Primary energy factors for electricity in buildings

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Toward a flexible electricity supply

-Confidential-

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Foreword

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Summary

There is no unified approach in European regulations regarding how to calculate primary energy when assessing energy performance of buildings. Each member state can select whatever method of calculating primary energy they wish. The fact that the primary energy factors for electricity in Europe will also be subject to changes as the share of renewables progresses towards 2050, adds to the problem of assessing building performance.

Different national electricity mixes, calculation methodologies, and a constantly evolving share of renewable electricity raise questions regarding how primary energy factors influence political and building design decisions. Evaluating the energy performance of buildings becomes problematic, particularly in regards to space heating (gas vs. electricity). Making the electricity supply more flexible is also an important argument. For this reason, it can be desirable to increase the share of electricity for heating. The goal of this paper is to assess the effect of changing primary energy factors on the building practices in European countries.

According to the national building regulations of seven countries, the following Primary Energy Factors (PEFs) for delivery of electricity to a building or project have been found:

	France	Germany	NL	Poland	Spain	Sweden	UK
PEF	2.58	2.6	2.56	3	2.6	2	2.92

The PEF for the majority of countries is approximately 2.6. The only countries at present with a renewable electricity share that is large enough to significantly influence the PEF are Spain and Sweden. Spain uses a PEF of 2.6, which is much higher than expected. Based on a calculated value with a weighting factor for nuclear equal to 3 and renewables equal to 1, one would expect a PEF of 2.0. For Sweden, the calculated PEF based on a factor for renewables varying from 0 to 1 and the factor for nuclear of 3 would be 1.6 to 2.1.

Most countries take renewable energy into account as non-zero, even though it is not clear what number is used and the exact algorithm is not known. There are clear indications for France, the Netherlands, and Sweden that the PEF does not arise purely from scientific arguments and a clear algorithm. If we assume the factor for renewables to be 1, the primary energy factors will converge to 1 as the penetration of renewables increases as 2050 approaches. Our own calculations show that by 2020, however, the factors for most countries are still expected to hover around 2 (or 2.5 to 3 in the case of Poland).

If the PEFs are adjusted downwards—recognizing the increasing renewable electricity share in the national mix—it could influence the balance between the share for electric

heating versus other methods of heating. It could, for example, provide a positive additional impulse for heat pumps. However, lower PEFs could also result in a decreased stimulus to make building-related electricity consumption, such as for lighting, ventilation, or air conditioning, more efficient.

Since the countries investigated have chosen not to differentiate between the PEF for delivered and produced electricity, they therefore give a maximum benefit to renewables on-site, as this method enables the subtraction of renewable electricity from the electricity demand.

Assuming that countries retain the coupling between the PEF for delivered electricity and produced electricity (and thereby lowering PEFs for delivered electricity and for produced electricity), the result would give on-site renewable electricity less impact on improving energy performance (to the same extent that the impact of electricity consumption will be less). This is unlikely to affect the development of such renewables however, as adequate financial support mechanisms are in place for small-scale systems in many countries.

Primary Energy Factors are not based entirely on scientific arguments and clear algorithms. Given the significant changes ahead in electricity supply, the PEF for electricity should be regularly revised and its method of calculation clearly documented and eventually harmonized. This provides the opportunity to present arguments to national discussions for establishing PEFs.

For most current calculation methods, a low PEF has a negative effect in that it reduces the stimulus for greater efficiency. Even though minimum requirements on energy efficiency of building – related consumption are already regulated through the ErP Directive, there is no stimulus for choosing the most efficient solution other than through building performance regulations. However, this can be avoided if the calculations for demand are separated from the calculations for supply, as has been proposed in the discussion of the calculations for determining Zero Energy Buildings.

We also briefly discuss which building-related electricity demand options can positively influence the flexibility of the electricity supply. The discussion on flexibility has a demand side management component, but it is not dominated by this component[1]. A topic worth further study is the extent to which increased flexibility of the electricity supply through incorporation of heat pumps can be a driver.

The following recommendations are made based on the above results:

- With the strong move toward zero energy buildings, there is a case for taking appliances into account in the electricity demand. This would give more reward for on-site renewable electricity, since it would more than double the electricity demand and enable compensation of this demand through renewable electricity.
- It is worthwhile to take a closer look at calculation methods for zero energy buildings, as they may provide new ways of calculating a building's energy performance that do not have the negative effects of lower PEFs. For non-ZEBs, special care is necessary to ensure that low PEFs do not lead to lower energy efficiency.
- For countries that use much higher PEFs than calculated, based on their national electricity mix (such as Sweden and Spain in this study), more work should be done to determine the details of the decision making process for the PEFs used in the past and those to be used in the future.
- Considering the rapid evolution of the electricity system, PEFs need regular revision, i.e. every 3 to 5 years.
- PEFs are used as a political factor, with sometimes unclear calculation methods. As a minimum, the calculation method to produce a PEF should be documented, especially for renewable electricity systems.

Table of contents

1 Introduction

There is no unified approach in European regulations regarding how to calculate primary energy when assessing energy performance of buildings. Each member state can select whatever method of calculating primary energy they wish. The fact that the primary energy factors for electricity in Europe will also be subject to changes as the share of renewables progresses towards 2050, adds to the problem.

Different national electricity mixes, calculation methodologies, and a constantly evolving share of renewable electricity raise questions regarding how primary energy factors influence political and building design decisions. Evaluating the energy performance of buildings becomes problematic, particularly in regards to space heating (gas vs. electricity). Making the electricity supply more flexible is also an important argument. For this reason, it can be desirable to increase the share of electricity for heating. The goal of this paper is to assess the effect of changing primary energy factors on the building practices in European countries.

More background on primary energy factors in relation to the Energy Performance of Buildings Directive (EPBD) and relevant CEN standards is given in Chapter 2. Our findings on the primary energy factors used by a number of European countries are discussed in Chapter 3. In Chapter 4 we show how these primary energy factors are expected to change with the increased incorporation of renewable energy in the electricity mix. We discuss the implications of changing primary energy factors for technologies used in the building sector in Chapter 5.

2 The EPBD and primary energy factors

2.1 Introduction

The recast of the Directive on the Energy Performance of Buildings (Directive 2010/31/EU) lays down the requirements regarding the general framework for a methodology for calculating the integrated energy performance of buildings. In general, the EPBD aims at a common approach, level playing field, and transparency. With regard to the procedures for calculating a building's energy performance though, it leaves room for Member States to differentiate at national or regional level[2].

Two quotes from the EPBD on this are:

- From Art 3: 'Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values and may take into account relevant European standards'
- From Annex I: 'The energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on-site production. The methodology for calculating the energy performance of buildings should take into account European standards and shall be consistent with relevant Union legislation, including Directive 2009/28/EC'

The relevant standard for primary energy factors is CEN standard EN 15603 'Energy performance of buildings. Overall energy use and definition of energy ratings.' It provides the calculation procedure to determine the annual overall energy use for heating, cooling, hot water, ventilation, and lighting. This standard is part of a series of CEN standards to support the EPBD[2].

A building generally uses more than one energy carrier, such as gas, coal, oil, wood, district heating or cooling, electricity, et cetera. Therefore, a common expression of all energy carriers is essential in order to aggregate the amounts used, which are otherwise sometimes expressed in different units and always leading to a variety of impacts. Clause 8 of the EN 15603 standard offers the following aggregation methods:

- Primary energy rating
- CO2 emissions rating
- National 'policy energy rating'

The first one is compulsory according to the EPBD. We report below how the primary energy rating is dealt with in the EN 15603 standard.

2.2 EN 15603

According to EN 15603, the primary energy factor always accounts for the extraction of the energy carrier and its transport to the utilization site, as well as processing, storage, generation, transmission, distribution, and delivery. Including the energy required in building transformation units and transportation systems, as well as in cleaning up or disposing of wastes, is optional.

There are two definitions of the primary energy factor (example-values are shown in the next chapter).

Total primary energy factor
All the energy overheads of delivery to the point of use are taken into account in this version of the conversion factor, including the energy from renewable energy sources. Consequently, this primary energy conversion factor always exceeds unity.

Non-renewable primary energy factor
As above, but excluding the renewable energy component of primary energy.
The renewable portion of delivered energy is considered as zero contribution to the primary energy use. Consequently, for a renewable energy carrier, this normally leads to a factor less than unity (ideally: zero).

If the primary energy rating is supposed to express the use of a fossil or other non-renewable or polluting energy source, this is the version to be used.

The CEN standards also reports recommended values for primary energy factors for electricity generation from various sources and from electricity generation from a UCPTE mix. Some of these values are given in the table below.

Table 2 - 1 Primary energy factors recommended in Annex E of CEN 15603:2008 (for full table in German see Appendix C).

Electricity generation type	Primary Energy Factor—non renewable	Primary energy factor—total
Hydroelectric power	0.5	1.5
Nuclear energy	2.8	2.8
Coal plant	4.05	4.05
Electricity mix UCPTE	3.14	3.31

Table 2-1 contains informative values of the primary energy factors from the national electricity mix. However, energy is not only consumed in (or near) buildings but can also be produced.

A distinction is made between primary energy factors of imported (delivered) energy and exported energy. These need not be the same. For example, for electricity: the exported electricity may be considered as competition for other new (high efficiency) electricity plants and/or may be considered as saving off-peak load rather than base load, while the delivered electricity in most countries is regarded as the national mix of existing plants that deliver to the grid. This is to be determined at the national level. For example, in the Netherlands, delivered electricity has a factor of 2.56 and exported electricity from CHP a factor of 2.00.

EN15603 says that, per energy carrier, the exported energy can be subtracted from the imported energy:

$$E_P = \sum (E_{del,i} f_{P,del,i}) - \sum (E_{\exp,i} f_{P,\exp,i})$$

Where
E_P = The primary energy demand
$E_{del,i}$ = final energy demand of energy carrier i
$f_{P,del,i}$ = primary energy factor for demand energy carrier i
$E_{\exp,i}$ = exported final energy of energy carrier i
$f_{P,\exp,i}$ = primary energy factor for export energy carrier i

The primary energy factors for demand and export need not be the same.
If they are, then the production is in effect subtracted from the demand, per energy carrier.

These factors are determined taking into account all upstream and downstream losses and therefore result in rather high values.

It should be noted that the values in Table 2-1 differ from what is proposed in some other official EU documents. For example the Annex of the Energy Services Directive recommends using values of 2.5 for the entire EU.

It should also be noted that while this standard is advisory to national governments, there is no obligation to precisely follow the standard.

Efforts are also taken to bring the CEN standardization of energy performance in buildings to ISO (world) level.

Within ISO, the ISO/TC 163/WG 4 (Joint Working Group of ISO TC 163 and TC 205 on energy performance of buildings using a holistic approach) is responsible for the coordination of the work on the energy performance of buildings. This joint WG has two co-convenors, Mr Dick van Dijk (the Netherlands) and Mr Essam E. Khalil (Egypt). This ISO joint working group agreed to use the CEN/EPBD standards as a major input to their work and is seeking further improvement of these standards, based on the current experiences in the European arena as well as aiming at improved EN ISO standards in the near future. One of the standards under preparation is based on EN 15603 (Overall energy use and definition of energy rating). Within that context, an inventory is being taken of the primary energy conversion factors used in various countries.

3 National primary energy factors

3.1 Method

Ecofys examined the relevant national standards of Germany, the Netherlands, and the UK, and talked to individuals in order to clarify issues when necessary.

Assistance from individuals and organizations outside of Ecofys was obtained for the other countries (see Foreword).

A standard reporting format was created for respondents to fill in. The standard reporting format and the reports from the various countries can be found in Appendices A through E.

Comprehensive information on how primary energy factors in the various countries are determined was not readily available in the national energy performance standards. Additional efforts involving personal contact with individuals and examination of relevant national documents were required to procure this information from several countries. In many cases there are no clear references or documents available that provided answers on how PEFs are determined, because the PEFs were to some extent a political factor.

3.2 Results

The primary energy factors for electricity generation as reported in the national standards on energy performance for buildings are shown in the table below.

Table 3 - 1 Primary Energy Factors (PEFs) for electricity generation used in energy performance for building regulation in reported countries

	France	Germany	NL	Poland	Spain	Sweden	UK
PEF	2.58	2.6	2.56	3	2.6	2	2.92

3.3 The algorithm

The primary energy factor for electricity generation depends on a number of elements, including:

1. For non-renewable (fossil and nuclear) and renewable plants: upstream losses associated with extraction of fossil fuels taken into account?
2. Are downstream losses (transmission and distribution losses) taken into account?
3. What efficiency is taken into account for conversion into electricity of non-renewable energy carriers?

4. Are state-of-the art or average efficiencies used?
5. How is renewable energy taken into account (0 or 1)?
6. How is CHP taken into account (what fraction is assigned to electricity)?
7. What is the mix of different energy carriers in the electricity mix?

As already explained, little information is given in the national standards on how the Primary Energy Factors are derived. Efforts have been made to find this out for several countries by contacting individuals and by examining related national documents. The results to date are summarized in Table 3-2.

Table 3 - 2 Overview on Primary Energy Factors (PEFs) and arguments used for PEFs in various countries. N.B. When italics are used, this value is assumed to be likely.

	France	**Germany**	**NL**	**Poland**	**Spain**	**Sweden**	**UK**
% RE	12.8%	10.3%	4.2%	2.7%	22.3%	50.2%	4.7%
PEF	2.58	2.6	2.56	3	2.6	2	2.92
PEF (RE=0)	2.63	2.54	2.30	3.23	1.78	1.60	2.43
PEF (RE=1)	2.77	2.65	2.35	3.26	2.01	2.14	2.48
Political?	Y	N	Y			Y	
RE factor	Unclear	Unclear	>0	unclear	>0	>0	>0
Upstream losses?		No	No	Yes	Yes	No	Yes
Downstream losses?		Yes	Yes	Yes	Yes		Yes
RE produced + consumed on site	Deducted demand	Deducted demand	Deducted demand		Deducted demand		Deducted demand
RE produced + exported on site			2				2.92
Updates?		Yes	No				Yes

In the above table, we first report the shares of renewable energy[1]. Next, the PEFs used in the various countries are reported. Two PEF calculations follow, one with a renewable factor 0 and one with a renewable factor 1. These factors include downstream losses and exclude upstream losses. Following the advice of CEN 15603, a weighting factor of 2.8 has been used in the calculations for nuclear generated electricity.

[1] From ECI spreadsheet. The numbers are in some cases on the low side, but for simplicity and because it will not change anything to the results we adhered to these numbers.

Next, a comment is made on whether the PEF is the result of a clear algorithm or the result of a political process (or mix of those). As previously mentioned, No clear algorithm is laid down in a report for the factors of France, the Netherlands, and Sweden. A comment has been made addressing this in the Dutch regulation (see Appendix A). The Swedish Energy Authority does not support the concept of primary energy factors. Consequently, there were no official primary energy factors published for application in Sweden. It seems that a 'political primary energy factor' has been set only for the building performance regulation. There, electricity is assigned a factor of approximately 2, while direct fuel or gas is 1.

Moving down one row in the above table, the factor for renewables that is actually used is reported. This was not clear in many cases, especially in countries where the factor is the result of a political process rather than a scientific calculation. For the Netherlands and Spain, documents from government agencies reporting RE> 0 have been found (see Appendices). Spain is the only country that reports PEFs of individual electricity generation technologies: the factor for nuclear is 3.03, for PV, wind and hydro it is 1, for CSP = 4.56. It appears that countries with a low share of renewables in the national mix do not consider it to be an issue yet. The two countries with high fraction of renewables (Spain and Sweden) in their mix have a fairly large PEF, suggesting a RE-factor > 0.

Moving on to the next row in the table, it is indicated whether upstream losses are taken into account. This was usually not explicitly reported. However, it can be deduced from the PEFs for fossil fuels: if the reported PEFs for, e.g. gas = 1, it is assumed that upstream losses for electricity have not been taken into account either. This was the case for the Netherlands and Sweden. In the UK and Poland, PEFs for fossil fuels are > 1 and therefore it is assumed that upstream losses are taken into account for electricity as well.

All the factors and issues discussed up to this point relate to the PEF for electricity delivered from the national electricity mix. As mentioned in the previous chapter, a different PEF may be used for electricity generated on-site.

Row 'RE on-site' reports how on-site renewables are treated.

In most cases, produced renewable electricity can be deducted from the electricity consumption of the building, up to the amount of the electricity consumption. Beyond this amount, it is considered to be exported. Only the Netherlands has a factor that differentiates the delivery of this electricity.

It was first thought that an average contribution for consumption due to appliances was taken into account in the UK. Further research revealed that this is only used for special subsidy or tax deduction purposes and not for the purpose of determining the energy performance of a building in regard to building regulations.

In the Netherlands, a standard has recently been issued wherein an average contribution of appliances is used to increase the amount of electricity produced on-site and that can be deducted from demand rather than exported. The deduction can take place in different ways:

1. Subtract the yearly totals of demand and production
2. Subtract on the basis of smaller time intervals to take into account simultaneity of production and demand

In practice, only yearly totals are used for the countries cited in the research.
For further details on the factors, refer to the appendices.

4 Developments electricity mix until 2050

An increasing share of renewables in a country will affect the emissions related to the use of energy, which is accounted for by a change of the primary energy factor used for electricity.

4.1 Methodology

In order to see how the primary energy factors might develop in France, Germany, the Netherlands, Poland, Spain, Sweden, and the United Kingdom, potential scenarios regarding the development of renewables shares were used to calculate resulting primary energy factors. Two future reference years were chosen for calculation: 2020 and 2050. The same methodology was applied for the new calculations as that employed for calculating the actual 2009 values[2].

4.2 NREAPs and scenarios as basis

2020: National Renewable Energy Action Plans

Under the terms of the Renewable Energy Directive, all EU Member States were required to deliver National Renewable Energy Action Plans (NREAPs) to the EU Commission by June 2010. By the end of the year, all Member States had submitted them[3]. Each country has to describe how they intend to reach the renewables targets set by the EU for the year 2020. A trajectory of the expected development of renewables shares in the heating/cooling, electricity, and transport sectors is included in Table 3 of the NREAP. This projected electricity renewables share of the NREAP was used in calculating the potential 2020 primary energy factors for each country.

2050: energy [r]evolution

No EU targets for Member States have been set yet for the year 2050. A scenario was therefore chosen as basis for the calculation. Any values for 2050 are of course subject to a high level of uncertainty. We took the EREC/Greenpeace energy

[2] For the remaining non-renewable part of electricity production, we assumed the shares of nuclear and thermal production to stay constant, i.e. if in 2009, 20% of the electricity in a country was produced from renewables, 40% from nuclear and 40% from thermal plants, the shares of non-renewables is split 50% for nuclear and 50% for thermal. If in 2020 the country generates 50% from renewables, than the remaining 50% would be split to nuclear and thermal plants according to their 2009 shares, thus 25% each.

[3] http://ec.europa.eu/energy/renewables/transparency_platform/action_plan_en.htm

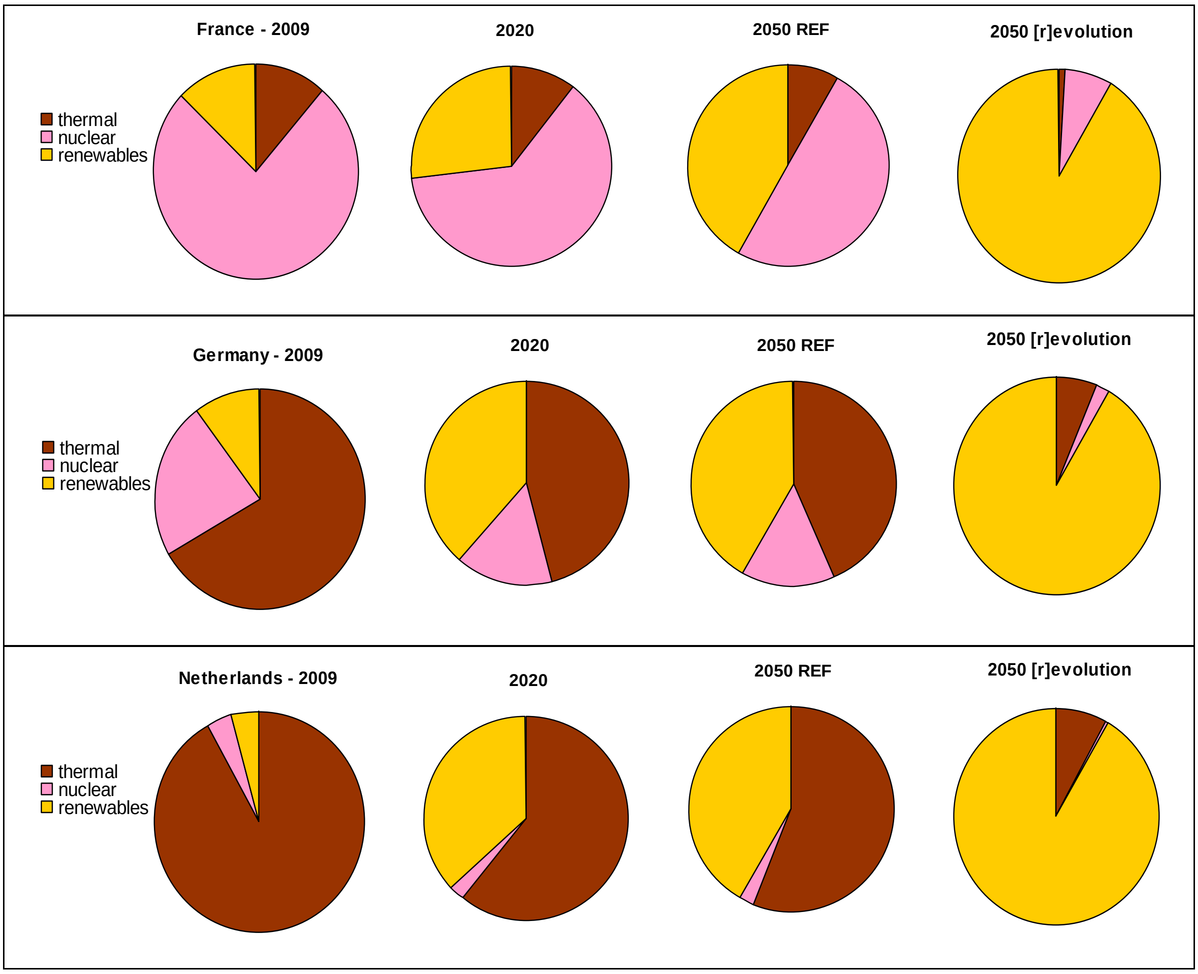
[r]evolution scenarios 2010[4] as our basis in order to show a 'corridor of possibilities.' This corridor includes:

a) A relatively conservative reference scenario based on the International Energy Agency's World Energy Outlook 2009
b) The energy [r]evolution scenario with the aim of drastically reducing the world's CO_2 emissions and thus exploiting renewables to a very high level

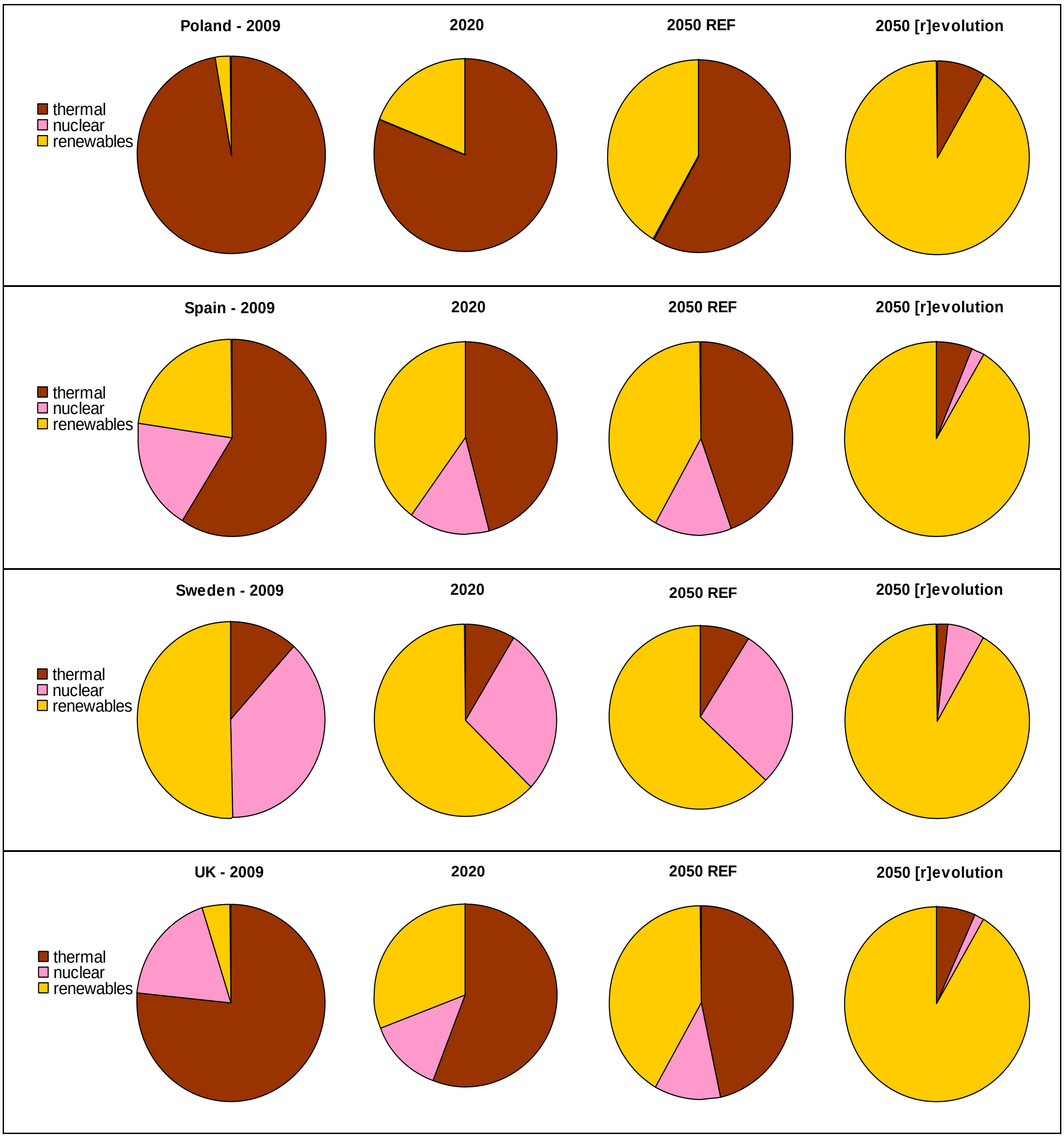
The shares of renewables that these scenarios project for Europe in 2050 were applied to all countries in the 2050 calculation with the exception of Sweden. Sweden has already set a higher goal for their renewables share in electricity production in 2020 than that of the Europe-wide share in the reference scenario for 2050.

4.3 Development of the electricity mix

The following graphs show the development of nuclear, thermal plants, and renewable shares resulting from the assumptions described above.



[4] EREC/Greenpeace: energy [r]evolution – a sustainable world energy outlook. 3rd edition, June 2010



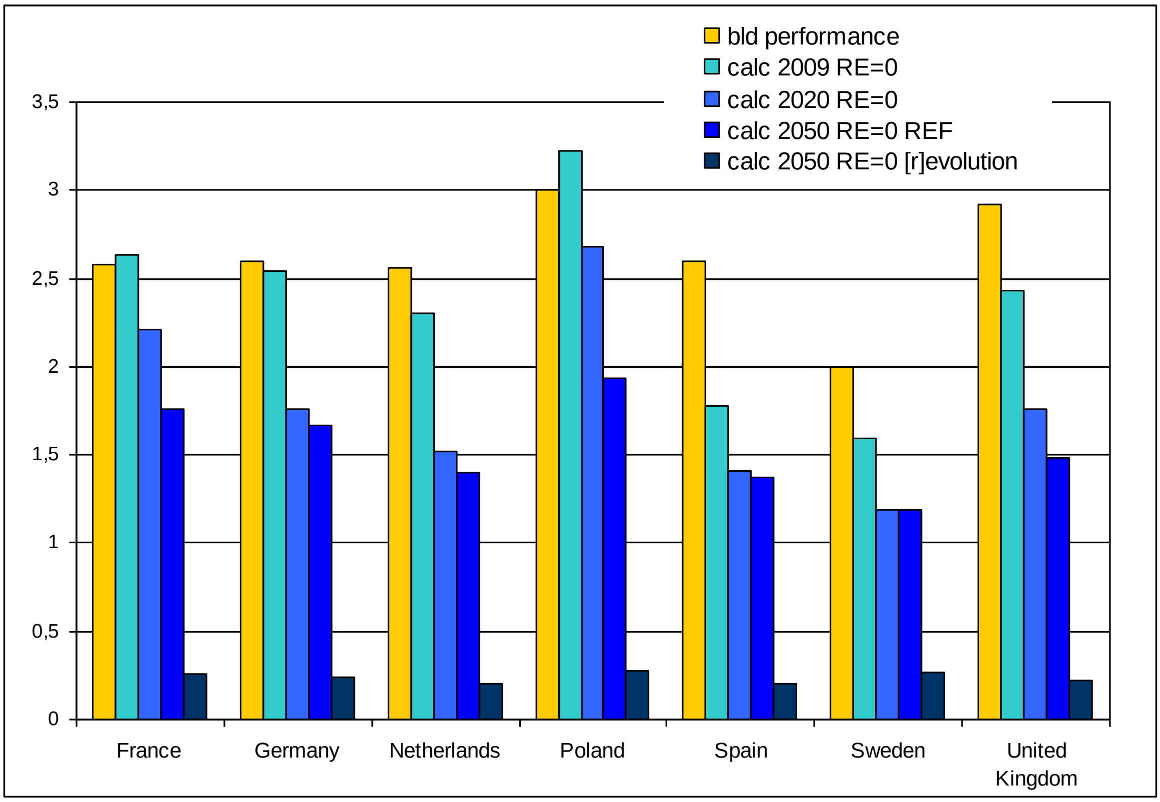
4.4 Development of primary energy factors

This growing share of renewables will result in decreasing primary energy factors. As with the two 2050 scenarios, the calculation of resulting primary energy factors was also done for two cases:

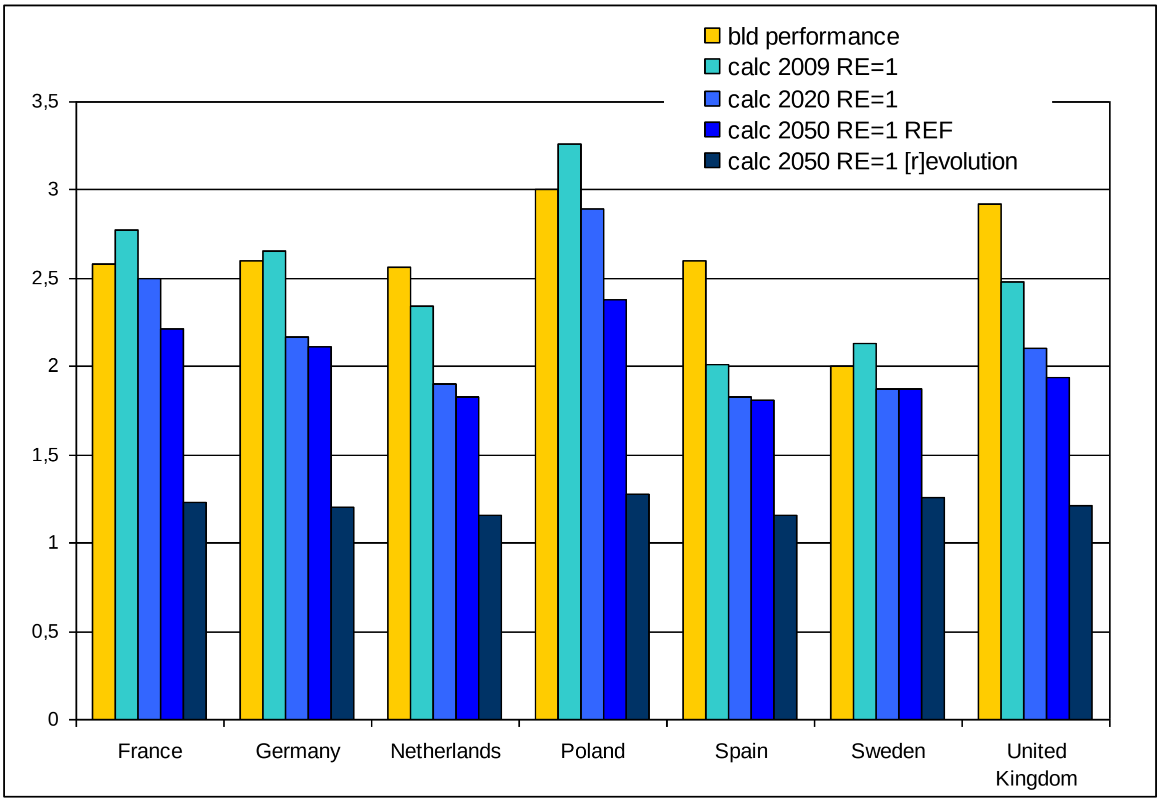
a) The factor used for renewable energies is 0
b) The factor used for renewable energies is 1

All other assumptions remained the same.

The results for the primary energy factors are depicted in the following graphs. The yellow bar is the factor actually used in the country's performance standards for buildings. The blue bars indicate the calculated factors for the years 2009, 2020 and both 2050 scenarios. The development of the factors and level of decrease depends on the country's initial situation, which are very different with regard to their current shares of renewables as well as their shares of thermal and nuclear plants. Poland for example starts with the highest factor for electricity (actually used as well as calculated) while Sweden, due to its highly developed hydroelectric power, has the lowest initial factors. Using a factor of 0 for renewable electricity, the primary energy factors for electricity would be between 1.2 and 2.7 in 2020, and range from 1.2 to 1.9 in the reference scenario and 0.2 and 0.28 in the [r]evolution scenario for 2050.



A factor of 1 for renewable electricity would generally yield higher overall primary energy factors. The factors would currently vary between 1.6 and 3.2 (actually used) or 2.01 and 3.26 (calculated for 2009), and would be projected to decrease in 2020 to factors between 1.8 and 2.9. In the year 2050, the primary energy factors would further decrease to values between 1.8 and 2.4 in the reference scenario and 1.16 and 1.28 in the [r]evolution scenario.


bld performance
calc 2009 RE=1
calc 2020 RE=1
calc 2050 RE=1 REF
calc 2050 RE=1 [r]evolution
3,5
3
2,5
2
1,5
1
0,5
0
France
Germany
Netherlands
Poland
Spain
Sweden
United Kingdom

5 Implications for technologies used in the building sector

5.1 From the previous chapters

Summarizing the observations relevant for this project from the previous chapters:

Renewable energy in the PEF for delivered electricity
(Delivered means delivered from the grid to the local project/building).
The primary energy factors for delivered electricity currently used in most countries is ±2.6. The UK and Poland have higher numbers (± 3) and Sweden has 2. It is striking that the two countries with the most renewables, Spain and Sweden, are the most conservative with their PEF. Poland is the only country with an optimistic PEF, considering the value calculated based on their energy mix. The other countries use values that are reasonably in line with calculated numbers.

Most countries take renewable energy into account as non-zero, even though it is not clear what number is exactly used and their exact algorithm is not known. There are clear signals that the PEFs for France, the Netherlands, and Sweden do not arise from purely scientific arguments and a clear algorithm. If we assume the factor for renewables to be 1, the primary energy factors will converge to 1 as the penetration of renewables increases as 2050 approaches. Our own calculations show that by 2020, however, the factors for most countries are still expected to hover around 2 (or 2.5 to 3 in the case of Poland).

Renewable energy in the PEF for produced electricity
In most countries, renewable electricity produced on-site can be deducted from the electricity demand. This implies that the same PEF is used for produced electricity as for delivered electricity. In the UK, the Netherlands, and a few other countries, export of electricity is possible and counts towards the energy performance of the building. Even though a number of options theoretically exist for this deduction, it seems that in practice all countries more or less employ the same method, which is: (1) subtraction of yearly totals, not taking into account whether demand and production take place at the same time, (2) subtraction from the electricity demand that is composed of building related electricity demand only (heating, cooling, ventilation, (de)humidification, lighting), not taking into account a contribution from users and their appliances. In France, a limit for production of PV that counts toward the performance of the building is imposed for homes, but not in the tertiary sector.

5.2 Implications for technology choices

PEF for delivered electricity

It can be expected that as PEFs for delivered energy decrease with increased incorporation of renewable energy into the national energy mix, this will be a stimulus for a fuel shift from oil or gas to electric heating. In general, electricity consumption will weigh less heavily in the total for the overall energy performance of the building. For example, air conditioning will contribute less to lowering the energy performance of a building. Therefore, it could also have the effect that use of efficient equipment (for ventilation, lighting, air conditioning) is not stimulated as much as with higher PEFs. As this is an undesirable effect, quite likely steps will be taken to remedy this should it become an observed trend. Such remedies might include the setting of minimum energy-efficiency performance standards through the ErP directive, in combination with labelling.

As already mentioned, the process of changing PEFs will be gradual, but with significant changes already apparent by 2020. It is logical to expect that countries will revise their PEFs on a regular schedule, e.g. every 3 to 5 years.

If a country such Spain, with much higher actual PEFs than those calculated, should start to use a PEF that is more in line with calculated values based on the national mix and a renewable factor of 1, then this would have an immediate lowering effect on their PEF.

PEF for produced electricity

As the countries investigated have chosen not to differentiate in the PEF for delivered and produced electricity, they have given a maximum benefit to renewables on-site from a PEF perspective.

Production of renewable electricity on-site can improve the energy performance of a building by reducing the overall electricity demand. If heat pumps are used as a heating option, this will increase the electricity demand (compared to using a gas boiler for example), enabling a larger amount of renewable electricity to be incorporated into the project, and therefore enabling greater improvement in the energy performance of the project. If the level of ambition is high, a heat pump and renewable electricity can be a good combination. If the ambition in a project is to just meet the minimum standards, it will not make much difference how much renewable electricity can be precisely deducted.

Assuming that countries retain the coupling between the PEF for delivered electricity and produced electricity, lowering PEFs for delivered electricity—and thereby lowering PEFs for produced electricity—would give on-site renewable electricity a less positive impact on the energy performance.

Another issue to consider when looking at produced electricity is the possibility of taking into account use-related electricity consumption into the building's performance. This is especially the case as buildings become more efficient and front-runner projects move toward very low or zero energy buildings. The point is ripe for debate whether taking into account user-related electricity consumption (from appliances such as computers, etc.) into a building's performance calculations makes sense. User-related consumption in such buildings exceeds the building related consumption and therefore the electricity demand in the building performance calculations would more than double. This would enable a larger amount of renewable electricity to be 'rewarded' in the building energy performance system.
In the UK, they do not take into account a user related component for the energy performance for buildings. However, in order to be eligible for a certain tax deduction, a calculation is made that does take an average contribution from cooking and appliances into account[3].

In the Netherlands, an appliance contribution is determined in the recently issued standard (April 2011). An average contribution of appliances is used to increase the amount of electricity produced on-site and that can be deducted from demand rather than exported. This contribution does not influence the final energy performance directly by increasing the demand, but it does allow for a greater deduction of renewable electricity produced on-site (and therefore can indirectly influence the building's energy performance).

5.3 A flexible electricity mix

Some of the technologies mentioned in the previous paragraph may have a beneficial effect on the flexibility of the electricity supply. With the increased incorporation of renewables in the national electricity mix, flexibility (the ability to modulate energy demand with variable supply) becomes increasingly important. For example, heat pumps generate heat that is then stored in the building (through buffer tanks with water).

To what extent does equipment that aids to electrification of the energy supply increase the flexibility of the electricity supply? To get a better grip on this question, we first composed a list of technologies that may possibly contribute to this flexibility, either as DSM (Demand Side Management) or on the supply side. The focus was on new technologies—at least new from the viewpoint of introducing greater flexibility.

On the supply side, new flexible technologies might include:

- CHP in combination with heat storage
- CSP (Concentrating Solar Power) with heat storage (Southern Europe)

On the demand side:

- Heat pumps (in winter)
- Air conditioning in combination with ice storage (in summer)
- Electric heating in passive homes (in winter)
- Cooling applications in the services sector[4]
- Electric and plug-in hybrid cars
- Micro and mini-CHP (in combination with heat storage)

Without claiming this list to be complete, it does reveal that many technologies can already have an influence on the flexibility of the electricity supply. Going into the details of the effects of each of these technologies on the flexibility of the electricity is beyond the scope of this study. Instead, we will comment on some of the electricity-based technologies that are within scope of this study:

- Heat pumps: it has already been mentioned that heat pumps have some degree of flexibility, because the heat they generate can be stored[5]. On the other hand, grid regulators also have qualms about large scale introduction of the heat pumps, because they could generate a tremendous peak load when people come back from skiing vacation in mid winter[6].
- Electric heating in passive homes: it is currently unclear whether electric boilers will be allowed under Ecodesign. An implementing measure on boilers could be ready by this summer or fall. Such a combination would in any case require tough building inspection and commissioning to ensure passive homes are built according their specifications.
- Air conditioning in combination with ice storage. If electricity flexibility is needed in the winter (which function can be fulfilled by heat pumps), quite likely flexibility is also necessary in summer. Air conditioners with ice storage have been developed that can fulfil this function. The equipment is manufactured in the US[7].

At present, regulations for energy performance of buildings do not reward flexibility.

5.4 Outlook for PEFs

The discussion above raises the question as to what Primary Energy Factors are most desirable if one favours electrification of the energy supply (for reasons of flexibility), without compromising and preferably increasing the sustainability of the energy supply? What is a reasonable expectation?

We have seen that lower PEFs for electricity delivery can favour electrification, but they can also impede increased efficiency of electricity consumption. A PEF of 0 for the contribution of renewables needs to be combined with stringent attention to energy efficiency.

We have also seen that lower PEFs for produced electricity can mean a decreased stimulus for locally produced renewable electricity.

There may also be possible solutions that enable a lower PEF without negative effects. Numerous calculation methods for Zero Energy Buildings are around at present[8]. One proposed calculation method is to separate the calculation of the demand and that of the supply to a building. In other words, the demand for energy is minimized first, then decisions are made on how the necessary energy is supplied, taking into account the efficiencies of these methods and the PEFs of the energy carriers. Incorporating this into the calculation methods for the energy performance of buildings would solve the issue of a lower PEF for electricity hindering electricity efficiency. In fact, a provision is already built into current French building regulations that prevent the compensating of an inefficient building with a lot of local renewables. They require a certain efficiency in the demand of the building before calculating the effects of supply and demand together.

6 Conclusions and recommendations

The following Primary Energy Factors (PEFs) for delivery of electricity to a building or project have been found in the national building regulations of these seven countries:

	France	Germany	NL	Poland	Spain	Sweden	UK
PEF	2.58	2.6	2.56	3	2.6	2	2.92

The PEF for the majority of these countries hovers around 2.6. The only countries with a renewable electricity share that is large enough to significantly influence the PEF at present are Spain and Sweden. Spain uses a PEF that is much higher than what would normally be expected based on a calculated value with a weighting factor for nuclear = 3 and renewables = 1. For Sweden, the factor for renewables is between 0 and 1, and assumes a factor for nuclear of 3.

Most countries take renewable energy into account as non-zero, even though neither the exact number used nor the exact algorithm is known. There are clear signals that the PEF does not arise from purely scientific arguments and a clear algorithm for France, the Netherlands, and Sweden. If we assume the factor for renewables to be 1, the primary energy factors will converge to 1 as the penetration of renewables increases towards 2050. However, using our own calculation methods and discarding any political arguments that might change this trend by 2020, the factors for most countries will still remain around 2 (or 2.5 to 3 in the case of Poland).

If the PEFs are adjusted downwards with an increasing renewable electricity share in the national mix, it could influence the balance between the shares for electric heating versus other methods of heating. It could, for example, provide a further positive impulse for heat pumps. However, lower PEFs could also result in a decreased stimulus to make building-related electricity consumption such as that for lighting, ventilation, or air conditioning more efficient.

The countries investigated have chosen not to differentiate between the PEF for delivered and produced electricity. They have provided a maximum benefit to on-site renewables from a PEF point of view, enabling subtraction of renewable electricity from the electricity demand.

Assuming that countries retain the present coupling between the PEF for delivered electricity and produced electricity, lowering PEFs for delivered electricity and thereby lowering PEFs for produced electricity would give renewable on-site electricity less impact on improving the energy performance (to the same extent that the impact of electricity consumption will be less). This is however unlikely to affect the development of such renewables, as adequate financial support mechanisms are in place for small-scale systems in many countries.

PEFs are not based entirely on scientific arguments and clear algorithms. Given the significant changes that lie ahead for electricity supply, the PEF for electricity should be revised regularly and its method of calculation clearly documented and eventually harmonized. A falling PEF has the negative effect of a lower stimulus for efficiency in most current calculation methods. Even though minimum requirements for building-related energy efficiency are already regulated through the ErP Directive, there is no stimulus for choosing the most efficient solution other than through regulations regarding building performance. However, this could be avoided if the calculations for demand are separated from the calculation of supply, as was proposed during discussions concerning calculations for determining Zero Energy Buildings.

We also briefly discussed which building-related electricity demand options could positively influence the flexibility of the electricity supply. Flexibility of the electricity supply certainly has a demand side management component, but the discussion is not dominated by this[9]. The extent to which increased flexibility of the electricity supply through incorporation of heat pumps can be a driver is a topic of further study.

Based on the above findings, the following recommendations are made:

- Given the strong move toward zero energy buildings, there is a case for taking appliances into account in the electricity demand. This would provide greater reward for renewable electricity on-site, as it would at least double the electricity demand and enable compensation of this demand through renewable electricity.
- It is worthwhile to take a closer look into the discussions on calculation methods for zero energy buildings. We believe they may provide new ways of calculating energy performance for buildings that do not have negative effects of lower PEFs. For non-ZEBs, special care needs to be given to ensure that low PEFs do not lead to lower energy efficiency.
- For countries that use much higher PEFs than those calculated based on their national electricity mix (Sweden and Spain), more work should be done to find out the details of the decision-making process behind the PEFs previously used and those to be used in the future.
- Considering the rapid evolution of the electricity system, PEFs need regular revision, e.g. every 3 to 5 years.
- PEFs are used as a political factor, with sometimes unclear calculation methods. As a minimum, the calculation method to produce a PEF should be documented, especially for renewable electricity systems.

Appendix A Primary Energy Factor—the Netherlands

A 1 Value used for electricity generation

39% (2.56)
50% (2.00) in case of electricity produced by CHP (within the project boundaries)

Reference:
NEN 2904:2004, 'Energieprestatie van utiliteitsgebouwen—Bepalingsmethode' ('Energy performance of non-residential buildings—Determination method')

A 2 Algorithm and assumptions used for value parameters

Exact algorithm not stated.

Stated:
Electricity production of average park, based on upper heating value, taking into account grid losses.

Also stated:
'Bij de vaststelling van de rekenwaarde van het rendement van de elektriciteits-voorziening is mede rekening gehouden met beleidsmatige overwegingen van de overheid.' Translation: 'Attention was given to government policy considerations when determining PEF values.'

Reference for algorithm:
NEN 2904:2004, 'Energieprestatie van utiliteitsgebouwen—Bepalingsmethode' ('Energy performance of non-residential buildings—Determination method')

Weighting factor nuclear:
Not stated, 33% (3) is likely.

Weighting factor renewables:
Not stated, 100% (1) is likely.

Thermal efficiency fossil plants:
Not stated

Thermal efficiency for electricity CHP plants:
Not stated

Comments:
A draft report reporting on alternatives for heat supply discusses various ways of determining conversion factors for primary energy used to generate electricity. They use 33% for nuclear and 100% for renewables and mention a power plant thermal efficiency of 49% on lower heating value.

Using 39% results in a factor of 2.56, whereas the spreadsheet reports 2.35 when using 3 for nuclear and 1 for renewables.
It appears that the number 39% has been used for a long time without having been updated to the latest developments in renewable energy production and thermal efficiency of fossil power plants.

In the Netherlands, 50% of all electricity is produced by CHP. Therefore, the discussion on allocation of primary energy to heat vs. electricity also plays an important role in determining the thermal efficiency.

Other references:

1. Uniforme Maatlat voor de warmtevoorziening in de woning—en utiliteitsbouw, Een protocol voor het vergelijken van alternatieven voor de warmtevoorziening op bouwlocaties—concept, feb. 2011. Page 79

Appendix B Primary Energy Factor—the UK

B 1 Value used for electricity generation

2.92 for all electricity, including that produced from CHP

Reference:
SAP 2009: The Government's Standard Assessment Procedure for Energy Rating of Dwellings—2009 edition

B 2 Algorithm and assumptions used for value parameters

No algorithm stated

Reference for algorithm:
-

Weighting factor nuclear:
Not stated

Weighting factor renewables:
Not stated

Thermal efficiency fossil plants:
Not stated

Thermal efficiency for electricity CHP plants:
Not stated

Comments:
The UK government adopted the Government's Standard Assessment Procedure for Energy Rating of Dwellings, in short SAP, as part of the national methodology to calculate the energy performance of buildings. It is also used to demonstrate a building's compliance with building regulations in England and Wales, Scotland, and Northern Ireland.

The current SAP 2009, which was revised in October 2009, has been applied since October 2010 to demonstrate a building's compliance with building regulations in England, Wales, and Scotland. New conditions will be decided for Northern Ireland at a later date.

In the former SAP 2005, the primary energy factor for all electricity, including CHP, was set at 2.8.

The SAP 2005 was still used for the issuing of Energy Performance Certificates; this was switched to SAP 2009 as of March 2011.

Other references:

2. . http://www.bre.co.uk/sap2009/page.jsp?id=1642
3. SAP 2005: The Government's Standard Assessment Procedure for Energy Rating of Dwellings. 2005 EDITION

From SAP 2009

Table 12: Fuel prices, additional standing charges, emission factors and primary energy factors

Fuel	Additional standing charge, £[a]	Unit price p/kWh	Emissions kg CO_2 per kWh	Primary energy factor	Fuel code
Gas:					
mains gas	106	3.10	0.198	1.02	1
LNG	106	3.10	0.198	1.02	8
bulk LPG	70	5.73	0.245	1.06	2
bottled LPG		8.34	0.245	1.06	3
LPG subject to Special Condition 18 [b]	106	3.10	0.245	1.06	9
Oil:					
heating oil		4.06	0.274	1.06	4
biodiesel from any biomass source [c]		5.7	0.047	1.30	71
biodiesel from used cooking oil only [d]		5.7	0.004	1.08	72
rapeseed oil		5.7	0.009	1.12	73
appliances able to use mineral oil or liquid biofuel		4.06	0.274	1.06	74
B30K [e]		4.6	0.193	1.06	75
bioethanol from any biomass source		42.0	0.064	1.34	76
Solid fuel: [f]					
house coal		2.97	0.301	1.02	11
anthracite		2.86	0.318	1.02	15
manufactured smokeless fuel		3.73	0.347	1.08	12
wood logs		3.42	0.008	1.05	20
wood pellets (in bags for secondary heating)		5.45	0.028	1.20	22
wood pellets (bulk supply for main heating)		4.93	0.028	1.20	23
wood chips		2.49	0.009	1.07	21
dual fuel appliance (mineral and wood)		3.21	0.206	1.04	10
Electricity:					
standard tariff		11.46	0.517	2.92	30
7-hour tariff (high rate) [g]		12.82	0.517	2.92	32
7-hour tariff (low rate) [g]	27	4.78	0.517	2.92	31
10-hour tariff (high rate) [g]		11.83	0.517	2.92	34
10-hour tariff (low rate) [g]	18	6.17	0.517	2.92	33
24-hour heating tariff	57	4.64	0.517	2.92	35
electricity sold to grid		11.46 [h]			36
electricity displaced from grid			0.529 [h]	2.92 [h]	37
electricity, unspecified tariff [i]					39
Community heating schemes: [j]	106 [k]				
heat from boilers – mains gas		3.78	0.198	1.02	51
heat from boilers – LPG		3.78	0.245	1.06	52
heat from boilers – oil		3.78	0.297 [l]	1.06	53
heat from boilers – B30D [e]		3.78	0.199	1.06	55
heat from boilers – coal		3.78	0.350 [m]	1.02	54
heat from electric heat pump		3.78	0.517	2.92	41
heat from boilers – waste combustion		3.78	0.040	1.28	42
heat from boilers – biomass		3.78	0.013 [n]	1.07	43
heat from boilers – biogas (landfill or sewage gas)		3.78	0.018	1.10	44
waste heat from power station		2.65	0.058 [o]	1.20	45
geothermal heat source		2.65	0.036	1.16	46
heat from CHP		2.65	as above[p]	as above[p]	48
electricity generated by CHP			0.529 [h]	2.92 [h]	49
electricity for pumping in distribution network			0.517	2.92	50

Appendix C Primary Energy Factor—Germany

C 1 Value used for electricity generation

2.6 for the non-renewable share of electricity. Electricity produced from renewable energy sources directly connected to the building can be deducted from the final energy demand.

Reference:
EnEV 2009: „Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Energieeinsparverordnung—EnEV) (Energy Saving Ordinance)

C 2 Algorithm and assumptions used for value parameters

No algorithm stated

Reference for algorithm:
EnEV 2009: „Verordnung über energiesparenden Wärmeschutz und energiesparende Anlagentechnik bei Gebäuden (Energieeinsparverordnung—EnEV) (Energy Saving Ordinance)

Weighting factor nuclear:
Not stated, 33% (3) is likely

Weighting factor renewables:
Not stated, 100% (0) is likely

Thermal efficiency fossil plants:
Not stated

Thermal efficiency for electricity CHP plants:
Not stated

Comments:
In the first version of the 2002 Energy Saving Ordinance, the primary energy factor for electricity was 3.0. In the 2007 revised version, the factor was 2.7. The current version (2009) has the value of 2.6.
Recently there has been a publication researching the actual primary energy factor that should be used in Germany in the year 2010. This study concludes that due to the increase in the number of renewable energy sources, the actual primary energy factor

has decreased to a factor of around 2.4 and will probably decrease further to around 2.3 in 2012, 2.1 in 2015, and 1.8 in 2020.
There are discussions underway regarding updating the current factor of 2.6 in EnEV, but no decisions have been made as yet.

Other references:

4. EnEV 2007: Energy Savings Ordinance from 2007. http://bmwi.de/BMWi/Redaktion/PDF/Gesetz/enev-novelle-2007,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf
5. Öko 2011: Der nichterneuerbare Primärenergieverbrauch des nationalen Strommix in Deutschland im Jahr 2010. Öko-Institut Darmstadt, 2011.

Appendix D Primary Energy Factor—Poland

D 1 Value used for electricity generation

3.0

Reference:
Regulation of the Polish Ministry of Infrastructure of 6 November 2008 on the 'methodology of calculation of energy characteristics of buildings, living apartments, or parts of buildings which constitute a separate technical and usable entity as well as on a method of preparation and forms of energy certificates of buildings' (Dz.U. 2008, nr. 201, position 1240).

D 2 Algorithm and assumptions used for value parameters

No algorithm stated

Reference for algorithm:
-

Weighting factor nuclear:
Not stated

Weighting factor renewables:
Not stated

Thermal efficiency fossil plants:
Not stated

Thermal efficiency for electricity CHP plants:
Not stated

Comments:

Other references:

Primary Energy Factors, from Polish regulations:

Energy carrier		Conversion factor
Fuel / energy source	Furnance oil Natural gas Liquid gas Hard coal Lignite Biomass Solar heating	1,10 1,10 1,10 1,10 1,10 0,20 0,00
Cogeneration	Fossil Biogas & biomass	0,80 0,15
District heating	Coal Gas or Oil Biomass	1,30 1,20 0,20
Electrical energy	Public power supply Photovoltaic	3,00 0,70

Appendix E Primary Energy Factor—Spain

E 1 Primary energy factors used in building regulations

The primary energy factors in the following tables are those used in the national building regulations. These factors are used in the CALENER instrument, the official national instrument for energy labelling of buildings. This instrument was designed as part as the national implementation of the EU EPBD. The factors are provided by idea, the national energy agency.

Type of energy recourse	Coefficient from final to primary energy (kWh/kWh)	CO2 coefficient (kg CO2/kWh)
Coal (domestic use)	1.000	0.347
Liquefied Petroleum Gas (LPG)	1.081	0.244
Diesel	1.081	0.287
Fuel Oil	1.081	0.280
Natural gas	1.011	0.204
Biomass and bio fuels	1.000	0.000
Electricity (peninsular)	2.603	0.649
Electricity (extra-peninsular)*	3.347	0.981

* Balearic Islands, Canary Islands, Cueta y Melilla

E 2 Spanish energy mix

The national energy mix for Spain's electricity is given in the next table. The CO_2 factor given by the national government is 0.27 kg CO_2/kWh and is based on these numbers. This is significantly lower than the factor used in national building regulations.

Electricity mix Spain (2009)	**Spain (%)**
Renewable energy	27.90%
Natural gas	27.30%
Nuclear	19.30%
Coal	12.10%
Cogeneration	9.30%
Cogeneration (high efficiency)	2.30%
Fuel	0.70%
Rest	1.10%

Total	**100.00%**

Factors

kg CO2/kWh	0.27
Residues radioactive mg/kWh	0.58

Export	3.10%

Emission factor for electricity production

From the national plan for renewable energy (PER 2005 – 2010) prepared by IDAE, the next factors are given:

Type of installation	Efficiency (%)	CO2 factor (kg CO2/kWh)
Coal central	36.1%	0.961
Combines cycle, natural gas	54.0%	0.372
Hydroelectric		0.000
Wind		0.000
Biomass		Neutral
Biogas		Neutral
PV		0.000
Solid waste	24.9%	0.243

Red Electria De Espana (REE), gives the following numbers, based on PER 2005-2010), June, 2009

Type of installation		CO2 factor (kg CO2/kWh)
Coal central		0.95
Combines cycle, natural gas		0.37
Fuel Oil central		0.70
Hydroelectric		0.00
Wind		0.00
Nuclear		0.00
Special regime (rest)*		0.25

*Special regime (rest)	Share (%)	CO2 factor (kg CO2/kWh)
Cogeneration	58.0%	0.37
Biomass	7.0%	0.00
Waste	7.6%	0.24
Waste treatment	8.5%	0.24
Hydroelectric (small scale)	12.8%	0.00
Solar	6.2%	0.00

Conversion factors for final and primary electricity production

IDAE provided the following conversion factors. Source: Factores de conversión de consumo o producción a energía primaria (EP) y factor (30 November 2010)

Type of energy recourse	**Final consumption (MWh)**	**Primary consumption at production (MWh)**	**Primary consumption at consumption (MWh)**	**Emission factor at production (kg CO2/kWh)**	**Emission factor at consumption (kg CO2/kWh)**
Nuclear	1.00	3.03	3.45	0.00	0.00
Renewable					
Wind and PV	1.00	1.00	1.14	0.00	0.00
Solar Concentrated Power	1.00	4.56	5.19	0.00	0.00
Biomass (electricity)	1.00	4.88	5.55	0.00	0.00
Biogas	1.00	3.70	4.22	0.00	0.00
Hydroelectric	1.00	1.00	1.14	0.00	0.00
Cogeneration					
Cogeneration (internal combustion motor)	1.00	1.67	1.79	0.44	0.50
Cogeneration (gas turbines)	1.00	1.61	1.74	0.36	0.41
Cogeneration (vapor turbines)	1.00	1.72	1.86	0.43	0.49
Cogeneration (gas and vapor turbines)	1.00	1.54	1.66	0.34	0.39

From:
Ronald Voskens
Eco Creations

E 3 Algorithm and assumptions on value parameters

No algorithm stated

Reference for algorithm:
-

Weighting factor nuclear:
3.03

Weighting factor renewables:
1.00 for PV and wind, 4.56 for CSP

Thermal efficiency fossil plants:
Not stated

Thermal efficiency for electricity CHP plants:
Not stated

Comments:

Other references:

Appendix F Primary Energy Factor—Sweden

F 1 Value used for electricity generation

The Swedish Energy Authority does not support the concept of primary energy factors. Consequently, there are no official primary energy factors published for application in Sweden.

An indirect political primary energy factor is set, e.g. by the energy requirements for new construction. Electricity is assigned a factor of approximately 2, when direct fuel or gas is 1. Electricity produced at the building (PV) is 0.

F 2 Algorithm and assumptions used for value parameters

No algorithm stated

Reference for algorithm:
-

Weighting factor nuclear:
Not stated

Weighting factor renewables:
Not stated

Thermal efficiency fossil plants:
Not stated

Thermal efficiency for electricity CHP plants:
Not stated

Comments:
Primary energy factor for Nordisk Elmix/Nordic electricity mix (Sweden, Norway, Denmark, Finland): 1.5

Reference for this:
SABO table
http://www.sabo.se/SiteCollectionDocuments/MILJOVARDERING20100927_lu.pdf

Other references:
From: Wolfram Trinius, Büro Trinius

Appendix G Primary Energy Factor—France

31-03-2011

Phone conversation with Jean Robert Millet:
The factor 2.58 is a political factor, but in practice not far off from what would be calculated based on the electricity mix and a coefficient of 3 for nuclear (more or less the internationally established standard). They do not want to change it every year. There are no documents explaining the algorithm, it is just stated in the RT2005 (this is for new buildings) and will be the same in the new version, the RT2012.

The same factor is used for locally produced electricity. So in practice it comes down to subtracting locally produced energy from demand, for example PV-production. Wind turbines are not in the regulations yet, but in theory the framework is there to introduce them. As long as it is part of the same project, it does not need to be attached to the building.

Residential PV: you can subtract a maximum of 12 kWh_{prim}/m^2. Any more will not count. There is no such limit for non-residential buildings. However, all buildings have to fulfil a certain standard (coefficient) without renewables. You cannot use PV to compensate for a building that has a bad energy performance.

Appendix H From EN 15603:2008-07

Annex E
(informative)

Factors and coefficients

Table E.1 — Primary energy factors and CO_2 production coefficients

	Primary energy factors f_P		CO_2 production coefficient K
	Non-renewable	Total	kg/MWh
Fuel oil	1,35	1,35	330
Gas	1,36	1,36	277
Anthracite	1,19	1,19	394
Lignite	1,40	1,40	433
Coke	1,53	1,53	467
Wood shavings	0,06	1,06	4
Log	0,09	1,09	14
Beech log	0,07	1,07	13
Fir log	0,10	1,10	20
Electricity from hydraulic power plant	0,50	1,50	7
Electricity from nuclear power plant	2,80	2,80	16
Electricity from coal power plant	4,05	4,05	1340
Electricity Mix UCPTE	3,14	3,31	617

Source: Oekoinventare für Energiesysteme - ETH Zürich (1996).

These factors include the energy to build the transformation and transportation systems for the transformation of the primary energy to delivered energy.

Appendix I References

[1] All Island Grid Study and DSM Update, for Sustainable Energy Ireland (SEI), Ecofys 2011. (http://www.ecofys.com/com/references/sei.htm).

[2] D. van Dijk, "Numerical indicator for the energy performance based on primary energy use and CO2 emissions Procedures according to CEN standard EN 15603", from www.buildingsplatform.eu.

[3] The Government's Standard Assessment Procedure for Energy Rating of Dwellings, SAP 2009, Chapter 16, L14, L16.

[4] 'Wenn Kühlhäuser kommunizieren', Sonne Wind & Waerme, 32, Nr.16, p. 34-36, 27 10 2008.

[5] See e.g. Morten Boje Blarke, Henrik Lund, "The Role of Heat Pump Technologies in the Design of Future Sustainable Energy Systems" (http://vbn.aau.dk/files/156729/031_Lund.pdf).

[6] O.P. van Pruijssen, I.G. Kamphuis , 'Grote concentraties warmtepompen in een woonwijk en gevolgen elektriciteitsnetwerk' (large concentrations of heat pumps in a neighbourhood and consequences for grid), ECN-E—10-088, sept. 2010 (http://www.ecn.nl/docs/library/report/2010/e10088.pdf).

[7] See e.g. http://cleantechnica.com/2010/05/22/53-megawatt-ice-energy-storage-trial-begins-in-california/

[8] A.J. Marszal et al, 'Zero Energy Building – A review of definitions and calculation methodologies', Energy and Buildings 43 (2011) 971–979.

[9] All Island Grid Study and DSM Update, for Sustainable Energy Ireland (SEI), Ecofys 2011. (http://www.ecofys.com/com/references/sei.htm).