building (NZEB).

According to table B.16 of ISO 52000-1 PEFs for delivered energy can be differentiated between perimeters (e.g. (informative) PEF from on-site PV could be 1.0 while electricity from the grid could be 2.5) and between delivered and exported (e.g. (informative) PEF for exported electricity could be 2.5 while PEF for on-site electricity from PV could be 1.0, see also Figure 2-3). Double counting of renewable energy has to be avoided.

There are three primary energy factors:

- Total primary energy factor (P_{tot});
- Non-renewable primary energy factor (P_{nren});
- Renewable primary energy factor (P_{ren}).

Figure 2-2: Calculation of PEFs (Source: ISO 52000-1:2017)



Key

A	energy source	4	non-renewable infrastructure related energy
B	upstream chain of energy supply	5	renewable infrastructure related energy
C	inside the assessment boundary	6	non-renewable energy to extract, refine, convert and transport
1	total primary energy	7	renewable energy to extract, refine, convert and transport
2	non-renewable primary energy	8	delivered non-renewable energy
3	renewable primary energy	9	delivered renewable energy

Figure 2-2 shows that upstream flows are divided into infrastructure related energy (flows 4 and 5) and energy related to extraction, refinery, conversion and transport (flows 6 and 7). Energy flows 4 and 5 do not have to be considered due to an informative default choice table (B.26 in ISO 52000-1:2017).

For co-generated heat/electricity it is defined that the same allocation method has to be applied for heat and electricity.

Figure 2-3: Default values for PEF and CO_2-factors (Source: ISO 52000-1:2017)

	Energy carrier Delivered from distant		f_{Pnren}	f_{Pren}	f_{Ptot}	K_{CO2e} (g/kW h)
1	Fossil fuels	Solid	1,1	0	1,1	360
2		Liquid	1,1	0	1,1	290
3		Gaseous	1,1	0	1,1	220
4	Bio fuels	Solid	0,2	1	1,2	40
5		Liquid	0,5	1	1,5	70
6		Gaseous	0,4	1	1,4	100
7	Electricity [c]		2,3	0,2	2,5	420
	Delivered from nearby					
8	District heating [a]		1,3	0	1,3	260
9	District cooling		1,3	0	1,3	260
	Delivered from on-site					
10	Solar	PV electricity	0	1	1	0
11		Thermal	0	1	1	0
12	Wind		0	1	1	0
13	Environment	Geo-, aero-, hydrothermal	0	1	1	0
	Exported					
14	Electricity [b c]	To the grid	2,3	0,2	2,5	420
15		To non EPB uses	2,3	0,2	2,5	420

[a] Default value based on a natural gas boiler. Specific values are calculated according to M3–8.5.

[b] It is possible to differentiate between different sources of electricity like wind or solar.

[c] These values are established in line with the default coefficient provided in Annex IV of Directive 2012/27/EU. This default coefficient is currently being reviewed and a later amendment of the above factors could be needed.

NOTE 1 Add a column in case of other requirements, e.g., CO_2 requirement.

NOTE 2 Add rows for each relevant energy carrier.

Figure 2-3 illustrates that PEFs are different for on-site, nearby or distant delivery or export. ISO 52000-1:2017 also provides detailed methodological procedures to calculate PEFs for district heating from CHP. The energy performance of buildings can either be based on total PEF or non-renewable PEF. Selection of the PEF should be specified.

EN 17423 Energy performance of buildings - Determination and reporting of Primary Energy Factors (PEF) and CO_2 emission coefficient - General Principles, Module M1-7; November 2020

This standard provides a transparent framework for reporting on the choices related to the procedure to determine PEFs and CO_2 Emission coefficients for energy delivered to and/or exported by the buildings as described in EN ISO 52000-1:2017. Exported PEFs and CO_2 Emission coefficients can be different from those chosen for delivered energy.

This document can be considered as a supporting/complementing standard to EN ISO 52000-1, as the latter requires values for the PEFs and GHG emissions factors to complete the EPB calculation[4]. Definitions in EN 17423 are taken from ISO 52000. In some cases, more detailed explanations were added. For the determination of PEFs and CO_2 EN 17423 provides an extensive and consistent structure for the documentation and reporting of methodological “choices” (Figure 2-4), which have a direct relation to the 2016 PEF study and on which the updated PEF for electricity in this study is based.

[4] Zirngibl, J. 2020: prEN 17423. Reporting of Primary Energy Factors and CO2 emission coefficient for a correct estimation of the real impact of building on energy and climate change. REHVA Journal February 2020.

Figure 2-4: Reporting template for methodological choices (Source: EN 17423:2020 (E))

Reference document (document describing the quantification of PEF and CO_2)				
(ref)				
Energy carrier	$f_{P;nren}$	$f_{P;ren}$	$f_{P;tot}$	K_{CO_2}

Choices related to the perimeter of the assessment (6.1)										
Name of geographical area:										
Geographical Perimeter	□	European	□	National	□	Regional	□	Local	□	Other

Choices related to calculation conventions (6.2)								
Period considered for calculation:								
Time resolution	□	Hourly	□	Monthly	□	Annual	□	Other
Data source	□	Real historic	□	Simulated historic	□	Forward looking	□	Other
Net or Gross Calorific Value	□	Net calorific value	□	Gross calorific value				

Choices related to data (6.3)										
Available energy sources	□	include all energy sources	□	exclude self-consumed on-site generation	□	exclude dedicated delivery contracts			□	Other
GHG considered	□	CO_2 only	□	CO_2 equivalent 20 years	□	CO_2 equivalent 100 years			□	Other
Biogenic carbon	□	carbon neutrality			□	biogenic CO_2, CH_4 accounted			□	Other
Conventions energy conversion	□	Zero equivalent ($f_{P;nren} = 0$)	□	Direct equivalent ($f_{P;we} = 1$)	□	Technical efficiencies	□	Physical energy content	□	Other
Conventions PEF exported energies	□	resources used to produce			□	resources avoided			□	Other

Choices related to the assessment methods (6.4)																
Energy exchanges	□	ignoring exchanges	□	net exchanges			□	Gross exchanges							□	Other
Multisource generation	□	Average calculation approach					□	Other (e.g. marginal) specify approach and technical reference								
Multi energy output system	□	Power bonus	□	Power loss simple	□	Power loss	□	Power loss ref	□	Carnot	□	Alter. Prod.	□	Resid. heat	□	Other
Life cycle analysis (LCA)	□	no LCA					□	full LCA							□	Other

EN 15316-4-5:2017 (E): Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-5: District heating and cooling, Module M3-8-5, M4- 8-5, M8-8-5, M11-8-5.

This 2017 European Standard (replacing the 2007 version) defines the determination of energy indicators of district energy systems, which can be district heating, district cooling or other district energy carriers. Several allocation methods for district heating from CHPs are described, including the “Alternative production method” which is similar to the “Finnish method” applied in the updated PEF for electricity calculation in this study. EN 15316-4-5:2017 provides default values for heat but also for electricity, where PEF = 2.5. For the application of the alternative production method, the following default reference values are given: etaCHP = 75% or 80%, depending on the CHP technology, $eta_{el,Ref}$ = 0.4 and $eta_{h,Ref}$ = 0.9.

3 Methodology for the calculation of PEFs

3.1 Introduction

The EU and its Member States strive for sharp reductions in their primary energy use, as determined in the flagship 2030 policy targets. Electricity based technologies for transport and buildings (electric vehicles, heat pumps, etc.) will play an increasingly important role in this regard, as electrification will, in principle, contribute to cost-efficiently reaching the energy and climate targets. This underpins the need to properly estimate the primary energy savings (and related GHG emissions) of electric appliances, for which adequate conversion factors such as GHG intensities and PEFs are needed. Both conversion factors reflect how the consumed electricity was produced. The calculation and use of conversion factors is a contentious issue because they can affect the outcome of a variety of analyses. For example, PEFs influence the degree to which the installation of a heat pump (HP) or PV solar panels results in the reduction of a building's primary energy use. From the perspective of HPs, a lower PEF is beneficial because it means that the consumed electricity is associated with a lower amount of primary energy use. However, a higher PEF for delivered energy is beneficial for solar panels, because their electricity production is typically multiplied by the PEF to calculate the reduction in a building's primary energy use. This assumes that the electricity production by solar panels displaces completely electricity production that would have otherwise taken place in the (national) electricity system. Due to their interactions with both HPs and solar panels, PEFs can also determine whether or not a building qualifies as a nearly zero energy building.

3.2 Criteria for the assessment of the PEF calculation methodology

The assessment of the calculation methodology for the PEF for electricity should be based on clearly defined criteria. There is not one closed list of criteria at hand. For this study, criteria were selected to reflect the needs of European energy and climate policy. The following criteria were selected:

- Meaningfulness
- Consistency
- Applicability
- Transparency

Meaningfulness means, that any headline indicator should provide relevant information for certain policies. The PEF for electricity is a metric for the efficiency of the electricity production system in terms of primary energy related to final energy consumption. An increase of the PEF means that the overall energy efficiency is reduced in the electricity production system. In the coming years, the PEF for electricity will further decrease but – with the build-up of additional storage systems – it is expected to increase again in the medium to long term. Thus, energy policy will have to deal with the fact, that even with a constant level of final energy consumption primary energy demand will increase as a result of the need to build large storage systems that allow to integrate volatile energy sources like wind power plants and PV facilities.

Even though the overall goal of the European Green Deal is to decarbonize the EU by 2050, the PEF is not – and does not claim to be - the appropriate indicator for monitoring the extent to which this target is reached. It is rather an indicator to measure energy efficiency achievements in the energy system in order to reduce primary energy demand.

Decarbonisation should be reflected by another indicator that considers the GHG emissions. For other policy areas, e.g. air pollution or material flows, additional indicators have to be applied. Headline indicators have their own field of application but it is important to mention that they are interlinked and that they should be organized in a way they provide together insightful results.

Consistency is an important criterion insofar that inconsistent methodologies lead to incomplete or misleading policy signals. An example could be the production of e-fuels that will require a significant amount of electricity. If the calculation of the PEF for e-fuels would not be based on the same methodological assumptions and parameters as for the PEF for electricity, information for primary energy demand will not sum up correctly and will not fit to official statistical reporting from EUROSTAT or any national energy statistics which are harmonised to a large extent. This is not only a problem for a correct data basis but it will also lead to policy decisions that might finally lead to unintended results.

A high level of inconsistency can be observed in the PEF for district heating from CHPs, where in some methodologies, heat is treated as waste from electricity production – leading to a small PEF for heat - which is typically preferred by some district heating stakeholders while on the other side stakeholders of the electricity system will be in favour of methodologies that allocate the primary energy use to the heat and electricity production more evenly. Hence, a comparison of different heat production systems like district heating and heat pumps based on different methodologies will lead to distorted or meaningless results in terms of primary energy use or GHG emissions.

Applicability refers to dimensions like data availability, complexity of calculation and application in policy areas. In the 2016 PEF study[5], the selection of methodological decisions was based on several criteria, 70% of the weight was given to "methodological suitability" which included:

- Precision (representation of the real world in the calculation methodology) – 50%
- Data availability (20%), further divided in
    - Effort required
    - Credibility
    - Data quality
    - Uncertainty
    - Flexibility

As an example, the calculation of hourly PEFs seems useful for the assessment of solar PV and heat pump installations. However, this would require the application of an encompassing power system model considering distribution of temperatures, solar radiation, wind, water flows etc. Hence, the complexity would be far too high to use such a model in EU policies. For single case studies, such an approach might be necessary.

Transparency

The calculation methodology for PEFs for electricity relies on several conventions and decisions[6]. As described in detail in the 2016 PEF study, the assessment of several methodological decisions does not lead to a single possible way to calculate the PEF but leaves several options. Trade-offs are unavoidable. A minimal requirement for the methodology for the PEF calculation is to be as transparent as possible and to declare any methodological decision and describe the methodology in great detail. For the PEF for electricity, the calculation method is defined in recital 40 of the EED (emphasis added):

*"Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the **default coefficient for savings in kWh electricity** should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy*

[5] https://energy.ec.europa.eu/publications/review-default-primary-energy-factor-pef-reflecting-estimated-average-eu-generation-efficiency_en

[6] Molenbroek, E. et al. 2011: Primary energy factors for electricity in buildings. Towards a flexible electricity supply. Study by Ecofys.

mix of the PEF for electricity are based on ***annual average values****.* ***The 'physical energy content' accounting method*** *is used for nuclear electricity and heat generation and the* ***'technical conversion efficiency' method*** *is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the* ***direct equivalent*** *based on the* ***'total primary energy' approach****. To calculate the primary energy share for electricity in* ***cogeneration, the method set out in Annex II to Directive 2012/27/EU*** *is applied. An* ***average rather than a marginal market position*** *is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the* ***PEF is 1 for all energy sources****. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the* ***PRIMES Reference Scenario*** *for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers* ***the Member States and Norway****. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data."*

In the following sensitivity assessment (see chapter 3.4) some major methodological decisions are analysed in quantitative terms.

3.3 Calculation of the PEF for electricity

The updated PEF value for electricity was calculated based on the assumptions mentioned in recital 40 of the EED. The report with the description of the methodology and the results was submitted in November 2022 to DG ENER. The full PEF report can be found in the Annex of this report.

3.4 Sensitivity of methodological decisions on the PEF

3.4.1 Selection of most relevant methodological decisions

Molenbroek et al.[7] state, that "there is no unified approach in European regulations regarding how to calculate primary energy". The overview and analysis of the PEFs used in Member States (chapter 4) clearly show that the calculation methodologies vary significantly. Lack of consistency and transparency is widely discussed in literature.[8]

Furthermore, during the implementation of task 2 of this assignment, the methodological decisions were discussed in workshops with stakeholders and experts. The main points of these discussions are summarized hereafter.

The following topics were raised by stakeholders and experts:

PEF and EU policy goals

It was argued that the PEF for electricity (PEF of 2.5, 2.1 or 1.9) should not incentivise the use of fossil fuels (with a PEF of 1). The most efficient technology should be preferred which is not the case if PEF for electricity is too high and if PEF of renewables is not treated differently to non-renewables.

PEF and decarbonisation

According to some stakeholders, decarbonisation should be directly reflected in the PEF. The concerned stakeholders argued that this is not the case as long as all renewable energies have a PEF of 1 (physical content method, direct equivalent method). Although it would make sense to also consider GHG emissions

[7] ibd.

[8] Hamels, S., et al. 2021: The use of primary energy factors and CO2 intensities – reviewing the state of play in academic literature; Hamels, S. 2021: CO2 Intensities and Primary Energy Factors in the Future European Electricity System. Energies 2021, 14, 2165; Hitchin, R. 2019: Primary Energy Factors and the primary energy intensity of delivered energy: An overview of possible calculation conventions. Building Serv. Eng. Res. Technol. 2019, Vol. 40(2), 198-219.

as a relevant criterion to assess the performance of buildings, it would not be appropriate to measure both the energy efficiency (currently indicated by the PEF value) and the climate impact into one indicator, as this would reduce the consistency and transparency of the methodology and of the resulting PEF.

Transparency of PEF calculation methodology

Transparency is seen as a major requirement for the PEF calculation. The methodology should be in line with European legislation and it should use existing standards. Examples of relevant standards with regard to PEF calculations are:

- EN ISO 52000-1:2017 on the Energy performance of buildings – Overarching EPB assessment, Part 1: General framework and procedures; includes definitions and default values for PEFs
- EN 15316-4-5:2017 on Energy performance of buildings – Method for calculation of system energy requirements and system efficiencies – Part 4-5: District heating and cooling; specifies calculation methods for PEFs of district heating systems, incl. from CHPs; default values for PEFs
- EN 17423:2020 (E) on Energy performance of buildings – Determination and reporting of Primary Energy Factors (PEF) and CO2 emission coefficient – General Principles; provides definitions, incl. LCA for upstream flows, calculation methodologies with several options; template for reporting of methodological decisions

Geographical resolution of PEF calculation

For the PEF for electricity calculation, the EU-27+Norway is the relevant geographical area, power exchange with other third countries should not to be considered as it would have a marginal impact but would increase complexity disproportionately. Applying one single PEF for electricity at EU level might be declined by some countries that have a significant different power production system, i. e. with a larger share of renewables. This remark may also apply for PEF calculations on a regional level, as the primary energy use for local electricity production of district heating may be highly different depending on the sub-region. In the framework of the EED, Member States are allowed to use their own PEF, the main requirement is that they can "justify" their calculation. For the EPBD, the PEF has to be provided by the Member States.

Forward looking PEF

For future investments in buildings or equipment, some stakeholders argued that a forward-looking PEF (calculated on the basis of the future electricity supply system) is required. Investment decisions taken today would have real effects in 5 or 10 years, and the concerned assets would be used during the coming 10 to 50 years. Hence, a PEF should reflect this long period. With a PEF reflecting the present electricity system, investments progress towards more efficient technologies would be hindered.

Time of use instead of annual average value

It was argued, that for electrical heating systems, it does not make sense to use an annual average for the PEF. Electric heaters are mostly used in winter and at night, when there is less electricity from PV.[9] This is considered as not adequately reflected in the PEF for electricity.

[9] AEBIOM, EGEC, ESTIF 2017: Primary energy factor for electricity in the energy efficiency directive. Joint Position Paper.

3.4.2 Sensitivity analysis of methodological decisions for the PEF for electricity

Based on methodological discussions in the literature a quantitative sensitivity analysis was carried out based on the calculation methodology of the PEF for electricity presented in the PEF report finished in November 2022.

In order to assess the quantitative and qualitative influence of specific methodological decisions for the calculation of the PEF for electricity, the calculation methodology has been adapted in one dimension without changing any of the other relevant parameters (ceteris paribus). With such an approach the direct effect of methodological decisions can be displayed and discussed. The baseline for the comparison of PEFs is the results from the modelling that accompanied the REPowerEU plan[10] (REP13).

The following methodological decisions are examined quantitatively:

- Exclusion of Norway (EU-27)
- Application of the “Zero Equivalent Method” for renewable energy (RES: PEF=0)
- Use of IEA allocation method (IEA method)
- Adaptation of reference values for CHP (CHP Ref. 40%/80%)
- Use of CHP efficiency of 85% (CHP 85%)
- Including upstream flows (LCA)

All scenarios are compared to the baseline (REP13) and summarized at the end of the chapter.

Exclusion of Norway in the calculation of the PEF for electricity

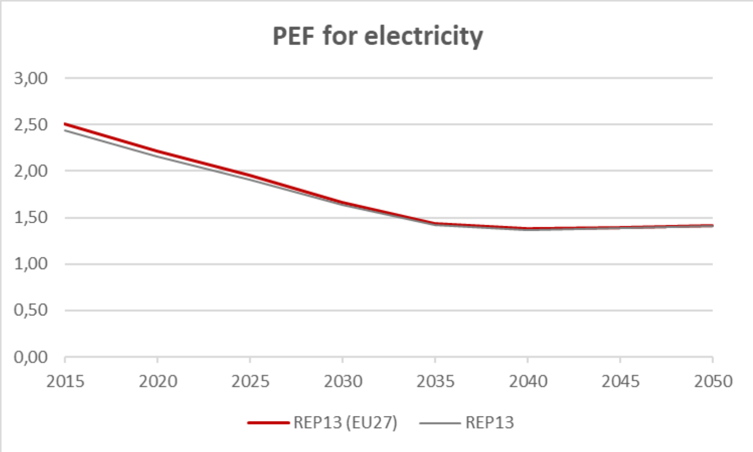
In the first scenario Norway is excluded from the calculation. In some comments received from stakeholders and experts it was argued that due to the completely different energy power system in Norway, the PEF is artificially lowered and thus Norway should not be considered in the PEF calculation.

Table 3-1: Comparison of REP13 with EU-27 (Exclusion of Norway); own calculations e7

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (EU-27)	2.50	2.21	1.95	1.66	1.44	1.38	1.40	1.41
REP13	2.44	2.16	1.91	1.64	1.42	1.37	1.39	1.40
Difference	*0.06*	*0.06*	*0.04*	*0.03*	*0.01*	*0.01*	*0.01*	*0.01*

[10] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

Figure 3-1: Development of PEF in the EU-27 scenario



With the exclusion of Norway, the PEF would be increased by 0.06 to 0.03 for the period from 2015 to 2030, after this period the difference would be around 0.01 reflecting the uptake of renewable energy in the power system of the EU-27.

Accounting methods for renewable energy resources

In the proposed calculation methodology for the PEF for electricity, the "total primary energy" was chosen as the appropriate PEF indicator, i.e. including renewable and non-renewable energy for all energy carriers. For the accounting of renewable energy resources, a PEF of 1 is applied for all fuels (wind, hydro, PV, biomass) according to the "physical energy content" that is also used by EUROSTAT. It is defined as "the first flow in the production process that has a practical energy use"[11]. For combustible energy carriers like natural gas, coal, oil or biomass it is defined as the heat generated during combustion. For non-combustible energy carriers it is defined as heat for nuclear energy, geothermal energy and solar thermal and as electricity as the primary energy form for PV, wind and hydropower. For geothermal energy an efficiency of 10% is assumed for its conversion to electricity and 50% for heat production. Nuclear energy is calculated with an assumed efficiency of 33%.
The most important methodological decision is about using the "zero equivalent method" instead of the "physical content method" for renewable energy resources, assuming a PEF of 0 for hydro, wind, PV, geothermal and biomass.

Table 3-2: Assumptions in the REP13 scenario (baseline)

	PEF of the energy carrier	Conversion efficiency
Hydro	1	100%
Wind	1	100%
PV	1	100%
Biomass	1	Calculated value
Geothermal (electricity)	1	10%
Nuclear	1	33%
Fossil fuels	1	Calculated value

Applying the "zero equivalent method" for renewable energy carriers leads to the following table:

[11] EUROSTAT

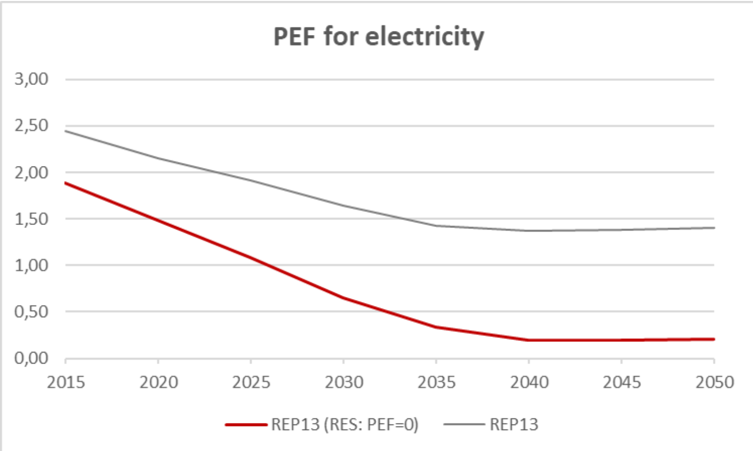
Table 3-3: PEF for fuels in the RES: PEF=0 scenario

	PEF of the energy carrier	Conversion efficiency
Hydro	0	100%
Wind	0	100%
PV	0	100%
Biomass	0	Calculated value
Geothermal (electricity)	0	10%
Nuclear	1	33%
Fossil fuels	1	Calculated value

Table 3-4: Comparison of REP13 with RES: PEF=0; own calculation e7

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (RES: PEF=0)	1.89	1.48	1.09	0.65	0.33	0.19	0.19	0.20
REP13	2.44	2.16	1.91	1.64	1.42	1.37	1.39	1.40
Difference	*-0.55*	*-0.67*	*-0.82*	*-0.99*	*-1.09*	*-1.17*	*-1.20*	*-1.20*

Figure 3-2: Development of PEF in the RES: PEF=0 scenario



For the RES: PEF=0 scenario the development of the PEF shows a significant different picture. PEF starts at 1.89 in 2015 decreasing fast to about 0.20 in 2040 and staying constant afterwards. This development reflects the decarbonisation of the power supply system but information on the overall efficiency of electricity production cannot be derived from these data. In other words, it is not possible to deduct whether the electricity is produced in an efficient way. A PEF calculation based on RES = 0 does also not allow to evaluate whether the Energy Efficiency First principle is respected as the PEF only focuses on supply and not on use. The recommended approach should be to first reduce the energy needs, and then to cover them by the most efficient processes and sources. This is of high relevance as the electricity consumption is expected to increase in coming decades and the production of electricity needs to be as efficient as possible. For the energy policy, the application of the zero-equivalent method could give the misleading signal that 'wasting energy' is not a problem in a decarbonized energy system, which is not the case. Quite the reverse is true: useful energy will also be scarce in the future and demand should be reduced first as far as possible and the still remaining energy demand should be produced with the highest efficiency and the lowest GHG emissions.

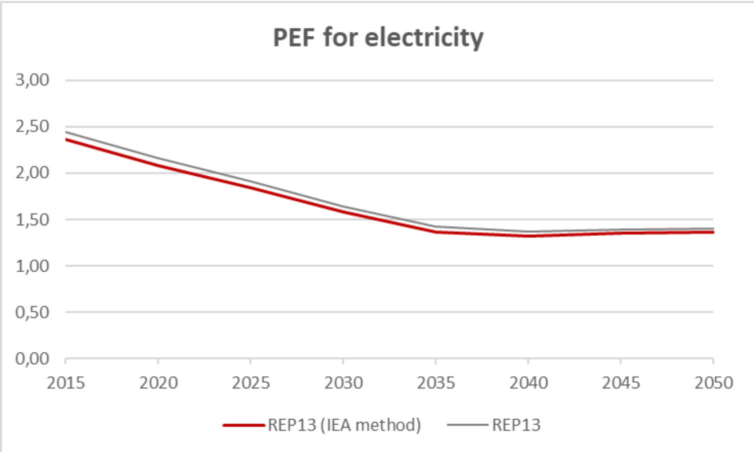
Allocation method for CHP: IEA method instead of the Finnish method

In the PEF for electricity calculation the so-called Finnish method was applied for the allocation of CHP primary energy input. EUROSTAT uses the IEA method leading to a larger share of primary energy allocated to heat. For the PEF for electricity calculation this means that the "heat bonus" would be larger and the PEF for electricity would be reduced accordingly.

Table 3-5: Comparison of REP13 with the IEA method scenario; own calculation e7

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (IEA method)	2.36	2.08	1.84	1.58	1.36	1.32	1.35	1.37
REP13	2.44	2.16	1.91	1.64	1.42	1.37	1.39	1.40
Difference	*-0.08*	*-0.08*	*-0.07*	*-0.06*	*-0.06*	*-0.05*	*-0.04*	*-0.03*

Figure 3-3: Development of PEF in the IEA method scenario



As expected and already shown in the 2016 PEF study the change of the allocation method used for the calculation of the heat bonus of CHP will have an effect on the PEF values. With the IEA method, a larger share of primary energy is allocated to heat leading to a reduction of the PEF for electricity of significantly less than 0.1 for the whole period.

Adaptation of reference values for CHP

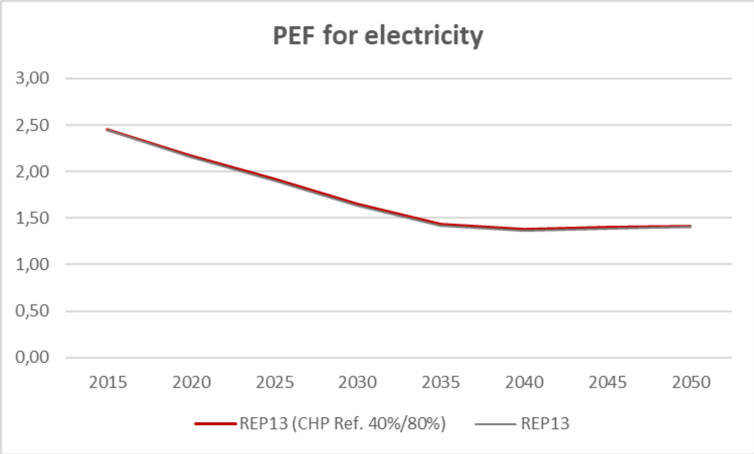
Beside the decision on the allocation method for CHP, reference values for heat and electricity production have to be selected. For the PEF for electricity calculation, reference values were taken from EUROSTAT for 2015 and 2020. For 2050 an improved energy efficiency was assumed ($eta_{Ref,th}$ = 92%, $eta_{Ref,el}$ = 53%). In the 2016 PEF study, values of 40% and 80% were assumed, based on expert judgement.

Table 3-6: Comparison of the REP13 with the CHP Ref. 40%/80% scenario; own calculation e7

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (CHP Ref. 40%/80%)	2.45	2.17	1.93	1.65	1.44	1.38	1.40	1.41
REP13	2.44	2.16	1.91	1.64	1.42	1.37	1.39	1.40
Difference	*0.01*	*0.02*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*

Even though the reference values differ quite significantly compared to the baseline, the effects on the PEF for electricity are insignificant. This is mainly due to the fact that in the Finnish method a change of the relation of both reference values will alter the results, while a change of the absolute reference values with the same relation between them will leave the results unchanged.

Figure 3-4: Development of PEF in the CHP Ref. 40%/80% scenario



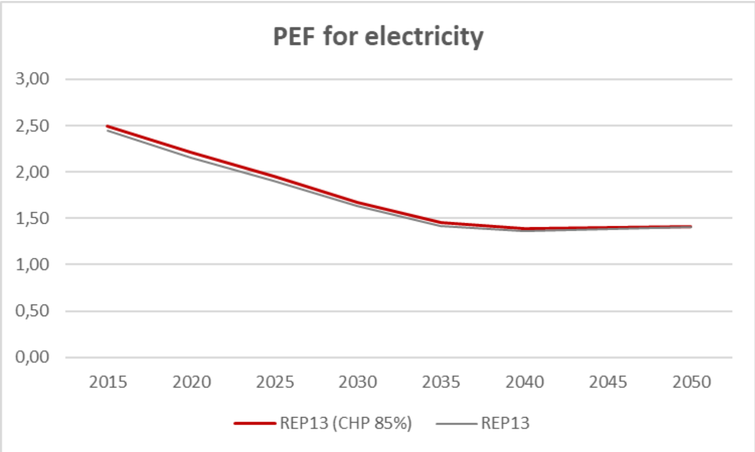
Adaptation of assumed efficiency of CHPs

As no data for the primary energy input into CHPs are available, the overall efficiency of CHPs has to be estimated or assumed. For the PEF calculation an increasing overall efficiency was assumed resulting in an efficiency of 75% in 2050. In the CHP 85% scenario an overall efficiency for CHP of 85% was assumed for the whole period (2015 – 2050).

Table 3-7: Comparison of the REP13 with the CHP 85% scenario; own calculation e7

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (CHP 85%)	2.50	2.21	1.96	1.67	1.45	1.39	1.40	1.41
REP13	2.44	2.16	1.91	1.64	1.42	1.37	1.39	1.40
Difference	*0.06*	*0.06*	*0.05*	*0.04*	*0.03*	*0.02*	*0.02*	*0.01*

Figure 3-5: Development of PEF in the CHP 85% scenario



With an assumed CHP overall efficiency of 85%, the PEF would be slightly higher. The difference is 0.06 in 2015 and 0.01 in 2050.

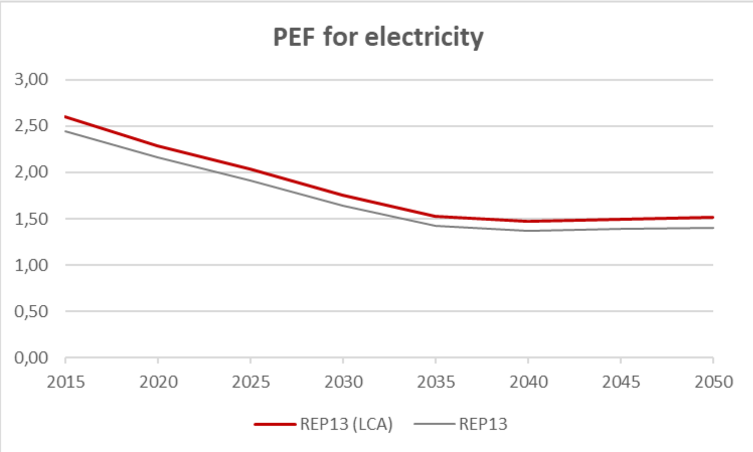
Considering losses in upstream flows (LCA) for fuels

It is an ongoing discussion whether and to what extent upstream losses of fuels (including bioenergy) should be included in the calculation of the PEF for electricity. In this LCA scenario all fuels except nuclear energy (PEF = 1) are calculated with a PEF of 1.1, a value frequently applied especially in cases where no detailed data exist.

Table 3-8: Comparison of the REP13 with the LCA scenario; own calculation e7

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (LCA)	2.60	2.29	2.04	1.75	1.52	1.47	1.50	1.52
REP13	2.44	2.16	1.91	1.64	1.42	1.37	1.39	1.40
Difference	*0.15*	*0.13*	*0.13*	*0.11*	*0.10*	*0.11*	*0.11*	*0.11*

Figure 3-6: Development of PEF in the LCA scenario

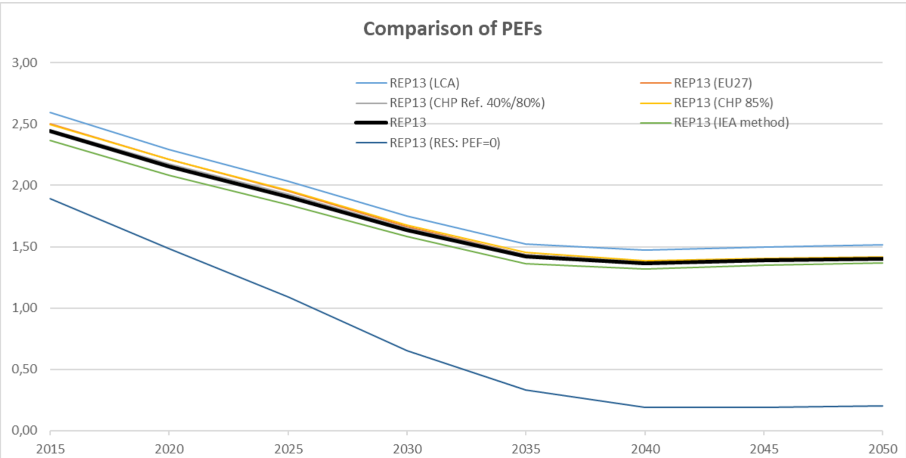


Including the losses in upstream flows for fossil fuels would lead to an increase of the PEF for electricity in the range of 0.11 to 0.15, with the latter in 2015.

Summary of the analysis

In this summary, the results of all scenarios are presented and compared.

Figure 3-7: Development of PEF in different scenarios



In general, it can be observed that the PEFs will in all scenarios decrease until 2035 or 2040 and afterwards there will be a period of stable PEF values (Figure 3-7).

Table 3-9: PEFs for electricity in the different scenarios

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (LCA)	2.60	2.29	2.04	1.75	1.52	1.47	1.50	1.52
REP13 (EU-27)	2.50	2.21	1.95	1.66	1.44	1.38	1.40	1.41
REP13 (CHP Ref. 40%/80%)	2.45	2.17	1.93	1.65	1.44	1.38	1.40	1.41
REP13 (CHP 85%)	2.50	2.21	1.96	1.67	1.45	1.39	1.40	1.41
REP13	**2.44**	**2.16**	**1.91**	**1.64**	**1.42**	**1.37**	**1.39**	**1.40**
REP13 (IEA method)	2.36	2.08	1.84	1.58	1.36	1.32	1.35	1.37
REP13 (RES: PEF=0)	1.89	1.48	1.09	0.65	0.33	0.19	0.19	0.20

Table 3-10: Differences of the PEFs for electricity in the different scenarios compared to REP13

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (LCA)	0.15	0.13	0.13	0.11	0.10	0.11	0.11	0.11
REP13 (EU-27)	0.06	0.06	0.04	0.03	0.01	0.01	0.01	0.01
REP13 (CHP Ref. 40%/80%)	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01
REP13 (CHP 85%)	0.06	0.06	0.05	0.04	0.03	0.02	0.02	0.01
REP13	**2.44**	**2.16**	**1.91**	**1.64**	**1.42**	**1.37**	**1.39**	**1.40**
REP13 (IEA method)	-0.08	-0.08	-0.07	-0.06	-0.06	-0.05	-0.04	-0.03
REP13 (RES: PEF=0)	-0.55	-0.67	-0.82	-0.99	-1.09	-1.17	-1.20	-1.20

Table 3-11: PEFs for electricity in the different scenarios (1-digit level)

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (LCA)	2.6	2.3	2.0	1.8	1.5	1.5	1.5	1.5
REP13 (EU-27)	2.5	2.2	2.0	1.7	1.4	1.4	1.4	1.4
REP13 (CHP Ref. 40%/80%)	2.5	2.2	1.9	1.7	1.4	1.4	1.4	1.4
REP13 (CHP 85%)	2.5	2.2	2.0	1.7	1.5	1.4	1.4	1.4
REP13	**2.4**	**2.2**	**1.9**	**1.6**	**1.4**	**1.4**	**1.4**	**1.4**
REP13 (IEA method)	2.4	2.1	1.8	1.6	1.4	1.3	1.3	1.4
REP13 (RES: PEF=0)	1.9	1.5	1.1	0.7	0.3	0.2	0.2	0.2

Table 3-12: Differences of the PEFs for electricity in the different scenarios compared to REP13

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (LCA)	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
REP13 (EU-27)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
REP13 (CHP Ref. 40%/80%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
REP13 (CHP 85%)	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
REP13	**2.4**	**2.2**	**1.9**	**1.6**	**1.4**	**1.4**	**1.4**	**1.4**
REP13 (IEA method)	-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
REP13 (RES: PEF=0)	-0.6	-0.7	-0.8	-1.0	-1.1	-1.2	-1.2	-1.2

Depending on the scenarios, the PEF values for electricity vary quite significantly. Especially large effects can be seen in the LCA scenario where the PEF is increased by 0.1 to 0.2, while the application of the zero equivalent method would lead to a significantly reduced PEF which even decreases to 0.2 or 0 from 2040 to 2050. All other scenarios only alter the PEF for electricity by an absolute value of 0.1 or less.

4 PEFs for electricity and other energy vectors used by EU Member States for buildings

To facilitate a comparison between the efficiency and energy consumption of energy systems fueled by different (primary and final) energy sources, a unified and easily interpretable approach is desirable connecting primary and final energy demand. An approach based on PEFs was proposed by the European Commission (EC) in 2006 as part of a methodology to achieve this purpose, incorporating the upstream chain of secondary energy carriers (electricity) in calculating their final efficiency, thus making them comparable to primary energy carriers on more equal terms. The approach to define and calculate the PEFs for electricity and other energy carriers differ however across EU Member States. This leads to confusion and opacity in the decision-making processes, having an influence on the energy efficiency/transition pathways taken by the EU-27 Member States. Specifically, establishing and comparing the energy performance of buildings is problematic with regards to space heating, characteristically relying on competing options of natural gas and electricity, depending on the energy mix of the EU Member States. A similar logic for energy carriers not requiring such a complex conversion process, such as natural gas, however incorporating the upstream energy need of exploration, transportation and distribution in the final energy demand via a calculated PEF value might be justifiable, allowing for a more accurate comparison with electricity. With the rapidly changing energy generation mix of the EU-27 and the increasing share of renewable electricity, it is also necessary to regularly revise the PEF values for electricity too.

PEFs are used in energy policy both on EU and national levels for:

- converting final energy use into primary energy consumption;
- to define and compare the energy efficiency of different devices fuelled by primary/final energy sources/carriers; and
- to assess the overall energy performance of buildings.

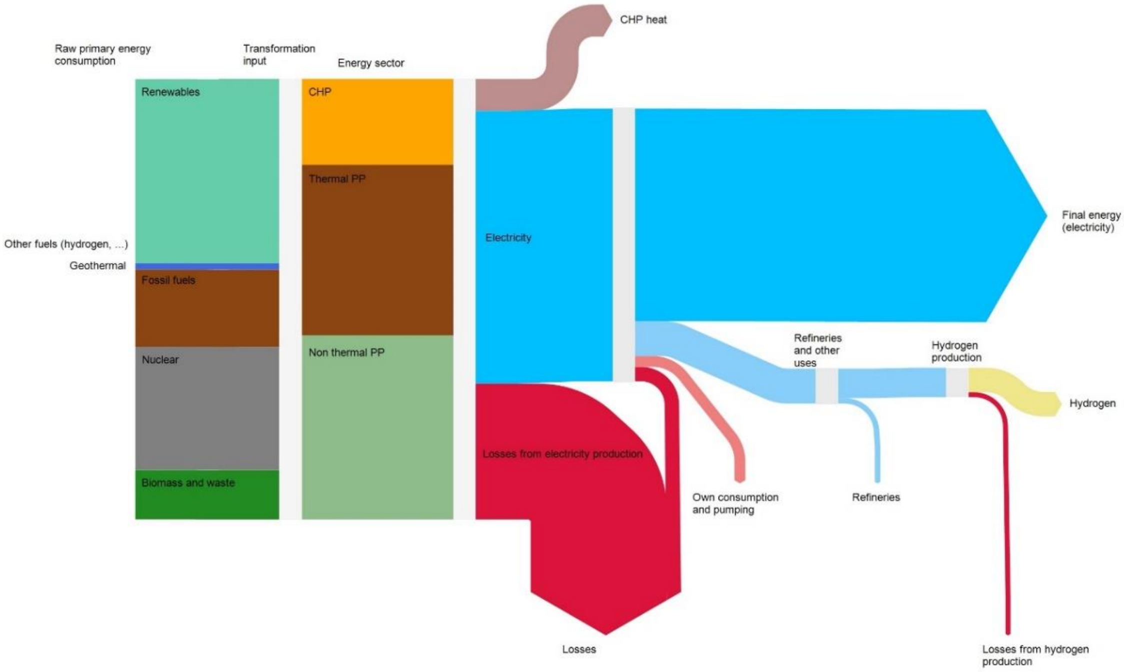
By setting the relevant EU energy saving targets on primary energy levels, the PEFs retain a crucial role in the assessment of measures taken by the EC and national governments.
This section focuses on the PEF values used by national authorities to assess the overall energy efficiency of buildings.

4.1 Calculation of the updated PEF for electricity

4.1.1 Methodology

Figure 4-1 provides an overview of all energy flows considered in the calculation of the PEF for electricity. It is also the basis to understand the calculation of PEF for fuels produced by electricity (green hydrogen, e-fuels). The energy flows represent EU-27+Norway in 2030.

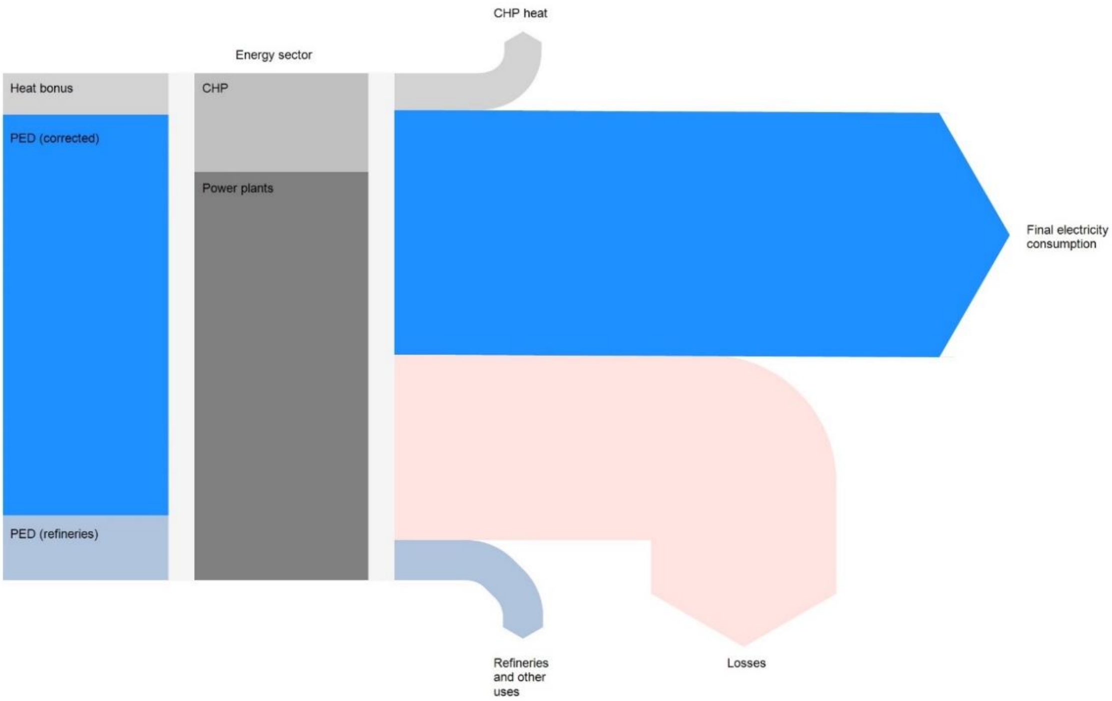
Figure 4-1: Calculation of PEF for electricity – energy flows (own figure e7)



For the calculation of the PEF for electricity, the final energy (electricity) consumption has to be divided by the related primary energy demand. The energy flows that stem from heat production from CHP and electricity consumed in refineries and other uses that are not transformed to electricity have to be excluded as well.

Simplified energy flows where relevant flows for the calculation of the PEF for electricity are highlighted in Figure 4-2. The detailed calculation methodology and results can be found in the PEF report in the annex (chapter 7.4).

Figure 4-2: Simplified energy flows for the calculation of the PEF for electricity (own figure e7)



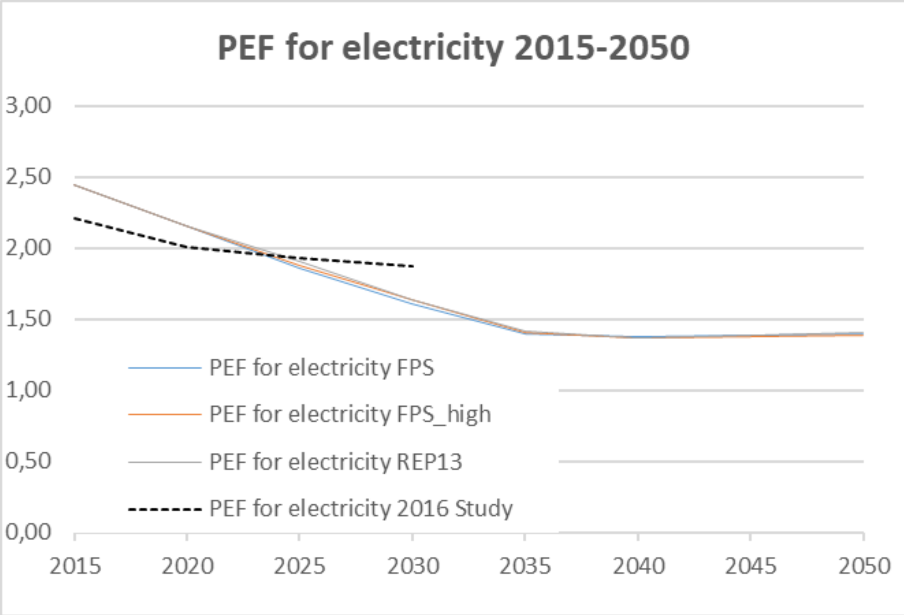
4.1.2 Results of the calculation of the PEF for electricity

The PEF calculation is documented in the PEF report that can be found in the annex (chapter 7.4): Table 4-1 summarizes the PEFs for electricity for all scenarios and the results from the 2016 PEF study.

Table 4-1: PEF for electricity in 2015-2050 for different PRIMES scenarios (Source: e7)

	2015	2020	2025	2030	2035	2040	2045	2050
FPS scenario	2.44	2.16	1.86	1.61	1.40	1.38	1.38	1.40
FPS_high scenario	2.44	2.16	1.88	1.64	1.41	1.37	1.38	1.39
REP13 scenario	2.44	2.16	1.91	1.64	1.42	1.37	1.39	1.40
PEF 2016 study	2.21	2.01	1.93	1.87	-	-	-	-

Figure 4-3: Development of PEF for electricity in 2015-2050 (Source: e7)



The PEF for electricity decreases from 2.44 in 2015 to 1.40 or 1.39 in 2050, depending on the scenario. From 2035 the PEF stays at a constant level, with a slight increase between 2040 and 2050 (Table 4-1). This increase is a result of the larger share of own consumption and pumping. The PEF values for electricity show very small variations between the different PRIMES scenarios.

Compared to the 2016 PEF study calculation, the updated PEF for electricity is higher in 2015 and 2020, it is at a similar level between 2020 and 2025 and it decreases faster after this period. The main reasons for these deviations come from the exit of UK from the European Union, changes in PRIMES scenario assumptions and the developments in Norway, where the electricity production from wind energy is expected to increase much faster than assumed in the 2016 PEF study.

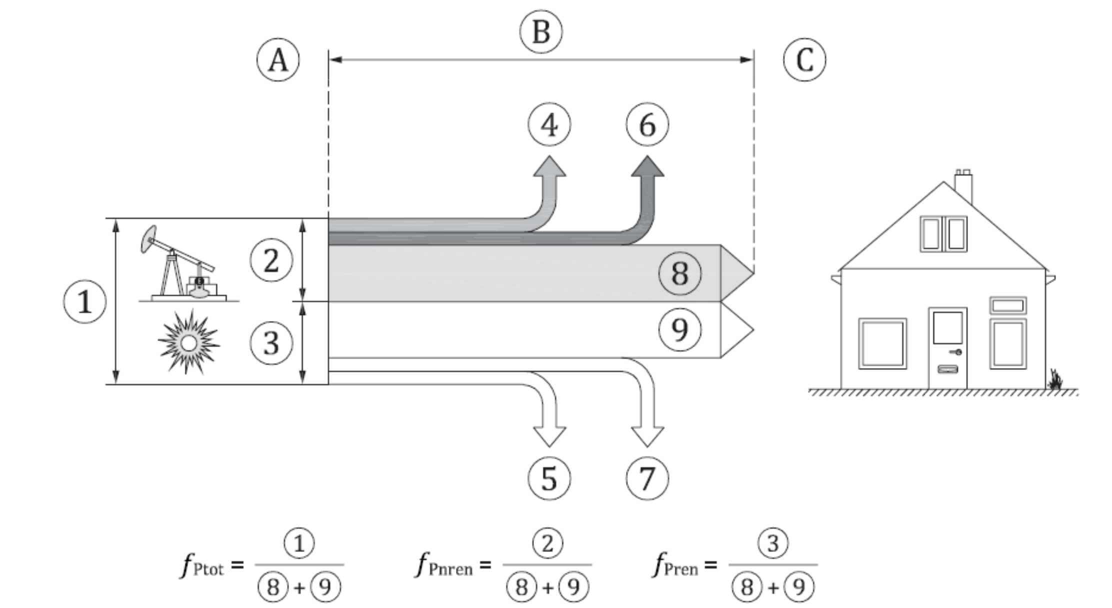
4.2 PEF for other energy carriers

With the transition towards a circular economy and increasing production of hydrogen and e-fuels, the question of the determination of PEF values for energy carriers other than electricity will gain more importance. In this chapter the methodological aspects are described and discussed.

According to the definitions from EUROSTAT, the primary energy content of directly combustible fuels (renewable and fossil fuels) is defined as the “heat value generated during combustion”. The PEF values of all fuels and also other energy carriers (wind and solar energy, hydro, etc.) are set at 1 based on the definition that primary energy is “the first flow in the production process that has a practical energy use”[12]. Electricity production (and district heat) is subject to extensive transformation processes in (thermal) power plants, storage facilities and distribution networks. Distribution losses for fuels are much lower than for electricity; according to the EUROSTAT energy balances, the natural gas distribution losses are for instance estimated at less than 1%. For most fuels valid data are not available in energy statistics and calculation (or estimation) would be quite complex resulting in uncomplete and highly unreliable values with a large variety.

[12] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Calculation_methodologies_for_the_share_of_renewables_in_energy_consumption&oldid=555286#Definition_of_the_primary_energy_content_of_fuels

Figure 4-4: Calculation of PEFs (Source: ISO 52000-1:2017)



Key

A	energy source	4	non-renewable infrastructure related energy
B	upstream chain of energy supply	5	renewable infrastructure related energy
C	inside the assessment boundary	6	non-renewable energy to extract, refine, convert and transport
1	total primary energy	7	renewable energy to extract, refine, convert and transport
2	non-renewable primary energy	8	delivered non-renewable energy
3	renewable primary energy	9	delivered renewable energy

In ISO 52000-1:2017 PEFs are defined as primary energy, further disaggregated to renewable and non-renewable divided by delivered energy (also disaggregated). Flows 6 and 7 relate to energy from extraction, refining, conversion and transport which have to be considered. As an option, also infrastructure related flows (4 and 5) can be included in the calculation.

For the case of electricity, energy for conversion and transport are included (as major parts of flows 6 and 7) in the calculation while extraction and refining are not directly relevant in this process but could be included with upstream flows of fuels. All these flows are part of the energy balance where the energy sector includes all these flows, however, only for domestic processes. Upstream flows of imports are not considered. Energy related to infrastructure, e.g. energy consumption related to building power plants or roads, is included in the energy balance but not associated with energy production and, hence, excluded there.

In principle, there are several ways to consider PEFs for other energy carriers:

- Include all processes included in EUROSTAT energy statistics or energy balances
- Carry out of life-cycle-analysis for all energy sources
- Consider life-cycle-aspects of other energy carriers with estimated or defined factors (e.g. 1.1 for all fuels)

It will be shown in the case study below that energy balance data allow to include major upstream flows in a consistent way. As for electricity, transformation, storage and distribution losses account for the largest share of upstream flows and should therefore be considered. Depending on the energy carrier under consideration this should be done on the European or Member State level. For the production of heat, depending on data availability, even local or regional calculations for PEFs seem appropriate.

It has briefly been discussed in the PEF report (chapter 7.4) that full LCAs would lead to high complex calculations with large uncertainties in resulting PEFs. "Furthermore, there is no standardized methodology resulting in inconsistent PEF values (based on inconsistent definitions of PEFs) in Member States"[13] concluding that it "is therefore very difficult to propose a consistent PEF of solid, liquid or gas fuels in the EU based on detailed life cycle and supply chain considerations."[14]

According to the current EU legislation, the determination of the methodology to calculate PEF values that reflect the primary energy content of electricity and other energy carriers used in buildings, is at the discretion of Member States. Due to diverging physical situations across the EU, there are (large) differences between the national PEF values for the same energy source, in particular for electricity (different power generation mix) and also to some extent for other energy carriers, e.g. because of differences in local network infrastructure for natural gas. Moreover, differences are not only related to physical specificities, but also to diverging national methodologies in the various steps of calculating PEF values. The review of the published national PEF values for other energy carriers, e.g. natural gas (see Chapter 5) reveals indeed that the currently used PEF values vary by more than the purely physical differences.

The PEF values for fossil energy vectors (natural gas, heating oil) are in principle mainly affected by national or regional specificities (e.g. different sources and transport modes, different network losses). If the upstream losses within the producing countries and along the transport route (e.g. LNG versus pipeline gas) would also have to be taken into account in the PEF determination, the calculation would be very complex and lead to highly different national values, depending on the natural gas sourcing mix. Including upstream energy losses that occur outside the EU would hence be very complicated and is not recommended, also due to the fact that upstream losses are at present not accounted for in the PEF for electricity. To avoid diverging national values which vary by more than the purely physical differences, a standard methodology could be recommended or imposed at EU level to estimate the losses within the EU. As the national physical differences for fossil fuel supplies are expected to be quite limited, the European Commission could also consider to recommend (or impose) a unique harmonised PEF value at EU level, which takes into account the average energy losses in the supply chain within the EU.

The PEF values for secondary or final energy vectors (such as hydrogen, biogas, biomethane, heat) are highly dependent on the production technology and local energy inputs. For this reason, calculating and recommending a standard PEF value at EU level would not be possible and appropriate. Therefore, it would be useful to agree on a harmonised methodology to define such national (or subnational) PEF values, in order to avoid that differences between national values effectively reflect specificities and are not due to diverging national methodologies.

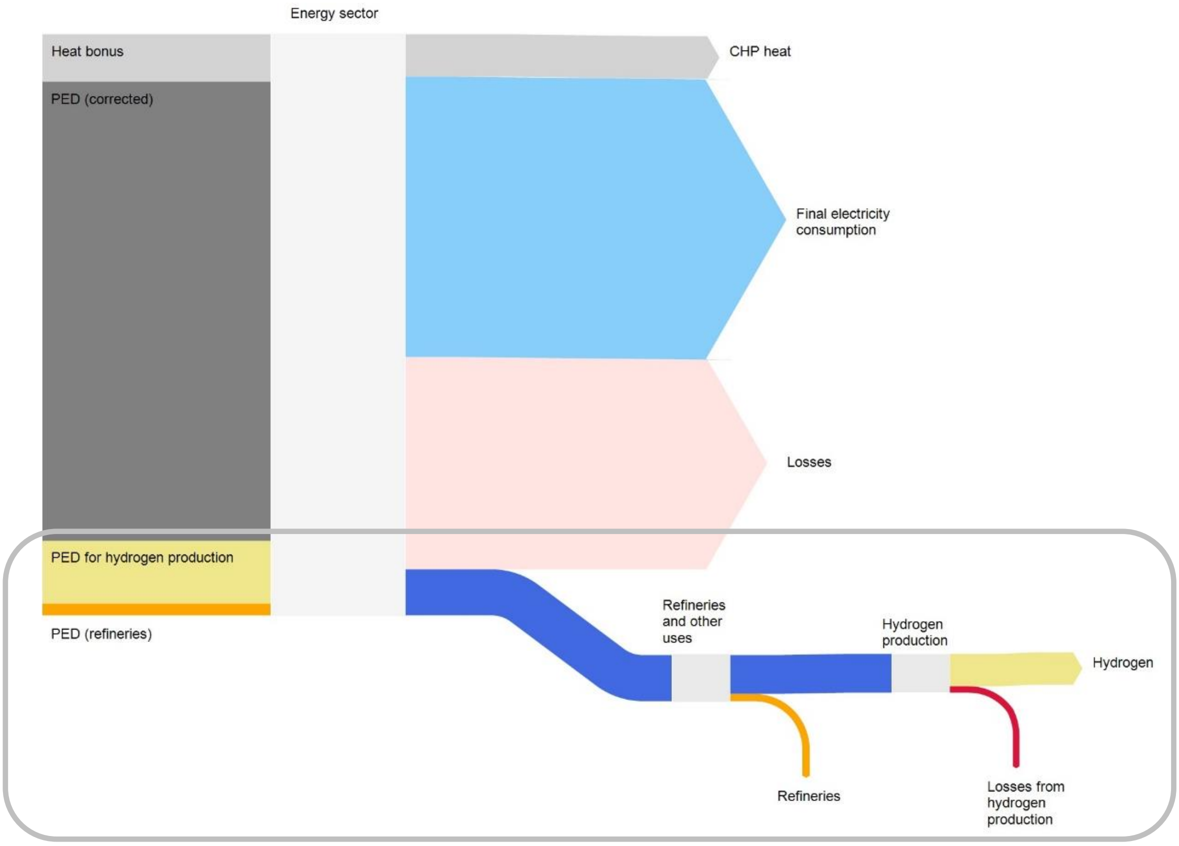
Anyhow, as energy vectors other than electricity are expected to play a decreasing role as main heating source for new or thoroughly renovated buildings (electrification is a more appropriate option and is promoted by most national governments), the costs and benefits of an initiative at EU level to determine a harmonized PEF methodology and/or default values for other energy vectors than electricity should be further evaluated.

[13] Hitchin, R. et al.: Primary Energy Factors and Members States Energy Regulations
Primary factors and the EPBD. Concerted Action Energy Performance of Buildings.
[14] 2016 PEF study

Case study: PEF of hydrogen and e-fuels

Green hydrogen produced in electrolysers using renewable electricity (power-to-gas) is expected to play an important role in the future energy system. It can directly be used in industrial processes and transport (possibly after conversion to derivates) and will allow to store surplus energy (electricity) for later use in back-up (peak) power plants. The different processes and upstream flows could be included in the calculation of fuels like hydrogen (or any other e-fuel). The following figure is an extraction of the overall energy flow figure used to explain the calculation of the PEF for hydrogen.

Figure 4-5: Energy flows for the production of hydrogen (2030) (Source: PRIMES, own figure e7)



Electricity will in the future increasingly be used for conversion to other energy fuels or energy carriers. Figure 4-5 represents the structure of the electricity system 2030. Based on PRIMES data, the PEF for electricity-based hydrogen can be calculated using the efficiency of the hydrogen production technology (electrolysis, appr. 75%) and of the electricity production system (PEF of 1.6 in 2030) resulting in a PEF of 2.1 for hydrogen. Assuming an efficiency of 75% for the production of e-fuels from hydrogen, the overall PEF of the particular e-fuel would be 2.8.

The calculation of the PEF for hydrogen and/or e-fuels should be fully consistent with the methodology applied for the PEF for electricity. The calculation will require full energy balance data either from EUROSTAT, PRIMES or national sources that are in line with European energy statistics. The PEFs for hydrogen and e-fuels will vary significantly depending on the technology for the conversion and the type of energy used in the conversion process. Hence, the PEFs for hydrogen or e-fuels should be differentiated per technology and per Member State, in order to properly reflect the specificities.

5 PEFs used by EU Member States for buildings

5.1 PEF values used by EU Member States

As mentioned in the previous chapters, the determination of the PEF values applied to calculate the primary energy content of electricity and other energy carriers used in buildings (supplied via the public network or produced on-site), is at the discretion of the Member States. From a physical perspective, differences between national (or sub-national) PEF values for the same energy source are justified and inevitable because of diverging local conditions in the energy supply, transmission and distribution system. However, national differences can also occur due to the fact that different methodologies and parameters are being used in the various steps of calculating PEF values, i.e. there are several different internationally recognised conventions for the calculation of primary energy content of electricity from renewable or nuclear energy sources. These can result in a differences of as much as a factor of three. At present, the PEF values reported by the Member States seem to vary for the aforementioned reasons more than the purely physical differences - undermining the reliability and credibility of the figures on primary energy savings (or consumption) in buildings aggregated from national totals. The consistency between cost-optimisation of national regulations and definitions of Nearly Zero Energy Buildings (NZEB) is also weakened. The national methodologies to determine PEFs are often not fully transparent, and this study, by identifying, and comparing the different (sub-) national methodologies and PEF values that are currently used, can pinpoint potential further initiatives to harmonise the approaches across EU Member States.

5.1.1 Data collection

The cost-optimality reports submitted by the EU Member States in 2018 served as a primary data source in carrying out this analysis. Twenty-five of these reports are publicly available on the European Commission's website[15], including that of the UK – still an EU Member State in 2018 but excluded from this analysis. The missing reports – Bulgaria, Belgium and Croatia – were made available by DG ENER. As the available cost-optimality reports were found to not contain all necessary information, additional/external data sources were required for three Member States - the Czech Republic, the Netherlands, and Italy. Reliable sources for the applicable primary energy factors were identified for these countries, presented in the Table 5-1 below.

In the Czech Republic, a revision of the PEF values already took place in 2020 (Decree No. 264/2020, replacing Decree No. 78/2013 on the energy performance of buildings, which was referenced in the 2018 cost-optimality report, as shown in Table 5-1 below). Therefore, the PEF values reported by the Czech Republic in its 2018 cost-optimality report and referred to in this study, differ from the official values published by the national authorities in 2020. The Swedish building code (Boverkets byggregler, BBR) has also been updated since 2018 (in 2020, as shown in Table 5-1 below) replacing the values of the 2018 cost-optimality report referenced in this study. These updates and the affected values are indicated in the presented tables and the analysis.

[15] https://energy.ec.europa.eu/eu-countries-2018-cost-optimal-reports_en

Table 5-1: Additional data sources for collecting national PEF values.

Country	Source for additional information	Explanation
Czech Republic	78/2013 Sb. Vyhláška o energetické náročnosti budov	Website publishing the laws and regulations of the Czech Republic with the updated 2020 PEF values.
The Netherlands	Energieprestatie gebouwen Normontwerp NEN 3654 voor buisleidingen en hoogspanningssystemen gepubliceerd voor commentaar	Website publishing the Dutch standards and the appropriate PEF values.
Italy	EPBD implementation in Italy	Energy Performance of Buildings Directive report for Italy
Spain	Factores de emisión de CO2 y coeficientes de paso a energía primaria de diferentes fuentes de energía final consumidas en el sector de edificios en España.	Official document that provides an overview of the PEF values and CO_2 coefficients for the building sector in Spain. The document also includes the detailed methodology for the calculation of PEFs that is in force since January 2016.
Sweden	Boverkets byggregler (2011:6) – föreskrifter och allmännaråd, BBR	Official document that provides an updated overview of the PEF values (vikningsfaktorer) for the building sector in Sweden, including the 2020 revision.

In addition, information on the CO_2 emission factors was collected from the cost-optimality reports, where available. For several EU Member States this information is not or only partially available. An overview is presented in Table 5-2 below.

Table 5-2: Information on the emission factor data in the cost-optimality reports of the EU-27 Member States. Source: own elaboration based on the 2018 national cost optimality reports.

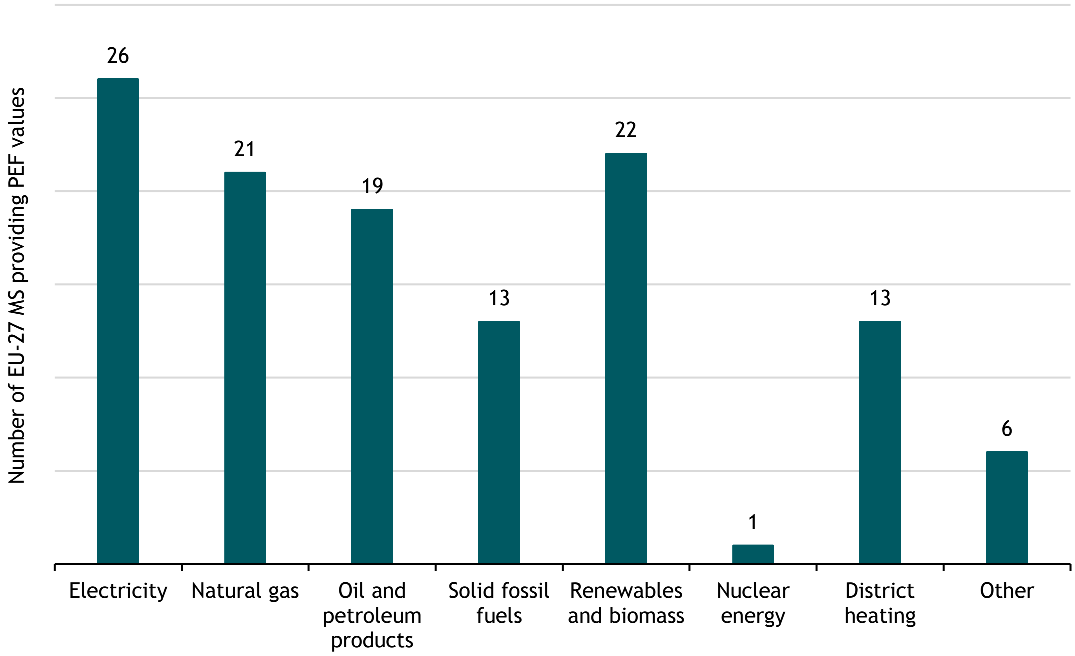
No information	Partial information	Full information
Belgium	Estonia	Austria
Cyprus	Greece	Denmark
Czech Republic	Latvia	Estonia
Finland	Malta	France
Germany	Netherlands	Hungary
Ireland	Romania	Lithuania
Italy	Sweden	Luxembourg
Poland		Portugal
		Slovakia
		Slovenia
		Spain
		Sweden

5.1.2 Analysis of the national PEFs in the EU-27

The number of EU Member States providing a PEF value for electricity and other energy sources/carriers is shown in Figure 5-1 below. Twenty-six EU Member States provided a PEF for electricity; as the cost-optimality report for Bulgaria is not available, it is unclear whether this country has also defined a PEF for electricity.

The Member States provide PEFs for other energy carriers on a widely varying level of aggregation. The PEFs for ‘oil and petroleum products’ reported by the Member States refer to the different energy carriers that fall into this category under the Eurostat terminology (i.e. crude oil, kerosene, fuel oil, LPG, diesel fuel, etc.). Similarly, ‘solid fossil fuels’ is an aggregate term for (black) coal, anthracite, and brown coal/lignite, while the PEF for ‘renewables and biomass’ contains values provided for solar energy, wind energy, hydropower or geothermal energy, and the different forms of biogas/biomass, i.e. wood chips/pellets/briquettes, etc. The ‘other’ category contains products that do not fit into the previous categories – like peat and peat products.

Figure 5-1: Number of EU-27 Member States that provided PEF values, by energy source. Source: own elaboration based on the 2018 national cost optimality reports.



Regarding the PEF values for electricity, some Member States made a distinction between grid-supplied and on-site electricity production. This was the case for 8 EU Member States – Italy, Belgium, Cyprus, Ireland, Latvia, Malta, Poland and Slovakia – that provided a separate PEF for on-site generated electricity, while the other EU Member States did not make a distinction and provided only one, generic PEF value for electricity.

Table 5-3 provides an overview of the PEFs reported by the Member States. It shows that the PEF values for electricity largely vary between Member States; Finland has the lowest level (1.20) while Malta applies the highest value (3.45). Large differences are also observed for biomass which was by some Member States – Cyprus, Germany, Lithuania, Latvia, Luxembourg, and Poland – considered (almost) fully renewable with PEF values lower than 1.00, while some others - Austria, Estonia, Greece, France, Ireland, and Romania - reported higher PEF values for biomass, close to 1.00. The PEF reporting for the different types of biomass covered strongly differs among Member States and makes the comparison difficult (see PEF values for biomass section for more details). A similar observation can also be made with regard to the PEFs for district heating (DH) (see section PEF for district heating (DH) systems).

Table 5-3: Overview of the PEFs provided by Member States. Source: own elaboration based on the 2018 national cost optimality reports.

	Electricity	Natural gas	Biomass	District heating
Min	1.20	1.00	0.60	0.10
Max	3.45	1.19	1.10	1.60
Average	2.34	1.08	0.68*	0.66**
Median	2.50	1.10	1.00*	0.80**

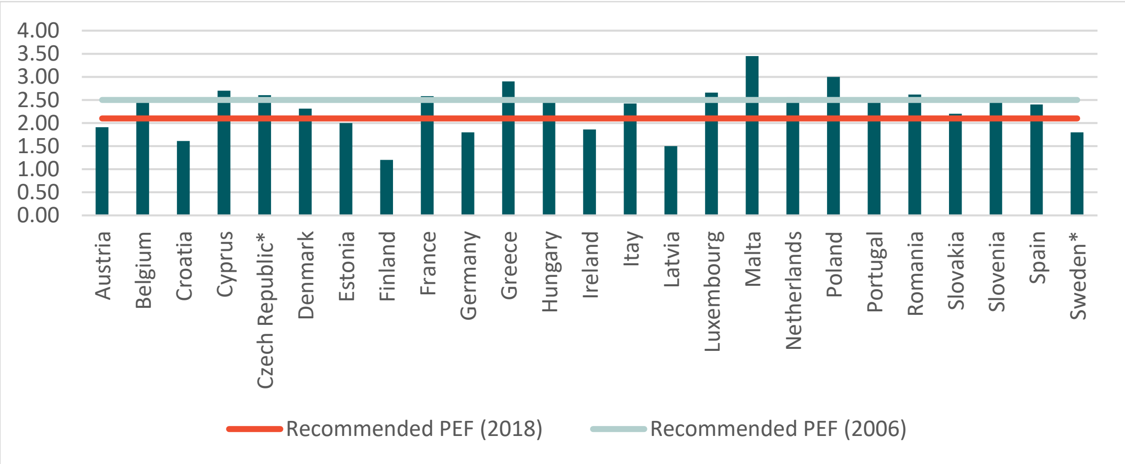
* the Average and Median values are based on the 19 Member States that provided PEF values for biomass
** the Average and Median values are based on the Member States that provided PEF values for DH without specifying the source of the energy (renewable or non-renewable) and the type of technology used

PEF values for electricity from the grid

Figure 5-2 shows the PEF values for electricity provided by the Member States. The horizontal lines represent the European reference values defined in 2006 (as 2.50, yellow line) and revised in 2018 (as 2.10, red line). By the time of publication of the latest cost-optimality reports in 2018, several countries (Belgium, Hungary, Portugal, and Slovenia) were still using the default PEF value for electricity defined at EU level in 2006 (as 2.50). The lowest PEF value for electricity was reported in Finland (1.20), and the highest in Malta (3.45).

Bulgaria and Lithuania are not included in the figure; the cost optimality report of Lithuania does not provide a PEF value for electricity from the grid, but only disaggregated PEF figures for electricity produced in hydroelectric power plants and by wind power plants of the country.

Figure 5-2: National PEF values for electricity (from the grid) compared to the European recommended values of 2.10 (2018) and 2.50 (2006). Source: own elaboration based on the 2018 national cost optimality reports.



*The Czech Republic and Sweden published a revision of their PEFs in 2020 already, the displayed values are up-to-date.

Box 5-1: Methodology applied in the Netherlands to calculate the PEF for electricity

Statistics Netherlands[16] publishes a yearly report on the PEF values and CO_2-emissions of the electricity supply, according to two standard methods: an integral (average) method and a marginal (reference park) method. The methodologies for both are described in a report published in 2012[17]. The integral method is based on the total (renewable and non-renewable) electricity production in relation to the use of natural gas, coal and nuclear energy allocated to electricity. Electricity from waste incineration plants and residual gases is not included. The reference park method is based on the central electricity production from natural gas, coal and nuclear energy, with the exception of those plants where the heat production exceeds 20 percent of the fuel input. In 2020 the average primary fossil fuel input for electricity from the grid was 1.44 kWh_{prim}/kWh_{fin}, using the integral method, while with the marginal method the value increases to 2.08 kWh_{prim}/kWh_{fin}.The integral method is used to calculate PEF values for the national building code. In 2021 the PEF value for electricity from the grid was changed from 2.56 to 1.45. The value is slightly lower than what was realized in 2020. The amount of renewable energy in the electricity grid is growing fast, and the PEF value is expected to reduce further to values below 1.00 in the future[18]. Estimates for the future PEF values are calculated in the annual climate and energy outlook[19].

Prior to the 2021 update, the PEF value for electricity had not been changed in the building code of the Netherlands since 1996. The country reported that implementing the EPBD was a good opportunity to change its PEF values.

Table 5-4 presents the detailed PEF values for electricity published by the EU-27 Member States, grouped by geographical aggregation levels of the reporting. Only Spain and Belgium published a PEF value for electricity on a sub-national level, and for Belgium, the values for the three regions – Flanders, Wallonia and Brussels Capital Region – correspond to the 2006 recommended EC value of 2.50. The distinction is hence administrative rather than methodological. Spain distinguishes its PEF for electricity between a national value and values for the 4 climactic regions (mainland, Balearics, Canaries, and Ceuta and Melila).

[16] CBS (2022). Yields, CO2 emissions electricity production, 2020. Available at: https://www.cbs.nl/nl nl/maatwerk/2022/05/rendementen-co2-emissie-elektriciteitsproductie-2020
[17] Harmelink Consulting, NL Agency, ECN, CBS and PBL (2012). Berekening van de CO2-emissies, het primair fossiel energiegebruik en het rendement van elektriciteit in Nederland. Available at: https://www.rvo.nl/sites/default/files/Notitie%20Energie-CO2%20effecten%20elektriciteit%20Sept%202012.pdf
[18] Direct communication with Netherlands Enterprise Agency RVO.
[19] PBL (2022). Climate and Energy Outlook 2021. Available at: https://www.pbl.nl/publications/climate-and-energy-outlook-2021

Table 5-4: Electricity PEFs per country on different aggregation levels. Source: own elaboration based on the 2018 national cost optimality reports.

Regional aggregation of electricity PEF	Country	PEF total	PEF renewable electricity	PEF non-renewable electricity
Regional	Spain	2.79 - 3.05	0.070 - 0.414	2.718 - 2.968
	Belgium	2.50	-	-
National	Croatia	1.61	-	-
	Austria	1.91	0.59	1.32
	Cyprus	2.70	-	-
	Czech Republic**	2.60	-	-
	Denmark	2.31	-	-
	Estonia	2.00	-	-
	Finland	1.20	-	-
	France	2.58	-	-
	Germany	1.80	-	-
	Greece	2.90	-	-
	Hungary	2.50	-	-
	Ireland	1.86	-	-
	Italy	1.00	0.47	1.95
	Latvia	1.50	-	-
	Lithuania*	-	1.00	0.01- 0.06
	Luxembourg	2.66	-	-
	Malta	3.45	-	-
	Netherlands	2.56	-	-
	Poland	3.00	-	-
	Portugal	2.50	-	-
	Romania	2.62	2.62	0.00
	Slovakia	0.00	-	-
	Slovenia	2.50	-	-
	Spain	2.40	0.40	2.01
	Sweden**	1.80	-	-

*Lithuania published two PEF values specifically for ‘Electricity produced in hydroelectric power plants’, and ‘Wind power plants’ only.

**The Czech Republic and Sweden published in 2020 a revision to their PEFs, the displayed values are the current ones.

In all national cost optimality reports electricity remains the major component of the PEF focus, and its importance is expected to grow due to the ongoing electrification of buildings’ heating and the increasing share of renewable and on-site electricity generation. However, only few Member States provide differentiated PEFs for renewable and non-renewable based electricity – these are Austria, Italy, Lithuania, Romania and Spain. With the increasing share of renewable energy sources in the electricity generation mix on the one hand, and the fast-growing electrification on the other hand, this differentiation would likely become increasingly relevant in the coming years for the other 22 Member States as well.

Box 5-2: Methodology applied in Spain to determine the PEF for electricity.

Spain is the only Member State reporting PEF values for grid-supplied electricity for each of its regions – the Peninsula, the Balearic islands, the Canary islands, Ceuta and Melilla – in its cost-optimality report. The responsible organization for determining and publishing the updated PEF values is the Ministerio de Industria, Comercio y Turismo[20] (Ministry of Industry, Energy and Tourism), issuing the report 'La Energía en España' every year (latest available 2019)[21]. In this report, the structure of electricity production by type of power plant – thermal, nuclear or renewable – and used fuel is detailed for the concerned years and for the specific regions. The report differentiates between gross production, self-consumption and net production of power plants accounting for the different types of losses during the generation process. The data is being published for two consecutive years at a time; the second year's values being the revised ones used for further calculations.

The report determines a PEF value for electricity consumption per type of fuel and power plant, based on the fuel consumption of the power plants. The calculation also accounts for the losses in the transmission/distribution networks. The transport loss factors used since 1 January 2009 are determined by ORDEN ITC/3801/2008 and were upheld in IET/107/2014. The PEF values for electricity used in Spain are hence different depending of the voltage level of the network, and the region[22].

Box 5-3: Methodology applied in Ireland to determine the PEF for electricity.

The Sustainable Energy Authority of Ireland (SEAI) published a new report in 2023 explaining the (proposed) methodology for the calculation of electricity PEF and CO_2 emission factors in the coming decades (in effect from January 2023) in the Domestic and Non-domestic Energy Assessment Procedures. The calculations are based on SEAI's own Data and Insights Modelling team's projected energy mix, taking into account the government's policy goals of decarbonization (namely, 80% renewable energy sources in electricity generation by 2030[23]). The detailed methodology is based on the provisions for assessing the energy performance of new and existing buildings as described in the EN ISO 52000-1 standard. An 8% overhead is applied to derive primary energy based on the growing dominance of gas in the Irish thermal generation mix and its dependence on imports from the UK (where an 8% overhead is also applied). The new PEFs and CO_2 emission factors are determined on a yearly basis with revised data (projections), as detailed in the newest SEAI methodology document. Based on this, a PEF = 1.75 is provided as an example value for the year 2025.

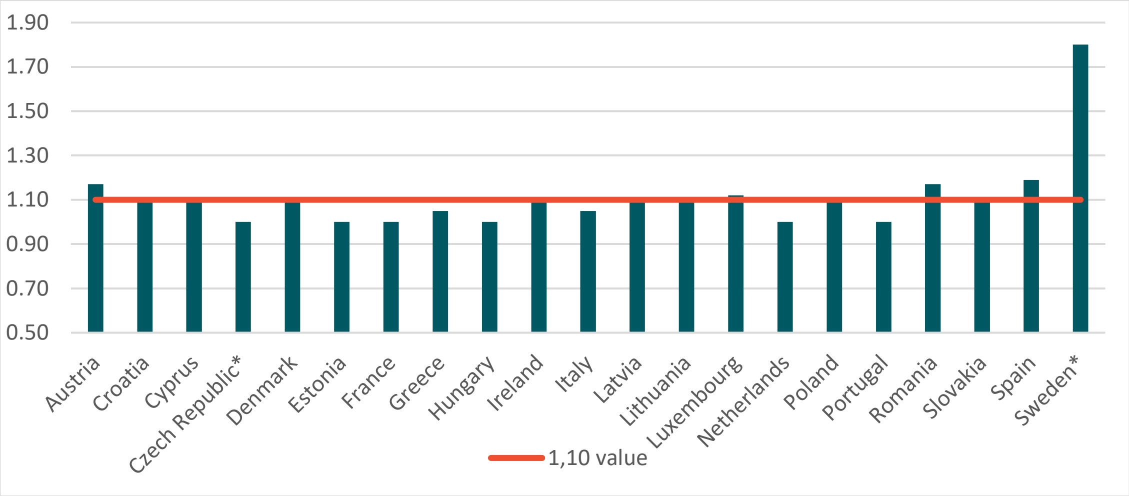
PEFs for natural gas

Figure 5-3 displays the PEF values for natural gas published by the EU Member States that provided this information in their 2018 cost-optimality reports. The horizontal line represents a PEF value for natural gas of 1.10, which is adopted by 8 Member States. 4 Member States adopted values higher than 1.10, namely Luxembourg (1.12), Austria and Romania (1.17), and Spain (1.19).

The national PEF values published in 2018 vary between a minimum of 1.00 adopted by 6 Member States, and a maximum value of 1.19 used by Spain. Sweden has meanwhile decided to apply a PEF of 1.80 as of 2020.

[20] https://www.mincotur.gob.es/en-us/paginas/index.aspx
[21] https://energia.gob.es/balances/Balances/LibrosEnergia/libro-energia-espana-2019.pdf
[22] Ministerio de Industria, Energía y Turismo. (2016). FACTORES DE EMISIÓN DE CO2 y COEFICIENTES DE PASO A ENERGÍA PRIMARIA DE DIFERENTES FUENTES DE ENERGÍA FINAL CONSUMIDAS EN EL SECTOR DE EDIFICIOS EN ESPAÑA
[23] https://www.gov.ie/en/publication/774e2-national-development-plan-2021-2030/

Figure 5-3: PEF values for natural gas provided by 21 EU Member States. Source: own elaboration based on the 2018 national cost optimality reports.



*The Czech Republic and Sweden published in 2020 a revision to their PEFs, the values displayed are the current values.

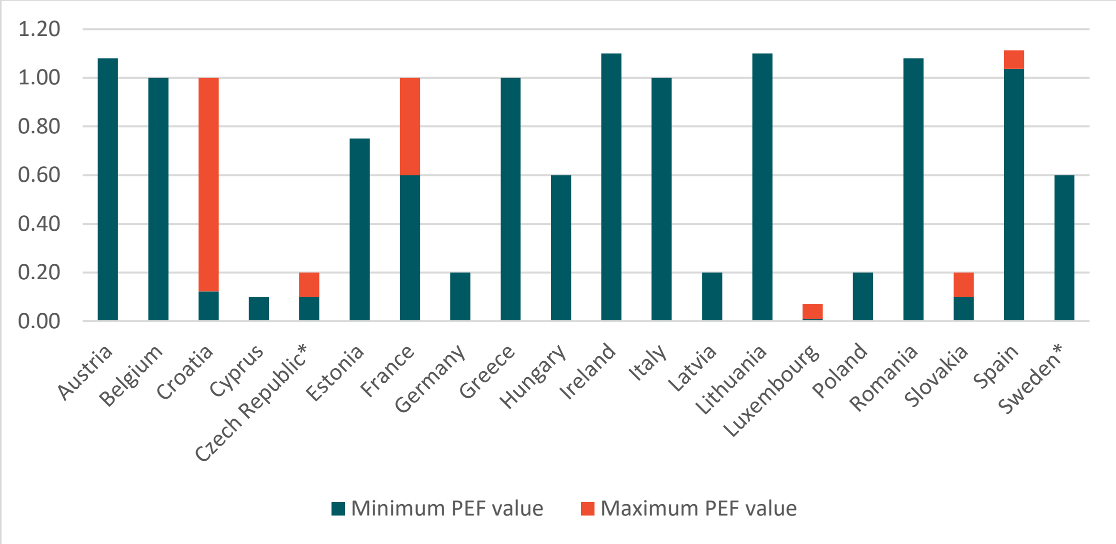
The differences between the national PEF values for natural gas may be related either to local physical specificities, such as higher energy use for compression or greater leakage levels due to the length and material of the gas pipelines, or differences in the calculation methodology used. An existing comparison in the literature of the calculated PEF values accounting for the methodology, however, indicates a weak correlation between the values reported by Member States[24].

PEF values for biomass

Figure 5-4 displays the range of PEF values for biomass provided by 19 EU Member States. Some Member States provided a single PEF value for biomass, while others made a distinction between different types of biomass (i.e. separate PEF values for wood pellets, wood chip, firewood, etc.). The green and red bars represent the minimum and maximum values respectively provided for any type of biomass by the Member States; Croatia, the Czech Republic, France, Luxemburg, Slovakia and Spain provided disaggregated values. Only one Member State – France - provided different PEF values for biomass depending on the type of building, with a lower PEF value (0.60) set for existing buildings, and a higher value (1.00) for new buildings with no further explanation for the rationale behind this differentiation. As shown in the graph, the PEF values for biomass range from 0.01 (Luxemburg) to 1.20 (Czech Republic). The Member States that consider biomass almost fully renewable - with PEF values close to zero - include Cyprus, Germany, Latvia, Luxembourg, Poland and Slovakia. Other Member States apply PEF biomass values similar to those for fossil fuels (with PEF values close to 1.00) – namely Austria, Belgium, Czech Republic, France, Greece, Ireland, Italy, Romania, Spain and Sweden. Estonia and Lithuania provided PEF values for biomass and biofuels in an aggregated form only, covering different energy carriers from renewable raw materials (e.g. wood, straw, bio-gas, bio-oil, etc.).

[24] https://epbd-ca.eu/wp-content/uploads/2018/04/05-CCT1-Factsheet-PEF.pdf

Figure 5-4: Range of PEF values for biomass provided by 19 EU Member States. Source: own elaboration based on the 2018 national cost optimality reports.



* The Czech Republic and Sweden published a revision to their PEFs in 2020, the values displayed are the current values.

6 EU Member States provided PEF values for biomass at a disaggregated level, distinguishing between densified (e.g. pellets) and non-densified (e.g. firewood) biomass. Table 5-5 shows an overview of these values. Romania provided the same PEF value for densified and non-densified biomass; however, as its respective PEF values for renewable and non-renewable energy sources were different, we included Romania in the table as well. Moreover, Croatia, Luxembourg and Slovakia provided PEF values differentiating between wood chips and pellets.

Table 5-5: PEF values for biomass, disaggregated by densified and non-densified biomass. Source: own elaboration based on the 2018 national cost optimality reports.

<table>
<tr><th rowspan="2">EU Member State</th><th colspan="2">Densified</th><th rowspan="2">Non-densified</th></tr>
<tr><th>Wood chips</th><th>Wood pellets</th></tr>
<tr><td>Croatia</td><td>0.154</td><td>0.123</td><td>1.000</td></tr>
<tr><td>Czech Republic*</td><td colspan="2">1.200</td><td>1.100</td></tr>
<tr><td>Luxembourg</td><td>0.060</td><td>0.070</td><td>0.010</td></tr>
<tr><td>Romania</td><td colspan="2">1.080</td><td>1.080</td></tr>
<tr><td>Slovakia</td><td>0.150</td><td>0.200</td><td>0.100</td></tr>
<tr><td>Spain</td><td colspan="2">1.113</td><td>1.037</td></tr>
</table>

*The revised Czech regulation of 2020 does not contain a PEF_{total} for biomass anymore.

PEF for district heating (DH) systems

This section presents data on PEF values for district heating for the EU Member States that have a relatively high share of DH in their heat supply and that have provided details of their PEF reporting methodology. For these countries, the data is provided in three formats[25]:

[25] Eduard Latõšov et al. Primary energy factor for district heating networks in European Union member states. Energy Procedia 116 (2017) 69-77

- ✓ Single fixed PEF value for DH: this PEF value is valid for all DH networks in the concerned country (e.g. Finland, Estonia and Bulgaria);
- ✓ Differentiated PEF values: the differentiation is based on the fuels used and/or energy production technologies applied (e.g. Latvia, Hungary and Czech republic);
- ✓ Individual PEF values per DH: in this case the PEF value is calculated for each DH network independently (e.g. Croatia, Germany, Italy and Poland).

Countries with a relevant share of DH that didn't report specific PEF values for DH in their 2018 cost optimality reports include Romania and the Netherlands[26]. Box 5-4 summarizes some observations for Member States with identified irregularities. In Romania, there is no relevant use of the PEF concept for DH and/or insufficient information can be obtained from the available studies, regulation and standards to make a solid statement about its situation regarding PEF values for DH[14]. In the case of the Netherlands, the national regulation of 2017 introduced a legal obligation for heating companies to report on the sustainability of their heat networks, which became mandatory only as of 2020; therefore the Dutch 2018 Cost Optimal report does not (yet) comprise specific information on the PEF value or methodology for DH.

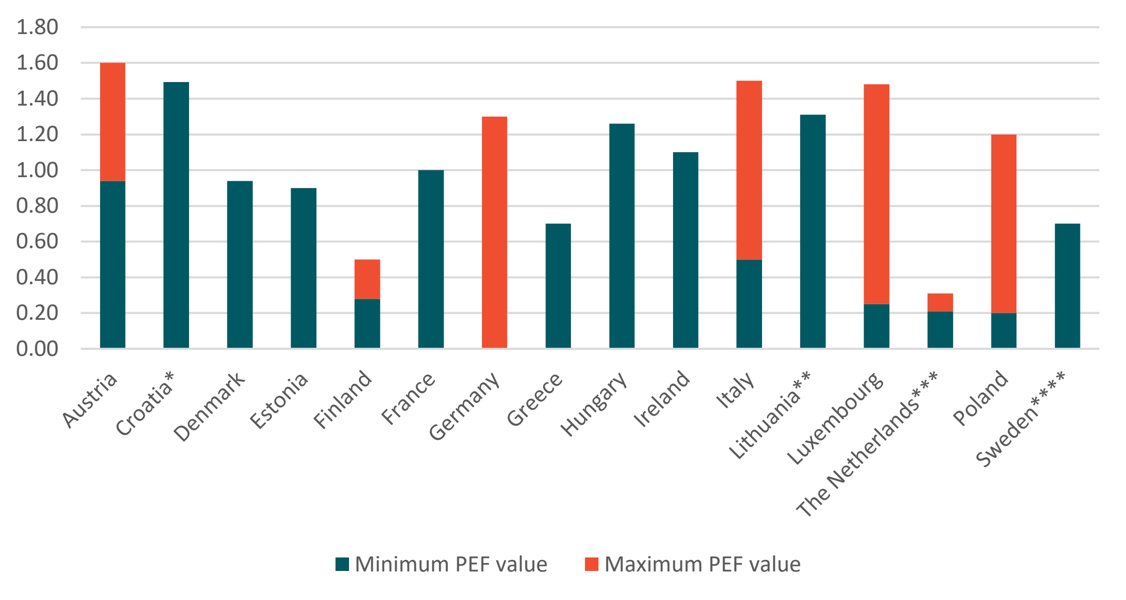
Box 5-4: Observations for Member States that didn't include PEF values for DH in their 2018 cost optimality reports.

Romania: No clear PEF value for DH is provided in the Romanian 2018 Cost Optimal Report[27].
The Netherlands: In 2017 the government introduced a legal obligation for district heating suppliers to report on: (1) CO_2 emissions per unit of heat delivered, (2) primary fossil energy use per unit of delivered heat and (3) share of RE sources . The 'Heat Act' is in place since 2017, and the reporting obligations became mandatory as of 2020. The PEF values reported by the Dutch district heating suppliers range from 0.21 to 0.61.

Figure 5-5 shows the distribution of PEF values for DH for the 16 Member States that provided this specific information. Austria, Finland, Germany, Italy, Luxemburg and Poland provided disaggregated figures based on either the source technology (heating plant or CHP) - like Austria, or on renewable/non-renewable energy carriers - like Italy and Poland, or both – like Germany and Luxembourg. Finland, Italy and Sweden also provided specific figures for district cooling.

[26] In the case of the Netherlands, the government introduced a reporting obligation for district heating suppliers in which they have to report on: (1) CO_2 emission per unit of heat delivered, (2) primary fossil energy use per unit of delivered heat and (3) the share of RE sources. Source: https://www.ca-eed.eu/ia_document/reporting-on-the-sustainability-of-district-heating-networks-mirjam-harmelink/
[27] RAPORT privind CALCULUL NIVELURILOR OPTIME, DIN PUNCT DE VEDERE AL COSTURILOR, ALE CEERINȚELOR MINIME DE PERFORMANȚĂ ENERGETICĂ. Source: https://energy.ec.europa.eu/eu-countries-2018-cost-optimal-reports_en

Figure 5-5: Range of district heating PEF values provided by EU-27 Member States. Source: own elaboration based on the 2018 national cost optimality reports.



*Croatia national average value for PEF_{DH}.

**Lithuania national average value for PEF_{DH}.

***The PEF values for the Netherlands included in the figure refer to the latest available range, published after the 2018 Cost Optimality Report.

****Based on the 2020 revision.

Croatia and Lithuania provided regional PEF values for DH systems. In the case of Croatia, the Ministry of Construction and Physical Planning has provided DH PEF values for **17** different regions of the country, as well as a national average value (so, 18 different values in total). This shows that the PEF calculation is differentiated depending on the technical characteristics of the DH networks. **However, there are lot more, about 110 DH systems in Croatia, still leaving around 90 DH systems to use the country average PEF value**[28]**.** In the case of Lithuania, the Member State published 27 different PEF values for district heating, disaggregated on regional/provider level, as well as a national average value included in the figure above.

Table 5-6 presents the Member States that have provided only a single PEF value for district heating. The values range from 0.10 in Germany, where the ratio of biofueled CHP is above 70% - to 1.30 – also in Germany, where district heating is provided by fossil fueled CHP.

[28] Eduard Latõšov et al. /Primary energy factor for district heating networks in European Union member states . Energy Procedia 116 (2017) 69–77

Table 5-6: EU-27 Member States providing a total PEF value only for district heating. Source: own elaboration based on the 2018 national cost optimality reports.

Country	PEF value
Denmark	0.94
Estonia	0.90
Finland	0.28 - 0.50
France	1.00
Germany	0.10 - 1.30
Greece	0.70
Hungary	1.26
Ireland	1.10
Sweden*	0.70

*Based on the 2020 revision.

Table 5-7 presents the PEF values for renewable and non-renewable energy fuelled DH from the Member States that have published these numbers (Austria, Italy, Luxemburg, Poland) on this level of aggregation. The PEF values for renewable energy fuelled DH range from 0 in Italy, without further specification, to 1.32 in Austria, where heating plants running on renewable sources support the district heating system. The PEF values for non-renewable energy fuelled DH range from 0.19 with CHP in Austria to 1.48 with heating plants on fossil fuels in Luxemburg.

Table 5-7: EU-27 Member States providing disaggregated PEF values for renewable/non-renewable energy fueled district heating. Source: own elaboration based on the 2018 national cost optimality reports.

Country	Renewable PEF	Non-renewable PEF
Austria	0.75-1.32	0.19 - 0.28
Italy	0	0.50
Luxemburg	0-0.25	0.62 - 1.48
Poland	0.20	0.80 - 1.20

Table 5-8 shows the list of Member States that did not make a distinction based on the energy source for the district heating system when calculating a PEF value.

Table 5-8: EU-27 Member States providing a single PEF value for district heating, undifferentiated by source. Source: own elaboration based on the 2018 national cost optimality reports.

Country	PEF value
Denmark	0.94
Estonia	0.90
Finland	0.28 - 0.50
France	1.00
Greece	0.70
Hungary	1.26
Ireland	1.10
Italy	0.50 - 1.50
Poland	0.20 - 1.20
Sweden*	0.70

*Based on the 2020 revision.

About a quarter of the Member States provided **differentiated PEF values** for district heating applications based on the source technology – CHP or heating plant. Most of them (5 out of 6) made no distinction based on the energy carrier, and Slovakia specified a PEF for using coal and natural gas (PEF = 0.70) next to the PEF value calculated based on the conventional supply chain. Moreover, while making no distinction based on source technology, Croatia followed the same practice as Slovakia for energy carriers – differentiating between district heating running on natural gas (with a PEF = 1.350), fuel oil (PEF = 1.444), and extra light fuel oil (PEF = 1.429).

Table 5-9 shows the minimum and maximum PEF values for DH provided by the 6 EU Member States that reported a figure for both CHP and other installations. Out of the 6 concerned Member States, Austria and Slovakia determined a similar PEF value for the two cases, whereas Germany, Luxemburg, Latvia and Poland further differentiated based on the renewable/fossil fuel.

Table 5-9: Minimum and maximum PEF values for district heating based on source technology

Country	PEF CHP minimum	PEF CHP maximum	PEF heating plant minimum	PEF heating plant maximum
Austria	0.94		1.60	
Germany	0	0.70	0.10	1.20
Luxemburg	0	0.62	0.25	1.23
Latvia	0	0.70	0.10	1.20
Poland	0.15	0.65	0.80	0.40
Slovakia	0.70		1.30	

The highest PEF value for DH with CHP is provided by Austria (0.94) and the lowest value by Germany, Luxemburg and Latvia (where this value is determined at 0 for CHP on renewable energy sources). Slovakia reported the same PEF value for district heating fuelled by natural gas and black coal (0.7 for CHP and 1.3 for other installations).

Furthermore, the Czech Republic provided a separate PEF value for 'ambient energy' in both electricity and heat (PEF_{total} = 1.00 and $PEF_{non\text{-}ren}$ = 0).

Box 5-5 Findings from national case studies: Austria[29]

In Austria, conversion factors for CO_{2eq} (f_{CO2eq}), primary energy (f_{PE}), further divided in non-renewable ($f_{PE,n.ren.}$) and renewable energy ($f_{PE,ern.}$), are available for 11 energy carriers. All factors are based on a full LCA approach, considering upstream flows with 'ecoinvent' as the main data source. Conversion factors were developed by a an expert group of the 9 Austrian provinces in collaboration with the OIB expert advisory board.

Primary energy factors for district heating

The calculation of the PEFs for district heating refers to the Austrian Standard ÖNORM EN 15316-4-5, documented in the explanatory document of the OIB guideline 6 (OIB Richtlinie 6, 2019) on energy savings and heat production. Values for district heating are provided for (1) district heating from heating plants (renewable), (2) district heating from heating plants (non-renewable) and (3) district heating from highly efficient cogeneration (CHP).

Energy carrier	f_{PE}	$f_{PE,n.ren.}$	$f_{PE,ren.}$	f_{CO2eq} [g/kWh]
Coal	1.46	1.46	0.00	375
Heating oil	1.20	1.20	0.00	310
Gas	1.10	1.10	0.00	247
Biomass (solid)	1.13	0.10	1.03	17
Biofuels (liquid)	1.50	0.50	1.00	70
Biofuels (gaseous)	1.40	0.40	1.00	100
Electricity (delivery mix)	1.63	1.02	0.61	227
District heating (heating plant, renewable)	1.60	0.28	1.32	59
District heating (heating plant, non-renewable)	1.51	1.37	0.14	310
District heating (highly efficient CHP)	0.88	0.00	0.88	75
Waste heat	1.00	1.00	0.00	22

For district heating from CHP, the power bonus method is used. For electricity produced by the CHP, the PEF for the displacement mix is applied, which leads to low PEFs for heat. While all calculations of factors are fully documented, including formulas, assumptions and sources, the method used in Austria is inconsistent with the PEF calculation applied in this study, where the Finnish method (or alternative production method according to EN 15316-4-5:2017) is applied. It is also not consistent with the IEA method used by EUROSTAT.

Primary energy factors for electricity

For electricity consumption, annual data were calculated for the period of 2014 to 2018, resulting in average factors for CO_{2eq} and primary energy based on domestic production and imports of electricity as reported by ENTSO-E. Annual data were further disaggregated on a monthly basis and factors were calculated on a 4-digit level for CO_{2eq} and primary energy. The data clearly show that the PEF is significantly higher in winter months, especially the values related to non-renewable primary energy. This is also reflected in f_{CO2eq} that is more than 2 times higher in winter months than in summer.

Month	f_{PE}	$f_{PE,n.ren.}$	$f_{PE,ren.}$	f_{CO2eq} [g/kWh]
January	1.8224	1.3540	0.4684	296
February	1.8250	1.3487	0.4763	295
March	1.7821	1.2596	0.5225	274
April	1.5141	0.8738	0.6403	195
May	1.2874	0.5381	0.7493	131
June	1.3235	0.5759	0.7476	135
July	1.3935	0.6742	0.7193	152
August	1.4035	0.6973	0.7062	158
September	1.5589	0.8722	0.6867	203
October	1.7602	1.1819	0.5783	266
November	1.7760	1.2358	0.5402	276
December	1.8813	1.3882	0.4931	301
Delivery mix	**1.6229**	**1.0189**	**0.6040**	**227**

Additionally, also factors for the displacement mix of electricity, calculated based on the PEFs of electricity imports from Germany and Czech Republic, are provided. The PEF for the displacement mix is approximately twice as high as the consumption mix (3.14 vs.1.63), also reflected in the higher value for CO_{2eq}. The displacement mix is also used for the allocation of energy input in CHPs for which the power bonus method is used.

Based on this data collection for DH, it is clear that the EU Member States have adopted very different approaches regarding the primary energy concept and methodology to define PEF values for DH. Some Member States reported single fixed PEF values for DH which are used for all DH networks in the country; other Member States reported fixed PEF values for DH which are differentiated depending on the fuels used and/or the heat production technologies applied, and in the final group of Member States a PEF value is calculated separately for each DH network.

Using a single fixed PEF value for all DH networks in a country is in general not considered appropriate for the following reasons:

- ✓ It is does not consider the differences in the mix of fuels and technologies used for heat production in DH networks. For example, renovated DH networks have lower energy losses and may benefit from heat load smoothing by heat storage systems, which may lead to lower primary energy consumption.
- ✓ The benefits of using industrial waste heat and renewable heat (via heat pumps) are not properly considered in a single PEF value. Recovery and reuse of waste heat generated in industrial processes and use of geothermal energy should be reflected in a lower PEF value compared to DH fed by fossil fuels.

Key findings from the data collection and analysis

Overall, the review of the cost optimality reports and other national specific PEF related reports shows that the methodologies adopted by the Member States to calculate national PEF values for electricity and

[29] This box is based on new regulation. Data mentioned in the 2018 cost optimality report was based on the previous regulation.

other energy vectors lack transparency and consistency. As a result, it is not possible to distinguish differences in PEF values resulting from physical specificities of the national energy supply system and from differences in the methodologies.

The analysis of the use of PEF in Member States is summarized below:

- ✓ **National PEF values for electricity** show large differences between Member States. These differences can partly be explained by differences in local conditions (primary energy mix, conversion technologies). While some Member States apply the default value recommended by the EC, most other Member States calculate a national value but they are not using the same methodology to define these national values. These observations have also been noted in previous reviews.[30] As most Member States seem to prefer defining a national PEF value rather than adopting the default PEF value recommended by the EC, a higher level of harmonization of the methodology to be used by Member States to determine the PEF value at national (or regional) level would be appropriate.
- ✓ The **national PEF values for natural gas** range between 1 and 1.19 (and 1.80 in Sweden since 2020), although this a standard product which is imported from the same sources and transported and distributed via similar networks. In order to stimulate and support the electrification of the heating uses in buildings, it would be appropriate to impose (rather than recommend) at EU level a PEF value for natural gas of (of at least) 1.10 in order to properly take into account the energy losses in the transport and distribution networks. In principle the energy losses in the upstream processes could also be taken into account, but as an LCA approach would require very complex calculations, which should take into account the different production sources and transport modes (pipelines versus LNG ships), a more simplified approach which only takes into account the energy losses within the EU seems an appropriate compromise. Such a 'simplified' approach for natural gas would be consistent with the current methodology for electricity, which also does not include the energy primary energy losses in the upstream processes. As **heating oil** is to some extent still used in the building sector, including for new buildings, a similar approach to determine an adequate PEF value could be adopted.
- ✓ There are very large variations in how Member States determine and report **PEF values for biomass**, which makes a comparison of methodologies and values very challenging. Some Member States don't differentiate between liquid biofuels and biomass, providing an aggregated PEF value for generic fuels derived from renewable sources. Other Member States have detailed approaches and differentiate between several types and sub-types of biomass (e.g. densified vs non-densified, wood chips vs wood pellets).
- ✓ With regard to **national PEFs for district heating**, most concerned Member States have adopted a primary energy calculation approach which takes into account the specific features of the heat provision for DH networks. The national values differ hence quite significantly. However, some Member States apply a single fixed PEF for all DH networks in their country; this approach is not considered in line with the PEF principles. It is recommendable to differentiate between PEFs for DH depending on the fuels used and/or applied energy production technologies, as currently applied in several Member States. In some Member States a specific PEF is calculated individually for each DH network, which is of course also an appropriate approach.
- ✓ All Members are at present using **yearly average PEF values**. However, a higher resolution such as **monthly PEF values** for electricity and other energy carriers used for buildings' heating would provide a better view of the temporal changes in the energy mix. This is particularly relevant in

[30] https://epbd-ca.eu/wp-content/uploads/2018/04/05-CCT1-Factsheet-PEF.pdf

the fast-changing EU energy system with an increasing share of solar and wind energy. Therefore, it would be appropriate to consider the seasonal fluctuations of the PEF value for electricity, in particular when the primary energy use associated with a heat pump is calculated, given the fact that both the PEF value itself and the electricity consumption of the heat pump can vary significantly depending on the season[31].

5.2 Impact of on-site production of energy on PEF values for buildings

A number of Member States provided in their cost-optimality reports **differentiated PEF values for on-site and off-site produced electricity**; these Member States are Belgium, Cyprus, the Czech Republic, Germany, Ireland, Italy, Malta, Poland, Romania and Slovakia. 5 **countries reported the same PEF values for on-site produced electricity as their national value for grid-supplied electricity** - these are Cyprus, Germany, Ireland, Malta and Romania. Some Member States determined more than one PEF value for on-site produced electricity. This information is summarized in Table 5-10 below.

Table 5-10: National PEF for on-site electricity production (renewable and non-renewable) by Member State. Source: own elaboration based on the 2018 national cost optimality reports.

<table>
<tr><th>Country</th><th>PEF electricity renewable</th><th>PEF electricity non-renewable</th></tr>
<tr><td>Belgium</td><td colspan="2">1.80 - 2.50</td></tr>
<tr><td>Cyprus</td><td colspan="2">2.70</td></tr>
<tr><td>Czech Republic</td><td colspan="2">1.00</td></tr>
<tr><td>Germany</td><td colspan="2">2.80</td></tr>
<tr><td>Ireland</td><td colspan="2">1.86</td></tr>
<tr><td>Italy</td><td>1.00</td><td>0</td></tr>
<tr><td>Malta</td><td colspan="2">3.45</td></tr>
<tr><td>Poland</td><td>0.70</td><td>-</td></tr>
<tr><td>Romania</td><td colspan="2">2.62</td></tr>
<tr><td>Slovakia</td><td colspan="2">0</td></tr>
</table>

One Member State (Slovakia) reported a PEF value of 0 for on-site electricity. Italy, Poland and Belgium provided more than one PEF values for on-site electricity, either because of a differentiation between renewable and non-renewable production (like in Italy) or because of regional differences (like the Flanders region in Belgium, which uses the lower value of 1.80, compared to 2.50 in the Brussels Capital region).

For **energy vectors other than electricity**, 7 Member States – namely the Czech Republic, Germany, Italy, Latvia, Lithuania, Poland and Romania – reported PEF values for on-site production of heat. There is a clear discrepancy between Member States in handling their on-site heat generation: Germany, Latvia and Poland reported for on-site heat production a PEF value of 0, whereas the Czech Republic, Lithuania, Italy and Romania reported a PEF value of 1.00. Romania determined a separate value for solar thermal panels and heat pumps – the latter having a higher PEF value (1.53) and considered thermal energy for cooling separately, assigning a PEF value of 1.00 to it.

When it comes to on-site heat production based on renewables and heat-pumps – Germany reported a PEF value for 'renewables and ambient heat', including energy carriers such as solar energy and ambient

[31] Sam Hamels (2021). CO2 Intensities and Primary Energy Factors in the Future European Electricity System, Energies 14(8), 2165 https://doi.org/10.3390/en14082165.

heat (heat pumps), for which the PEF value is 0, while Latvia reported a PEF value of 0 for all renewables and heat pumps (‘wind, solar, aerothermal, hydrothermal and sea energy, hydraulic energy’). Poland reported for solar thermal energy also a PEF value of 0. Italy and Romania reported for thermal solar energy a PEF value of 1.00 (Romania reported for ‘thermal energy for free cooling’ also a PEF value of 1.00).
Based on this, it can be concluded that there is a clear discrepancy on the values assigned to energy from solar thermal collectors and heat pumps.

For on-site heat production based on fossil fuels - Estonia reported a PEF value of 1.00 for peat and peat briquettes. Finland distinguishes between ‘fossil fuels’ and ‘renewable fuels’ and reported PEF values of 1.00 and 0.50 respectively. The Czech Republic reported a PEF value for ‘thermal energy’ but it is unclear whether it refers to on-site heat production or DH. Some uncertainties and inconsistences remain; some member states provided PEF values for fossil fuels (e.g. heating oil and other oil products), without specifying whether the values refer to on-site or off-site production, and whether they refer to power or heat generation specifically.

5.3 Discussion of the PEF calculation methodology for buildings

The review of the PEF values for buildings as mentioned in the national cost optimality reports shows a significant lack of transparency and consistency:

- Besides missing documentation of applied methodologies, it is obvious that one main reason for large differences is the methodology used to consider renewable energy resources in the calculation of PEFs. In several cases where the PEF for biomass is less than 1 the “zero equivalent method” was applied or a PEF value between 0 and 1 was determined.
- A second area of inconsistency is the use of different allocation methods for DH that includes CHPs.
- A third reason for inconsistencies is the use of a full LCA approach in some countries while in others upstream flows are only considered in a simplified approach (e.g. by determining ‘fixed’ PEF values).
- For on-site production of energy, the PEFs vary to a large extent, from 0 up to 3.45, which cannot be explained by national particularities of the energy system but rather by different methodological decisions.

Even though Member States are responsible for the calculation of PEFs in the context of the EPBD, more methodological guidance would be appropriate in order to have consistent and comparable results of energy performance and/cost optimality calculations.

6 Key findings and conclusions

This chapter summarizes the key findings and conclusions based on the analysis of the calculation methodology of the PEF for electricity and other energy carriers in the context of the EED and EPBD.

6.1 PEF calculation methodology

6.1.1 The calculation methodology applied for the default PEF value for electricity is consistent and transparent

The applied calculation of the **PEF for electricity is based on a consistent and transparent methodology**. Even though the calculation methodology requires several methodological decisions which affect the result of the calculation, the methodology defined in recital 40 of the EED complies with the main assessment criteria:

- meaningfulness,
- consistency,
- applicability, and
- transparency.

Furthermore, the **sensitivity analysis** has shown that the considered changes in methodological decisions or in assumptions or reference values do not significantly change the value and future development of the PEF.

The application of an **LCA approach for fuels** would not be consistent with the EUROSTAT definitions and methodology, and would increase the PEF value for electricity without changing the future trend; using this method would lead to higher data uncertainty and increased calculation complexity. On the other hand, the use of the **zero-equivalent approach for RES** where the primary energy factor for RES is set at 0 would lead to lower PEF values but it would mix up energy efficiency with decarbonization, reduce the meaningfulness of the adapted PEF value and lead to inconsistencies with the EUROSTAT data.

6.1.2 PEF is the main headline indicator for energy efficiency

Headline indicators should provide relevant information for policy. **PEF is considered as the main headline indicator for the energy efficiency of the energy production system**, as it provides useful information on the primary energy use related to final energy consumption. The total PEF can further be differentiated into a PEF for renewables and a PEF for non-renewables.

All indicators have limitations and shortcomings. Due to the definition of primary energy according to EUROSTAT, the PEF does not provide information on the energy efficiency of renewable energy production technologies like photovoltaics, wind energy turbines or hydro power plants, although these technologies are still subject to major improvements of their conversion efficiency. The method does also not reflect the energy efficiency of appliances but it allows to compare end-uses for which different energy carriers can be applied (e.g. electric heating compared to gas boilers), however limited to primary energy use.

Even more important, the **PEF does not provide direct information on decarbonisation of the energy system**. For this purpose, specific additional indicators like the emission of greenhouse gases are required.

6.1.3 National PEF calculations by EU Member States lack consistency and transparency

The analysis of the cost optimality reports shows a **large variety of national PEF values for electricity**. This variety can partly be explained by differences in national electricity production conditions but it is widely unclear which calculation methodologies are applied by Member States. Generally, all Member States use yearly average PEF values for electricity. With the increasing share of solar and wind energy and with the growth of electricity as the main source for heating, a **higher temporal resolution** would provide a more appropriate basis for assessing the primary energy use. Monthly data are provided in some Member States but it is unclear to what extent these data are applied in the assessment of the energy performance of buildings.

For **natural gas** which is a standard product traded on European markets, the PEF values reported in 2018 varied between 1.0 to 1.19 (Sweden applies since 2020 a PEF of 1.80). Obviously, upstream flows are considered in different ways, with some countries that apply a PEF value of 1 do not consider upstream flows, while in other Member States (some) upstream losses are accounted for. Several Member States use a default value of 1.1 which considers a certain share of upstream flows (e.g. pipeline losses) but avoids complex calculations of a full LCA.

The **PEF values for biomass** also lack a common definition leading to widely incomparable data. Some countries only report non-renewable PEFs while others use total PEFs or provide data on renewable and non-renewable PEFs.

For **district heating** the situation is even more complex. Some Member States use a single national PEF value for district heating, others reported PEFs for individual networks or have different values for different district heating technologies (e.g. district heating from highly efficient CHPs). Transparency and consistency of the methodology are widely lacking, mainly concerning the use of allocation methods for CHPs and the use of the zero equivalent method or equivalent method for the PEFs of renewables.

PEF values for on-site production of electricity or heat are only provided by a few Member States. The variety in the reported PEFs is large, and consistency and transparency are widely lacking.

6.1.4 Consistent calculation methodology could be developed for PEFs of "new" energy vectors

As the PEF values for "new" gaseous energy vectors (hydrogen, biogas, biomethane) are highly dependent on the production technology and local energy inputs, **a single standard PEF value at EU level would not be appropriate**. However, in the previous chapters of this study, we have shown that for energy vectors other than electricity, the **PEF could be calculated in a consistent way by using data included in detailed national energy balances**. Energy balances allow to consider transformation and distribution losses within the energy sector but they do not include upstream (energy) flows related to extraction and associated infrastructure.

6.2 Recommendations for further developments

6.2.1 Methodological guidance for the calculation of PEFs by Member States

The study shows a large variety of national PEF values for electricity and other energy carries. It is widely unclear which calculation methodologies are at present applied by the Member States.

It is therefore recommended to increase the consistency by the provision of detailed methodological guidance in view of a higher harmonization of the calculation methods of the PEFs:

- Determination of general methodological decisions (particularly: use of PEF_{tot}; PEF of RES; LCA; allocation of primary energy use in CHPs)
- PEF for electricity (particularly: temporal resolution – annual and monthly data; simplified method for the consideration of power exchange)
- PEF for other energy carriers (harmonized determined PEF values for e.g. natural gas)
- PEF for “new” energy carriers (calculation based on national energy balances data)
- PEF for on-site production (clarification of “correct” PEF; further clarification of the use of PEF from nearby and/or off-site production)
- PEF for district heating (particularly: temporal and spatial resolution; allocation method for CHPs)

6.2.2 Calculation of the default PEF value for electricity at EU level

The energy transition in the European Union will lead to dramatic changes in the energy mix with a further shift from fossil-fuelled power plants to electricity production from wind energy, PV and other RES. For the calculation of the PEF for electricity, the geographical area was defined as EU-27 plus Norway. The sensitivity analysis has shown that the inclusion of Norway has only a very limited effect on the current and future PEF values. However, as the electricity production in Norway is not included in the EUROSTAT and PRIMES data, including Norway in the PEF calculation requires more complex modelling and calculations based on several assumptions.

It is therefore recommended to limit the calculation of the default PEF value for electricity to EU-27, fully represented in PRIMES data, which allows simplifying the calculation and increasing the consistency of data.

6.2.3 Forward-looking PEF values for electricity

Primary energy factors are a major factor to underpin decisions on long term investments in buildings and related energy appliances. As the primary energy use for electricity generation is expected to quite significantly further change in the future, dynamic and forward looking PEF values for electricity would allow more appropriate assessments of long-term investment decisions. Although this approach would increase the complexity of the PEF calculations and the assessment of the impacts of considered investments, it would provide an improvement compared to the current situation.

It is therefore recommended to provide PEFs for different time periods, e.g. PEF_1 for 2025 to 2030, PEF_2 for 2030 to 2040, and PEF_3 for 2040 to 2050. In any case, it is required to regularly update the PEFs, for instance every 4 to 5 years in order to align them with the updated energy scenarios.

6.2.4 Provision of a consistent database for the EU-27 Member States

The further improvement of the consistency of the PEF calculations by Member States requires appropriate data availability. The provision of a comprehensive database e.g. by Eurostat would enable EU Member States to directly and consistently apply the methodological guidance as recommended in 6.2.1.

It is therefore recommended to provide a consistent database with annual and monthly data for all EU-27 Member States. This database should reflect the energy system scenarios until 2050 and should be structured similarly to the energy balances.

6.2.5 Minimum requirement: full methodological transparency

Primary energy factors (and any other headline indicator) should meet the requirements of meaningfulness, consistency, applicability and transparency. The primary requirement should be transparency as this is the basis also for the assessment of other criteria like consistency.

It is recommended to require from Member States full transparency for the calculations of the national PEFs for electricity and other energy carriers according to EN 17423:2020.

6.3 Considerations regarding other methodological approaches

This section presents some methodological options that have been considered in this study but that are not recommended for implementation at this stage. Although they could represent improvements from an academic perspective, some major assessment criteria, applicability and consistency would not be ensured. Nevertheless, further research will be needed.

6.3.1 Dynamic PEF values for electricity

The PEFs for electricity will further decrease in the coming years reflecting the changes in the energy mix for electricity production. Moreover, the primary energy factor of electricity is increasingly becoming variable depending on the availability of wind and solar energy. Hence, average PEF values do not properly reflect the actual primary energy use of appliances such as heat pumps. For the calculation of energy efficiency improvements and actual primary energy savings of investment projects in buildings and related equipment, a dynamic PEF value for electricity could be more appropriate. As the use of dynamic PEFs would significantly increase the complexity of the calculations of primary energy use and savings, and would require huge administrative efforts from project owners and authorities, it would not be recommended to implement such an approach.

6.3.2 PEF values for electricity based on the "marginal asset" in the merit order

PEF values for electricity could be calculated based on the marginal market position, which means that (short term or marginal) changes in the electricity production system resulting from changes in final energy demand (e.g. switching on heat pumps in time periods when electricity market prices and/or grid tariffs are low) would be considered in the analysis. The necessary time resolution would be minutes, 15 minutes or hours. Obviously, implementing the marginal market position approach raises several issues which are difficult to address:

- In a forward looking PEF, how would scenarios have to be constructed in a way that meaningful and reliable outcomes would still be possible?
- The application of the marginal market position for the PEF calculation would mean that similar energy efficiency projects would lead to different primary energy savings, depending on the marginal power plant at the time of use?
- How can appliances be rated in terms of energy efficiency, if the PEFs depend on the time of use?
- Application of the marginal market position approach for the PEF calculation would require to apply this same approach to all policy areas. Otherwise, consistency would not be possible (e.g. by mixing up assessments built on the average system approach with assessments that use the marginal market position approach).
- Assessments would require to run the whole electricity system model for the relevant market (regional, national or supra-national).

6.3.3 PEF values based on hourly and daily data resolution

In this study, average annual and monthly data are presented. In the context of the EPBD, monthly data for PEFs that vary significantly between the winter and summer season provide a more appropriate picture for the assessment of heating systems. A further increase of the temporal resolution up to daily data would increase data requirements and complexity of calculation but would only have limited value added[32]. If hourly data were used, the complexity of calculation would further increase but additional insights could be possible, e.g. by including the potential of flexibility provided by demand response. Further research on this approach is needed.

6.3.4 Full LCA approach for PEF calculation of energy carriers

A full LCA approach for upstream and downstream flows would substantially increase the complexity of data gathering and calculation. The analysis has shown that the energy losses related to upstream flows of energy carriers (fossil fuels) vary to a large extent depending on the type of fuel, its origin and the transport mode (e.g. LNG tankers versus pipelines). Lack of standardisation of the calculation methodology, the high complexity of the calculation and still large uncertainties in results lead to the conclusion that a full LCA approach is not recommended for PEF calculations.

[32] Van den Brande, K., et al. 2019: The effect of dynamic primary energy factors on building energy performance. Proceedings of Building Simulation 2019: 16th Conference of IBPSA. In: Building Simulation Conference proceedings 16. p.4033-4039; http://hdl.handle.net/1854/LU-8707623

7 Annexes

7.1 Expert and stakeholder workshop #1

The focus of the workshop #1 was on the PEF for electricity in the framework of the EED. The objectives were: to present and discuss the methodology for the calculation of the PEF for electricity, give an overview of the PEF in EU legislation and remind participants of the previous (2016) PEF study commissioned by the European Commission.

Date: 30 June 2022, 9.00 to 11.00 CET

Place: online (via WEBEX)
Participants: 125 attendees (experts and stakeholders, project team, DG ENER)

Agenda

Topic	Time	Presenter
Welcome and introduction of participants	5 min	European Commission
Brief overview of the PEF study	10 min	e7 (Christof Amann)
PEFs in European legislation	15 min	e7 (Christof Amann)
Summary of the 2016 study and proposal for the update of the PEF for electricity	30 min	e7 (Christof Amann)
Comments and Discussion	60 min	e7 (Christof Amann)
Closing	5 min	European Commission

Presentations: see following pages

Support to Primary Energy Factors Review (PEF)

ENER/2020/OP/0021 ENER/C3/2020-724

Expert and Stakeholder Workshop #1
30 June 2022

www.trinomics.eu

Agenda

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Agenda

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Welcome and introduction of participants	5 min	European Commission
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Closing	5 min	European Commission

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Brief overview on the PEF study

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PEF Review

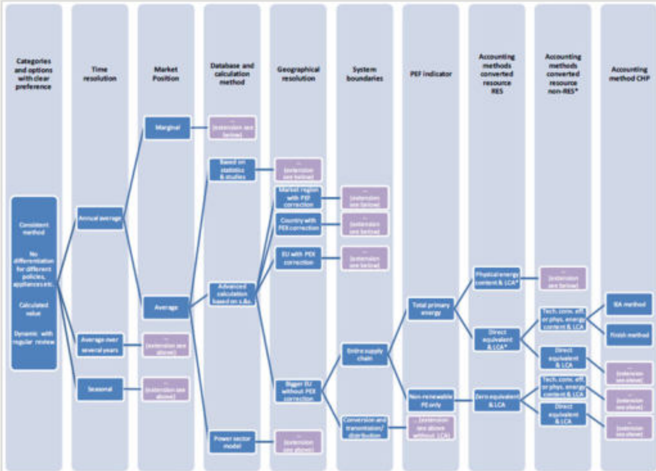
- Title: Support to Primary Energy Factors Review (PEF)
- Client: European Commission, Directorate-General for Energy, Directorate B - Just Transition, Consumers, Energy Efficiency and Innovation
- Tender in the context of the Multiple Framework Contract ENER/2020/OP/0021 ENER/C3/2020-724
- Duration: June 2022 - February 2023
- Contractor:
  - Trinomics/Brussels
  - e7/Vienna
  - Fraunhofer ISI/Karlsruhe
  - >> same team as for the 2016 PEF study

Objectives

- Technical support for PEF in the context of EED and EPBD
- Review of calculation methodology of PEF for electricity
- Assessment of the necessity for PEFs for other energy carriers
- Update PEF for electricity
- Analysis of the role and calculation methodology of PEFs in EPBD
- Assessment of national, regional or local PEFs for different energy carriers
- Exploration of the treatment of on-site and off-site production of RES in the energy performace calculation

Tasks I

- Task 1 - Update of the framework for the PEF values
  - Analysis of EU legislation
  - Assessment of PEF methodology
- Task 2 - Data gathering and calculation of PEF values
  - Calculation of PEF for electricity
  - Impact assessment of methodological decisions



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Tasks II

- Task 3 - PEF values for buildings
  - Analysis of the framework for PEFs in the building sector
  - Analysis of PEF values at national level
  - Analysis of the treatment of on-site production

- 3 Workshops with experts and stakeholders
  - PEF for electricity
  - PEF in EED and EPBD
  - Final report

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PEFs in European legislation

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Why do we need PEFs?

- Comparability of energy consumption regardless of the energy carrier used
- Conversion from final energy use to primary energy consumption
- Ensure equal treatment for all fuels

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Legal context (1)

- EED (EU Directive 2006/32 and 2012/27/EU)
  - 20% of primary energy savings in 2020
  - Annex IV, Footnote 3: „For savings in kWh electricity Member States may apply a default coefficient of 2,5. Member States may apply a different coefficient provided they can justify it."
- EED (EU Directive 2018/2002)
  - For savings in kWh electricity, Member States may apply a default coefficient of 2,1 or use the discretion to define a different coefficient, provided that they can justify it.
  - Recital 40
  - Annex IV, Footnote 3
- Proposal for a recast of EED
  - "For savings in kWh of other energy carriers, Member States shall apply a coefficient in order to accurately calculate the resulting primary energy consumption savings."

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Recital 40

Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the **default coefficient for savings in kWh electricity** should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy mix of the PEF for electricity are based on **annual average values**. **The 'physical energy content' accounting method** is used for nuclear electricity and heat generation and the **'technical conversion efficiency' method** is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the **direct equivalent** based on the **'total primary energy' approach**. To calculate the primary energy share for electricity in **cogeneration, the method set out in Annex II to Directive 2012/27/EU** is applied. An **average rather than a marginal market position** is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the **PEF is 1 for all energy sources**. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the **PRIMES Reference Scenario** for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers **the Member States and Norway**. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data.

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Annex IV, footnote 3

Applicable when energy savings are calculated in primary energy terms using a **bottom-up approach based on final energy consumption**. For **savings in kWh electricity**, Member States shall apply a coefficient established through a **transparent methodology** on the basis of national circumstances affecting primary energy consumption, in order to ensure a precise calculation of real savings. Those circumstances shall be **substantiated, verifiable and based on objective and non-discriminatory criteria**. For savings in kWh electricity, Member States may apply a default **coefficient of 2,1** or use the discretion to define a different coefficient, provided that **they can justify it**. When doing so, Member States shall take into account the energy mix included in their integrated national energy and climate plans to be notified to the Commission in accordance with Regulation (EU) 2018/1999. By **25 December 2022** and every four years thereafter, the Commission shall **revise the default coefficient on the basis of observed data**. That revision shall be carried out taking into account its effects on other Union law such as Directive 2009/125/EC and Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU (OJ L 198, 28.7.2017, p. 1).

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Legal context (2)

- EBPD (EU Directive (EU) 2018/844)
  - The calculation of primary energy shall be based on **primary energy factors** or **weighting factors per energy carrier**, which may be based on **national, regional or local annual, and possibly also seasonal or monthly**, weighted averages or on more specific information made available for individual district system.
  - Primary energy factors or weighting factors shall be **defined by Member States.**
  - Member States may take into account renewable energy sources supplied through the energy carrier and renewable energy sources that are **generated and used on-site**, provided that it applies on a non-discriminatory basis.
  - The **reduction in the use of primary energy** for end-uses covered by the EPBD is an important policy goal, both through **minimum performance requirements** and for EPCs.
- Poroposal for recast of EBPD
  - Distinction between the “non-renewable primary energy factor”, “renewable primary energy factor” and “total primary energy factor”
  - Annual, seasonal, monthly, daily or hourly basis

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recast of EPBD

- 9. ‘primary energy’ means **energy from renewable and non-renewable sources** which has **not undergone any conversion or transformation** process
- 10. ‘non-renewable primary energy factor’ means non-renewable primary energy for a given energy carrier, including the delivered energy and the **calculated energy overheads of delivery to the points of use**, divided by the delivered energy
- 11. ‘renewable primary energy factor’ means renewable primary energy from an **on-site, nearby or distant energy source** that is delivered via a given energy carrier, including the delivered energy and the calculated energy overheads of delivery to the points of use, divided by the delivered energy
- 12. ‘total primary energy factor’ means the **weighted sum of renewable and non-renewable primary energy factors** for a given energy carrier

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recast of EPBD

- The calculation of primary energy shall be based on primary energy factors, (distinguishing non-renewable, renewable and total) per energy carrier, which have to be recognised by the national authorities. Those primary energy factors may be based on **national, regional or local information**. Primary energy factors may be set on an **annual, seasonal, monthly, daily or hourly** basis or on more specific information made available for individual district systems.
- Primary energy factors or weighting factors shall be **defined by Member States**. The choices made and data sources shall be reported **according to EN 17423** or any superseding document. **Member States may opt for an average EU primary energy factor for electricity** established pursuant to Directive (EU) …/… [recast EED] instead of a primary energy factor reflecting the electricity mix in the country.

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Legal context (3)

- Eco-design and energy labelling
    - As a result of the changed default PEF for electricity in the EED (2.1 instead of 2.5), the minimum space heating values, the Eco-design lot1 revision and the energy labelling classes had to be adjusted in order to take into account the higher overall energy efficiency of the electricity system.

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Summary of legal context

- Several legal documents refer to PEFs
- Definition of PEF differ in time and policy area
- Some flexibility for Member States left

- >> Need for consistent methodology

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Summary of 2016 PEF study

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2016 PEF study

- Title: Review of the default primary energy factor (PEF) reflecting the estimated average EU generation efficiency referred to in annex IV of Directive 2012/27/EU and possible extension of the approach to other energy carriers
- Client: European Commission, Directorate-General for Energy
- Duration: September 2015 - March 2016
- Contractor:
  - Trinomics/Brussels
  - Fraunhofer ISI/Karlsruhe
  - e7/Vienna

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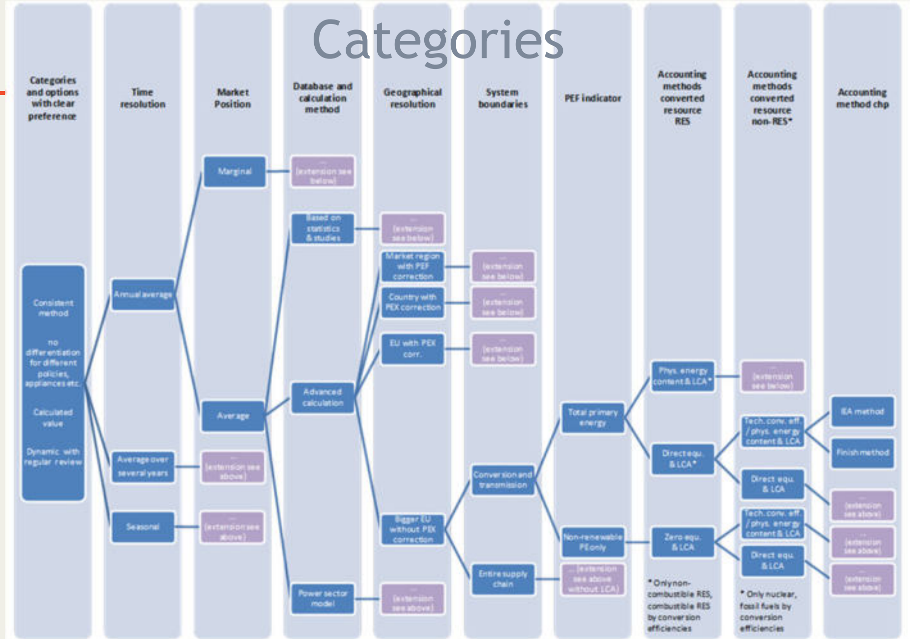
Resulting decision tree

Options



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Thematic groups and categories

Strategic / Political considerations	
PEF purpose	Applicability
Adjustment & review process	Database and calculation method
Representation of the electricity sector	
Geographical resolution	Power exchange correction
Development over time	Time resolution
Market position	Perspective
General PEF methodology	
PEF accounting methods	Supply chain boundaries
Methodological differentiation for infinite (renewable) resources	

13 possible categories are identified
Partial dependency between the categories

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Categories and options I

Category	Option
Strategic and political considerations	
PEF purpose	Desired
	Calculated
Applicability	Abolish the use of a PEF
	No differentiation
	Different for different policies
	Differentiated for appliances
	Differentiated by appliances
	Different for delivered and produced electricity
Adjustment and review process	Constant over time
	Regular review/adjustment
Database and calculation method	Based on statistics and studies
	Advanced calculations based on statistics and studies
	Power sector model calculations

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Categories and options II

Category	Option	
Representation of the electricity sector		
Geographical resolution	Bigger EU	With PEX correction
		No PEX Correction
	EU	With PEX correction
		No PEX Correction
	Member States	With PEX correction
		No PEX Correction
	Market regions	With PEX correction
		No PeX Correction
	Subnational regions	With PEX correction
		No PEX Correction
Development over time	Constant	
	Dynamic	
Time resolution	Average over several years	
	Annual average	
	Seasonal	
	Hourly time of use	
Market position	Average electricity production	
	Marginal electricity production	

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Categories and options III

Category	Option
General PEF methodology	
PEF indicator	Total primary energy
	Non-renewable energy only
System boundaries	Entire supply chain
	Total energy conversion only (including transport losses)
Accounting Method converted resource nuclear	Technical conversion efficiencies (nuclear eff. Ca. 33%)
	Direct equivalent (nuclear eff. 100%)
	Physical energy content (nuclear eff. Ca. 33%)
Accounting Method converted resource non combustible RES	Zero equivalent
	Substitution method
	Direct equivalent (100%)
	Physical energy content
	Technical conversion efficiencies
Accounting Method converted resource combustible RES (biomass)	Zero equivalent
	Technical conversion efficiencies
Methodological consistency	Same method for all PEF
	Different methods for different countries
	Different methods with correction mechanism

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Evaluation criteria

- Two categories of evaluation criteria
  - **Methodological suitability:** influence of the selected options on the method to calculate the PEF with regard to feasibility and achievement of objectives
  - **Acceptance:** criteria which evaluate the selected option with a focus on a broad acceptance to use the PEF calculation later on
- Ranks ranging from 1 (best) to 5 (worst) for each evaluation criterion
- Cut off criterion leading to an exclusion of the option

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Weighting of criteria

Methodological Suitability						Acceptance					
70 %						30 %					
Precision	Data Availability 20 %					Target: internal market	Target: 2020 climate	Target: 2020 Security of supply	Target: Long-term decarboni-sation	Complexity	Trans-parency
	Effort	Credibility	Data quality	Uncertainty	Flexibility						
50 %	2 %	4 %	6 %	6 %	2 %	8 %	4 %	4 %	6 %	4 %	4 %

Category	Option	Rank	Methodological suitability: Precision	Methodological suitability: Data availability	Acceptance
Representation of the electricity sector					
Market position	Average	1,87	2,00	1,89	1,00
	Marginal	5,00	4,00	5,00	5,00

Accounting method: PEF for electricity

	Zero equivalent	Direct equivalent	Physical energy content	Technical conversion efficiencies
Hydro	0	1	1	n.a.
Wind	0	1	1	n.a.
Solar PV	0	1	1	n.a.
Solar (thermal)	0	1	3	n.a.
Geothermal	0	1	10	n.a.
Biomass	0	n.a.	Ca. 3-4	Ca. 3-4
Nuclear	n.a.	1	Ca. 3	Ca. 3

Selection of 4 PEF scenarios

- Method 1: Close to Eurostat
- Method 2: Climate protection and LCA
- Method 3: Adapted Eurostat - finish method
- Method 4: Adapted Eurostat - finish method - LCA

Method	2000	2005	2010	2015	2020	2025	2030
Method 1	2.41	2.37	2.26	2.08	1.87	1.79	1.74
Method 2	2.41	2.36	2.14	1.90	1.59	1.46	1.35
Method 3	2.52	2.49	2.38	2.21	2.01	1.93	1.87
Method 4	2.65	2.61	2.49	2.30	2.09	2.00	1.93

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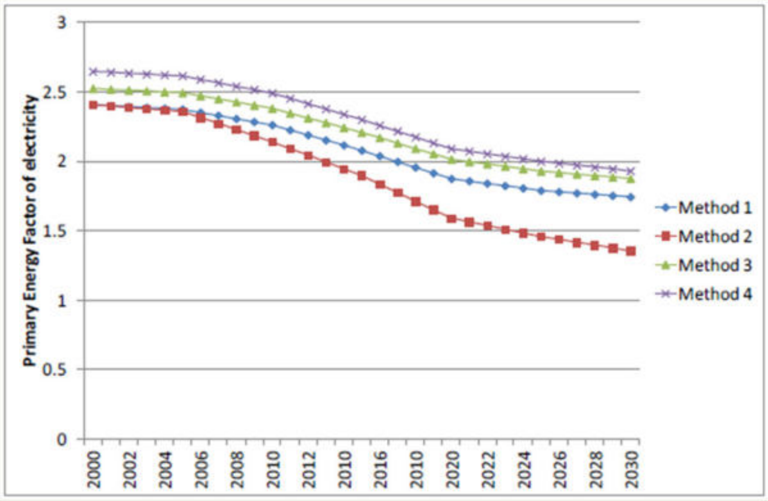
PEF of electricity



Source: 2016 PEF study

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PEFs for other energy carriers

- Definition of EUROSTAT does not follow an LCA approach
- Definition of primary energy factor from EN 15603:2008 (Energy Performace of Buildings)

  - For a given energy carrier, non-renewable and renewable primary energy divided by delivered energy, where the primary energy is that required to supply one unit of delivered energy, taking account of the energy required for **extraction, processing, storage, transport, generation, transformation, transmission, distribution**, and **any other operations necessary** for delivery to the building in which the delivered energy will be used

  - NOTE: The **total** primary energy factor always exceeds unity.
  - NOTE: The **non-renewable** primary energy factor can be less than unity if renewable energy has been used

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PEFs for other energy carriers

- Conventions for primary energy factors

  - The primary energy factors **shall include** at least:
    - Energy to extract the primary energy carrier;
    - Energy to transport the energy carrier from the production site to the utilization site;
    - Energy used for processing, storage, generation, transmission, distribution, and any other operations
    - Energy necessary for delivery to the building in which the delivered energy is used.

  - The primary energy factors **may also include**:
    - Energy to build the transformation units;
    - Energy to build the transportation system;
    - Energy to clean up or dispose the wastes.

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Complexity of PEF calculation for fuels

- Different fuel origin
  - Different extraction processes
- Different transformation processes
- Different transport processes
- Different distribution processes

Continuously changing, influenced by energy prices and geopolitics

Data for 2011 oil & gas production		Total	Africa	Asia	Europe	FSU	ME	NA	SA
OGP reported production	Mt/a	2221	387	356	452	127	411	296	194
	%	100%	17%	16%	20%	6%	19%	13%	9%
Total production (BP	Mt/a	6951	600	819	406	1366	1775	1454	531
Statistical Review)	%	100%	9%	12%	6%	20%	26%	21%	8%
OGP coverage[1]	% of total	32%	65%	43%	111%	9%	23%	20%	37%
Energy Consumption (OGP production only)									
Total energy	PJ/a	3333	515	611	515	141	321	903	328
Specific energy	GJ/t	1.50	1.33	1.72	1.14	1.11	0.78	3.06	1.69
Specific energy[3]	**MJ/MJ**	**0.036**	0.032	0.041	0.027	0.026	0.019	0.073	0.040
Emissions from energy production, flaring, venting and fugitive losses (OGP production only)									
CO_2	Mt/a	294.0	83.1	65.2	33.9	12.7	19.5	53.3	26.4
	t/kt	132.4	215	184	75	100	47	181	136
CH_4	kt/a	2801	592	998	185	75	66	649	237
	t/kt	1.26	1.53	2.81	0.41	0.59	0.16	2.20	1.22
GHG as CO_{2eq}[2]	Mt/a	364.0	97.9	90.1	38.5	14.6	21.2	69.5	32.3
	t/kt	164	253	254	85	115	51	236	167
% GHG due to CH_4		19%	15%	28%	12%	13%	8%	23%	18%
Specific GHG emissions	**g CO_{2eq}/MJ**	**3.90**	6.02	6.04	2.03	2.73	1.23	5.61	3.97
Figures prorated to total oil & gas production									
GHG as CO_{2eq}[2]	Mt/a	1077.2	151.8	207.8	38.5	156.7	91.4	342.5	88.5
	t/kt	155							
Total energy	PJ/a	10969	798	1409	515	1516	1385	4449	897
Specific energy[3]	**MJ/MJ**	**0.038**							
Specific GHG emissions	**g CO_{2eq}/MJ**	**3.69**							

Example of CO2 and energy use for production of oil & gas around the world

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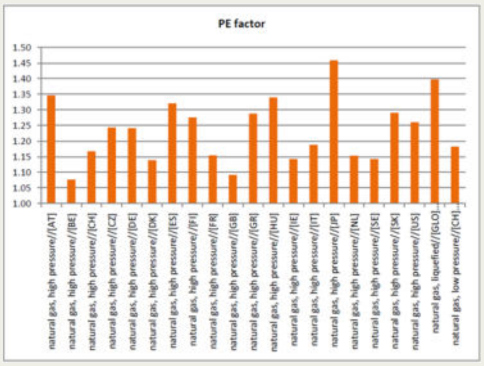
Current practice – PEF for fuels

- Large differences on the PEF results (Ecoinvent 3.1)
- Actual variations on supply chains and processes
- Different assumptions, boundaries, default values, quality of the source data (**lack of a harmonized LCA methodology** for the energy sector.)
- Very **large uncertainty** on primary energy calculations for fuels from a life cycle (LCA) perspective



PE factors for natural gas (high pressure) for various countries

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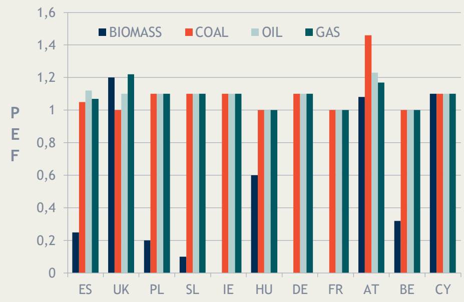
Current practice – PEF for fuels

- Many cases do have some consideration of the supply chain (PEF>1)
- Many countries choose to adopt a standard typical value of 1.1 for fossil fuels
- Some countries use a PEF of 1, which means the energy carrier are considered as a primary energy source
- Some countries perform a more detailed supply chain analysis, leading to higher - and more variable - PEFs
- For biomass, there are large differences because the use of different evaluation criteria



PEFs for fuels for different EU countries.
(EPBD National Cost-Optimal Regulations)

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Summary from the 2016 PEF study

"Overall, we can conclude that calculation of primary energy factors for fuels from a life cycle perspective presents **data gathering complexity** and **very large uncertainties.**"

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EU Directive 2018/2002 - Recital 40

Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the **default coefficient for savings in kWh electricity** should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy mix of the PEF for electricity are based on **annual average values**. **The 'physical energy content' accounting method** is used for nuclear electricity and heat generation and the **'technical conversion efficiency' method** is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the **direct equivalent** based on the **'total primary energy' approach**. To calculate the primary energy share for electricity in **cogeneration, the method set out in Annex II to Directive 2012/27/EU** is applied. An **average rather than a marginal market position** is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the **PEF is 1 for all energy sources**. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the **PRIMES Reference Scenario** for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers **the Member States and Norway**. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data.

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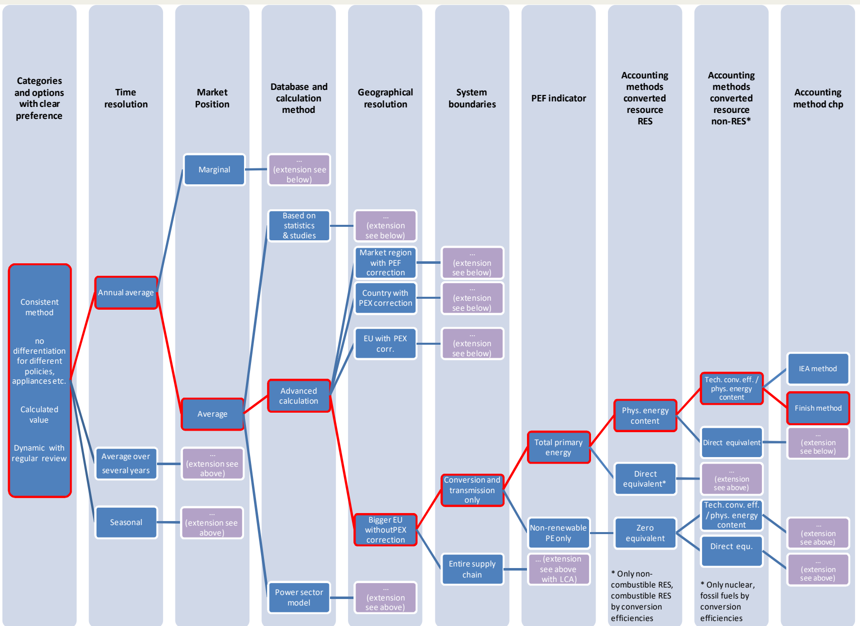
Method 3 applied by the EC



Default PEF for electricity

2,1

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Proposal for the update of the PEF for electricity

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Summary review of the 2016 PEF study

- The 2016 PEF study provides a comprehensive and transparent approach for the selection of the PEF calculation methodology.
- No PEF calculation method can claim absoluteness.
- Some PEF calculation methods are more appropriate than others.
- Some methodological decisions are controversial by nature depending of individual interests of stakeholders.
- Decisions are required.
- PEF does not tell the whole story!
- PEF has to be supplemented by other indicators like CO_{2eq}.

Main criteria for the update of PEF

- Calculation of PEF ...
  - has to be in line with EU legislation,
  - should be built on publicly available data (EUROSTAT, PRIMES),
  - should be compatible with IEA/EUROSTAT energy statistics and energy balances,
  - should allow comparison over time and
  - between countries, and
  - should help to achieve EU energy and climate goals
  - with reasonable effort.

EU Directive 2018/2002 - Recital 40

Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the **default coefficient for savings in kWh electricity** should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy mix of the PEF for electricity are based on **annual average values**. **The 'physical energy content' accounting method** is used for nuclear electricity and heat generation and the **'technical conversion efficiency' method** is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the **direct equivalent** based on the **'total primary energy' approach**. To calculate the primary energy share for electricity in **cogeneration, the method set out in Annex II to Directive 2012/27/EU** is applied. An **average rather than a marginal market position** is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the **PEF is 1 for all energy sources**. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the **PRIMES Reference Scenario** for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers **the Member States and Norway**. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data.

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Comments and discussion

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A PEF poll

https://ahaslides.com/QVVAW

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ENERGY INNOVATION ENGINEERING

Thank you for your attention, please contact us for more information.

Christof AMANN

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European Commission

7.2 Expert and stakeholder workshop #2

The focus of WS#2 was to select the most relevant topics for the review of PEF calculation methodology in the EED and EPBD to be further developed and to identify gaps in legislation, definitions and application.

Date: 20 October 2022, 9.00 to 11.00 CET

Place: online (via WEBEX)

Participants: 128 attendees (experts and stakeholders, project team, DG ENER)

Agenda

Topic	Time	Presenter
Welcome and introduction	5 min	European Commission
Part 1: Calculation of the PEF for electricity	20 min	Christof Amann (e7)
Q&A	10 min	Christof Amann (e7)
Part 2: Preliminary results from PEFs in EPBD	15 min	Perla Torres (Trinomics)
A report from the practice	15 min	Wolfgang Stumpf (e7)
Part 3: Summary of methodological topics from WS#1 and position papers	20 min	Christof Amann (e7)
Discussion of future methodological topics	60 min	Christof Amann (e7)
Closing	5 min	European Commission

Presentations: see following pages

Support to Primary Energy Factors Review (PEF)

ENER/2020/OP/0021 ENER/C3/2020-724

Expert and Stakeholder Workshop #2
20 October 2022

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Agenda

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Closing	5 min	European Commission

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Purpose of Workshop #2

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Purpose WS#2

- Presentation of the calculations and the selection of the value for the PEF for electricity
- Presentation of preliminary results from PEFs in the EPBD
- Discuss future relevant topics for the PEF calculations

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Part 1
Calculation of the PEF for electricity

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EED (EU Directive 2018/2002) - Recital 40

Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the **default coefficient for savings in kWh electricity** should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy mix of the PEF for electricity are based on **annual average values**. **The 'physical energy content' accounting method** is used for nuclear electricity and heat generation and the **'technical conversion efficiency' method** is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the **direct equivalent** based on the **'total primary energy' approach**. To calculate the primary energy share for electricity in **cogeneration, the method set out in Annex II to Directive 2012/27/EU** is applied. An **average rather than a marginal market position** is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the **PEF is 1 for all energy sources**. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the **PRIMES Reference Scenario** for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers **the Member States and Norway**. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data.

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Data sources: PRIMES Scenarios

- **Full Package Scenario**
  - Update of the Mix 55 scenario taking into account all the proposals tabled for the Fit for 55 package (FPS scenario)
- **Full Package Scenario High Prices**
  - Update of the Full Package Scenario taking into account higher fossil fuels prices (FPS_high)
- **REPowerEU Scenario**
  - Encompasses a phase out of Russian fossil fuel dependence, higher energy prices and decreased use of natural gas. This scenario also models an increased energy efficiency target of 13% and a higher renewable energy targets of 45% which ensures the achievement of the Fit for 55 package (REP13)

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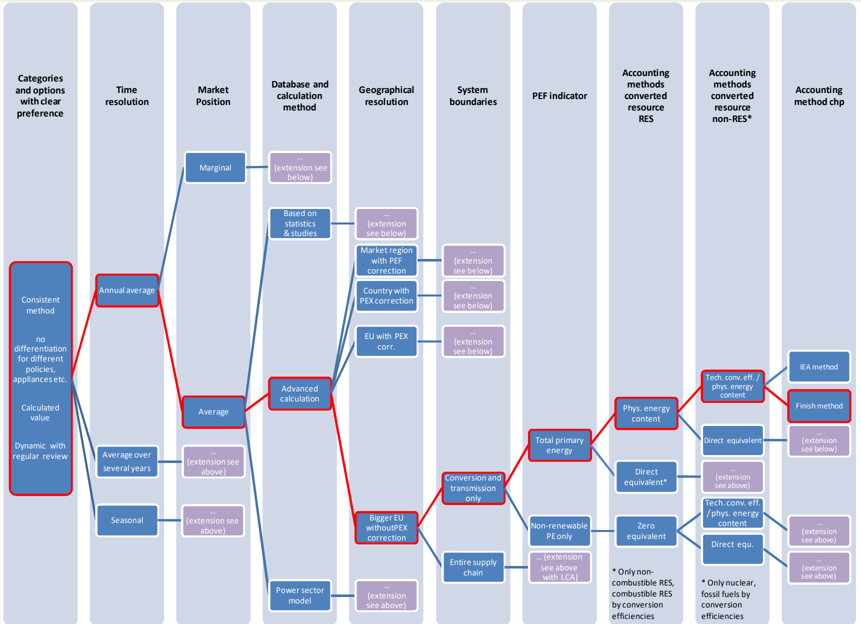
Method 3 from the 2016 PEF study



PEF of fuels and conversion efficiency

	PEF of the fuel	Conversion efficiency	PEF for electricity
Hydro	1	100%	1
Wind	1	100%	1
Solar PV	1	100%	1
Geothermal	1	10%	10
Biomass	1	From real data	From real data
Nuclear	1	33%	3
Fossil fuels	1	From real data	From real data
CHP	Finish method		

Source: 2016 PEF Study

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Step 1: Final electricity consumption

- REP13 Scenario
- EU27 + Norway
- Assumptions for Norway
  - Self-consumption of energy sector (%) of EU27
  - Transmission & distribution losses (%) of EU27
- Power exchange between EU27 and Norway not considered

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production* EU27+Norway	3 017	2 776	3 115	3 720	4 420	5 271	6 333	6 979
Self-consumption of energy sector	245	195	233	623	959	1 543	2 342	2 879
Grid losses	189	174	186	197	218	226	228	222
Final electricity consumption* EU27+Norway	**2 582**	**2 407**	**2 696**	**2 899**	**3 243**	**3 502**	**3 763**	**3 878**

Source: PRIMES, ENTSO-E, own calculation e7

Step 2: Raw primary energy demand

- Conversion efficiencies of power plants, PEF for fuels (PEF = 1)
- Calculation of raw primary energy demand (RPED) for electricity production of EU+Norway
- Correction: Only RPED necessary for final energy consumption

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Final electricity consumption EU27+Norway	2 582	2 407	2 696	2 899	3 243	3 502	3 763	3 878
Grid losses (share of final electricity consumption)[15]	7,3%	7,2%	6,9%	6,8%	6,7%	6,5%	6,1%	5,7%
Own consumption and pumping (share of final electricity consumption)	6,5%	5,4%	4,8%	5,1%	4,5%	5,5%	8,4%	9,8%
Gross electricity production (corrected) EU27+Norway	**2 939**	**2 710**	**3 012**	**3 243**	**3 607**	**3 922**	**4 306**	**4 479**
Gross electricity production EU27+Norway	3 017	2 776	3 115	3 720	4 420	5 271	6 333	6 979
Correction factor	97,4%	97,6%	96,7%	87,2%	81,6%	74,4%	68,0%	64,2%
RPED EU27+Norway	7 229	6 062	6 096	6 153	6 433	7 118	8 304	9 067
Raw primary energy demand (corrected) EU27+Norway	**7 043**	**5 917**	**5 896**	**5 364**	**5 250**	**5 296**	**5 646**	**5 818**

Source: PRIMES, ENTSO-E, own calculation e7

Step 3: Heat bonus

- Correction of heat produced by CHP plants
- Finnish method (EUROSTAT uses the IEA method)
- Reference value for CHP: 75%, eta_{el}: 53%, eta_{th}: 92%

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Raw primary energy demand (corrected) EU27+Norway	7 043	5 917	5 896	5 364	5 250	5 296	5 646	5 818
Heat bonus	839	815	863	731	675	542	459	415
Primary energy demand (corrected) EU27+Norway	6 205	5 103	5 033	4 633	4 575	4 754	5 187	5 404

Source: PRIMES, ENTSO-E, own calculation e7

e7 Trinomics

(Final) Step 4: PEF for electricity

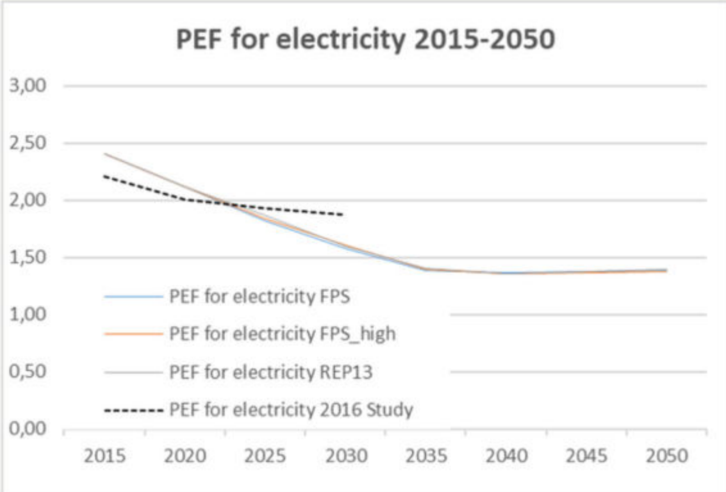
[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Primary energy demand (corrected) for electricity production in EU27+Norway	6 205	5 103	5 033	4 633	4 575	4 754	5 187	5 404
Final electricity consumption EU27+Norway	2 582	2 407	2 696	2 899	3 243	3 502	3 763	3 878
PEF for electricity (REP13 scenario)	2,40	2,12	1,87	1,60	1,41	1,36	1,38	1,39

	2015	2020	2025	2030	2035	2040	2045	2050
FPS scenario	2,40	2,12	1,82	1,58	1,39	1,37	1,38	1,39
FPS_high scenario	2,40	2,12	1,84	1,61	1,40	1,36	1,37	1,38
REP13 scenario	2,40	2,12	1,87	1,60	1,41	1,36	1,38	1,39
PEF 2016 study	*2,21*	*2,01*	*1,93*	*1,87*				

Source: PRIMES, ENTSO-E, own calculation e7

e7 Trinomics

Development of the PEF for electricity



Source: PRIMES, ENTSO-E, own calculation e7

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Discussion of results

- Increasing electricity production for e-fuels etc. is excluded from calculation >> PEF for e-fuels etc.
- Transition towards RES and decarbonisation
- Shift from conventional thermal power plants towards non-combustible RES
- Significant increase in conversion efficiency in remaining thermal power plants
- Increase of storage (pumped hydro mainly, hydrogen) which leads to a slight increase of PEF due to storage losses after 2040
- Differences between the PEF for electricity in the different scenarios are rather insignificant

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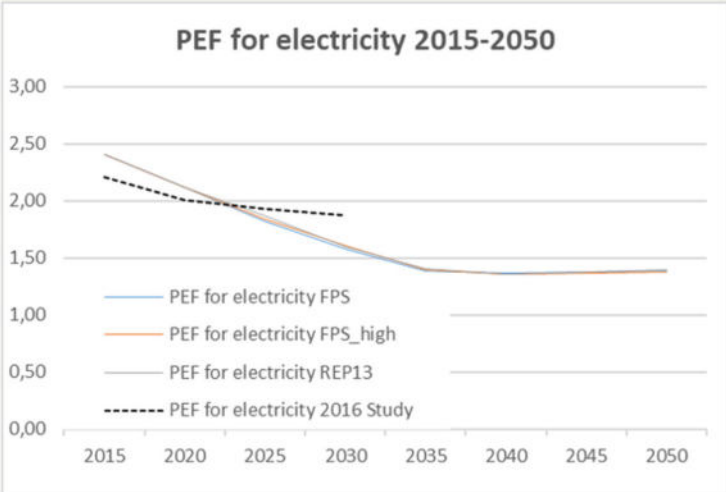
Development of the PEF for electricity



Source: PRIMES, ENTSO-E, own calculation e7

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Part 2
Preliminary results from PEFs in the EU27

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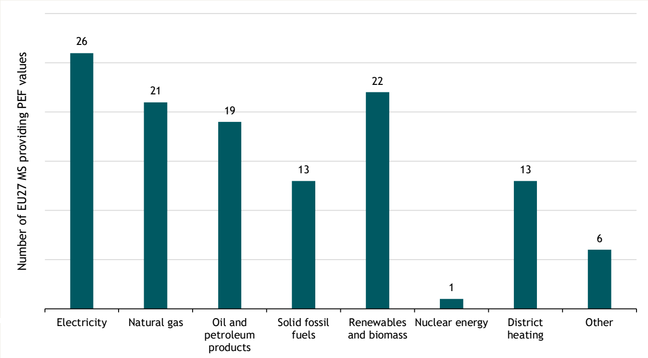
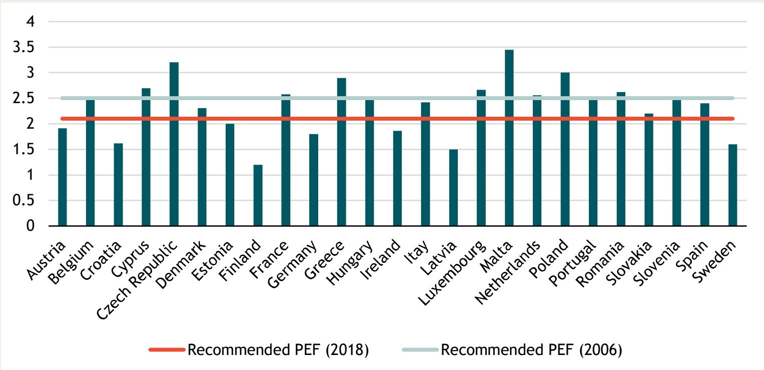
Overview of PEFs collected

- Main source: Cost-optimal reports submitted by MS in 2018.
- All MS (except BG?) apply a PEF for electricity.
- Most MS have also a PEF for natural gas, oil and RES.



PEFs for electricity

National PEF_{Total} values for grid-supplied electricity



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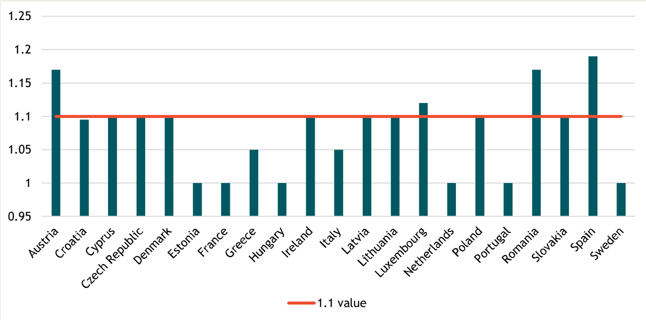
PEFs for natural gas

National PEF_{Total} values for natural gas



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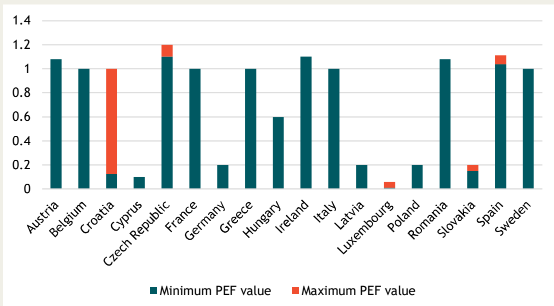
PEFs for biomass

Range of PEF for biomass

- Wide variety in the provided numbers
- 7 MS provide disaggregated data (for densified and non-densified biomass)

Member State	Densified		Non-densified
	Wood chips	Wood pellets	
Croatia	0.154	0.123	1
Czech Republic	1.2		1.1
Lithuania	0.1 (non-RES) - 1 (RES)		
Luxembourg	0.06	0.07	0.01
Romania	1.08		1.08
Slovakia	0.15	0.2	0.1
Spain	1.113		1.037



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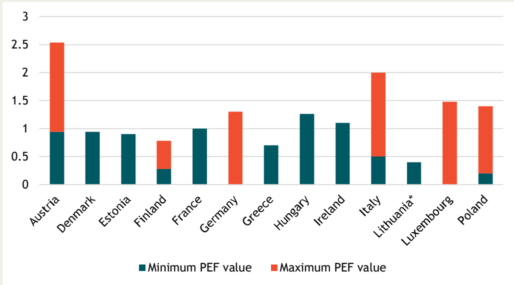
PEFs for district heating

National PEF_{DH} values

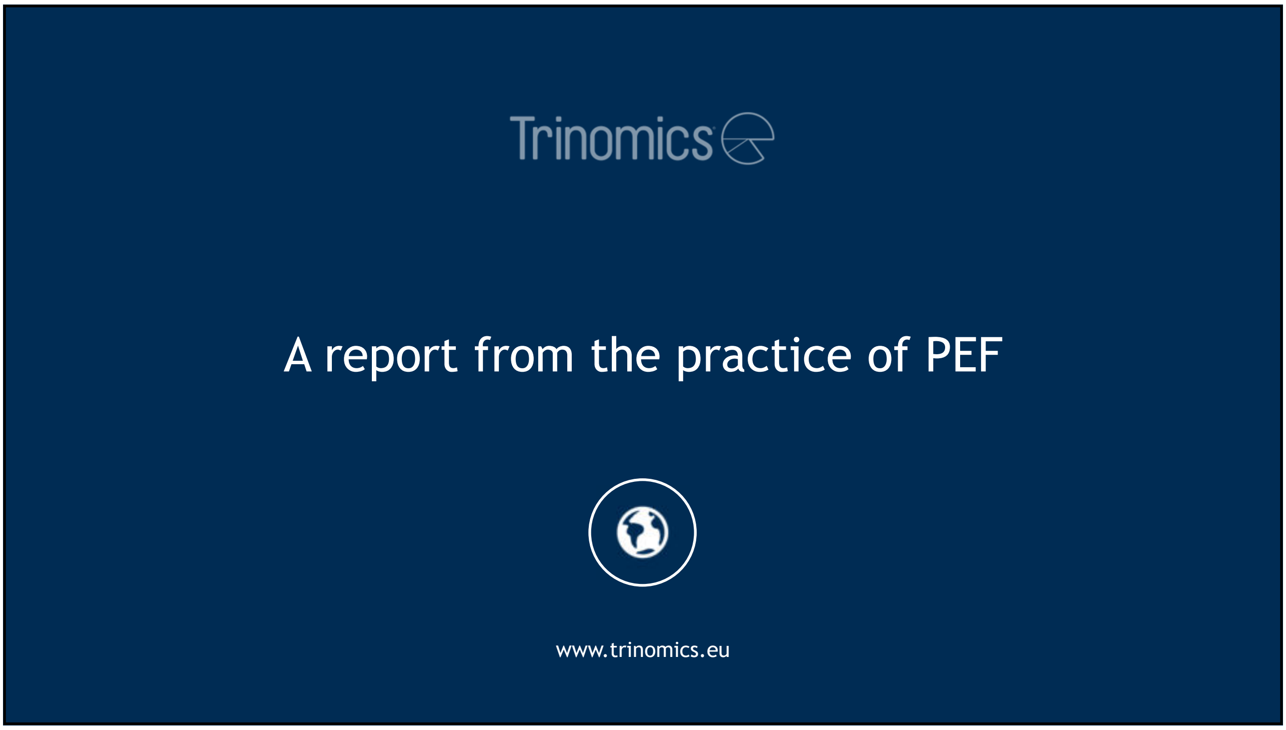
- 13 MS provided a PEF for district heating
- 6 MS provided a disaggregated value (either based on source tech. or ren./non-ren. carrier)



Key findings and next steps

- Great variations in how MS report their PEFs
  - Labeling of energy sources
  - PEF_{Total} vs details on PEF_{RES}, $PEF_{non\text{-}REs}$
- Large variation in PEF methodologies and values:
  - Most evident in Electricity
  - Affects also Biomass and District Heating
- Next steps:
  - Case studies on the methodology of selected MS

Please send any comments on the presented figures to perla.torres@trinomics.eu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A report from the practice of PEF
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Part 3
Discussion of metholdogical topics
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PEF Workshop

A Report from the Practice

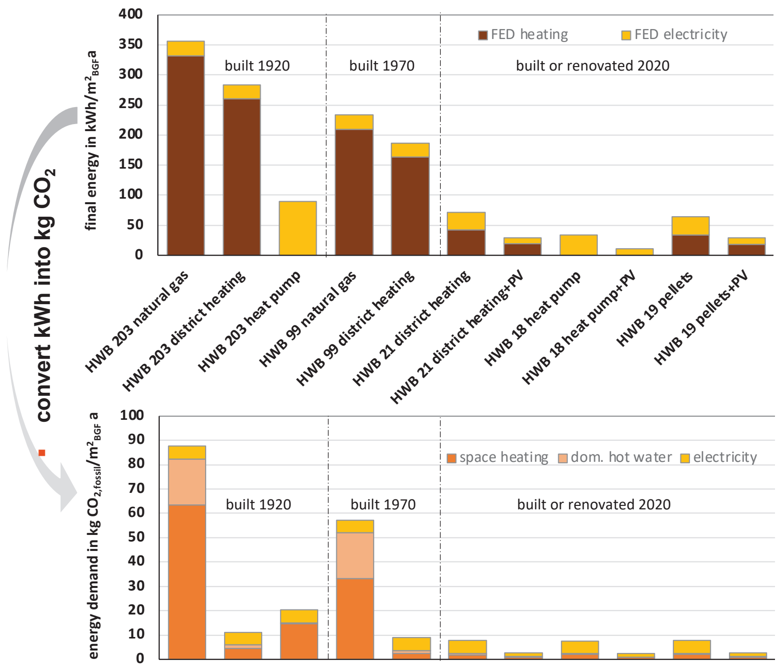
Wolfgang Stumpf, e7

We use conversion factors for the assessment of

Climate-neutral Buildings

Which building energy system causes the lowest CO_2-emissions during operation?

$FED \times f_{CO2} = CO_2$ $FED \times f_{PE} = PED$



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Which building energy system causes the lowest CO_2-emissions during operation?

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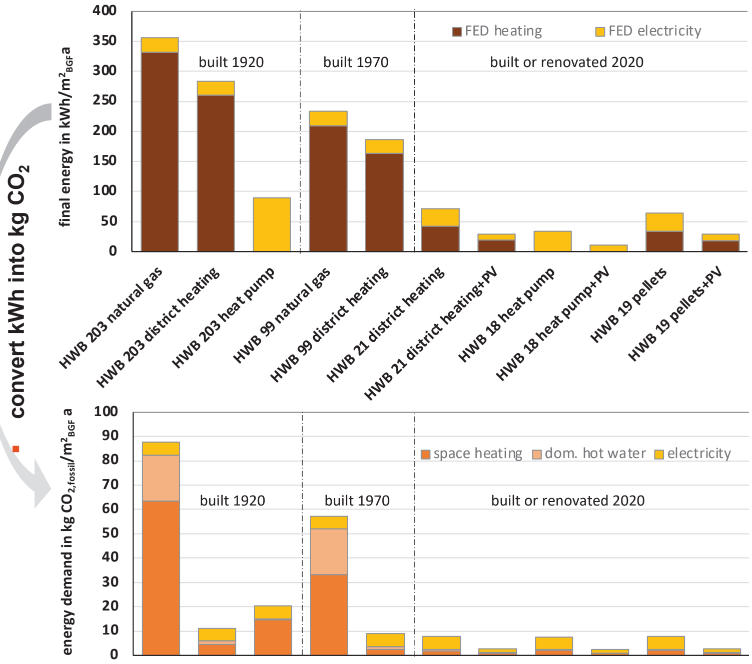
	Energieträger	f_{PE} [-]	$f_{PE,n.ern.}$ [-]	$f_{PE,ern.}$ [-]	f_{CO2eq} [g/kWh]
1	Kohle	1,46	1,46	0,00	375
2	Heizöl	1,20	1,20	0,00	310
3	Erdgas	1,10	1,10	0,00	247
4	Biomasse (Biobrennstoffe fest)	1,13	0,10	1,03	17
5	Biobrennstoffe flüssig (Inselbetrieb) (1)	1,50	0,50	1,00	70
6	Biobrennstoffe gasförmig (Inselbetrieb) (1,2)	1,40	0,40	1,00	100
7	Strom (Liefermix)	1,63	1,02	0,61	227
8	Fernwärme aus Heizwerk (erneuerbar) (3)	1,60	0,28	1,32	59
9	Fernwärme aus Heizwerk (nicht erneuerbar) (3)	1,51	1,37	0,14	310
10	Fernwärme aus hocheffizienter KWK (3,4)	0,88	0,00	0,88	75
11	Abwärme (3)	1,00	1,00	0,00	22

(1) ... Unter Inselbetrieb sind hier ausschließlich Anlagen zu verstehen, bei denen auch die Produktion des Brennstoffes im Gebäude oder in unmittelbarer Nähe des Gebäudes stattfindet.
(2) ... Für Grüngas und Synthesegas sind Werte den Erläuternden Bemerkungen zu entnehmen.
(3) ... Im Falle eines Einzelnachweises sind die Randbedingungen den Erläuternden Bemerkungen zu entnehmen.
(2) ... Als hocheffiziente Kraft-Wärme-Kopplung (KWK) werden all jene angesehen, die der Richtlinie 2004/8/EG entsprechen.

source: Austrian Building Code (OIB Richtlinie 6, 2019)
www.oib.or.at



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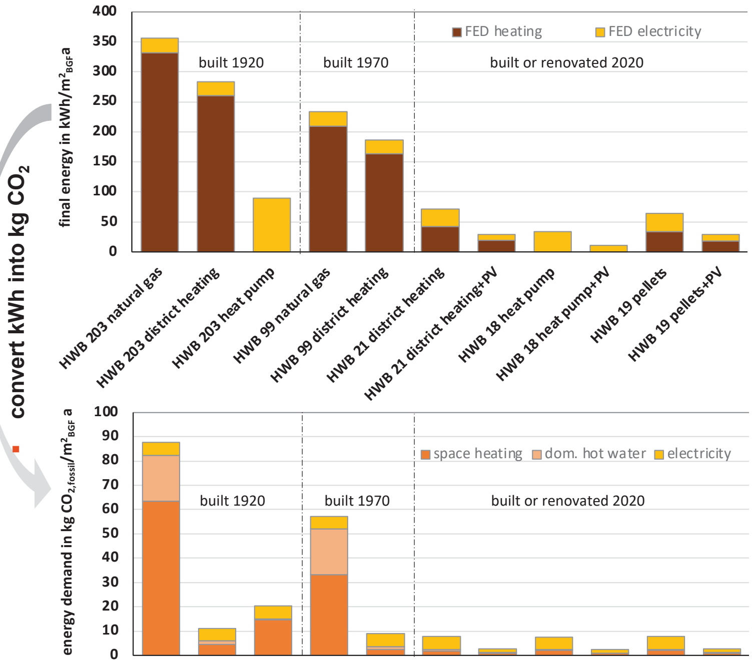
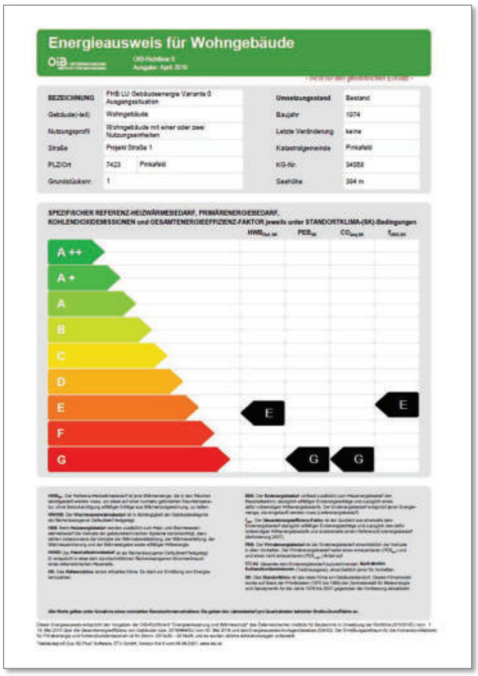


- ***Problem:***
  There is no binding policy on the use of conversion factors.

We use the conversion factors from the Austrian Building Code for the

Energy Performance of Buildings Certificate



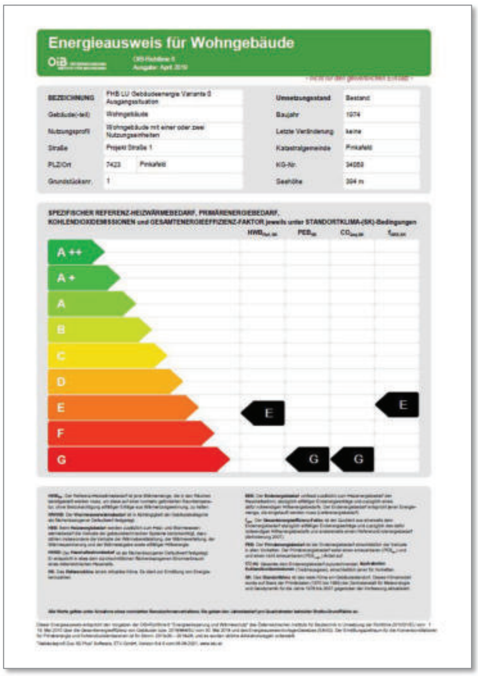
Energieausweis für Wohngebäude

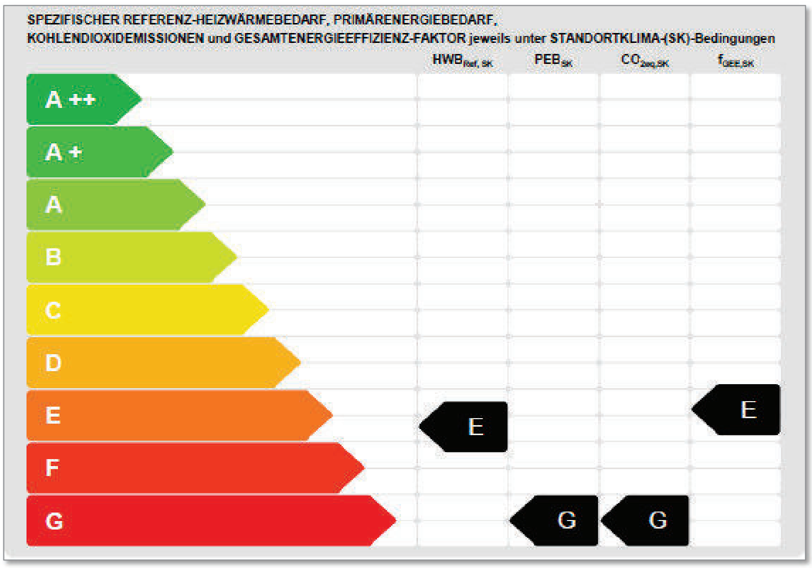
BEZEICHNUNG	PHB LU Gebäudeenergie Variante 0 Ausgangssituation	Umsetzungsstand	Bestand
Gebäude(-teil)	Wohngebäude	Baujahr	1974
Nutzungsprofil	Wohngebäude mit einer oder zwei Nutzungseinheiten	Letzte Veränderung	keine
Straße	Projekt Straße 1	Katastralgemeinde	Pinkafeld
PLZ/Ort	7423 Pinkafeld	KG-Nr.	34050
Grundstücksnr.	1	Seehöhe	394 m

SPEZIFISCHER REFERENZ-HEIZWÄRMEBEDARF, PRIMÄRENERGIEBEDARF, KOHLENDIOXIDEMISSIONEN und GESAMTENERGIEEFFIZIENZ-FAKTOR jeweils unter STANDORTKLIMA-(SK)-Bedingungen

We use the conversion factors from the Austrian Building Code for the

Energy Performance of Buildings Certificate





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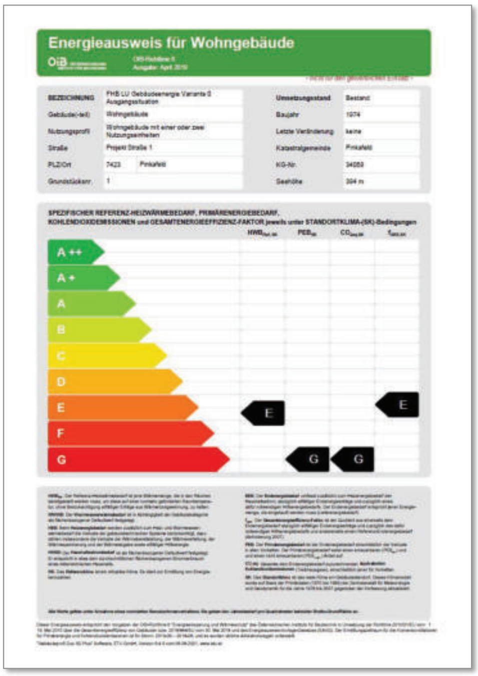

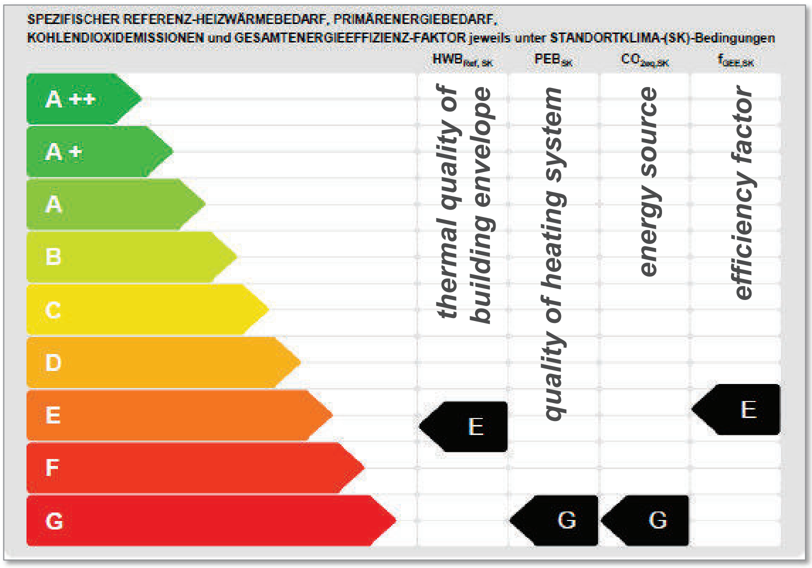

Will there be a problem on the way to

2030 in AT: Electricity from 100% Renewable Energy

electricity	PE	PENR	PER	CO2
	-	-	-	g/kWh
2011	2,62	2,15	0,47	417
2015	1,91	1,32	0,59	276
2019	1,63	1,02	0,61	227
2030	1,xx	0,00	1,xx	0

www.oib.or.at

Will there be a problem on the way to

2030 in AT: Electricity from 100% Renewable Energy

ENERGY INNOVATION ENGINEERING

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2030	1,xx	0,00	1,xx	0

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district heating from high efficient CHP

	PE	PENR	PER	CO2
	-	-	-	g/kWh
2011	0,92	0,20	0,72	73
2015	0,94	0,19	0,75	28
2019	0,88	0,00	0,88	75
Vienna 2019	0,30	0,00	0,30	20

www.wien.gv.at/wohnen/baupolizei/pdf/merkblatt-waermeschutz-19.pdf

Will there be a problem on the way to

2030 in AT: Electricity from 100% Renewable Energy

ENERGY INNOVATION ENGINEERING

electricity	PE	PENR	PER	CO2
	-	-	-	g/kWh
2011	2,62	2,15	0,47	417
2015	1,91	1,32	0,59	276
2019	1,63	1,02	0,61	227
2030	1,xx	0,00	1,xx	0

www.oib.or.at

district heating from high efficient CHP

	PE	PENR	PER	CO2
	-	-	-	g/kWh
2011	0,92	0,20	0,72	73
2015	0,94	0,19	0,75	28
2019	0,88	0,00	0,88	75
Vienna 2019	0,30	0,00	0,30	20

www.wien.gv.at/wohnen/baupolizei/pdf/merkblatt-waermeschutz-19.pdf

OIB Richtlinie 6, 2011

Energieträger	f_{PE} [-]	$f_{PE,n.ern.}$ [-]	$f_{PE,ern.}$ [-]	f_{CO2} [g/kWh]
Kohle	1,46	1,46	0,00	337
Heizöl	1,23	1,23	0,00	311
Erdgas	1,17	1,17	0,00	236
Biomasse	1,08	0,06	1,02	4
Strom (Österreich-Mix)	2,62	2,15	0,47	417
Fernwärme aus Heizwerk (erneuerbar)	1,60	0,28	1,32	51
Fernwärme aus Heizwerk (nicht erneuerbar)	1,52	1,38	0,14	291
Fernwärme aus hocheffizienter KWK[1] (Defaultwert)	0,92	0,20	0,72	73
Fernwärme aus hocheffizienter KWK[1] (Bestwert)	≥ 0,30	gemäß Einzelnachweis[2]		
Abwärme (Defaultwert)	1,00	1,00	0,00	20
Abwärme (Bestwert)	≥ 0,30	gemäß Einzelnachweis		

2015

Energieträger	f_{PE} [-]	$f_{PE,n.ern.}$ [-]	$f_{PE,ern.}$ [-]	f_{CO2} [g/kWh]
Kohle	1,46	1,46	0,00	337
Heizöl	1,23	1,23	0,01	311
Erdgas	1,17	1,16	0,00	236
Biomasse	1,08	0,06	1,02	4
Strom-Mix Österreich (inkl. Netto-Importe)	1,91	1,32	0,59	276
Fernwärme aus Heizwerk (erneuerbar)	1,60	0,28	1,32	51
Fernwärme aus Heizwerk (nicht erneuerbar)	1,52	1,38	0,14	291
Fernwärme aus hocheffizienter KWK (1) (Defaultwert)	0,94	0,19	0,75	28
Fernwärme aus hocheffizienter KWK (1) (Bestwert)	≥ 0,30	gemäß Einzelnachweis (2)		≥ 20
Abwärme (Defaultwert)	1,00	1,00	0,00	20
Abwärme (Bestwert)	≥ 0,30	gemäß Einzelnachweis (2)		≥ 20

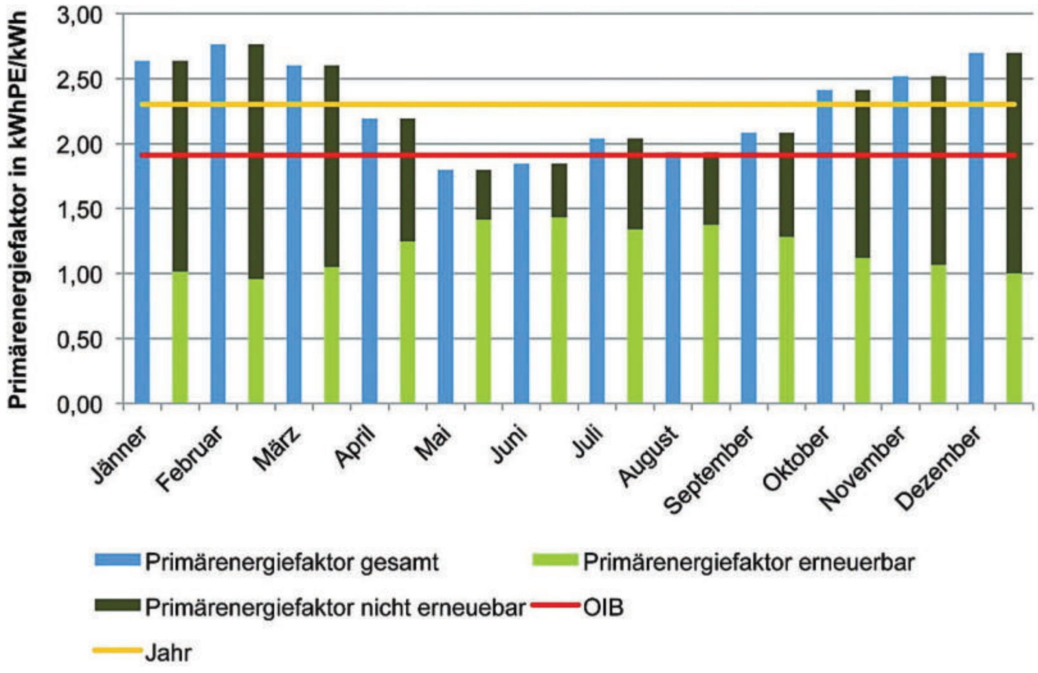
2019

Energieträger	f_{PE} [-]	$f_{PE,n.ern.}$ [-]	$f_{PE,ern.}$ [-]	f_{CO2eq} [g/kWh]
Kohle	1,46	1,46	0,00	375
Heizöl	1,20	1,20	0,00	310
Erdgas	1,10	1,10	0,00	247
Biomasse (Biobrennstoffe fest)	1,13	0,10	1,03	17
Biobrennstoffe flüssig (Inselbetrieb) (1)	1,50	0,50	1,00	70
Biobrennstoffe gasförmig (Inselbetrieb) (1,2)	1,40	0,40	1,00	100
Strom (Liefermix)	1,63	1,02	0,61	227
Fernwärme aus Heizwerk (erneuerbar) (3)	1,60	0,28	1,32	59
Fernwärme aus Heizwerk (nicht erneuerbar) (3)	1,51	1,37	0,14	310
Fernwärme aus hocheffizienter KWK (3,4)	0,88	0,00	0,88	75
Abwärme (3)	1,00	1,00	0,00	22

➢ ***A strict methodical framework is required for the determination of the PEFs in national and regional law!***

EPBD 2018/844/EU: PEF “can be” per year / month / hour

PEF for electricity in Austria, 2014

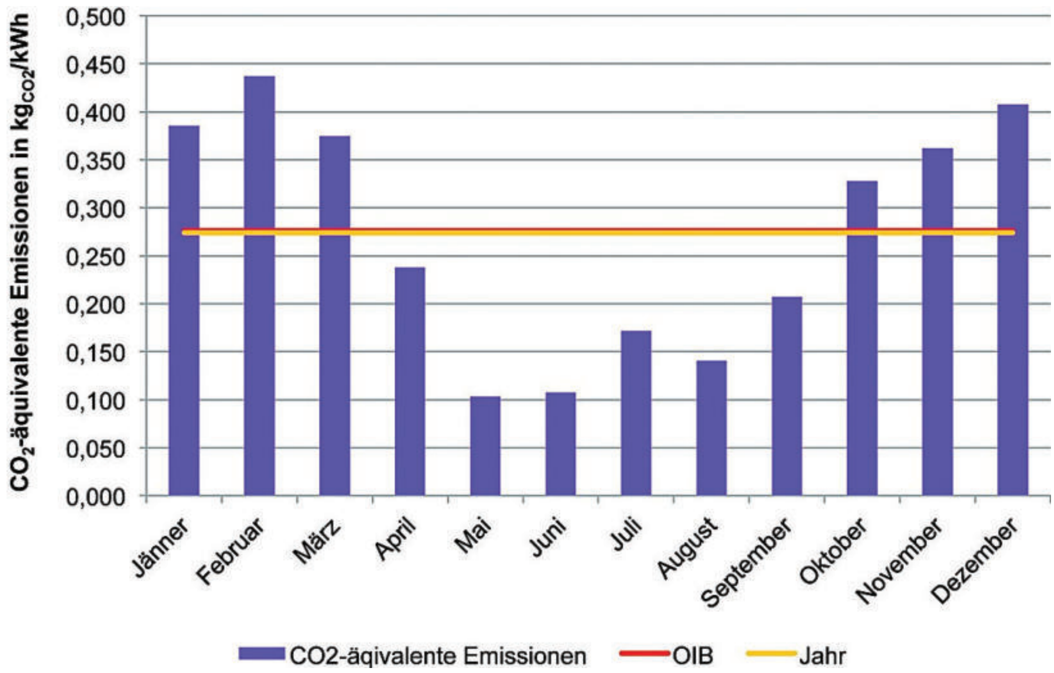


- *PEF “shall be” per month / hour*

M. Ploss (2018): Ermittlung monatlicher Konversionsfaktoren für den Energieträger Strom. Energieinstitut Vorarlberg
www.ibo.at/wissensverbreitung/ibomagazin-online/ibo-magazin-artikel/data/ermittlung-monatlicher-konversionsfaktoren-fuer-den-energietraeger-strom

EPBD 2018/844/EU: PEF “can be” per year / month / hour

f_{CO2} for electricity in Austria, 2014



- *f_{CO2} “shall be” per month / hour*

M. Ploss (2018): Ermittlung monatlicher Konversionsfaktoren für den Energieträger Strom. Energieinstitut Vorarlberg
www.ibo.at/wissensverbreitung/ibomagazin-online/ibo-magazin-artikel/data/ermittlung-monatlicher-konversionsfaktoren-fuer-den-energietraeger-strom

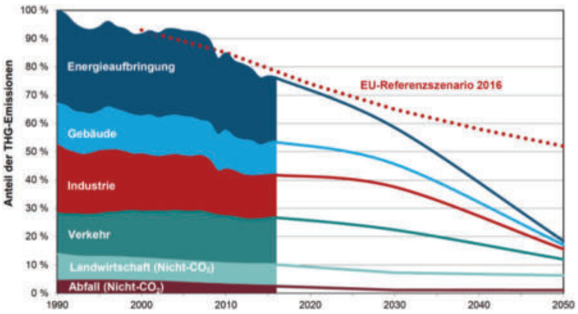
Continuous adjustment of PEF to the situation in 2030, 2050?

Primary Energy Sources for the Production of Electricity

PE (total) = PENR (non renewable) + PER (renewable)

2050: PE = PER = 1.x?

➢ Adjustment of PEF over time?

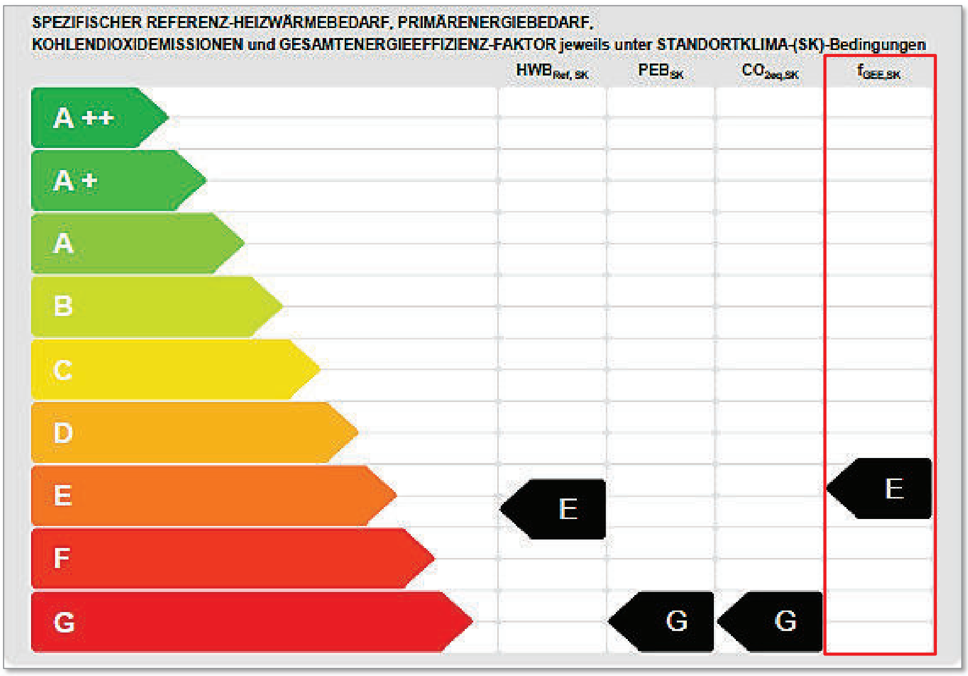


	Bilanzjahr 2010	2030	2050
		in PJ	
Kohle	17,7	0,2	0,0
Kohlegase	6,4	3,3	0,0
Öl	4,6	2,7	0,0
Erdgas	51,7	10,5	3,6
Abfall	2,2	3,8	3,6
Wasserkraft	138,1	153,8	163,0
Biomasse	16,1	24,0	17,5
Geothermie	0,0	0,0	0,0
Photovoltaik	0,3	53,4	84,8
Wind	7,5	62,7	75,9
Stromerzeugung	**244,6**	**314,4**	**354,4**
Nettostromimporte*	8,4	-50,9	-71,0

Umweltbundesamt, Österreich (2016): Szenario Erneuerbare Energie 2030 und 2050. www.umweltbundesamt.at/fileadmin/site/publikationen/rep0576.pdf

Indicator of

Efficiency ("first"!)



- ➢ understandable categories?
- ➢ transparent assessment?
- ➢ more indicators?

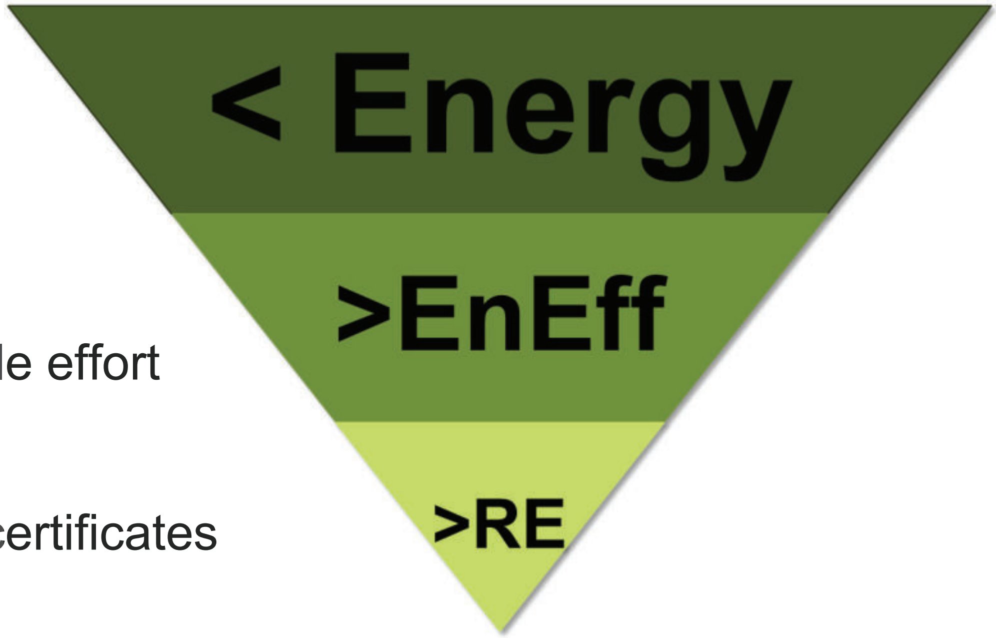
On the way to climate-neutral building operation, we remember the

Kyoto Pyramid

REDUCE
energy demand

OPTIMIZE
efficiency:
high benefit with little effort

USE
~~renewable energy~~ certificates
-> zero emission



Conclusion

- ➢ **yes, efficiency first**
- ➢ **define a strict methodological framework to provide standardized and transparent PEF**
- ➢ **PEF per month (seasonal variation) or even per hour**
- ➢ **fossil fuels shall not be climate-neutral**

Thank you!

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Discussion papers and comments

- Joint statement of AVERE, EIHA, EUEW, EUHA, Eurelectric, European Copper Institute, EuropeOn, Glen Dimplex, Green Power Denmark, RGI, SolarPower Europe, T&D EuropeEurelectric, WindEurope
  - EuropeOn
  - EUHA
  - EUEW
  - Finnish Electrotechnical Trade Association
- EHPA
- BRE
- The Norwegian Water Resources and Energy Directorate
- eu.bak
- Secretariat of State for Energy, Spain
- IBERDROLA
- ecos

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Categories and options I

Category	Option
Strategic and political considerations	
PEF purpose	Desired
	Calculated
Applicability	Abolish the use of a PEF
	No differentiation
	Different for different policies
	Differentiated for appliances
	Differentiated by appliances
	Different for delivered and produced electricity
Adjustment and review process	Constant over time
	Regular review/adjustment
Database and calculation method	Based on statistics and studies
	Advanced calculations based on statistics and studies
	Power sector model calculations

- Critical topic
- Discussion point
- No discussion

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Categories and options II

Category		Option	
Representation of the electricity sector			
Geographical resolution		Bigger EU	With PEX correction
			No PEX Correction
	PEF (for electricity)	EU	With PEX correction
			No PEX Correction
		Member States	With PEX correction
			No PEX Correction
		Market regions	With PEX correction
			No PeX Correction
	District heating	Subnational regions	With PEX correction
			No PEX Correction
Development over time		Constant	
		Dynamic	
Time resolution	EED, Ecodesign	Average over several years	
		Annual average	
	EPBD	Seasonal	
		Hourly time of use	
Market position		Average electricity production	
		Marginal electricity production	

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Categories and options III

Category		Option
General PEF methodology		
PEF indicator		Total primary energy
		Non-renewable energy only
System boundaries		Entire supply chain
		Total energy conversion only (including transport losses)
Accounting Method converted resource nuclear		Technical conversion efficiencies (nuclear eff. Ca. 33%)
		Direct equivalent (nuclear eff. 100%)
		Physical energy content (nuclear eff. Ca. 33%)
Accounting Method converted resource non combustible RES	RES	Zero equivalent
		Substitution method
		Direct equivalent (100%)
		Physical energy content
		Technical conversion efficiencies
Accounting Method converted resource combustible RES (biomass)		Zero equivalent
		Technical conversion efficiencies
Methodological consistency		Same method for all PEF
		Different methods for different countries
		Different methods with correction mechanism

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Summary of discussion points/comments

- **Does the PEF incentivize EU policy goals?**
  - „PEF hampers the roll-out of electrification"
  - „PEF favours use of fossil fuels" (PEF of 2.1 for electricity instead of 1 for fossil fuels)
  - „PEF should not incentivice the use of fossil fuels"
  - "Incentives for cleanest alternative?"
- **Should the PEF use the zero-equivalent approach (PEF = 0) instead of the direct-equivalent-approach (PEF = 1)?**
  - PEF for non-combustible RES: 0, 0.5 or 1?
  - LCA: PEF > 1.0?
- **How can the PEF contribute to Energy efficiency and decarbonisation?**
  - „PEF should be consistent with decarbonisation"
  - „PEF should enhance climate goals and use of cleaner energy"
- **„Forward looking PEF (2030) needed for long-term investment"**

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Summary of discussion points/comments

- **How should the PEF of storage be calculated?**
  - Avoid double counting
  - Considering losses only
- **How can we secure transparency in PEF methodology?**
  - European legislation: EED, EPBD, Ecodesign, ...
  - Use of existing standards
    - EN 17423 - PEF methodology, transparancy
    - EN 15316-4-5 - district heating/allocation
    - EN 52000-1
    - ...
- **What is the appropriate geographical resolution?**
  - EU27+Norway or national PEFs for electricity
  - National or sub-national level for PEF (especially for district heating)?

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Our perspective

- Focus of **PEF** is on **energy efficiency** of the energy system
- Energy transition and decarbonisation requires **additional indicators** (e.g.)
  - GHG emissions - climate change, decarbonisation
  - Emissions of air pollutants
  - Material flow accounting (MFA)
- **Criteria** for appropriate indicators
  - Meaningfulness
  - Consistency
  - Applicability
  - Transparency
- **Conventions/Decisions** on methodology needed

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Comments and discussion

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Question #1

- How can the PEF help to **incentivize energy transition**?
  - Electrification
  - Energy security
  - Decarbonisation

Question #2

- How can we reach **consistency**?
  - Consistency between policies
  - Consistency within policies
  - Consistency between (and within) MS
  - Consistency with official data and reporting

Question #3

- How should PEFs in EU policies be **further developed**?

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Question #4

- What are the most important **methodological conventions** for the calculation of PEFs?

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Thank you for your attention, please contact us for more information.

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European Commission

7.3 Expert and stakeholder workshop #3

The focus of WS#3 was to present the results of the study and to discuss further developments of the methodology for PEF calculations (e.g. PEF of other energy carriers like hydrogen and e-fuels).

Date: 22 February 2023, 10.00 to 12.00 CET

Place: online (via WEBEX)

Participants: 124 attendees (experts and stakeholders, project team, DG ENER)

Agenda

Topic	Time	Presenter
Welcome and introduction	5 min	European Commission
Part 1: Main findings of the PEF review study	50 min	Christof Amann (e7) Perla Torres (Trinomics)
Part 2: Recommendations for the further development of the PEF calculation methology	20 min	Christof Amann (e7)
Comments and Discussion	30 min	
Closing remarks	15 min	European Commission

Presentations: see following pages

Support to Primary Energy Factors Review (PEF)

ENER/2020/OP/0021 ENER/C3/2020-724

Expert and Stakeholder Workshop #3
22 February 2023

www.trinomics.eu

Purpose of Workshop #3

www.trinomics.eu

Purpose of WS#3

Presentation of **main findings** of the PEF study in the frame of the EED and EPBD

Presentation and discussion of **major recommendations** for the **future development of the PEF calculation methodology**

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Agenda

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Agenda

Topic	Time	Presenter
Welcome and introduction	5 min	European Commission
Part 1: Main findings of the PEF review study	50 min	Christof Amann (e7) Perla Torres (Trinomics)
Part 2: Recommendations for the further development of the PEF calculation methology	20 min	Christof Amann (e7)
Comments and Discussion	30 min	
Closing remarks	15 min	European Commission

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Part 1
Main findings of the PEF review study

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Criteria for review of PEF (1/2)

- Meaningfulness
  - PEF should provide relevant information for policy
  - PEF: Energy efficiency of the energy production system
    - (not of devices and appliances)
    - (not of energy production technologies like PV, wind turbines, water power plants)
  - Decarbonisation needs to be reflected in supplementary indicator (e.g. GHG emissions)
- Consistency
  - Comparability requires a set of methodological assumptions and definitions
  - E.g. PEFs in the context of the EPBD in Member States (RES)
  - E.g. PEFs for district heating systems (allocation in CHPs)

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Criteria for review of PEF (2/2)

- Applicability
  - Data availability (official statistics, scenarios)
  - Complexity of calculation
  - Practical application in policy areas (in contrast to scientific work)
- Transparency
  - PEF calculation methodology requires definitions, conventions and decisions
  - Minimum requirement: documentation and justification of methodology (e.g. according to EN 17423:2020)

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EN 17423:2020

Reference document (document describing the quantification of PEF and CO_2)				
(ref)				
Energy carrier	$f_{P;nren}$	$f_{P;ren}$	$f_{P;tot}$	K_{CO_2}

Choices related to the perimeter of the assessment (6.1)					
Name of geographical area:					
Geographical Perimeter	☐ European	☐ National	☐ Regional	☐ Local	☐ Other

Choices related to calculation conventions (6.2)				
Period considered for calculation:				
Time resolution	☐ Hourly	☐ Monthly	☐ Annual	☐ Other
Data source	☐ Real historic	☐ Simulated historic	☐ Forward looking	☐ Other
Net or Gross Calorific Value	☐ Net calorific value	☐ Gross calorific value		

Choices related to data (6.3)					
Available energy sources	☐ include all energy sources	☐ exclude self-consumed on-site generation	☐ exclude dedicated delivery contracts		☐ Other
GHG considered	☐ CO_2 only	☐ CO_2 equivalent 20 years	☐ CO_2 equivalent 100 years		☐ Other
Biogenic carbon	☐ carbon neutrality		☐ biogenic CO_2, CH_4 accounted		☐ Other
Conventions energy conversion	☐ Zero equivalent ($f_{P;nren}$ = 0)	☐ Direct equivalent ($f_{P;we}$ = 1)	☐ Technical efficiencies	☐ Physical energy content	☐ Other
Conventions PEF exported energies	☐ resources used to produce		☐ resources avoided		☐ Other

Choices related to the assessment methods (6.4)								
Energy exchanges	☐ ignoring exchanges	☐ net exchanges		☐ Gross exchanges				☐ Other
Multisource generation	☐ Average calculation approach			☐ Other (e.g. marginal) specify approach and technical reference				
Multi energy output system	☐ Power bonus	☐ Power loss simple	☐ Power loss	☐ Power loss ref	☐ Carnot	☐ Alter. Prod.	☐ Resid. heat	☐ Other
Life cycle analysis (LCA)	☐ no LCA			☐ full LCA				☐ Other

Energy performance of buildings - Determination and reporting of Primary Energy Factors (PEF) and CO_2 emission coefficient - General Principles, Module M1-7

Source: EN17423:2020

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EED (EU Directive 2018/2002) - Recital 40

Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the **default coefficient for savings in kWh electricity** should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy mix of the PEF for electricity are based on **annual average values**. **The 'physical energy content' accounting method** is used for nuclear electricity and heat generation and the **'technical conversion efficiency' method** is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the **direct equivalent** based on the **'total primary energy' approach**. To calculate the primary energy share for electricity in **cogeneration, the method set out in Annex II to Directive 2012/27/EU** is applied. An **average rather than a marginal market position** is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the **PEF is 1 for all energy sources**. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the **PRIMES Reference Scenario** for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers **the Member States and Norway**. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data.

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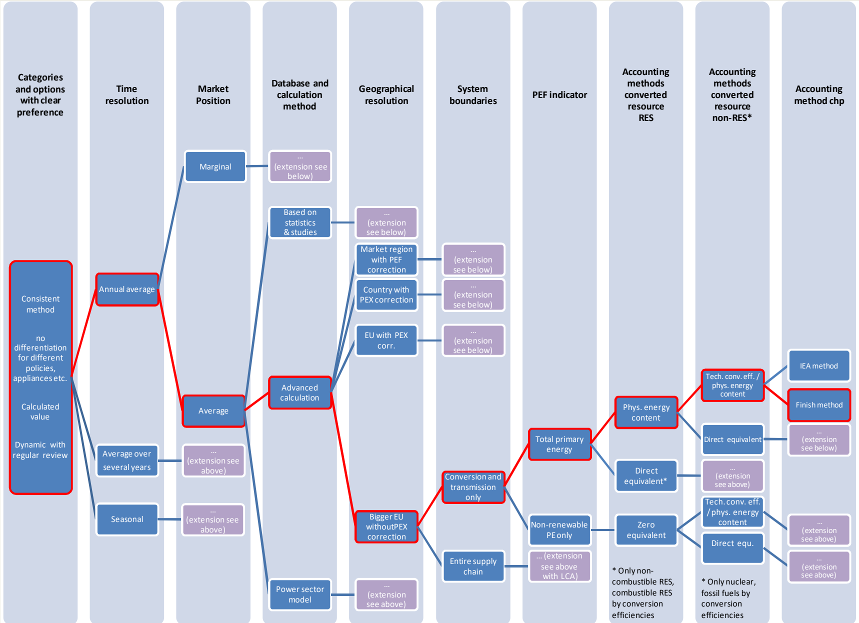
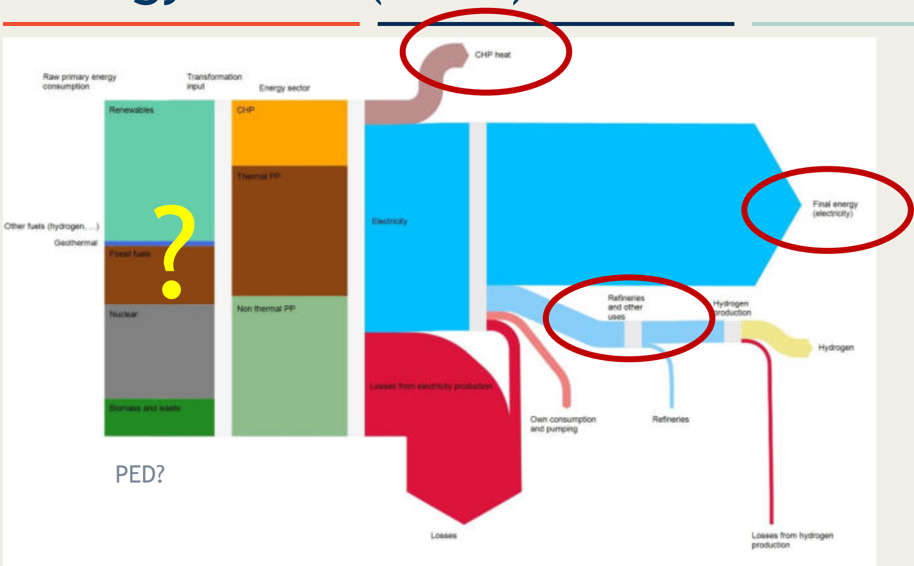
Methodological decisions



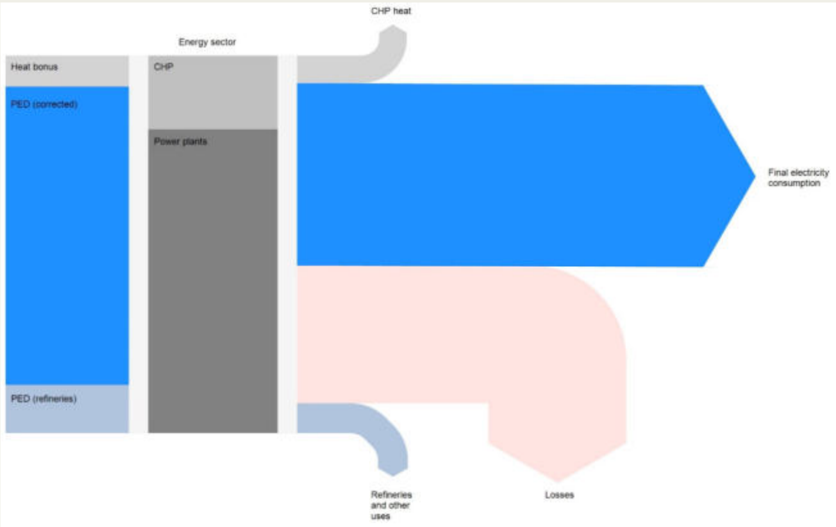
Source: 2016 PEF Study

Energy flows (2030) - corrections



Source: e7

PEF = PED (corr)/FEC



- PED (corr) =

  PED
  - Heat bonus
  - PED (refineries)

- PEF = PED (corr) / FEC

Source: e7

e7 Trinomics

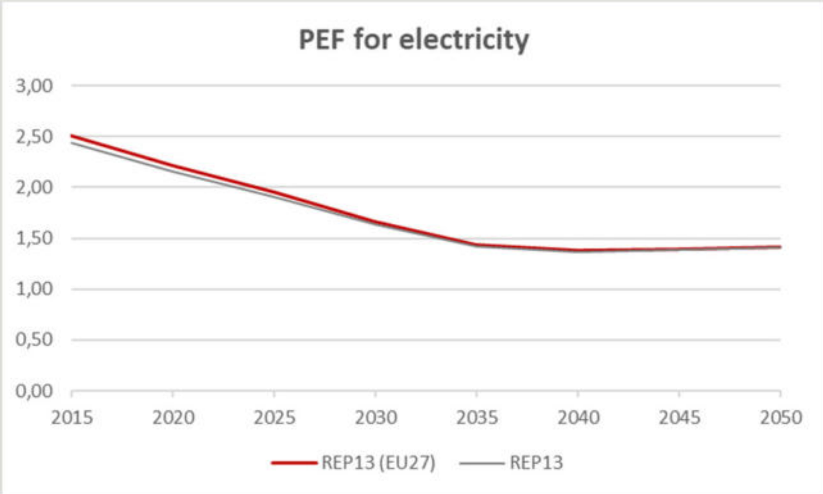
Sensitivity of methodolgical decisions

- Reference scenario: REPowerEU
- Ceteris paribus

- Scenarios
  - Exclusion of Norway
  - Zero-equivalent method for RES
  - Allocation of CHP: IEA method
  - Adaptation of CHP reference values (40%/80%)
  - CHP efficiency: 85%
  - Including upstream flows for fuels (PEF 1.1)

e7 Trinomics

Exclusion of Norway



Source: PRIMES, e7

e7 Trinomics

PEF of fuels and conversion efficiency

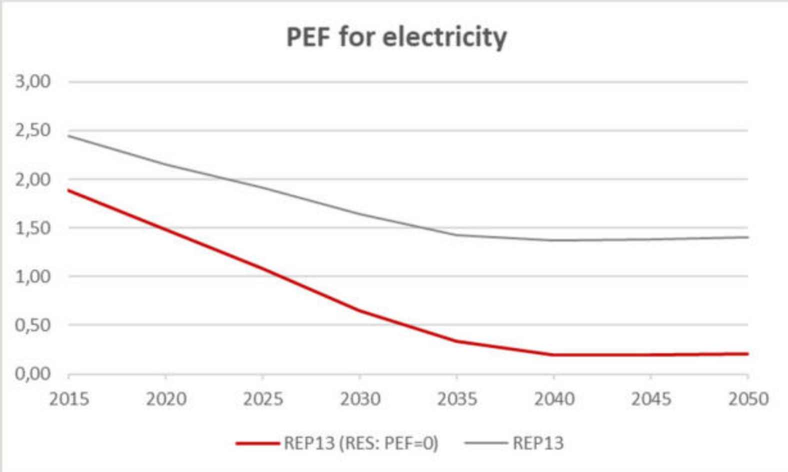
	PEF of the energy carrier	Conversion efficiency
Hydro	1	100%
Wind	1	100%
PV	1	100%
Biomass	1	Calculated value
Geothermal (electricity)	1	10%
Nuclear	1	33%
Fossil fuels	1	Calculated value

	PEF of the energy carrier	Conversion efficiency
Hydro	0	100%
Wind	0	100%
PV	0	100%
Biomass	0	Calculated value
Geothermal (electricity)	0	10%
Nuclear	1	33%
Fossil fuels	1	Calculated value

Source: 2016 PEF Study

e7 Trinomics

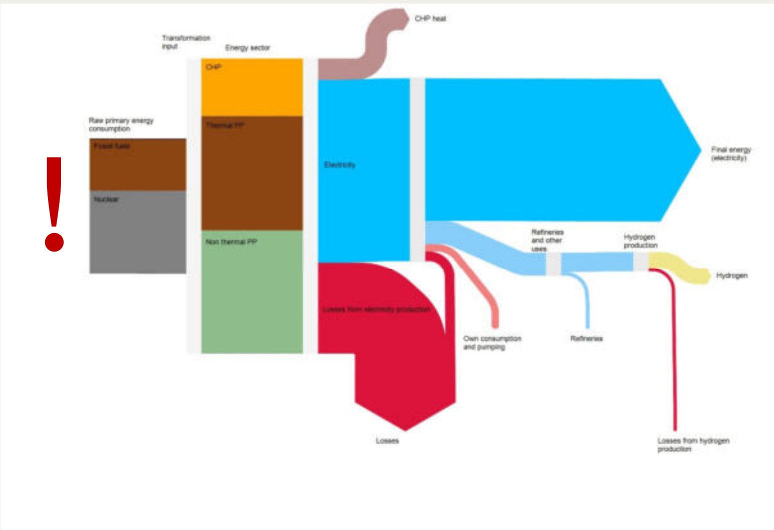
Zero-equivalent method for RES



Source: PRIMES, e7

e7 Trinomics

PEF (PEF_{RES} = 0)

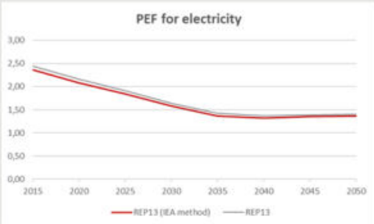


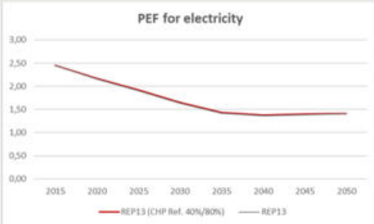
Source: e7

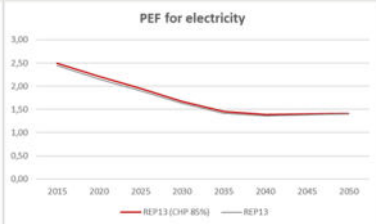
e7 Trinomics

IEA method, CHP reference values, …

IEA method | 40%/80% | 85%







Source: PRIMES, e7

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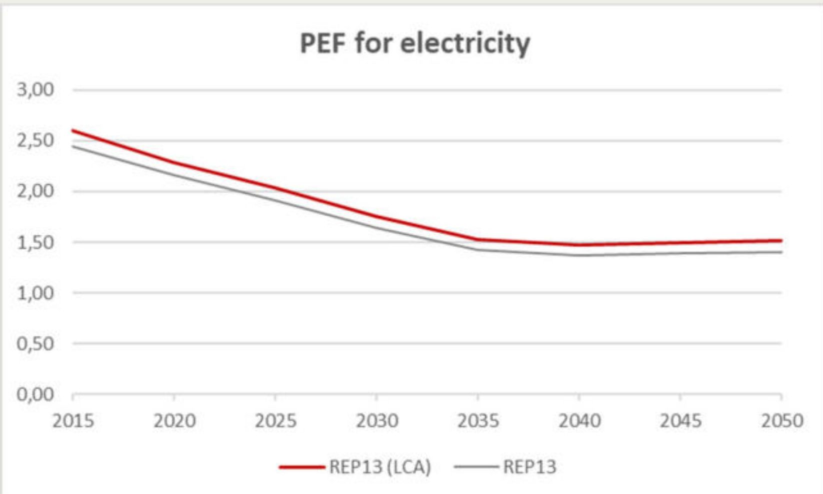
Including upstream flows (LCA)



Source: PRIMES, e7

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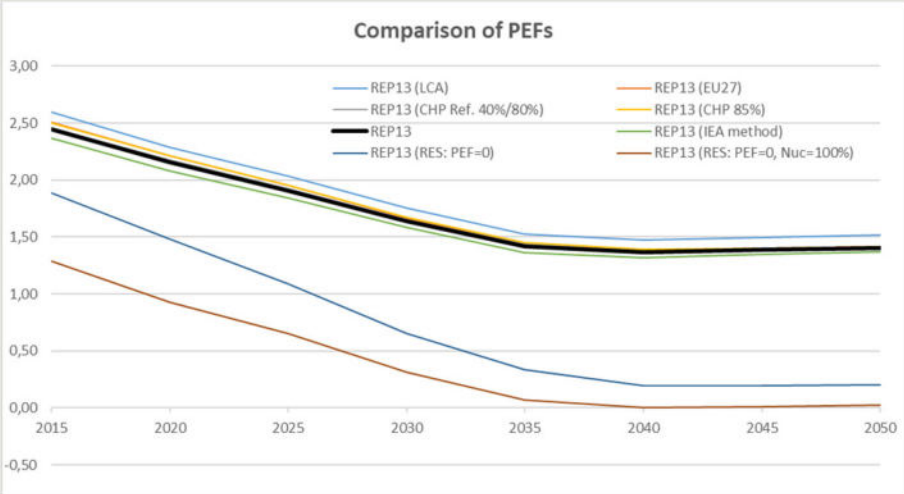
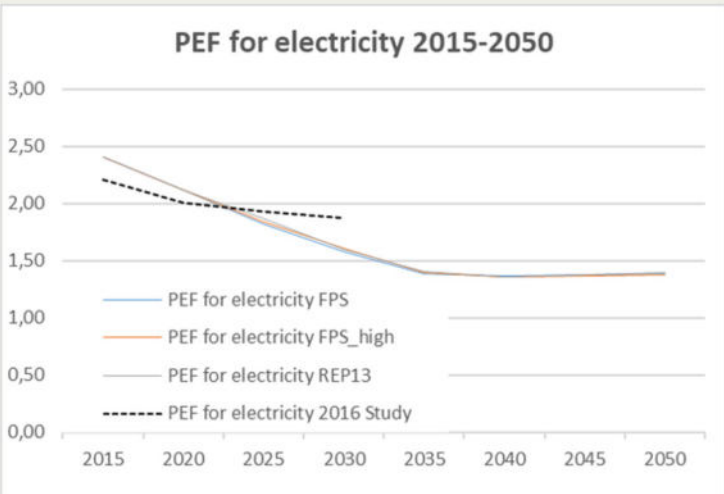
Comparison of PEFs depending on method



Source: PRIMES, e7

Evolution of the PEF for electricity



Source: PRIMES, ENTSO-E, own calculation e7

Source: PRIMES, e7

Differences of PEF calculations

	2015	2020	2025	2030	2035	2040	2045	2050
REP13 (LCA)	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1
REP13 (EU27)	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0
REP13 (CHP Ref. 40%/80%)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
REP13 (CHP 85%)	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0
REP13	**2,4**	**2,2**	**1,9**	**1,6**	**1,4**	**1,4**	**1,4**	**1,4**
REP13 (IEA method)	-0,1	-0,1	-0,1	-0,1	-0,1	0,0	0,0	0,0
REP13 (RES: PEF=0)	-0,6	-0,7	-0,8	-1,0	-1,1	-1,2	-1,2	-1,2
REP13 (RES: PEF=0, Nuc=100%)	-1,2	-1,2	-1,3	-1,3	-1,4	-1,4	-1,4	-1,4

Source: PRIMES, e7

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Discussion of results

- Same trend of PEFs
  - decreasing PEF until 2035/2040
  - constant/slightly increasing PEF (increased losses due to electricity storage)
  - losses for hydrogen production for other uses are not considered!
- Only minor effects on PEF (0.1 or below), except for zero-equivalent method (PEF_{RES} = 0)
- Zero equivalent method is not consistent with energy balance and energy flows
- Exclusion of Norway would lead to a reduced complexity and increased consistency (Norway is not in PRIMES scenario) with a very low effect on PEF

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PEF for other energy carriers

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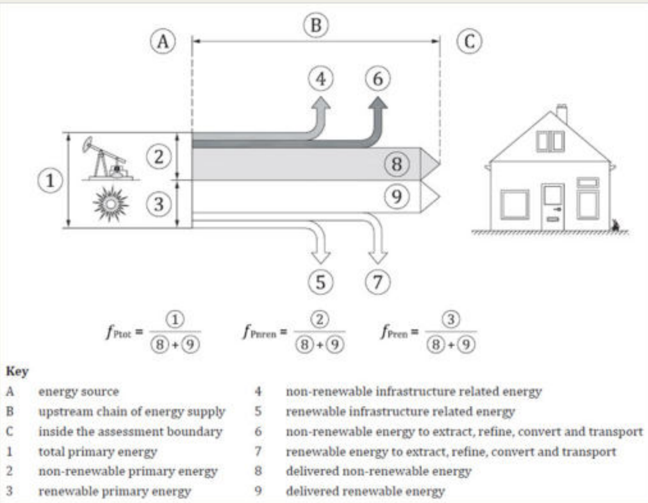
Upstream flows (LCA)



- Electricity
  - energy for conversion and transport losses are included (flows 6 and 7)
  - energy for production of infrastructure (power plants, grid) is not included in calculation of PEF
- Energy related to infrastructure is included in the energy balance but not directly associated with energy production (energy sector)
- Only domestic upstream energy flows are considered in the energy balance
- Full LCA: include also flows 4 and 5

Source: ISO 52000-1

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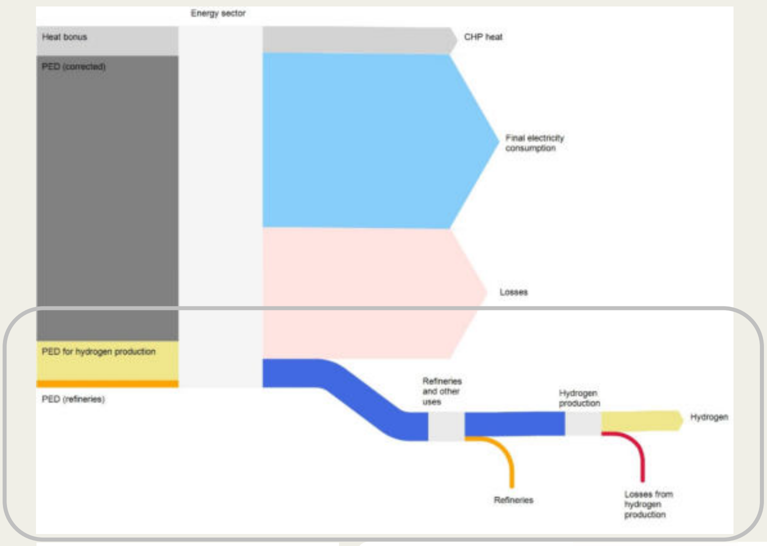
PEF for other energy carriers

- Status quo according to EUROSTAT definition: PEF of energy carriers = 1
- Inconsistency, if losses of energy carriers in the energy balance are not considered, but:
  - losses of gas: < 1%
  - data gaps for most fuels
  - high complexity in calculation
  - large uncertainties
- Increasing importance of hydrogen and e-fuels
- Case study: PEF for hydrogen production for other uses (than electricity)

e7 Trinomics

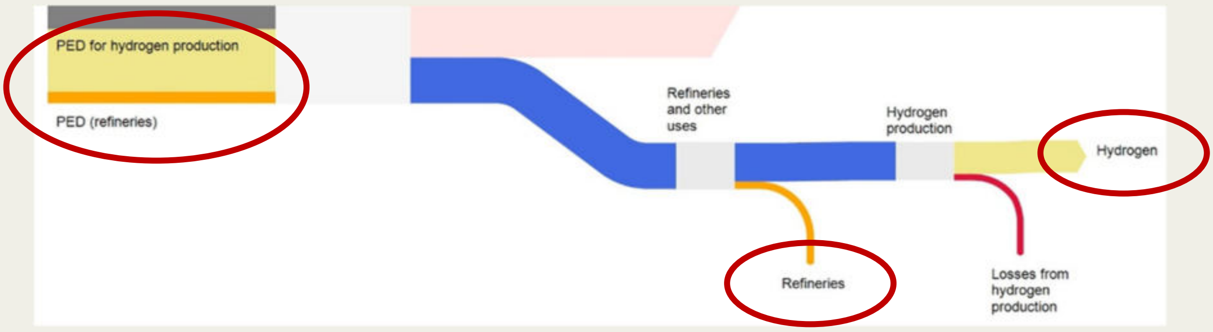
Case study: PEF of hydrogen (other uses)



Source: e7

e7 Trinomics

Calculation of PEF (hydrogen)



- PEF (hydrogen) = hydrogen / PED for hydrogen production
- Only energy flows from the energy balance considered
  - Losses from hydrogen production
  - Losses from electricity production (proportionally)

Source: e7

Ways to consider upstream flows

- Include all processes in energy sector
- Include all processes from energy balances
  - infrastructure and transport energy is allocated to different sectors
  - only domestic energy flows, upstream flows of imports are not considered
  - complex adjustments for exports necessary
- Application of default LCA/PEF factors: e.g. 1.1 for all fuels
- Carry out a full life-cycle-analysis for all energy carriers
  - high complexity in calculation
  - large uncertainty and variety of results due to missing standardisation of methods and lack of reliable data
  - large variety over time and origin of fuels

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National PEFs in the EU27

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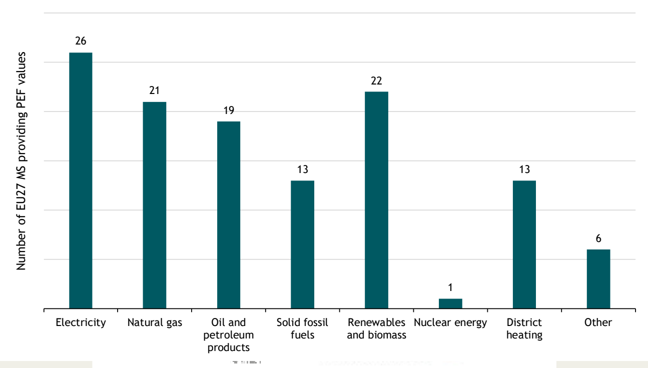
Overview of PEFs collected

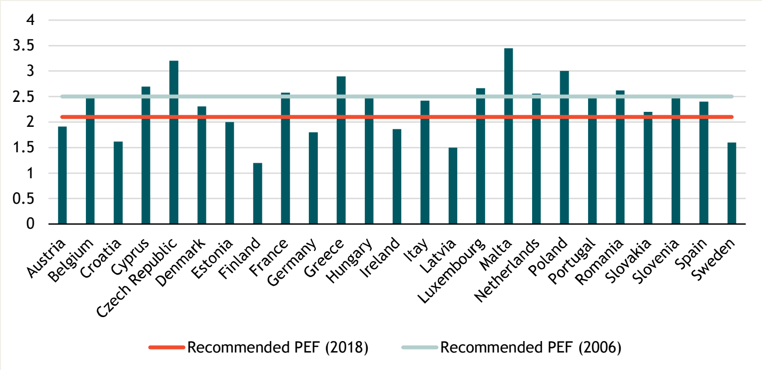
- Main source: cost-optimal reports submitted by MS in 2018.
- All MS (except BG?) reported a PEF value for electricity.
- Most MS also reported PEF values for natural gas, oil and RES.



Source: Cost-optimality reports, Trinomics

PEFs for electricity

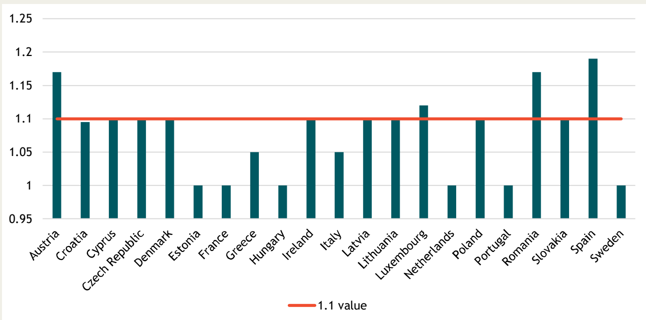
National PEF values for grid-supplied electricity



Source: Cost-optimality reports, Trinomics

PEFs for natural gas

National PEF values for natural gas

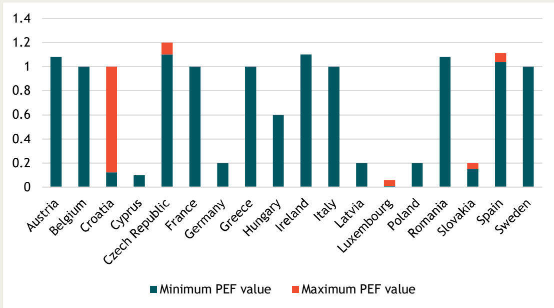


Source: Cost-optimality reports, Trinomics

PEFs for biomass

Range of PEFs for biomass

- Wide variety in the reported PEF values
- Different methodologies and definitions of PEFs
- 7 MS provided disaggregated data (for densified and non-densified biomass)



Member State	Densified		Non-densified
	Wood chips	Wood pellets	
Croatia	0.154	0.123	1
Czech Republic	1.2		1.1
Lithuania	0.1 (non-RES) - 1 (RES)		
Luxembourg	0.06	0.07	0.01
Romania	1.08		1.08
Slovakia	0.15	0.2	0.1
Spain	1.113		1.037

Source: Cost-optimality reports, Trinomics

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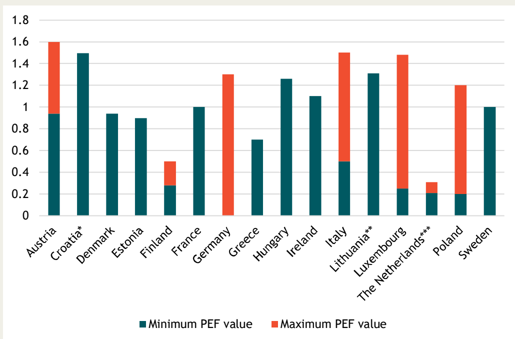
PEFs for district heating

National PEF values for DH

- 16 MS provided PEF values for district heating
- 6 MS provided a disaggregated value (either based on technology or RES/non-RES carrier)



Source: Cost-optimality reports, Trinomics

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PEF for on-site production

- Electricity production on-site: 9 MS provided PEF values for on-site electricity production.
  - 5 of which reported same values as for grid-supplied electricity
  - 4 MS reported values for RES-based electricity

- Heat production on-site
  - 7 MS reported PEF values for RES-produced heat.
  - PEF values for these vary between 0,1 and 1.53

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Key findings from National reports (1/3)

- The methodologies adopted by the MSs to calculate national PEF values for electricity and other energy vectors lack transparency and consistency
  - Difficult to distinguish differences in PEF values resulting from physical specificities of the national energy supply system vs differences in the methodologies
  - More harmonisation (e.g. via standards) might be appropriate

- PEF for electricity
  - Only few MSs apply the default PEF value recommended by the EC
  - Most MSs calculate a national PEF value but they are not using the same methodology

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Key findings from National reports (2/3)

- Natural gas: national PEF values range between 1 and 1.19
  - Natural gas is a standard product, imported from same sources and transported and distributed via similar networks => 19% difference is due to diverging methodology rather than to physical differences
- Biomass: large variations in how MSs determine PEF values
  - Different definitions of PEF (PEF_{Tot} vs PEF_{Ren})
  - Liquid vs biomass differentiation
  - Detailed approaches with values for different (sub)types of biomass
- Great variations in how MS report their PEFs
  - Labeling of energy sources
  - PEF_{Tot} vs details on PEF_{Ren} and $PEF_{non\text{-}Ren}$

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disproportionately

Key findings from National reports (3/3)

- District Heating: most concerned MS adopted a primary energy calculation approach
  - Some MS apply a single fixed PEF for all DH systems in their country
  - PEF principles: differentiated PEFs for DH depending on the fuels used and/or applied energy production technologies
  - Different allocation methods for heat from CHP
- Use of differentiated PEFs depending on season
  - At present: yearly PEF values (averages)
  - Higher resolution (monthly PEF values) would provide a better view of seasonal fluctuations in energy mix
  - Daily resolution would increase complexity of calculation and data requirements without increasing appropriateness significantly
  - Hourly resolution would allow more detailed analysis (e.g. PV, load profiles) but data requirements and complexity would increase disproportionately - high relevance for research and design

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Part 2
Recommendations for the further development of the PEF calculation methodology

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Calculation of the PEF for electricity

- PEF calculation is based on a consis**tent and transparent methodology**
- Data availability: EUROSTAT, PRIMES scenarios
- Definitions according to IEA/EUROSTAT (except for CHP)
- Focus of **PEF** is on **energy efficiency** of the energy system
  - PEF total as headline indicator
  - PEF tot = PEF ren + PEF non-ren
  - Missing additional elements: efficiency of RES production (wind turbines, PV)
- Energy transition and decarbonisation requires **additional indicators** (e.g. GHG emissions)

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Recommendations

- PEFs for different time periods (e.g. PEF_1 for 2025-2030; PEF_2 for 2030-2040; PEF_3 for 2040-2050)
- Regular updates of PEFs (4 to 5 years)
- Norway could be excluded from the calculation
- Provide **methodological guidance** for national PEFs
  - Full transparency according to EN 17423:2020
  - Provide data access (national PRIMES data base, including power exchange)
  - Determination of metholdogical decisions (RES, LCA, allocation CHP, power exchange)
  - Power exchange (simplified method)

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PEFs in the building sector

- Large national/regional differences in the electricity generation mix: **national PEFs** for electricity more appropriate than EU average
  - Consideration of power exchange
  - Seasonal (monthly) PEFs
- **PEFs for fossil energy carriers**
  - Limitedly affected by national technical specificities
  - Harmonized PEF values on EU level
  - Losses in supply chain could be considered
  - Upstream flows for infrastructure and transport should not be considered (consistency with PEF for electricity)
- PEFs for “new” energy vectors (**hydrogen, biogas, biomethane and e-liquids**) are highly dependent on production technology and local energy inputs
  - Recommending standard PEF value at EU level would not be appropriate
  - Useful to agree on harmonised methodology to define PEF
  - Renewable gas/e-liquid are expected to have minor future role in new/renovated buildings: defining PEFs may not be very useful for all MS

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cont.

- National data should be provided by EUROSTAT/PRIMES
  - scenarios for 2050
  - monthly data
- Harmonized (consistent) methodology
  - PEF for electricity
  - PEF for other energy carriers
  - PEF for on-site production
  - PEF for district heating (P_{tot}, allocation method CHP, temporal and spatial resolution)
- Harmonized PEF values for other (primary) energy carriers
- **Minimum requirement: full transparency**

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What is NOT recommended

- Dynamic PEFs
  - High complexity in application
- Marginal market position
  - Data availibility
  - Complexitiy of calculation
  - Application is limited
- Hourly and daily data resolution
  - Data availability
  - Applicability
- Full LCA approach for energy carriers
  - Variability of results
  - Calculation effort

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Agenda

Topic	Time	Presenter
Welcome and introduction	5 min	European Commission
Part 1: Main findings of the PEF review study	40 min	Christof Amann (e7) Perla Torres (Trinomics)
Part 2: Recommendations for the further development of the PEF calculation methology	30 min	Christof Amann (e7) Perla Torres (Trinomics)
Comments and Discussion	30 min	
Closing remarks	15 min	European Commission

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Comments and discussion

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Thank you for your attention, please contact us for more information.

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European Commission

7.4 PEF Report

Support to Primary Energy Factors Review (PEF)

PEF Report

Contract details

European Commission, DG ENER

Support to Primary Energy Factors Review (PEF), Specific Tender ENER/B2/2021-593/2022-467 – under framework contract ENER/2020/OP/0021 ENER/C3/2020-724:

Presented by

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Date

Rotterdam, 11 November 2022

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Disclaimer

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Rotterdam, 11 November 2022

Client: European Commission, DG ENER

"Support to Primary Energy Factors Review (PEF)"
under framework contract ENER/2020/OP/0021 ENER/C3/2020-724

PEF Report

In association with:

CONTENTS

1 Introduction

The primary energy factor (PEF) report describes the methodology applied to calculate the updated PEF for electricity for EU27 and Norway, and it provides the PEF values for electricity for the period of 2015 to 2050.

The applied methodology used in this report is consistent with the methodology mentioned in Recital 40 and Annex IV of the 2018/2002 Directive amending the 2012/27/EU Directive on energy efficiency (EED). The methodology was developed by Fraunhofer ISI in 2016 in a study for the European Commission (2016 PEF study) and documented in detail in the final report[1]. However, since the completion of the 2016 PEF study the geographical scope (Brexit) and the energy system scenarios (PRIMES scenarios) have changed, leading to different PEF values.

In June 2022, a stakeholders and experts workshop was held, where the methodology and legal requirements for the PEF calculation were presented and discussed.

2 Policy framework

In the 2018/2002 Directive amending the 2012/27/EU Directive on energy efficiency (EED) the legal framework for the 2022 revision of the PEF value is given. As stated in Annex IV, footnote 3 of the EU Directive 2018/2002, "By 25 December 2022 and every four years thereafter, the Commission shall revise the default coefficient on the basis of observed data."[2]

In recital 40 of the EED the methodological framework for the calculation of the PEF for electricity is defined:

“Reflecting technological progress and the growing share of renewable energy sources in the electricity generation sector, the **default coefficient for savings in kWh electricity** should be reviewed in order to reflect changes in the primary energy factor (PEF) for electricity. Calculations reflecting the energy mix of the PEF for electricity are based on **annual average values**. **The ‘physical energy content’ accounting method** is used for nuclear electricity and heat generation and the **‘technical conversion efficiency’ method** is used for electricity and heat generation from fossil fuels and biomass. For non-combustible renewable energy, the method is the **direct equivalent** based on the **‘total primary**

[1] Esser, A., Sensfuss, F. 2016: Review of the default primary energy factor (PEF) reflecting the estimated average EU generation efficiency referred to in Annex IV of Directive 2012/27/EU and possible extension of the approach to other energy carriers. Final report.

[2] Annex IV, footnote 3 of EU Directive 2018/2002: “Applicable when energy savings are calculated in primary energy terms using a bottom-up approach based on final energy consumption. For savings in kWh electricity, Member States shall apply a coefficient established through a transparent methodology on the basis of national circumstances affecting primary energy consumption, in order to ensure a precise calculation of real savings. Those circumstances shall be substantiated, verifiable and based on objective and non-discriminatory criteria. For savings in kWh electricity, Member States may apply a default coefficient of 2,1 or use the discretion to define a different coefficient, provided that they can justify it. When doing so, Member States shall take into account the energy mix included in their integrated national energy and climate plans to be notified to the Commission in accordance with Regulation (EU) 2018/1999. By 25 December 2022 and every four years thereafter, the Commission shall revise the default coefficient on the basis of observed data. That revision shall be carried out taking into account its effects on other Union law such as Directive 2009/125/EC and Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU (OJ L 198, 28.7.2017, p. 1).”

energy' approach. To calculate the primary energy share for electricity in **cogeneration, the method set out in Annex II to Directive 2012/27/EU** is applied. An **average rather than a marginal market position** is used. Conversion efficiencies are assumed to be 100 % for non-combustible renewables, 10 % for geothermal power stations and 33 % for nuclear power stations. The calculation of total efficiency for cogeneration is based on the most recent data from Eurostat. As for system boundaries, the **PEF is 1 for all energy sources**. The PEF value refers to 2018 and is based on data interpolated from the most recent version of the **PRIMES Reference Scenario** for 2015 and 2020 and adjusted with Eurostat data until 2016. The analysis covers **the Member States and Norway**. The dataset for Norway is based on the European Network of Transmission System Operators for Electricity data."

In this study the PEF for electricity is calculated using the methodology defined above.

3 Description of the calculation method

3.1 PRIMES Scenarios

The PEF for electricity is calculated for 3 different PRIMES scenarios available for the period of 2000-2050 in 5-years steps:

- Full Package Scenario: Update of the Mix 55 scenario taking into account the proposals tabled for the Fit for 55 package (FPS)
- Full Package Scenario High Prices: Update of the Full Package Scenario taking into account higher fossil fuels prices until 2030 (FPS_high)
- REPowerEU Scenario: Encompasses a phase out of Russian fossil fuel dependence, higher energy prices and decreased use of natural gas. This scenario also models an increased energy efficiency target of 13% and a higher renewable energy targets of 45% which ensures the achievement of the Fit for 55 package (REP13)

Data for the scenarios were provided by the European Commission and include detailed data on electricity generation and consumption, consumption of heat and electricity, fuel input in thermal power plants and indicators for electricity and steam/heat.

3.2 Methodological decision tree

In the 2016 PEF study, a decision tree with 15 categories was developed. For all categories several options were evaluated along the criteria of methodological suitability and acceptance. Four different methods were selected for the calculation of the PEF for electricity. Finally, the method presented in red in Figure 1 was selected by the European Commission to calculate the default PEF for electricity as described in the EED.

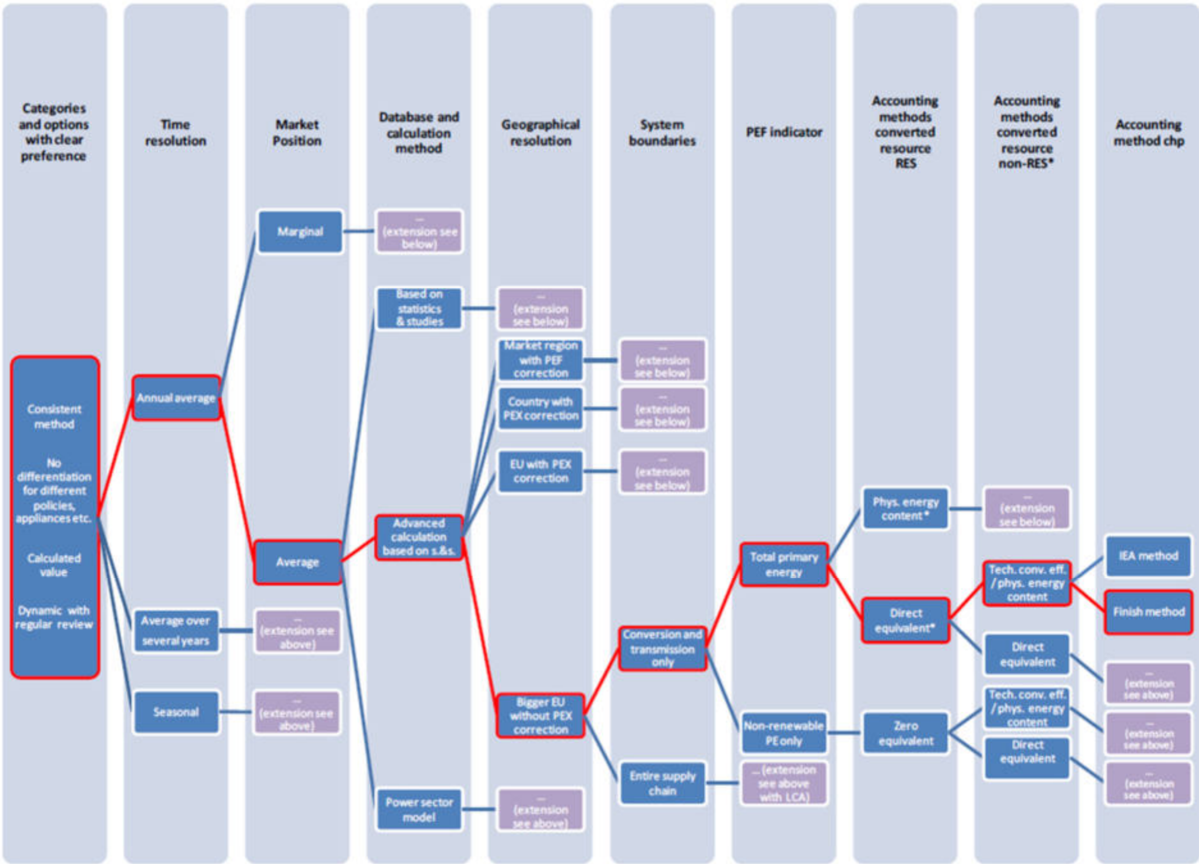

Figure 1: Decision tree for the calculation of the PEF for electricity (Source: 2016 PEF study)

Category	Option
PEF purpose	Calculated
Applicability	No differentiation
Adjustment and review process	Regular review/adjustment
Database and calculation method	Advanced calculations based on statistics and studies
Geographical resolution	Bigger EU, No PEX correction
Development over time	Dynamic
Time resolution	Annual average
Market position	Average electricity production
Methodological consistency	Same method for all PEF/MS
Accounting method for nuclear electricity (and heat) generation	Physical energy content
Accounting method electricity (and heat) generation using biomass	Technical conversion efficiencies
PEF indicator	Total primary energy (fossil fuels only)
System boundaries	Total energy conversion only (including transport losses)
Accounting method for power (and heat) generation using non-combustible RES	Direct equivalent
Accounting method for CHP	Finish method

Table 1: Definition of calculation methodology (Source: 2016 PEF study)

The calculation methodology applied in this study uses definitions, assumptions, system boundaries and calculation approaches of the European Statistical Office (EUROSTAT), in particular regarding the accounting method for PEFs of renewable energy sources. For combined heat and power (CHP) the Finnish method or reference system method was used in the calculation contrary to EUROSTAT which uses the IEA method. The Finnish method “allocates a higher share of fuel input to electricity. Thus, it seems more realistic and better suited than the IEA method to reflect the actual primary energy consumption of electricity generation in combined processes.”[3]

	PEF of the fuel	Conversion efficiency	PEF for electricity
Hydro	1	100%	1
Wind	1	100%	1
Solar PV	1	100%	1
Geothermal	1	10%	10
Biomass	1	From real data	From real data
Nuclear	1	33%	3
Fossil fuels	1	From real data	From real data
CHP	Finish method		

Figure 2: PEF of fuels and conversion efficiencys (Source: 2016 PEF study)

In order to be consistent with official data provided by EUROSTAT and PRIMES the following definitions of primary energy content of different energy carriers are used:

“For directly combustible fuels (fossil and renewable fuels/products) the primary energy content is calculated as the heat value generated during combustion of this fuel.
For non-conventional energies (hydro, wind, solar photovoltaic, geothermal, nuclear and others) it is necessary to establish energy boundaries and make methodological choices in order to define their nature and quantity of primary energy.
The choice for Eurostat's energy statistics and energy balances is to use the physical energy content method. The general principle of this method is that the primary energy form is taken as the first flow in the production process that has a practical energy use. This leads to different situations depending on the energy product:

- For directly combustible energy products (for example lignite, natural gas, motor gasoline, biogas, firewood and combustible municipal waste) the primary energy is defined as the heat generated during combustion.
- For products that are not directly combustible, the application of this principle leads to:
    - the choice of heat as the primary energy form for nuclear, geothermal, solar thermal and ambient heat; and
    - the choice of electricity as the primary energy form for solar photovoltaic, wind, hydro, tide, wave, ocean.

[3] 2016 PEF study

In cases when the amount of heat produced in the nuclear reactor is not known, the primary energy equivalent is calculated from the electricity generation by assuming an efficiency of 33 %. In the case of electricity and heat generated by geothermal energy: if the actual amount of geothermal heat is not known, the primary energy equivalent is calculated assuming an efficiency of 10 % for electricity production and 50 % for derived heat production. If two energy balances are constructed with different methodological choices and respective assumptions on efficiency conversions and calorific values, it will lead to different results for the share of renewables."[4]

In the following sections the calculation of the PEF for electricity is described step-by-step for the full package scenario (FPS scenario). For the detailed calculation for the full package scenario with high price (FPS_high scenario) and the REPowerEU scenario (REP13 scenario) please see section 6 where the calculation for these scenarios and corresponding tables are provided.

3.3 Calculation of final electricity consumption for EU27+Norway

The basis for the calculations for the PEF for electricity is the final energy consumption of electricity (Table 2). This is calculated by subtracting self-consumption of electricity of the energy sector and grid losses from gross electricity production. Data for self-consumption and grid losses are taken from PRIMES data and applied for the whole calculation process (i.e., including Norway, where no such data are available).

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity consumption EU27	**2 866**	**2 641**	**2 856**	**3 420**	**4 092**	**5 148**	**6 533**	**7 149**
Self-consumption of energy sector	233	185	186	439	872	1 677	2 798	3 283
of which: own consumption & pumping	*160*	*123*	*102*	*111*	*118*	*190*	*329*	*382*
of which: Refineries & other uses	*73*	*63*	*85*	*328*	*755*	*1 487*	*2 469*	*2 901*
Transmission & distribution losses	180	165	173	189	202	211	214	210
Final electricity consumption EU27	**2 453**	**2 290**	**2 497**	**2 792**	**3 018**	**3 260**	**3 522**	**3 657**
Self-consumption of energy sector	8,1%	7,0%	6,5%	12,8%	21,3%	32,6%	42,8%	45,9%
Transmission & distribution losses	6,3%	6,3%	6,1%	5,5%	4,9%	4,1%	3,3%	2,9%

Table 2: Calculation of shares of self-consumption of the energy sector and transmission and distribution losses (Source: PRIMES, own calculation e7)

Data for Norway are not included in the PRIMES dataset. Therefore, the calculation of the electricity production of Norway is based on data from the ENTSO-E transparency database, which provides publicly available data on electricity production on an hourly basis. Scenarios were developed by e7 based on a study by DNV providing a forecast for the energy sector of Norway for 2050.[5] All electricity production data for Norway are interpolated between 2020 and 2050.

For the calculation of the final electricity consumption of EU27+Norway, the gross electricity production of the whole region is reduced by self-consumption of the energy sector and transmission &

[4] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Calculation_methodologies_for_the_share_of_renewables_in_energy_consumption&oldid=555286#Definition_of_the_primary_energy_content_of_fuels

[5] DNV 2021: Energy transition Norway 2021. A national forecast to 2050.

distribution losses applying the shares of EU27. Power exchange (PEX) between EU27 and Norway is not considered in these figures (Table 3).

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production* EU27+Norway	3 017	2 780	3 029	3 616	4 318	5 374	6 771	7 411
Self-consumption of energy sector	245	195	198	464	920	1 750	2 899	3 403
Grid losses	189	174	183	200	213	221	222	217
Final electricity consumption* EU27+Norway	**2 582**	**2 411**	**2 648**	**2 952**	**3 184**	**3 404**	**3 650**	**3 790**

* Power exchanges are not considered

Table 3: Calculation of final electricity consumption of EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

3.4 Calculation of the raw primary energy demand

In a next step, primary energy demand for the electricity system has to be calculated. As the total primary energy demand is not only used for electricity production but also for heat, it is called raw primary energy demand (RPED). The share that is used for heat production in CHP plants has to be considered in the calculation of PEF as heat bonus. An increasing amount of electricity is used within the energy sector, e.g. for the production of e-fuels, which does not lead to final electricity consumption. This share has to be subtracted from the RPED, it is then called corrected RPED.

3.4.1 Calculation of electrical efficiencies of power plants

For thermal power plants, electrical efficiencies can be directly calculated by dividing their gross electricity production by their fuel input; data are available for EU27 in the PRIMES dataset and are applied for EU27+Norway. Table 4 shows data for the gross electricity production and the corresponding fuel input for EU27 as well as electrical efficiencies according to EUROSTAT definitions. For geothermal power generation facilities an efficiency of 10% is assumed, for other non-combustible RES based power generation is considered as 100% and for nuclear power plants an efficiency of 33% is applied.

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production EU27								
Fossil fuels	1 204	904	789	557	268	157	136	151
Biomass and waste	173	174	172	202	286	488	532	609
Other fuels (hydrogen, methanol)	0	0	0	0	4	15	32	34
Fuel consumption EU27								
Fossil fuels	3 156	2 152	1 768	1 194	513	288	243	276
Biomass and waste	553	574	577	644	786	1 112	1 167	1 286
Other fuels (hydrogen, methanol)	0	0	0	0	7	26	57	58
Electrical efficiencies								
Fossil fuels	38,2%	42,0%	44,7%	46,7%	52,3%	54,5%	56,0%	54,6%
Biomass and waste	31,3%	30,4%	29,8%	31,4%	36,4%	43,9%	45,6%	47,4%
Other fuels (hydrogen, methanol)	n/a	n/a	n/a	n/a	54,5%	55,9%	56,6%	59,3%
Geothermal**	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
Renewables**	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Nuclear**	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%

** EUROSTAT definition

Table 4: Calculation of electrical efficiencies of power plants (Source: PRIMES, own calculation e7)

3.4.2 Definition of PEFs for fuels

The primary energy content of directly combustible fuels (fossil and renewable fuels) is defined by EUROSTAT as the heat value generated during combustion. Thus, all these fuels have a PEF of 1. Distribution losses for other energy carriers than electricity are not considered in the calculation due to the lack of reliable data and complexity of the calculation. For all energy carriers (except for heat and electricity) losses are below 1% of final energy consumption with the largest value for gas (0.87% in 2020 leading to a PEF of 1.087). These losses should be considered for final energy consumption of gas, but there are no valid data for losses related to gas supply to thermal power plants, which are not connected to the distribution grid. For several energy carriers losses are not reported in energy statistics.

3.4.3 Calculation of raw primary energy demand for electricity production

The next step is to calculate the raw primary energy demand for EU27+Norway. The calculation of the raw primary energy demand (RPED) is based on the gross electricity production of EU27+Norway. Gross electricity production is divided by the electrical efficiency and multiplied with the PEF for fuels. This RPED includes the whole primary energy demand related to the electricity use, i.e., not only final electricity demand but also own consumption & pumping as well as electricity used for refineries & other uses which grows from 73 TWh in 2015 to 2.901 TWh in 2050 (Table 5). This is mainly due to the electricity based production of hydrogen (electrolysers), which is predominantly used in other sectors rather than for electricity production (e.g., as feedstock for chemical products or for production of e-fuels).

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production EU27+Norway	**3 017**	**2 780**	**3 029**	**3 616**	**4 318**	**5 374**	**6 771**	**7 411**
Fossil fuels	1 208	906	792	559	270	159	138	152
Biomass and waste	173	175	172	202	286	488	533	609
Geothermal	7	7	7	9	11	17	21	23
Other fuels (hydrogen, methanol)	0	0	0	0	4	15	32	34
Renewables	843	1 017	1 485	2 335	3 257	4 234	5 540	6 066
Nuclear	786	675	574	510	490	461	508	527
Raw primary energy demand EU27+Norway	**7 008**	**5 862**	**5 640**	**5 813**	**6 163**	**7 236**	**8 756**	**9 511**
Fossil fuels	3 165	2 158	1 773	1 198	517	291	246	279
Biomass and waste	553	575	578	644	787	1 112	1 167	1 287
Geothermal	65	66	67	89	111	174	207	225
Other fuels (hydrogen, methanol)					7	26	57	58
Renewables	843	1 017	1 485	2 335	3 257	4 234	5 540	6 066
Nuclear	2 381	2 046	1 739	1 547	1 485	1 398	1 539	1 596
RPED EU27+Norway	**7 008**	**5 862**	**5 640**	**5 813**	**6 163**	**7 236**	**8 756**	**9 511**

Table 5; Calculation of raw primary energy demand for electricity production in EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

3.4.4 Calculation of corrected raw primary energy demand for electricity production

As the RPED that is necessary for the production of electricity for refineries & other uses should not be part of the PEF for electricity calculation, it needs to be corrected. Only RPED necessary for the production of electricity that goes to final energy consumption has to be part of the PEF calculation. RPED needed for the production of electricity that is used for the production of e-fuels or products needed in other sectors than electricity production needs to be subtracted. Primary energy demand for this share of electrictiy production will have to be considered in the PEF for e-fuels or other products in order to be consistent.

In this calculation it is assumed that Norway has a similar structure of electricity use in the energy sector and that the correction of the RPED is done in the same way as in EU27. The basis for the correction is the final energy consumption, calculated in chapter 3.3. For the calculation of the corrected RPED it is necessary to calculate the corrected gross electricity production for EU27+Norway. This is done by calculating factors for transmission and distribution losses and for own consumption & pumping based on the final electricity consumption for EU27+Norway.

A factor for the relation of gross electricity production with and without electricity consumption for refineries and other uses can now be derived. This correction factor will then be applied to the RPED. Table 6 shows the calculation of the corrected RPED for EU27+Norway.

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Final electricity consumption EU27+Norway	**2 582**	**2 411**	**2 648**	**2 952**	**3 184**	**3 404**	**3 650**	**3 790**
Grid losses (share of final electricity consumption)[6]	7,3%	7,2%	6,9%	6,8%	6,7%	6,5%	6,1%	5,7%
Own consumption and pumping (share of final electricity consumption)	6,5%	5,3%	4,1%	4,0%	3,9%	5,8%	9,3%	10,5%
Gross electricity production (corrected) EU27+Norway	**2 939**	**2 714**	**2 939**	**3 270**	**3 521**	**3 822**	**4 212**	**4 404**
Gross electricity production EU27+Norway	3 017	2 780	3 029	3 616	4 318	5 374	6 771	7 411
Correction factor	97,4%	97,6%	97,0%	90,4%	81,6%	71,1%	62,2%	59,4%
RPED EU27+Norway	7 008	5 862	5 640	5 813	6 163	7 236	8 756	9 511
Raw primary energy demand (corrected) EU27+Norway	**6 829**	**5 723**	**5 473**	**5 256**	**5 026**	**5 146**	**5 447**	**5 652**

Table 6: Calculation of corrected raw primary energy demand for electricity prodcution (Source: PRIMES, ENTSO-E, own calculation e7)

The corrected RPED is the basis for the PEF for electricity calculation after considering the heat bonus from the CHP power plants.

3.5 Calculation of the heat bonus

The next step is the calculation of the heat bonus, which is the amount of RPED used for heat production in CHP plants.

The RPED includes primary energy, fuel input, used for heat produced in CHP power plants. The heat bonus is calculated on the basis of the fuel input share allocated to the heat production from CHP power plants that has to be subtracted from the corrected RPED. While EUROSTAT applies the IEA method for the allocation of fuel input of CHP plants to heat and electricity, the Finnish method, reference system method, will be applied here.

Heat and electricity production from CHPs for EU27 are part of the PRIMES dataset. For Norway CHP production is neglected since electricity production from CHPs in Norway was less than 1,5% in 2020 according to EUROSTAT data.

For the calculation of the fuel consumption of CHP plants figures for the overall efficiency for CHPs where taken from the EUROSTAT database[7], considering only main producers. For 2050 an increased overall efficiency of 75% was assumed.[8] Based on the fuel consumption of CHP plants, efficiencies for heat and electricity are calculated (Table 7).

As a first step, the primary energy saving (PES) has to be calculated using the formula from Annex II of the EU Directive 2012/27/EU (1).

[6] Please not that these numbers do not correspond to data in Table 2 as the basis here is the final electricity consumption instead of gross electricity production.
[7] https://ec.europa.eu/eurostat/data/database
[8] Odeh, N. et al. 2020: Review of the Reference Values for High Efficiency Cogeneration (2022-2025). Final Report.

$$PES = 1 - \frac{1}{\frac{eta\ th}{eta\ th{,}Ref} + \frac{eta\ el}{eta\ el{,}Ref}} \tag{1}$$

In a second step, fuel consumption of heat and electricity is calculated with the following formulas (2) and (3):

$$Fuel\ input\ (heat) = (1 \ - PES) \times \frac{eta\ th}{eta\ th{,}Ref} \tag{2}$$

$$Fuel\ input\ (electricity) = (1 \ - PES) \times \frac{eta\ el}{eta\ el{,}Ref} \tag{3}$$

For the efficiency of the reference systems, needed for the allocation of fuel consumption, EUROSTAT data were taken for 2015 and 2020, for 2050 it was assumed that electricity production has an increased efficiency of 53% and heat production has an increased efficiency of 92%.[9]

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production CHP EU27	348	401	413	361	409	400	366	372
Gross heat production CHP EU27	445	447	489	455	524	443	391	356
Gross CHP energy output	**792**	**847**	**902**	**815**	**933**	**843**	**757**	**728**
CHP overall efficiency	61,4%	63,3%	65,3%	67,2%	69,2%	71,1%	73,1%	75,0%
Fuel consumption CHP	**1 290**	**1 338**	**1 382**	**1 213**	**1 349**	**1 185**	**1 036**	**971**
eta el	26,9%	30,0%	29,9%	29,7%	30,3%	33,8%	35,3%	38,3%
eta th	34,5%	33,4%	35,4%	37,5%	38,8%	37,4%	37,7%	36,7%
eta el,Ref	45,2%	50,3%	50,8%	51,2%	51,7%	52,1%	52,6%	53,0%
eta th,Ref	84,2%	87,4%	88,2%	88,9%	89,7%	90,5%	91,2%	92,0%
PES	**0,5%**	**-2,3%**	**-1,0%**	**0,2%**	**2,0%**	**5,7%**	**7,9%**	**10,8%**
Fuel consumption electricity	765	815	822	703	777	724	641	625
Fuel consumption heat	**525**	**523**	**560**	**510**	**573**	**461**	**395**	**345**

Table 7: Calculation of the heat bonus of CHPs (Source: PRIMES, own calculation e7)

In a third step, the heat bonus is subtracted from the corrected raw primary energy demand for electricity production (Table 8) leading to the corrected primary energy demand for EU27+Norway.

[9] Odeh, N. et al. 2020: Review of the Reference Values for High Efficiency Cogeneration (2022-2025). Final Report.

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Raw primary energy demand (corrected) EU27+Norway	6 829	5 723	5 473	5 256	5 026	5 146	5 447	5 652
Heat bonus	525	523	560	510	573	461	395	345
Primary energy demand (corrected) EU27+Norway	**6 304**	**5 200**	**4 913**	**4 746**	**4 454**	**4 685**	**5 052**	**5 307**

Table 8: Calculation of primary energy demand (corrected) for electrcity production in EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

3.6 Calculation of PEF for electricity

Table 9 shows the PEF for electricity that is calculated by dividing the primary energy demand dedicated to electricity production by the final electricity consumption.

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Primary energy demand (corrected) for electricity production in EU27+Norway	6 304	5 200	4 913	4 746	4 454	4 685	5 052	5 307
Final electricity consumption EU27+Norway	2 582	2 411	2 648	2 952	3 184	3 404	3 650	3 790
PEF for electricity (FPS scenario)	**2,44**	**2,16**	**1,86**	**1,61**	**1,40**	**1,38**	**1,38**	**1,40**

Table 9: Calculation of the PEF for electricity for the FPS scenario (Source: PRIMES, ENTSO-E, own calculation e7)

4 PEF for electricity

Table 10 summarizes PEFs for electricity for all scenarios and the results from the 2016 PEF studies.

	2015	2020	2025	2030	2035	2040	2045	2050
FPS scenario	2,44	2,16	1,86	1,61	1,40	1,38	1,38	1,40
FPS_high scenario	2,44	2,16	1,88	1,64	1,41	1,37	1,38	1,39
REP13 scenario	2,44	2,16	1,91	1,64	1,42	1,37	1,39	1,40
PEF 2016 study	2,21	2,01	1,93	1,87				

Table 10: PEF for electricity in 2015-2050 for different PRIMES scenarios (Source: e7)

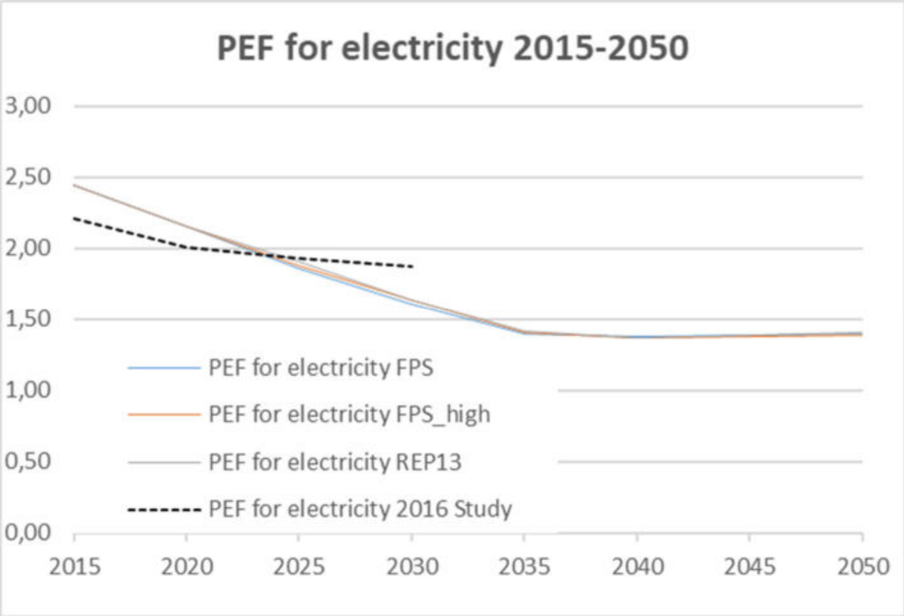

Figure 3: Development of PEF for electricity in 2015-2050 (Source: e7)

The PEF for electricity decreases from 2,44 in 2015 to 1,40 or 1,39 in 2050, depending on the scenario. From 2035 the PEF stays at a constant level, with a slight increase between 2040 and 2050 (Table 10). This increase is a result of the larger share of own consumption and pumping. PEF values for electricity show very small variations between the different PRIMES scenarios.

Compared to the 2016 PEF study calculation, the updated PEF for electricity is higher in 2015 and 2020, it is at a similar level between 2020 and 2025 and it decreases faster after this period. The main reasons for these deviations come from the exit of UK from the European Union, changes in PRIMES scenario assumptions and the development in Norway, where electricity production is expected to increase electricity from wind power much faster than assumed in the 2016 PEF study.

PRIMES provides energy data for a five years period. Table 11 shows annual values for 2020 to 2030 where PEF data are interpolated.

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
FPS scenario	**2,16**	2,10	2,04	1,98	1,92	**1,86**	1,81	1,76	1,71	1,66	**1,61**
FPS_high scenario	**2,16**	2,10	2,05	1,99	1,93	**1,88**	1,83	1,78	1,73	1,69	**1,64**
REP13 scenario	**2,16**	2,11	2,06	2,01	1,96	**1,91**	1,85	1,80	1,75	1,69	**1,64**
PEF 2016 study	**2,01**	1,99	1,98	1,96	1,95	**1,93**	1,92	1,91	1,89	1,88	**1,87**

Table 11: Interpolated PEFs for 2020-2030

5 Discussion of methodology and results

The development of the PEF for electricity reflects the transition of the electricity production towards renewable energy sources (RES) and decarbonization. The decrease of the PEF value mainly stems from a shift from conventional thermal power plants (with high PEFs) towards non-combustible RES (with a PEF of 1). Moreover, the remaining thermal power plants (fueled by gas and biomass & waste) show a significant increase in efficiency. The electrical efficiency of biomass & waste-based power plants would increase from 31,3% in 2015 to 47,4% in 2050 (fossil fuel power plants: 38,2% to 54,6%). With the increase of demand for electricity storage (e.g., pumped hydro, power-to-gas-to-power) storage losses will increase accordingly. This might lead to an increase of the PEF which can be observed in all three scenarios where the PEF values increase slightly from 2040 to 2050.

During the workshop with experts and stakeholders in June 2022 the calculation of the PEF for electricity was presented and discussed. Participants were asked about their opinion on future developments of the PEF calculation, on the application of PEFs in different policy areas, on requirements for harmonization in Member States and additional indicators. It was clearly confirmed by the participants that a PEF for electricity is required and that the methodology should be harmonized and should be consistent with the EUROSTAT energy balances. A majority of the participants were in favour of using one PEF value for all policies. Participants also thought that PEF values should be calculated by Member States and should include upstream energy use, i.e., an LCA approach including distribution and transmission losses but also energy used for the production of assets (facilities) should be taken into account. The discussion also focused on the purpose of PEFs. Furthermore, it was mentioned that the PEF should not be based on historical figures but should rather be forward looking as, e.g., products that are developed today will come into the market in a few years and will consume energy for a long time in the future. This should be considered in the methodology for the calculation of the PEF for electricity.

As confirmed during the workshop, the calculation methodology chosen in this study is based on EU legal requirements (see Recital 40 of EU Directive 2018/2002). This methodology is in line with the EUROSTAT energy balances and definitions with the exception of the allocation method of fuel input for heat and electricity in CHP plants. Instead of the IEA method used by EUROSTAT, the so-called Finnish method ("reference system method") is used which allocates a larger share of fuel inputs to electricity resulting in a more realistic and better suited allocation. The Finnish method is described in Annex II of EU Directive 2012/27/EU and it is recommended by national energy agencies in e.g. Austria and Germany.

Concerning the system boundaries, conversion and transmission/distribution losses are taken into account as these data are available from EUROSTAT and PRIMES and they are regularly reported in national energy balances. As discussed during the workshop, the application of an LCA approach, where the entire upstream flows and losses are considered, was analysed and discussed in the 2016 PEF study. It was shown that the PEF values for fuels would vary to a large extent, e.g., for natural gas the PEF would vary from 1,05 to 1,45 depending on the geographical source of the gas, the gas type and production processes and the transport conditions (transport mode, distance, …)[10]. Furthermore, there is no standardized methodology resulting in inconsistent PEF values (based on inconsistent definitions of

[10] See also: BRE 2019: Briefing Note – Derivation and use of Primary Energy factors in SAP

PEFs) in Member States.[11] The 2016 PEF study comes to the following conclusion: “Two main observations can be extracted from this review:

- There is a data gathering complexity and very large uncertainty on the calculation of PEFs for fuels taking into account a life cycle perspective.
- Application of PEF of fuels in policy is currently not harmonized, and methodologies and PEF values are very different in EU countries.

It is therefore very difficult to propose a consistent PEF of solid, liquid or gas fuels in the EU based on detailed life cycle and supply chain considerations.”[12]

The most relevant methodological decisions for the calculation of PEFs for electricity and fuels are the use of the “direct equivalent” method based on the “total primary energy” approach for non-combustible renewable energy and the use of the “technical conversion efficiency” method for electricity and heat generation from biomass. At first glance this might look like incentivising fossil fuels technologies against RES and electrical applications like heat pumps. From a policy perspective, the energy efficiency first principle is one of the key principles of the EU energy policy which is intended to ensure secure, sustainable, competitive and affordable energy supply in the EU. This principle should ensure that

- only the energy really needed is produced;
- investments in stranded assets are avoided; and
- demand for energy is reduced and managed in a cost-effective way[13].

The PEF is the most important indicator for energy efficiency and energy savings, while it needs to be supplemented by an indicator for the emissions of GHG reflecting the path towards decarbonization. Assuming a PEF of 0 for non-combustible RES would not be appropriate as it would imply that wasting energy from RES would not be a relevant problem, which is not the case. All RES are scarce in that sense that investments in technology and/or political decisions are necessary to extract them (e.g., securing dedicated areas for wind energy power), for some technologies there are some quite strict limitations (e.g., hydro power). On the long run, with an increasing need for storage technologies, it will be a huge challenge to find the most efficient storage solution reducing – unavoidable - losses as far as possible.

The default PEF for electricity is calculated for EU27 plus Norway without any power exchange (PEX) correction. This is of high relevance because PEX correction would increase complexity – and inaccuracy - of the calculation significantly. For calculations at Member State level the 2016 PEF study came to the conclusion that “for coupled markets with significant power flows between the markets, not considering power imports and exports can lead to significant distortions of the national PEF.” Including PEX would increase precision, but “it is considered more difficult to derive reliable and credible data

[11] Hitchin, R. et al.: Primary Energy Factors and Members States Energy Regulations
Primary factors and the EPBD. Concerted Action Energy Performance of Buildings.
[12] 2016 PEF study
[13] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-first-principle_en

for a power exchange correction with regions other than Europe. As such a power exchange correction with uncertain data is likely to lead to a lower precision in the end."[14]

As the PEF should reflect the impact of energy efficiency in the future, it is recommended to use a future PEF value for electricity rather than a PEF value based on historical figures. As the PEF will be reviewed and updated every 4 years and the next period will be from 2023 to 2026, the average value of the years 2024 and 2025 could be used for the default value for the PEF for electricity resulting in a PEF of approximately 1,9 for all the scenarios. Another alternative could be to use the calculated PEF value for 2026 as default value for the time period 2023-2026. A future value would provide a more adequate indicator than an historical value to steer investments in buildings or energy equipment/appliances. As investments in electricity generation are planned 5 to 10 years before their commissioning, the current estimates regarding the power generation capacity in 2023 to 2026 should be quite accurate; however, the load factor may of course be different depending on demand and price developments.

[14] 2016 PEF study

6 Annex: Calculation of PEF of scenarios

6.1 Full package with high energy prices scenario (FPS_high scenario)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity consumption EU27	**2 866**	**2 641**	**2 982**	**3 486**	**4 141**	**5 185**	**6 546**	**7 184**
Self-consumption of energy sector	233	185	210	458	872	1 671	2 778	3 283
of which: own consumption & pumping	160	123	119	121	121	193	334	392
of which: Refineries & other uses	73	63	91	337	751	1 477	2 445	2 891
Transmission & distribution losses	180	165	180	192	206	215	217	212
Final electricity consumption EU27	**2 453**	**2 290**	**2 592**	**2 836**	**3 062**	**3 300**	**3 550**	**3 688**
Self-consumption of energy sector	8,1%	7,0%	7,0%	13,1%	21,1%	32,2%	42,4%	45,7%
Transmission & distribution losses	6,3%	6,3%	6,0%	5,5%	5,0%	4,1%	3,3%	3,0%

Table 12: Calculation of shares of self-consumption of the energy sector and transmission and distribution losses (Source: PRIMES, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production* EU27+Norway	3 017	2 780	3 156	3 683	4 365	5 405	6 788	7 446
Self-consumption of energy sector	245	195	222	484	919	1 742	2 881	3 403
Grid losses	189	174	190	203	217	224	225	220
Final electricity consumption* EU27+Norway	**2 582**	**2 411**	**2 743**	**2 996**	**3 229**	**3 440**	**3 682**	**3 823**

* Power exchanges are not considered

Table 13: Calculation of final electricity consumption of EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production EU27								
Fossil fuels	1 205	904	756	544	246	137	131	149
Biomass and waste	173	174	187	216	314	486	528	602
Other fuels (hydrogen, methanol)	0	0	0	0	3	14	32	33
Fuel consumption EU27								
Fossil fuels	3 156	2 152	1 820	1 272	506	258	235	267
Biomass and waste	553	574	623	675	849	1 120	1 179	1 280
Other fuels (hydrogen, methanol)	0	0	0	0	6	27	57	59
Electrical efficiencies								
Fossil fuels	38,2%	42,0%	41,6%	42,8%	48,6%	53,3%	55,8%	55,7%
Biomass and waste	31,3%	30,4%	30,0%	32,0%	37,0%	43,4%	44,7%	47,0%
Other fuels (hydrogen, methanol)	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
Geothermal**	n/a	n/a	n/a	n/a	52,9%	53,8%	56,0%	56,2%
Renewables**	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Nuclear**	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%

** EUROSTAT definition

Table 14: Calculation of electrical efficiencies of power plants (Source: PRIMES, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production EU27+Norway	**3 017**	**2 780**	**3 156**	**3 683**	**4 365**	**5 405**	**6 788**	**7 446**
Fossil fuels	1 208	906	758	546	248	139	133	150
Biomass and waste	173	175	187	216	315	486	528	602
Geothermal	7	7	8	10	12	18	21	23
Other fuels (hydrogen, methanol)	0	0	0	0	3	14	32	33
Renewables	843	1 017	1 620	2 391	3 294	4 285	5 570	6 122
Nuclear	786	675	583	520	494	463	504	515
Raw primary energy demand EU27+Norway	**7 008**	**5 862**	**5 913**	**6 015**	**6 270**	**7 273**	**8 783**	**9 522**
Fossil fuels	3 165	2 157	1 825	1 277	509	261	238	270
Biomass and waste	553	575	624	676	849	1 121	1 180	1 280
Geothermal	65	66	78	96	115	176	210	229
Other fuels (hydrogen, methanol)					6	27	57	59
Renewables	843	1 017	1 620	2 391	3 294	4 285	5 570	6 122
Nuclear	2 381	2 046	1 766	1 576	1 496	1 403	1 527	1 562
RPED EU27+Norway	**7 008**	**5 862**	**5 913**	**6 015**	**6 270**	**7 273**	**8 783**	**9 522**

Table 15; Calculation of raw primary energy demand for electricity production in EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Final electricity consumption EU27+Norway	**2 582**	**2 411**	**2 743**	**2 996**	**3 229**	**3 440**	**3 682**	**3 823**
Grid losses (share of final electricity consumption)[15]	7,3%	7,2%	6,9%	6,8%	6,7%	6,5%	6,1%	5,8%
Own consumption and pumping (share of final electricity consumption)	6,5%	5,4%	4,6%	4,3%	4,0%	5,9%	9,4%	10,6%
Gross electricity production (corrected) EU27+Norway	**2 939**	**2 714**	**3 059**	**3 327**	**3 574**	**3 866**	**4 253**	**4 449**
Gross electricity production EU27+Norway	3 017	2 780	3 156	3 683	4 365	5 405	6 788	7 446
Correction factor	97,4%	97,6%	96,9%	90,3%	81,9%	71,5%	62,7%	59,7%
RPED EU27+Norway	7 008	5 862	5 913	6 015	6 270	7 273	8 783	9 522
Raw primary energy demand (corrected) EU27+Norway	**6 829**	**5 722**	**5 733**	**5 434**	**5 133**	**5 201**	**5 503**	**5 690**

Table 16: Calculation of corrected raw primary energy demand for electricity prodcution (Source: PRIMES, ENTSO-E, own calculation e7)

[15] Please not that these numbers do not correspond to data in Table 2 as the basis here is the final electricity consumption instead of gross electricity production.

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production CHP EU27	348	401	383	383	417	401	367	390
Gross heat production CHP EU27	445	447	500	468	540	461	411	378
Gross CHP energy output	**792**	**848**	**884**	**851**	**957**	**862**	**778**	**767**
CHP overall efficiency	61,4%	63,3%	65,3%	67,2%	69,2%	71,1%	73,1%	75,0%
Fuel consumption CHP	**1 290**	**1 339**	**1 354**	**1 266**	**1 384**	**1 212**	**1 064**	**1 023**
eta el	26,9%	30,0%	28,3%	30,3%	30,1%	33,1%	34,5%	38,1%
eta th	34,5%	33,4%	37,0%	37,0%	39,0%	38,0%	38,6%	36,9%
eta el,Ref	45,2%	50,3%	50,8%	51,2%	51,7%	52,1%	52,6%	53,0%
eta th,Ref	84,2%	87,4%	88,2%	88,9%	89,7%	90,5%	91,2%	92,0%
PES	**0,5%**	**-2,3%**	**-2,3%**	**0,7%**	**1,8%**	**5,2%**	**7,3%**	**10,7%**
Fuel consumption electricity	765	816	773	744	793	729	647	656
Fuel consumption heat	**525**	**523**	**581**	**523**	**591**	**483**	**418**	**367**

Table 17: Calculation of the heat bonus of CHPs (Source: PRIMES, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Raw primary energy demand (corrected) EU27+Norway	6 829	5 722	5 733	5 434	5 133	5 201	5 503	5 690
Heat bonus	525	523	581	523	591	483	418	367
Primary energy demand (corrected) EU27+Norway	**6 304**	**5 199**	**5 152**	**4 911**	**4 542**	**4 718**	**5 086**	**5 323**

Table 18: Calculation of primary energy demand (corrected) for electrcity production in EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Primary energy demand (corrected) for electricity production in EU27+Norway	6 304	5 199	5 152	4 911	4 542	4 718	5 086	5 323
Final electricity consumption EU27+Norway	2 582	2 411	2 743	2 996	3 229	3 440	3 682	3 823
PEF for electricity (FPS_high scenario)	**2,44**	**2,16**	**1,88**	**1,64**	**1,41**	**1,37**	**1,38**	**1,39**

Table 19: Calculation of the PEF for electricity for the FPS_high scenario (Source: PRIMES, ENTSO-E, own calculation e7)

6.1 REPowerEU scenario (REP13 scenario)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity consumption EU27	**2 866**	**2 637**	**2 942**	**3 523**	**4 193**	**5 048**	**6 089**	**6 712**
Self-consumption of energy sector	233	185	220	590	910	1 478	2 252	2 769
of which: own consumption & pumping	160	122	123	139	139	185	303	364
of which: Refineries & other uses	73	63	97	451	771	1 293	1 949	2 405
Transmission & distribution losses	180	165	176	187	207	216	219	214
Final electricity consumption EU27	**2 453**	**2 287**	**2 546**	**2 746**	**3 076**	**3 354**	**3 618**	**3 730**
Self-consumption of energy sector	8,1%	7,0%	7,5%	16,8%	21,7%	29,3%	37,0%	41,2%
Transmission & distribution losses	6,3%	6,3%	6,0%	5,3%	4,9%	4,3%	3,6%	3,2%

Table 20: Calculation of shares of self-consumption of the energy sector and transmission and distribution losses (Source: PRIMES, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production* EU27+Norway	3 017	2 776	3 115	3 720	4 420	5 271	6 333	6 979
Self-consumption of energy sector	245	195	233	623	959	1 543	2 342	2 879
Grid losses	189	174	186	197	218	226	228	222
Final electricity consumption* EU27+Norway	**2 582**	**2 407**	**2 696**	**2 899**	**3 243**	**3 502**	**3 763**	**3 878**

* Power exchanges are not considered

Table 21: Calculation of final electricity consumption of EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production EU27								
Fossil fuels	1 205	900	725	421	224	96	78	104
Biomass and waste	173	174	184	219	314	483	528	593
Other fuels (hydrogen, methanol)	0	0	0	1	4	15	33	31
Fuel consumption EU27								
Fossil fuels	3 156	2 145	1 797	1 048	482	185	141	191
Biomass and waste	554	574	613	674	846	1 111	1 175	1 267
Other fuels (hydrogen, methanol)	0	0	0	4	8	28	58	54
Electrical efficiencies								
Fossil fuels	38,2%	42,0%	40,3%	40,2%	46,3%	51,7%	55,2%	54,5%
Biomass and waste	31,3%	30,3%	30,0%	32,4%	37,0%	43,5%	44,9%	46,8%
Other fuels (hydrogen, methanol)	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%	10,0%
Geothermal**	n/a	n/a	n/a	n/a	51,1%	53,4%	55,9%	57,7%
Renewables**	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Nuclear**	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%	33,0%

** EUROSTAT definition

Table 22: Calculation of electrical efficiencies of power plants (Source: PRIMES, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production EU27+Norway	**3 017**	**2 776**	**3 115**	**3 720**	**4 420**	**5 271**	**6 333**	**6 979**
Fossil fuels	1 208	903	727	423	225	97	79	106
Biomass and waste	173	175	184	219	314	483	528	594
Geothermal	7	7	7	9	12	18	21	24
Other fuels (hydrogen, methanol)	0	0	0	1	4	15	33	31
Renewables	843	1 017	1 601	2 513	3 353	4 211	5 172	5 704
Nuclear	786	675	595	555	512	447	500	520
Raw primary energy demand EU27+Norway	7 008	5 854	5 894	6 012	6 363	7 073	8 275	9 040
Fossil fuels	3 165	2 150	1 802	1 053	487	188	144	194
Biomass and waste	554	575	614	675	847	1 111	1 176	1 268
Geothermal	65	66	73	85	117	180	208	244
Other fuels (hydrogen, methanol)					8	28	58	54
Renewables	843	1 017	1 601	2 513	3 353	4 211	5 172	5 704
Nuclear	2 381	2 045	1 803	1 683	1 551	1 355	1 516	1 576
RPED EU27+Norway	7 008	5 854	5 894	6 012	6 363	7 073	8 275	9 040

Table 23; Calculation of raw primary energy demand for electricity production in EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Final electricity consumption EU27+Norway	**2 582**	**2 407**	**2 696**	**2 899**	**3 243**	**3 502**	**3 763**	**3 878**
Grid losses (share of final electricity consumption)[16]	7,3%	7,2%	6,9%	6,8%	6,7%	6,5%	6,1%	5,7%
Own consumption and pumping (share of final electricity consumption)	6,5%	5,4%	4,8%	5,1%	4,5%	5,5%	8,4%	9,8%
Gross electricity production (corrected) EU27+Norway	**2 939**	**2 710**	**3 012**	**3 243**	**3 607**	**3 922**	**4 306**	**4 479**
Gross electricity production EU27+Norway	3 017	2 776	3 115	3 720	4 420	5 271	6 333	6 979
Correction factor	97,4%	97,6%	96,7%	87,2%	81,6%	74,4%	68,0%	64,2%
RPED EU27+Norway	7 008	5 854	5 894	6 012	6 363	7 073	8 275	9 040
Raw primary energy demand (corrected) EU27+Norway	**6 829**	**5 715**	**5 700**	**5 242**	**5 192**	**5 262**	**5 626**	**5 801**

Table 24: Calculation of corrected raw primary energy demand for electricity prodcution (Source: PRIMES, ENTSO-E, own calculation e7)

[16] Please not that these numbers do not correspond to data in Table 2 as the basis here is the final electricity consumption instead of gross electricity production.

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Gross electricity production CHP EU27	348	401	367	348	403	399	358	381
Gross heat production CHP EU27	445	447	477	439	533	454	401	367
Gross CHP energy output	**792**	**848**	**844**	**787**	**936**	**852**	**759**	**749**
CHP overall efficiency	61,4%	63,3%	65,3%	67,2%	69,2%	71,1%	73,1%	75,0%
Fuel consumption CHP	**1 290**	**1 338**	**1 293**	**1 171**	**1 353**	**1 199**	**1 039**	**998**
eta el	26,9%	30,0%	28,4%	29,7%	29,8%	33,3%	34,4%	38,2%
eta th	34,5%	33,4%	36,9%	37,5%	39,4%	37,9%	38,6%	36,8%
eta el,Ref	45,2%	50,3%	50,8%	51,2%	51,7%	52,1%	52,6%	53,0%
eta th,Ref	84,2%	87,4%	88,2%	88,9%	89,7%	90,5%	91,2%	92,0%
PES	**0,5%**	**-2,3%**	**-2,3%**	**0,2%**	**1,6%**	**5,4%**	**7,3%**	**10,8%**
Fuel consumption electricity	765	815	740	678	769	724	631	642
Fuel consumption heat	**525**	**523**	**554**	**492**	**585**	**475**	**408**	**356**

Table 25: Calculation of the heat bonus of CHPs (Source: PRIMES, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Raw primary energy demand (corrected) EU27+Norway	6 829	5 715	5 700	5 242	5 192	5 262	5 626	5 801
Heat bonus	525	523	554	492	585	475	408	356
Primary energy demand (corrected) EU27+Norway	**6 304**	**5 192**	**5 147**	**4 749**	**4 608**	**4 787**	**5 218**	**5 445**

Table 26: Calculation of primary energy demand (corrected) for electrcity production in EU27+Norway (Source: PRIMES, ENTSO-E, own calculation e7)

[TWh]	2015	2020	2025	2030	2035	2040	2045	2050
Primary energy demand (corrected) for electricity production in EU27+Norway	6 304	5 192	5 147	4 749	4 608	4 787	5 218	5 445
Final electricity consumption EU27+Norway	2 582	2 407	2 696	2 899	3 243	3 502	3 763	3 878
PEF for electricity (REP13 scenario)	2,44	2,16	1,91	1,64	1,42	1,37	1,39	1,40

Table 27: Calculation of the PEF for electricity for the REP13 scenario (Source: PRIMES, ENTSO-E, own calculation e7)

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