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Energy demand of tumble driers with respect to differences in technology and ambient conditions

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1 Introduction

Tumble driers have a high ratio of and increasing impact on total electricity demand of households. In contrast to different other household appliances the market is not saturated and therefore growing selling rates can be expected.

Mainly two systems of tumble driers are currently available on the market: condenser tumble driers and air vented tumble driers, both powered by electricity. Tumble driers of both systems are mainly classified in the energy efficiency classes C and D. There are no driers on the market with a B classification and only one drier (type) reaches an A-classification (condenser tumble drier with a heat pump). Also available on the market is a gas heated tumble drier. This drier is not covered by the energy efficiency labelling scheme yet, due to the fact, that the directive only covers electrical heated tumble driers.

So far energy efficiency labelling of tumble driers[1] takes into account the electricity demand of the different driers when used under standard conditions[2]. There are two different scales to classify driers, one for air vented driers, one for condenser driers. The one for air vented driers having slightly higher requirements to reach a certain energy efficiency class. Regarding only the electricity demand when used under standard conditions these two scales represent the present situation, where condenser tumble driers in average have a higher specific electricity demand than air vented tumble driers.

Nevertheless under real life conditions in the households additional parameters influence the energy demand of the two drying systems. Examples of those parameters are:

- **Control**: tumble driers can either be humidity controlled or time controlled. Humidity controlled driers stop drying when the chosen humidity of the clothes is reached. Time controlled driers stop after a certain time that is set by the user. Usually time controlled driers work longer than necessary resulting in a higher energy demand for a certain amount of clothes compared to humidity controlled driers.
- **Type of fabric**: some types of fabric “hold” the water stronger than others, thus increasing the energy needed to dry them.
- **Loading of the drier**: the specific energy demand (in kWh per kilogramme) is higher the less fabric is within the drier.
- **Remaining water in the clothes after spinning in the washing machine**: the more efficient clothes are being spun, the smaller is the energy needed for drying them in the tumbler. To remove an equal amount of humidity the thermal process in a tumble drier needs more energy than the mechanical process in washing machines. This is a relatively important factor with respect to energy demand of tumble driers.[3]

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[1] Comm 1995.

[2] EN 61121

[3] Gensch/Rüdenauer n.d.

- **Effects on energy demand for space heating**: when the drier is located *within heated rooms*, the energy demand for space heating has to be considered when comparing the total energy demand of the two different drier types. Air vented tumble driers have an additional energy demand as the warm and humid air is blown to the outside and is replaced by cold air that has to be reheated by the space heating system. Condenser tumble driers cool down the warm and humid air and condense the steam. The tumble driers warm up and give this heat to the ambient air thus replacing a certain amount of space heating. At least during the heating period the consideration of space heating energy demand may lead to additional energy demand of air vented tumble driers and to credits for saved heating energy for condenser tumble driers. To a minor extend air vented driers also give a certain amount of heat to the ambient air. As this amount is relatively small and difficult to quantify it is not considered in this study.
- **Ambient temperature**: under standard conditions 20°C is set as ambient temperature. If the ambient temperature is lower (higher) the energy demand of the drier increases (decreases). This effect is stronger for air vented driers than for condenser driers. Changes in energy demand due to changes in the ambient temperature mainly have to be taken into account when the tumble driers are located *outside heated rooms* (e.g. in not heated cellars or garages).

2 Goal of the study

Against the described background the goal of this study is to compare the electricity demand of the two different drier technologies (air vented and condenser tumble driers) used under standard conditions with the energy demand when used under real life conditions especially with respect to the following effects:

- differences in ambient temperature (relevant when driers are located outside heated rooms, directly influencing the electricity demand of the drier)
- energy demand for space heating (relevant when driers are located inside heated rooms, causing an additional energy demand or energy demand credits next to the direct electricity demand of the driers)

The results shall be applicable as scientific background for suggested correction factors for the energy demand of the two drier systems under real life conditions.

3 Scope of the study

Functional unit:

The functional unit is defined as one year's private laundry that is dried with an electric tumble drier in the dry cotton programme. This amount is defined as 400 kg (see also chapter 4).[4]

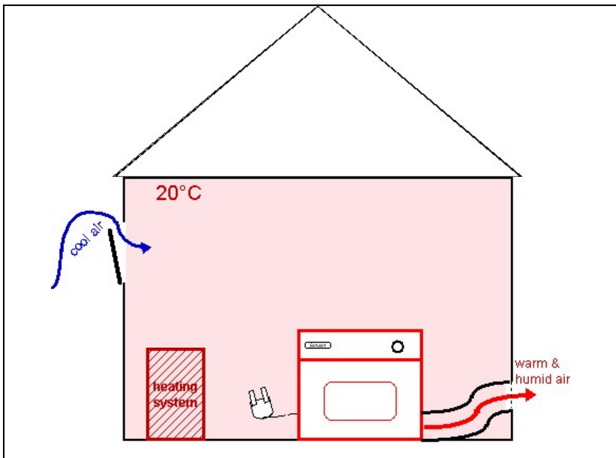
System boundaries:

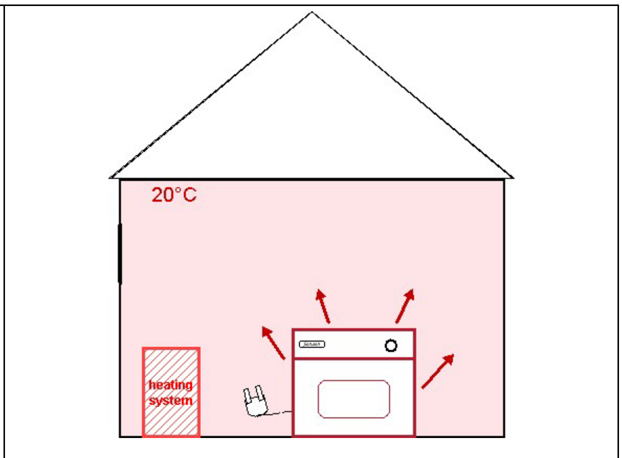
This study only deals with the energy demand during the use phase of electrical heated tumble driers. The production, distribution and disposal of tumble driers is not considered. It is assumed that there are no (major) differences between the regarded drier technologies in these phases of the ecological life cycle.

The energy demand of tumble driers during the use phase is determined by the specific electricity demand of the regarded tumble drier and a certain amount of space heating energy demand (in case of inside use air of air vented driers) and credits for space heating energy demand (in case of inside use of condenser driers and to a minor extend also of air vented driers).

As at the moment there is no statistical data available concerning the location of the driers (inside or outside heated rooms) both possibilities are considered.

The following figures (fig 3.1 to 3.4) show the four basic possibilities that are regarded in this study (see also chapter 7).

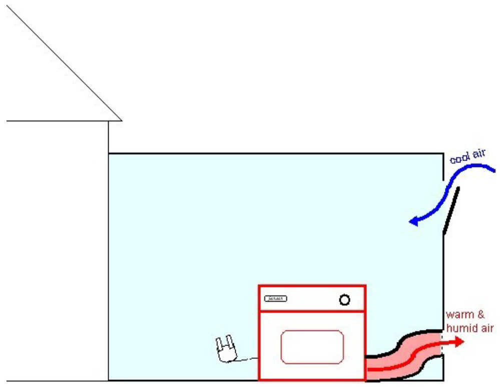


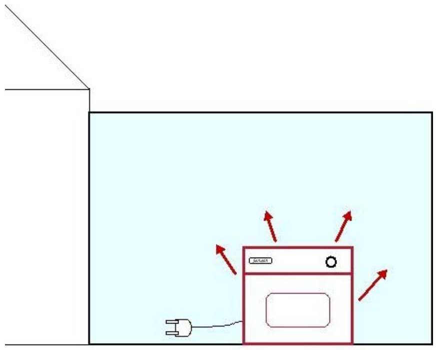


Air vented drier inside heated rooms	Condenser drier inside heated rooms

Fig. 3.1 to 3.2: drier use insite heated rooms

[4] Gensch/Rüdenauer (n.d.)





Air vented drier outside heated rooms	Condenser drier outside heated rooms

Fig. 3.3 to 3.4: drier use outsite heated rooms

Table 3.1 shows the parameters that have an influence on the annual energy demand of the four basic possibilities. The used drying programme also has an influence on drier electricity demand. In this study only the ‘cotton dry’ programme is regarded. Therefore this parameter is not listed in table 3.1.

Table 3.1: relevant parameters differentiated for the four basic possibilities

Air vented drier, inside use	**Condenser drier, inside use**
For drier electricity demand: - Specific electricity demand air vented drier - Annual amount of laundry - Loading of the drier - Remaining water after spin - Relative humidity of air - Use pattern: whole year or only heating period - Length of the heating period* *For space heating demand*: - Air extraction rate - Length of the drying cycles - Number of drying cycles - Temperature difference outside/inside (heating degree-days) during heating period - Length of the heating period	*For drier electricity demand*: - Specific electricity demand condenser drier - Annual amount of laundry - Loading of the drier - Remaining water after spin - Use pattern: whole year or only heating period - Length of the heating period* *For space heating credits*: - Extend of electricity to be credited - Length of the heating period - Electricity demand of the drier during heating period

Table 3.1 (continued)

Air vented drier, outside use	**Condenser drier, outside use**
For drier electricity demand: - Specific electricity demand air vented drier - Annual amount of laundry - Loading of the drier - Remaining water after spin - Relative humidity of air - Average mean monthly temperatures - Use pattern: whole year or only heating period - Length of the heating period*	*For drier electricity demand*: - Specific electricity demand condenser drier - Annual amount of laundry - Loading of the drier - Remaining water after spin - Average mean monthly temperatures - Use pattern: whole year or only heating period - Length of the heating period*

* when regarding use only during the heating period

In the case of the indoor use two different types of end energy are involved (space heating and electricity). These can't be compared directly. Therefore it is necessary to transfer them into a common "energy currency". In this study the primary energy demand is chosen and as a sensitivity calculation the global warming potential (see also paragraph on indicators below).

In chapter 4 the influencing parameters are described in more detail.

Geographical scope:

To ensure the applicability of this study for different European regions climatic differences within Europe have to be considered as climate influences both of the regarded effects on the energy demand of different drier types (ambient temperature and space heating effects).

The different climatic conditions in Europe can roughly be summed up in three climatic zones. The *'cold climatic zone'* (comprising Finland, Norway and Sweden), the *'moderate climatic zone'* (comprising countries as Belgium, Denmark, Germany, France, Great Britain, Ireland, Luxembourg, the Netherlands, Austria and Switzerland) and the *'warm climatic zone'* (comprising Greece, Italy, Portugal, Spain and Turkey).[5]

To determine most relevant countries for this study, also data about energy infrastructure and data about the drier market were used besides the climatic data. With a multi-criteria approach the countries Norway, Germany, France and Spain were chosen (see table 3.2). The following criteria were considered:

[5] Petersdorff et al. 2002

- electricity generation by source
- space heating supply
- marked data
- saturation rates
- growth rates

Table 3.2: regarded countries

Climatic zone	**Country**
cold climatic zone:	Norway
moderate climatic zone:	Germany France
warm climatic zone:	Spain

Indicators:

Energy demand can mean both end energy demand e.g. in form of electricity (as declared on the energy efficiency label) and primary energy demand which is used to produce a certain amount of end energy (including energy demand for mining and distribution, transformation losses, etc.). Depending on the type of end energy there are quite big differences in the corresponding amount of primary energy.

As indicators for energy consumption by the different scenarios the *electricity demand of the tumble driers* and the *energy demand for space heating* is calculated.

Nevertheless to compare systems that use different types of end energy (like electricity demand plus a certain amount of space heating that is often supplied by other end energy sources like oil or natural gas) it is necessary to regard also the primary energy demand. Therefore also the indicator *cumulated energy demand CED* is calculated using data about electricity generation and space heating supply in the regarded countries. The CED includes all types of primary energy sources. In the following the abbreviation CED is used for the primary energy demand.

The ratio to which different primary energy sources are used to produce electricity and space heating determines the global warming potential to produce a certain amount of end energy. Therefore as sensitivity analysis the *global warming potential* (GWP) of the alternatives is calculated.

4 Parameters

In the following paragraphs, the parameters that have an influence on the electricity demand of driers and the space heating energy demand or credits (see table 3.1) are described in more detail.

According to CECED Database of all produced models in the EU the least **specific electricity demand** is 0.640 kWh/kg for air vented driers and 0.680 kWh/kg for condenser driers. Both figures are valid for driers on the marked in 2002 with a capacity of 5 kg determined under conditions according to EN 61121.[6] This specific electricity demand doesn't represent the specific electricity demand of driers in stock or the electricity demand of driers that were sold in the respective year. The specific electricity demand is influenced by several parameters (see table 3.1).

According to [Gensch/Rüdenauer (n.d.)] the total yearly **amount of private laundry** is estimated to be 500 kg. 80 % of the total amount can be dried in a tumble drier in the 'dry cotton' programme.[7] Thus all calculations refer to an amount of 400 kg fabric dried in the 'dry cotton' programme.

The capacity of the regarded driers is 5 kg, whereas average **loading** is generally assumed to be 3.2 kg. Due to reduced loading the specific energy demand of driers (electricity demand per kilogramme fabric) is higher than with optimised loading. The total and the specific energy demand against loading is shown in table 4.1. Under standard conditions (EN 61121) the loading for 'cotton dry' programme is set 5 kg (for driers with a capacity of 5 kg).

Table 4.1: total and specific energy demand with respect to loading of the drier

Loading	5 kg	4.5 kg	4 kg	3.5 kg	3.2 kg	3 kg
Total energy demand (per cycle)	100 %	93 %	85 %	78 %	73 %	70 %
Specific energy demand (per kg)	100 %	103 %	106 %	111 %	114 %	117 %
Data quality	m	m	m	m	i	m

m = measured data for 'cotton dry' programme[8]

i = interpolation

[6] CECED 2003; for air vented driers data of the best *market relevant* driers are taken. This is an energy demand of 3.20 kWh per cycle (capacity of 5 kg).

[7] Gensch/Rüdenauer (n.d.)

[8] Technical data by AEG, October 1999

When assumed that there are no seasonal differences in the amount of laundry, the monthly amount of laundry is 33.3 kg. Together with the loading of the driers, the average **number of drying cycles** can be calculated (e.g. 6.7 cycles/month with ideal loading or 10.4 cycles/month with average loading).

The spin speed of the foregoing washing process in an average washing machine in stock is approximately 1,000 rpm. The relative energy demand against **percentage of water remaining after spin** is assumed according to table 4.2. Under standard conditions (EN 61121) the remaining water after spin for ‘cotton dry’ programme is set 70 %.

Table 4.2: relative energy demand with respect to spin speed/remaining water after spin

Water remaining after spin (cotton)	70%	60%	50%
Corresponding approximately spin speed	800	1000	1400
Relative energy demand (‘cotton dry’ programme)[9]	100%	89%	74%

Humidity is the amount of water vapour in the air and can be described as “absolute humidity” or "relative humidity". Abolute humidity is the mass of water vapour in a given volume of air, usually expressed in grams per cubic meter or grams per kg. Relative humidity is the term used most often. It is the amount of water vapour in the air compared with the amount of vapour needed to saturate the air at current temperature. The amount of vapour needed to saturate the air increases with rising temperatures. Therefore the relative humidity of 65 % means different absolute humidities at different temperatures.

The humidity of the air influences the energy demand of air vented driers. With a lower humidity the energy demand decreases.

Under standard conditions the relative humidity is set 65 %. With the standard temperature of 20°C the relative humidity of 65 % means an absolute humidity of 9.45 g per kg air.

The dependency of electricity consumption of air vented driers against absolute humidity at a certain temperature can be calculated according to the following function:[10]

$$\Delta E_H = (0.00832 * x - 0.079) * 100$$

with
ΔE_H = deviation from electricity demand at standard conditions in % and
x = absolute humidity in g/kg dry air

[9] Miele 2000, interpolation for 60% of water remaining after spin

[10] Miele 2004

The function can be used directly at the standard temperature of 20°C. At other temperatures the difference from standard humidity (65 %) has to be calculated in several steps, as the calculation of the energy demand at different temperatures already includes the difference due to the lower absolute humidity (as the relative humidity is kept constant at 65 %).

1. calculation of energy demand at non-standard temperature, with 65 % r.h. (calculation see below *ambient temperature*)
2. calculation of deviation due to different relative humidity:
   a. calculation of deviation of the electricity demand with a different absolute humidity due to the different temperature
      (*example*: at 10°C the absolute humidity with 65 % r.h. is only 4.96 g/kg compared to 9.45 g/kg at 20°C. The deviation of electricity demand due to this difference can be calculated with the function above.
      Here: ΔE_{H1} = - 3.7 % or 0.963).
   b. Calculation of deviation of the electricity demand with a different absolute humidity due to a lower relative humidity
      (*example*: at 10°C the absolute humidity with 40 % r.h. is only 3.05 g/kg compared to 9.45 g/kg at 20°C.
      Here: ΔE_{H2} = - 5.4 % or 0.946).
   c. Calculation of the factor x to calculate the deviation from “10°C, 65 % r.h.” to “10°C, x r.h.”
      (example: 0.963 * x = 0.946; x = 0.946 / 0.963 = 0.982)

Table 4.3 gives an overview of the maximum saturation and the absolute humidity of air at different temperatures.

Table 4.3: maximum saturation and absolute humidity at different temperatures and relative humidities

Temperature (in °C)	maximum saturation (in g/kg)	absolute humidity (in g/kg)		
		65% r.h.	40% r.h.	25% r.h.
0	3.76	2.45	1.50	0.94
5	5.43	3.53	2.17	1.36
10	7.63	4.96	3.05	1.91
15	10.59	6.88	4.23	2.65
20	14.53	9.45	5.81	3.63
25	19.76	12.84	7.90	4.94
30	26.41	17.16	10.56	6.60

Unfortunately there is no statistical data about the **annual use pattern** available. To cover different situations both the use of the drier during the whole year and the use of the drier only during the heating season have to be regarded.

The **length of the heating period** varies between the different countries. Of course it is not possible to draw a sharp line between ‘heating season/use of the drier’ and ‘non-heating season/no use of the drier’ as not only temperature but also other weather conditions make people use their drier in the summer (e.g. when it is raining). But this is assumed to be compensated by the contrary effect during the heating season, when the laundry is hanged on a clothesline on a sunny and dry day.

Considering the average mean temperatures per month in the different countries (see paragraph below) the following months could roughly be estimated as “heating season/months when the drier is used”. The dark grey highlighted months in table 4.4 are considered as months where the drier is used the whole month, the lighter grey highlighted months are considered as months where the drier is used only half of the month and the not highlighted months are considered as months where the drier is not used at all. Because of different climatic conditions, the definition of “heating season” is obviously different for the regarded countries.

Table 4.4: heating and non-heating periods in the regarded countries (equals use- and non-use months)

country/month	***J***	***F***	***M***	***A***	***M***	***J***	***J***	***A***	***S***	***O***	***N***	***D***
Norway												
Germany												
France												
Spain												

Air extraction rates of air vented driers cannot be determined exactly. Values between 120 and 150 m^3/h (under standard conditions) are assumed to be realistic. With an **average duration** of 90 minutes per cycle the total amount of extracted air is between 180 and 225 m^3. With longer cycle times the total amount of extracted air increases. With increasing or decreasing electricity demand due to different parameters (see above), longer or shorter cycle times are assumed with a therefore larger or smaller amount of total air extracted. In this study air extraction only plays a role regarding the energy demand when the drier is located *inside* heated rooms. As inside heated rooms ambient temperatures of 20°C are assumed the amount of air extracted only has to be changed with respect to loading, remaining water after spin and as sensitivity analysis itself. The **number of drying cycles** per month is calculated above with the amount of laundry and the loading.

To calculate the space heating energy demand it is also necessary to determine the **difference between outside and inside temperatures** over the year. As indicator of this temperature difference the heating degree-days of the regarded countries are used. Heating degree-days give an indication of the coldness of the climate by measuring how often daily temperatures are below a certain reference temperature and to what extend. The number of heating degree-days is the sum of the difference between desired room temperature and outdoor temperature for each day at which the outdoor temperature is below the reference temperature. The unit is Kelvin*Day/Year (Kd/a). The following table (table 4.5) shows the heating degree-days that are assumed for the regarded countries.

Table 4.5: monthly heating degree-days (in Kd/a) of the regarded countries[11]

country/month	***J***	***F***	***M***	***A***	***M***	***J***	***J***	***A***	***S***	***O***	***N***	***D***	***total***
Norway	630	568	545	426	279	166	108	130	238	372	496	598	4.556
Germany	620	540	492	359	216	92	56	61	163	330	465	577	3.971
France	422	367	335	244	147	63	38	41	111	224	316	392	2700
Spain	273	238	217	158	95	41	25	27	72	145	205	254	1750

To calculate **credits for space heating substitution** in the case of condenser driers, the extend to which the electricity demand can be credited against space heating has to be defined. With a minimal room ventilation rate of 0.5 to 1 per hour it can be assumed that approximately 50 % of the electricity demand of the condenser drier can be credited against space heating. With a high room ventilation rate of 4 per hour it can be assumed that only approximately 25 % of the electricity demand of the condenser drier can be credited against space heating. Both figures only apply during the heating period and only play a role when the drier is located *inside* heated rooms. These figures comply with figures used in other calculations.[12]

The electricity demand of the tumble driers depends on the **ambient temperature**. For both drier systems the energy demand increases when the ambient temperature decreases and vice versa. Air vented driers are more sensitive to temperature differences than condenser driers. Within 5°C and 30°C the dependency of electricity consumption against temperature

[11] Norway: Meteorologisk institutt 2002, Germany: Energiewirtschaftliche Tagesfragen 1994, Heft 3, S. 134, France, Spain: Phylipsen et al. 1998

[12] for example Kionka (1997) assumes that 70 % of the electricity demand of condenser driers can be credited against space heating energy demand during the heating period. Gensch/Rüdenauer (n.d.) assume that 50 % are accountable during the heating period.

can be calculated according to the following functions (with a constant relative humidity of 65 % r.h.; see also paragraph above *humidity*):[13]

air vented drier:

Δ E = (- 0.01153 * T + 0.231) * 100

condenser driers:

Δ E = (- 0.002147 * T + 0.04293) * 100

with
Δ E = deviation from electricity demand at standard conditions in % and
T = ambient temperature in °C

In case of use within heated rooms, an ambient temperature of 20°C is assumed for all regarded countries (like standard condition). In case of use outside heated rooms the average mean outside temperatures per month are assumed for the regarded countries (with a lowest outside temperature of 5°C and a highest outside temperature of 30°C, according to the applicability of the above mentioned functions), see table 4.6.

Table 4.6: average mean monthly temperatures (in °C) of the regarded countries[14]

country/month	***J***	***F***	***M***	***A***	***M***	***J***	***J***	***A***	***S***	***O***	***N***	***D***
Norway	-5.2	-5.2	-3.4	-0.3	4.8	8.6	10.8	10.4	7.1	3.1	-1.2	-3.8
Norway ‘levelled’	**5.0**	**5.0**	**5.0**	**5.0**	**5.0**	**8.6**	**10.8**	**10.4**	**7.1**	**5.0**	**5.0**	**5.0**
Germany	0.3	1.4	5.5	9.3	14.9	17.0	19.2	19.0	14.4	9.9	3.9	1.4
Germany ‘levelled’	**5.0**	**5.0**	**5.5**	**9.3**	**14.9**	**17.0**	**19.2**	**19.0**	**14.4**	**9.9**	**5.0**	**5.0**
France	4.5	5.5	7.8	10.5	14.0	17.3	19.7	19.4	16.5	13.0	8.1	5.3
France ‘levelled’	**5.0**	**5.5**	**7.8**	**10.5**	**14.0**	**17.3**	**19.7**	**19.4**	**16.5**	**13.0**	**8.1**	**5.3**
Spain	9.2	10.7	12.9	14.8	17.2	20.3	23.1	23.4	21.4	17.5	13.6	10.2
Spain ‘levelled’	**9.2**	**10.7**	**12.9**	**14.8**	**17.2**	**20.3**	**23.1**	**23.4**	**21.4**	**17.5**	**13.6**	**10.2**

[13] Miele 2003

[14] www.klimadiagramme.de, www.vayacamping.net/weather.asp?lang=de, Deutscher Wetterdienst (www.dwd.de), the ‘levelled’ temperature means, that the lowest ambient temperature is set as 5°C in this study.

5 Electricity and space heating supply

Starting with electricity demand and space heating demand, the cumulated energy demand and the global warming potential associated with the supply of this amount of electricity and space heating is modelled with data from the latest version of the Gemis software.[15] The type and ratio of the different primary energy sources to produce electric and space heating energy is different for each country. This results in different efficiencies of electricity and space heating production and correspondingly to different primary energy demand (CED) and global warming potential (GWP) for a certain amount of end energy.

6 Correction factors

Correction factors for one of the two drier technologies might be a possibility to consider the energy demand of tumble driers under real life conditions in a labelling scheme.

In this chapter a possible way of calculating factors is described. The factors correct the standard electricity demand of one of the drier systems in such a way, that the resulting corrected figures represent the ratio of the energy demand of the two drier systems under real life conditions. Here the condenser drier is defined as the technology to be corrected.

To calculate these potential correction factors the standard energy demand is compared to the energy demand of the driers in different real life environments.

- The *standard energy demand* means the electricity (and the related CED and global warming potential GWP) that is required resp. caused by the different driers when used under standard conditions. This *standard* energy demand stays constant for most of the scenarios. It is not adjusted for (minor) loading, ambient temperature and humidity of air. In case of the sensitivity analyses with lower percentage of remaining water after spin, the standard electricity demand is adjusted with the factors pointed out in table 4.2. Obviously space heating effects are not considered.
- The *total energy demand under real life conditions when used inside heated rooms* consists of the electricity demand plus space heating effects and the respective CED (and GWP).
- The *total energy demand under real life conditions when used outside heated rooms* only consists of the drier electricity demand that is adjusted with respect to ambient temperature. The respective CED and GWP are calculated but these indicators are not relevant for the calculation of the potential correction factors.

In case of **inside use of the driers** this means, that the standard electricity demand of the condenser driers (abbreviation: el(cond-std)) has to be corrected by a certain factor in such a way, that the resulting relation between the corrected electricity demand of this drier technology (abbreviation: el(cond-corr)) and the standard electricity demand of the air vented

[15] GEMIS 2002

driers (abbreviation: el(av-std)) is the same as the relation between the total CED of the condenser driers (abbreviation: CEDtotal(cond)) and the total CED of the air vented driers (abbreviation: CEDtotal(av)). This is shown in the following two equations:

$$el(cond - corr) = el(cond - std) \times correction\,factor \quad (1)$$

$$\frac{el(cond - corr)}{el(av - std)} = \frac{CEDtotal(cond)}{CEDtotal(av)} \quad (2)$$

Thus the relation between the corrected electricity demand of the condenser drier and the standard electricity demand of the air vented drier represents the relation between the respective CED of the two technologies.

The potential correction factors are calculated with equation (3) which is derived from the equations (1) and (2):

$$correction\,factor = \frac{CEDtotal(cond)}{CEDtotal(av)} \times \frac{el(av - std)}{el(cond - std)} \quad (3)$$

In case of **outside use of the driers** it is not necessary to calculate the CED of the energy demand under real life conditions as electricity is the only energy source required and therefore it is not necessary to use another common "energy currency" (see chapter 3 above).

The potential correction factors are calculated according to the calculation of the indoor factors, but with the electricity demand of the condenser driers under real life conditions (abbreviation: el(cond-rl)) and the electricity demand of the air vented driers under real life conditions (abbreviation: el(av-rl)) instead of the respective CED. This is shown in equation (3')

$$correction\,factor = \frac{el(cond - rl)}{el(av - rl)} \times \frac{el(av - std)}{el(cond - std)} \quad (3')$$

As a **methodological sensitivity analysis**, potential correction factors are calculated that are based on the comparison of the standard electricity demand with the total GWP instead of the total CED. In the case of inside use, where the CED is used to calculate potential correction factors, this might lead to changes.

The correction factors (GWP) are calculated in an analogous manner as the correction factors based on the total CED (see equations (4) to (6)).

$$el(cond - corr) = el(cond - std) \text{ x } correction\,factor\ (GWP) \quad (4)$$

$$\frac{el(cond - corr)}{el(av - std)} = \frac{GWPtotal(cond)}{GWPtotal(av)} \quad (5)$$

$$correction\,factor\ (GWP) = \frac{GWPtotal(cond)}{GWPtotal(av)} \text{ x } \frac{el(av - std)}{el(cond - std)} \quad (6)$$

With the results of the different scenarios in this study (see following chapter) it has to be examined if the calculated potential correction factors differ between inside and outside use and between different countries and if the results are sensitive to one of the parameters where a sensitivity analysis is conducted.

7 Scenarios and sensitivity analyses

The following basic scenarios are defined to discuss the derived correction factors with respect to inside vs. outside use and use in the different countries:

Table 7.1: base case scenarios

	inside heated rooms ("indoor")	**outside heated rooms ("outdoor")**
Norway	Norway indoor: air vented vs. condenser drier	Norway outdoor: air vented vs. condenser drier
Germany	Germany indoor: air vented vs. condenser drier	Germany outdoor: air vented vs. condenser drier
France	France indoor: air vented vs. condenser drier	France outdoor: air vented vs. condenser drier
Spain	Spain indoor: air vented vs. condenser drier	Spain outdoor: air vented vs. condenser drier

The characterising parameters are set as shown in table 7.2. For some of these parameters sensitivity analyses are calculated (for detailed description see chapter 4).

Table 7.2: Parameter values in base case scenarios and sensitivity analyses

Parameters	***values in base case scenarios***	***values in sensitivity analyses***
specific electricity demand	air-vented: 0.640 kWh/kg condenser: 0.680 kWh/kg	not applicable
amount of laundry	400 kg	not applicable
loading resulting number of cycles per month	5 kg 6.7	3.2 kg 10.4
use	whole year	during heating period
remaining water after spin	70 %	60 %, 50 %
air extraction rate (air-vented drier, inside use)	120 m^3/h	150 m^3/h
Length of drying cycle (air-vented driers)	90 min	120 min, 240 min
relative humidity of air	65 %	40 %, 25 %

Tab. 7.2 (continued)

heating degree-days	inside use: see table 4.4 outside use: not relevant	not applicable
space heating credits (condenser drier, inside use)	50%	25%
ambient temperature	inside use: 20°C outside use: see table 4.5	not applicable

8 Results

8.1 General trends of the energy demand

Figure 8.1 shows the general structure of the CED of driers when **used inside heated rooms** in real life environment in kWh per year. In case of air vented driers the CED of space heating demand has to be added to the CED of the electricity demand to give the total CED. In case of condenser driers, the credits for space heating substitution have to be subtracted from the CED of the electricity demand to give the total CED.

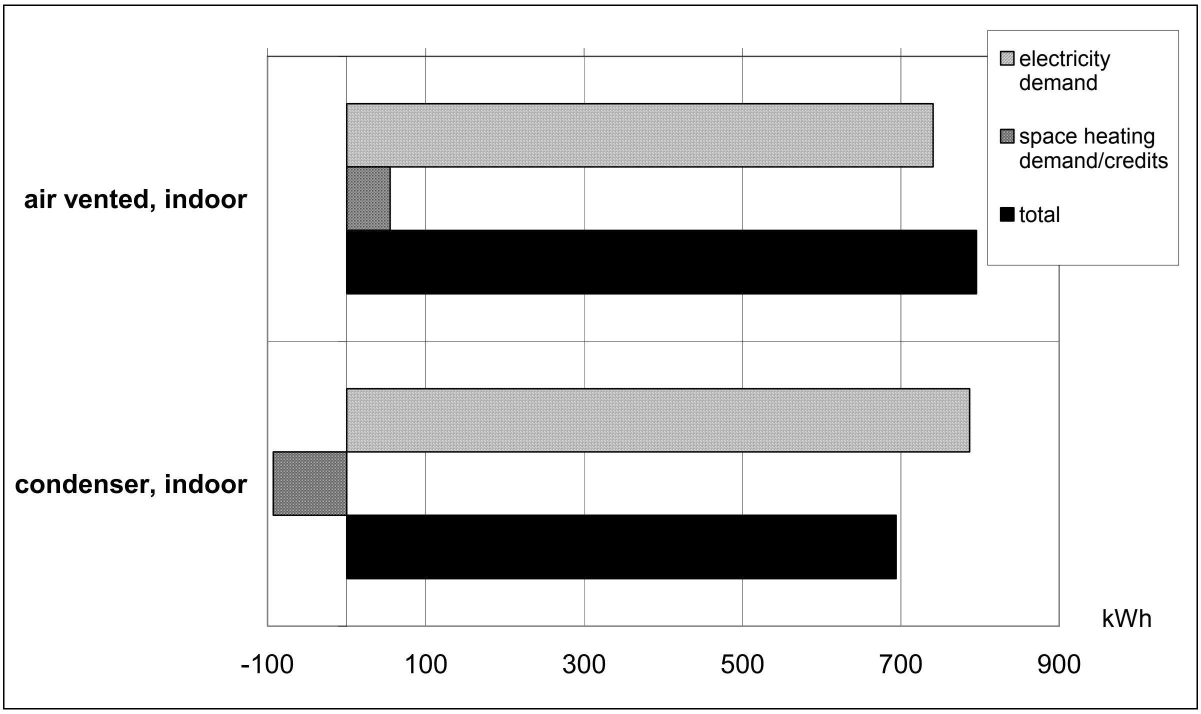


Fig. 8.1 structure of the CED of indoor drier use under real life conditions (example: *Germany indoor base case*)

The relative differences between standard and real life energy demand of the two drier systems when used indoors are shown in figure 8.2.

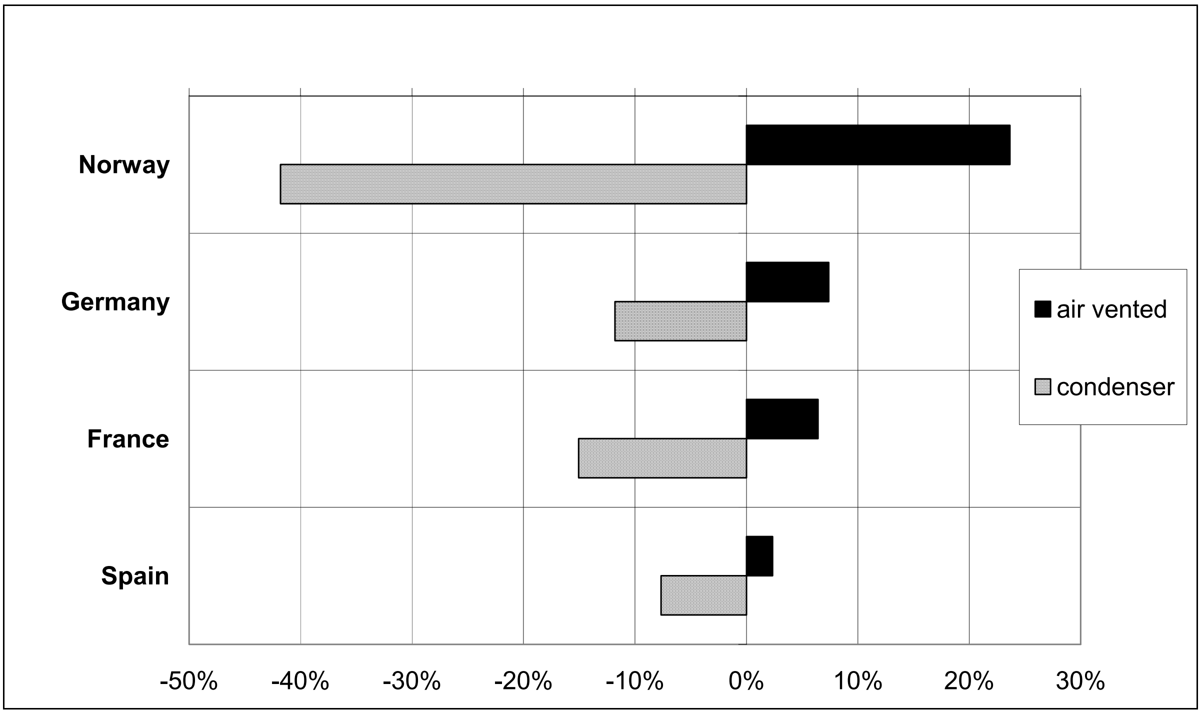


Fig. 8.2 relative differences of CED between standard and real life energy demand (*indoor scenarios*)

The black bars depict the increase of energy demand of air vented driers when use under real life conditions is compared with use under standard conditions. In all countries the energy demand of the air vented drier increases when used under real life conditions. In contrast the energy demand of the condenser driers decreases when used under real life conditions compared to use under standard conditions (grey bars). This also applies to all countries.

When regarding the **use of the driers outside heated rooms**, there is no space heating effect. The difference between standard and real life energy demand is a direct effect of the different ambient temperatures on the specific electricity demand. Air vented driers are more sensitive with respect to temperature than condenser driers[16]. This means that the electricity demand of air vented driers increases to a greater extend than that of condenser driers when the ambient temperature falls below the temperature under standard conditions (20°C). A higher electricity demand of condenser driers compared to air vented driers under standard conditions can thus be compensated and might result in an overall lower electricity demand

[16] Wendker 2003

of condenser driers compared to air vented driers. On the other hand, the electricity demand of air vented driers also decreases to a greater extend than that of condenser driers when temperature rises above temperature under standard conditions. This effect results in an increase of an already existing difference between air vented and condenser driers under standard conditions.

Nevertheless in total the outside temperatures in Europe are more often and to a greater extend below 20°C than above 20°C, resulting in an (energetically) advantage for condenser driers.

Figure 8.3 shows the standard electricity demand and the electricity demand under real life conditions of the two drier systems (with the example of the German base case scenario).

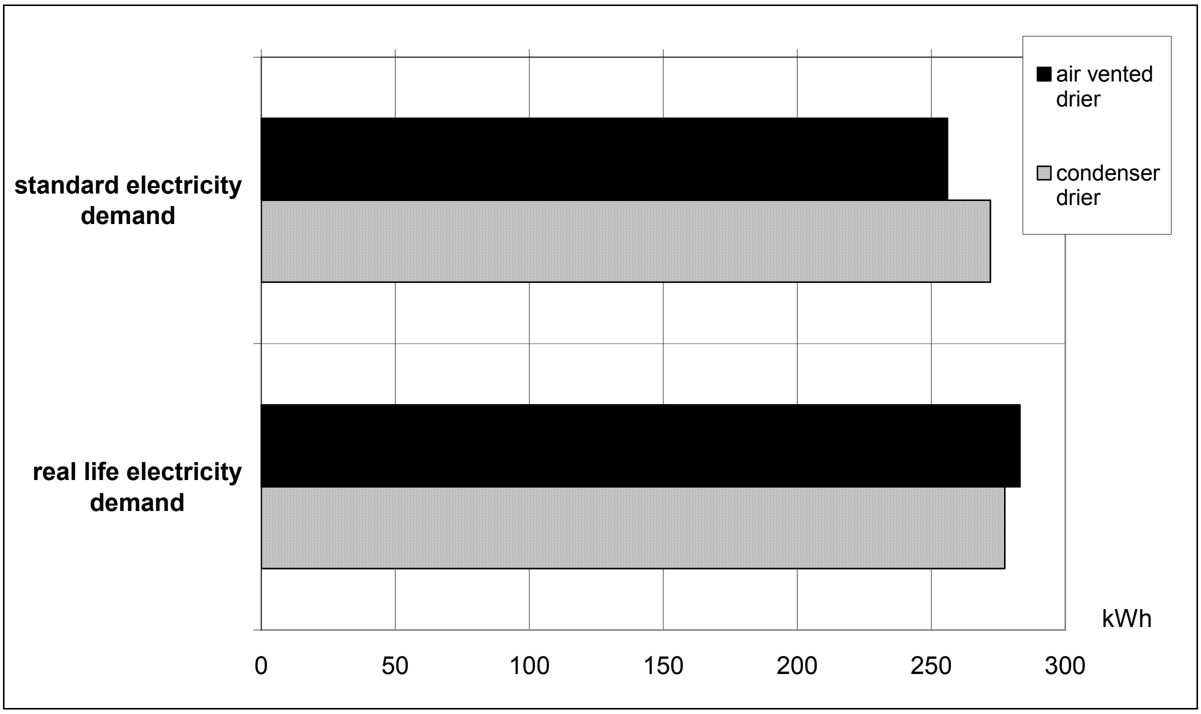


Fig. 8.3 standard and real life electricity demand of air vented and condenser driers (*Germany outdoor*)

The relative differences between standard and real life energy demand of the two drier systems when used outdoors are shown in figure 8.4.

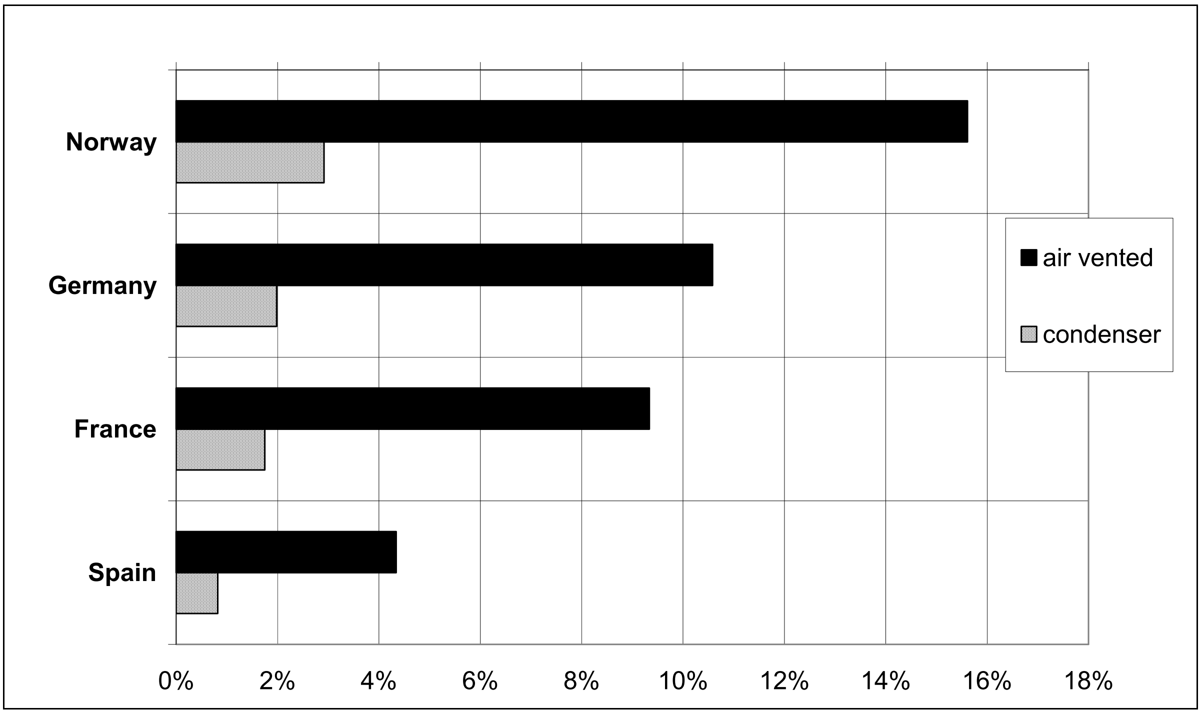


Fig. 8.4 relative differences of electricity demand between standard and real life energy demand (*outdoor scenarios*)

The black bars show the differences for air vented driers, the grey bars the differences for condenser driers. In contrast to the indoor scenarios also the primary energy demand of the condenser drier increases when used under real life conditions. However this increase is smaller compared to the increase in case of air vented driers.

Both when used **indoors and outdoors**, the differences between energy under real life conditions and energy demand under standard conditions are the highest for Norway as a country with cold climate and decrease when moving to warmer countries, being the smallest for Spain as a country with warm climate.

8.2 Correction factors 'Base case'

For the *Germany indoor scenario* the derivation of the correction factors is shown in detail. The potential correction factor is calculated as follows:

$$correction\,factor = \frac{CEDtotal(cond)}{CEDtotal(av)} \times \frac{el(av-std)}{el(cond-std)} \quad (3)$$

$$= \frac{694.1}{795.4} \times \frac{256.0}{272.0} = 0.821$$

The resulting correction of the electricity demand is illustrated by figure 8.5. It shows the relation of the standard electricity demand of the two drier technologies, the corresponding total CED (in real life environment) and the subsequently corrected electricity demand.

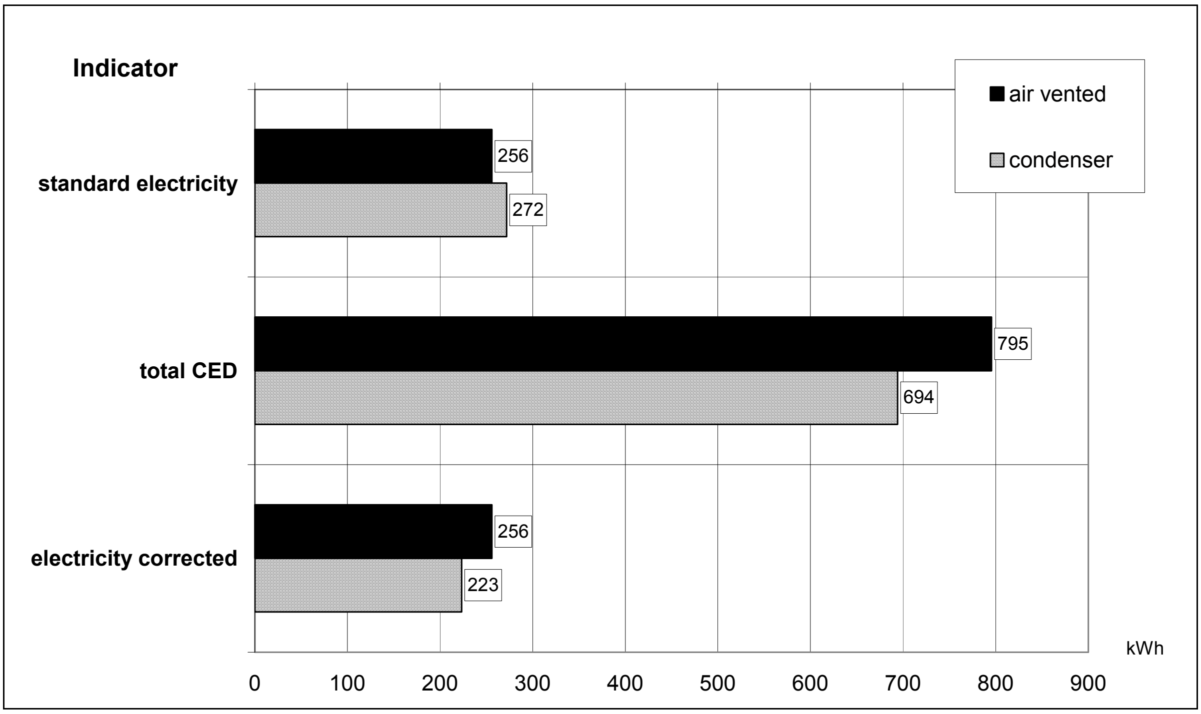


Fig. 8.5 standard electricity demand, total CED and corrected electricity demand (*Germany indoor*)[17]

[17] standard electricity: electricity demand under standard conditions, total CED: total CED in real life environment, electricity corrected: electricity demand where the value for air vented driers is corrected with the derived factor

It can be seen, that the standard electricity demand of the air vented drier is smaller than that of the condenser drier. Nevertheless the CED under real life conditions of air vented driers is higher than that of condenser driers. The derived factor (0.821) corrects the electricity demand of the condenser drier in such a way, that the relation between the corrected electricity demand of condenser and air vented driers is the same as the relation between the total CED of the two technologies.

Fig 8.6 shows the relation of the standard electricity demand of the two drier technologies, the corresponding total CED and the corrected electricity demand for the *German outdoor scenario* (correction factor: 0.922).

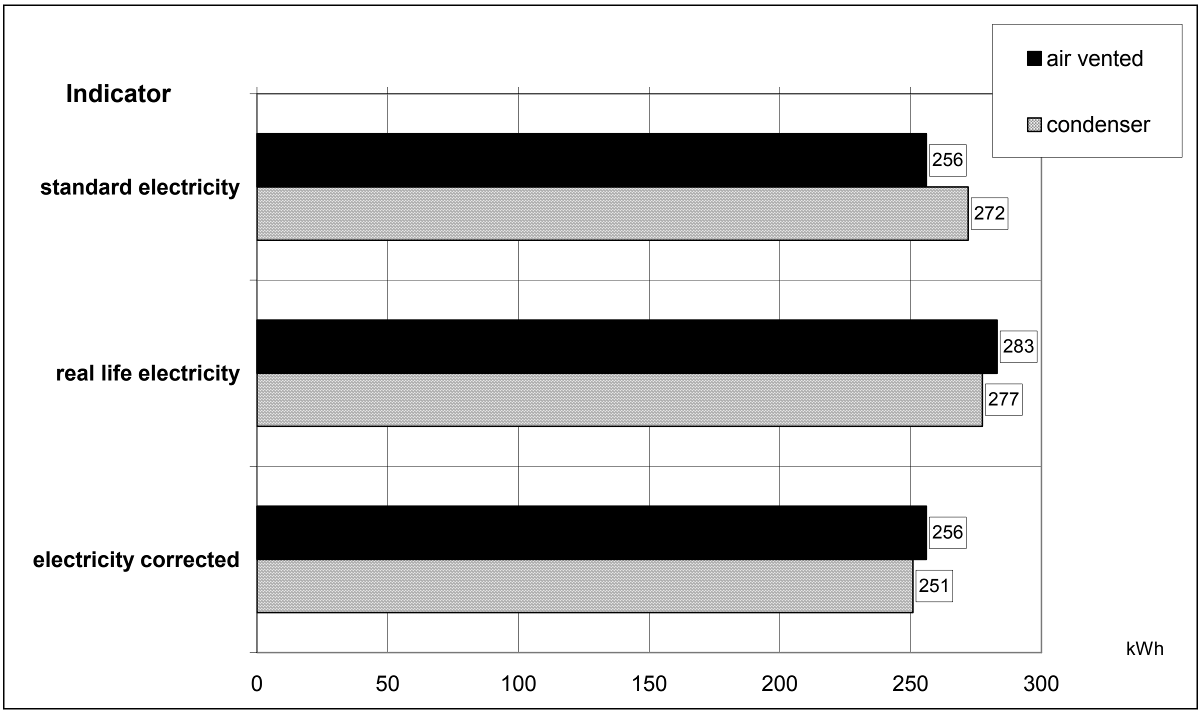


Fig. 8.6 standard electricity demand, real life electricity demand and corrected electricity demand (*Germany outdoor*)

The resulting correction factor is slightly bigger than the correction factor in the *German indoor* scenario. Analogous to the relation in the total CED the resulting corrected electricity demand of the condenser drier is slightly smaller than the electricity demand of the air vented drier.

The figures 8.7 to 8.12 show this correction for the other regarded countries.

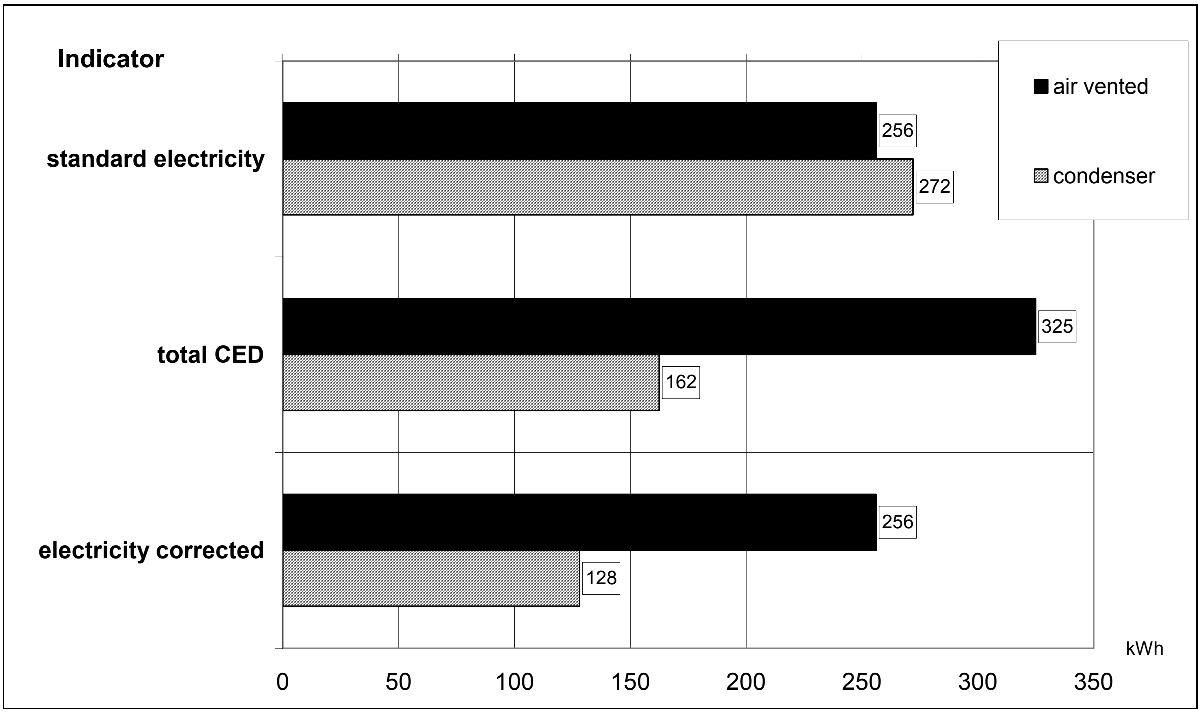


Fig. 8.7 standard electricity demand, CED and corrected electricity demand (*Norway indoor*)

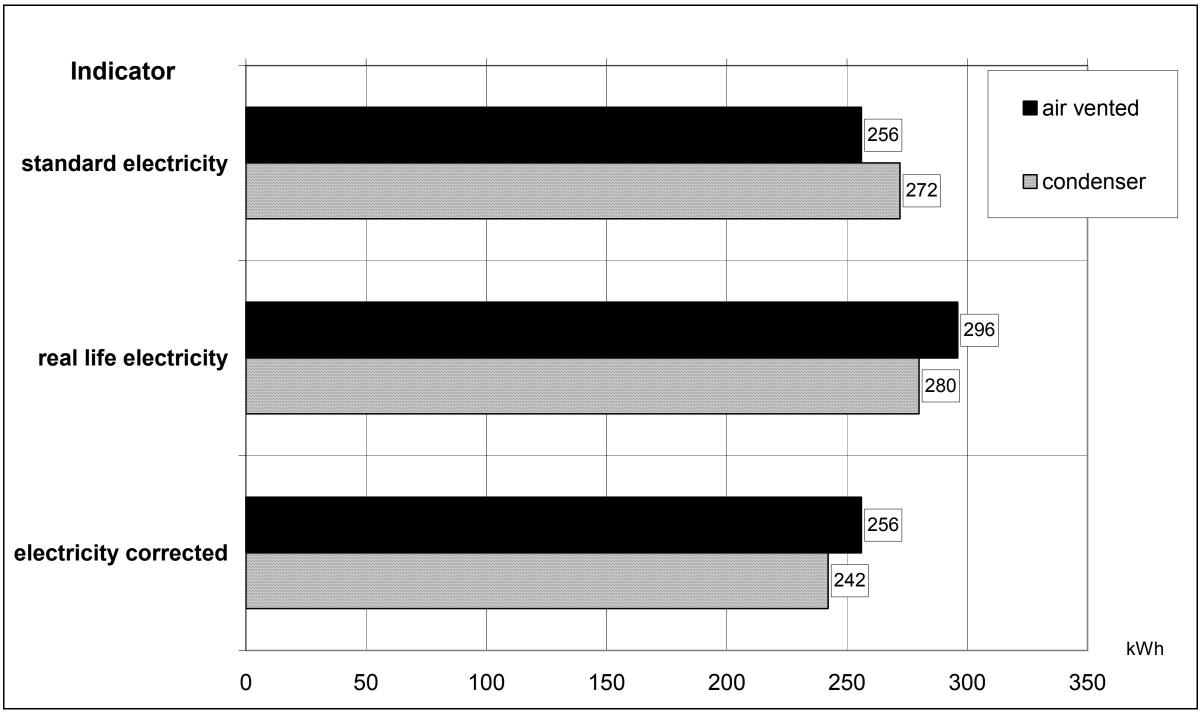


Fig. 8.8 standard electricity demand, real life electricity demand and corrected electricity demand (*Norway outdoor*)

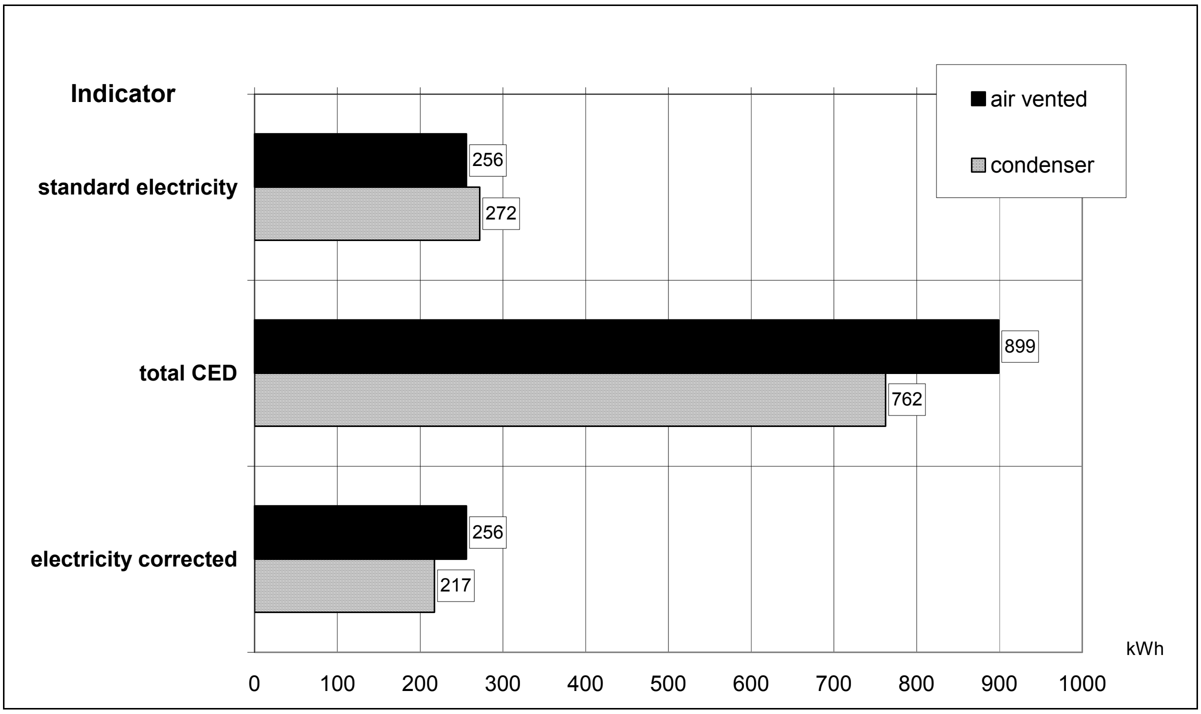


Fig. 8.9 standard electricity demand, CED and corrected electricity demand (*France indoor*)

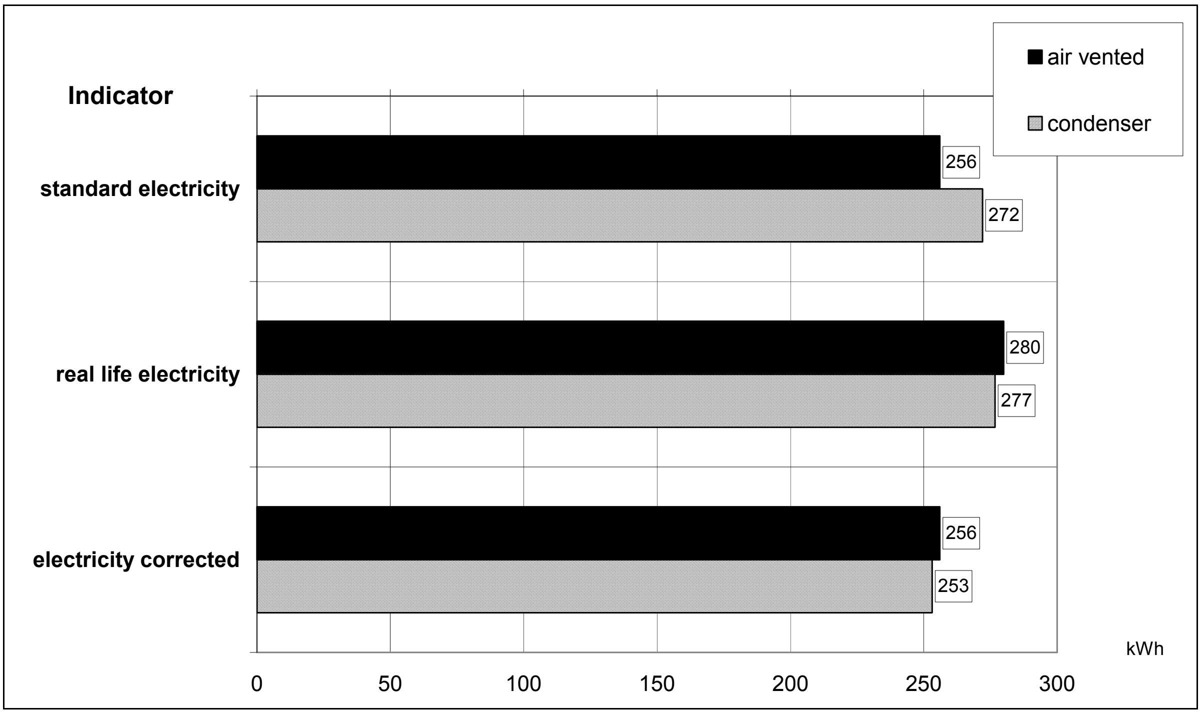


Fig. 8.10 standard electricity demand, real life electricity demand and corrected electricity demand (*France outdoor*)

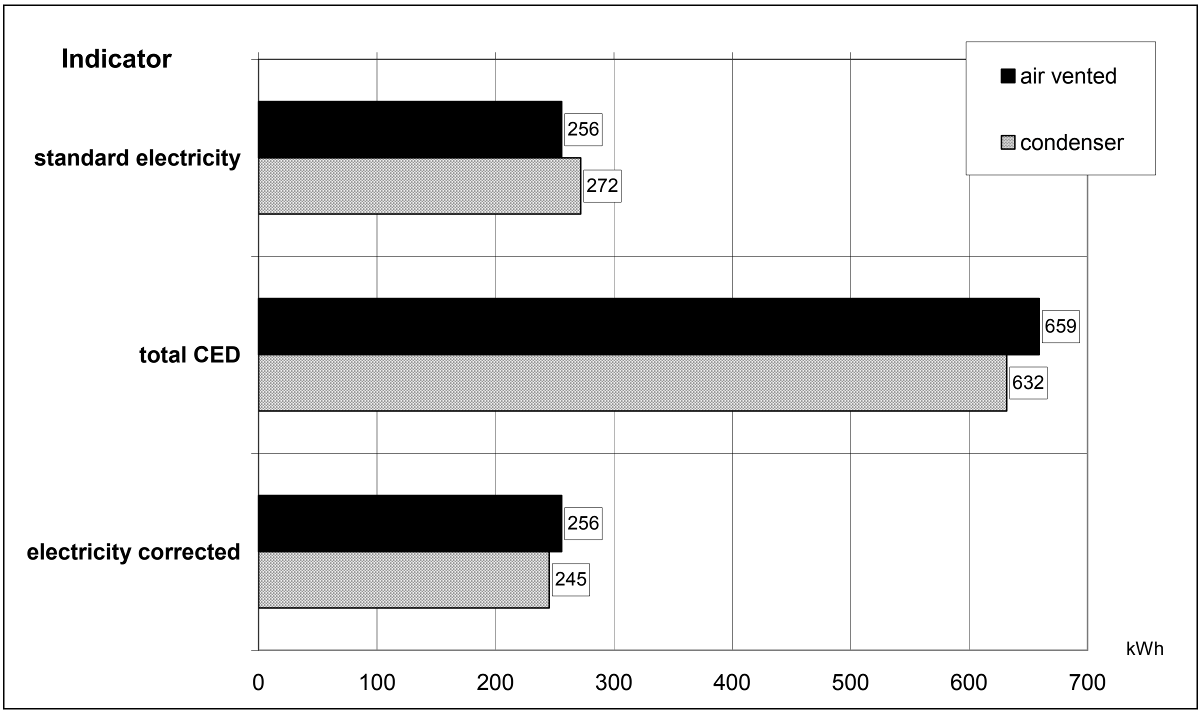


Fig. 8.11 standard electricity demand, CED and corrected electricity demand (*Spain indoor*)

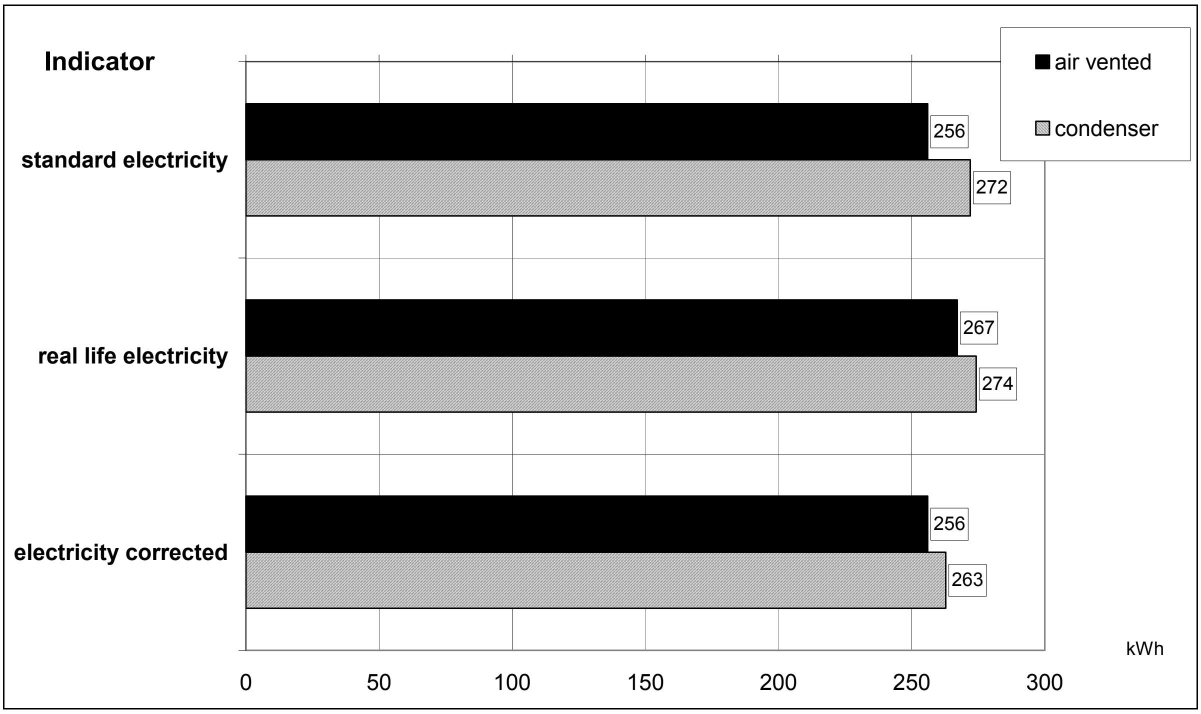


Fig. 8.12 standard electricity demand, real life electricity demand and corrected electricity demand (*Spain outdoor*)

The following table (table 8.1) gives an overview about the correction factors of all regarded base case scenarios.

Table 8.1: correction factors of the *base case scenarios* and relative differences between indoor and outdoor and between the countries

	Indoor	Outdoor	Relative difference outdoor/indoor
Norway	0.471	0.890	+ 89%
Germany	0.821	0.922	+ 12%
France	0.798	0.931	+ 17%
Spain	0.902	0.966	+ 7%
Norway	-	-	
Germany	+ 74%	+ 4%	
France	+ 70%	+ 5%	
Spain	+ 92%	+ 9%	

It can be stated that in all regarded countries the correction factors “indoor” are smaller (meaning a greater reduction) than the correction factors “outdoor”. This means that the consequences of the space heating effect (considered effect indoors) are bigger than the consequences of different ambient temperatures (considered effect outdoors). In Norway the difference between the indoor and the outdoor correction factors is quite (~90 %) big in Spain quite small (7 %, see last column).

The correction factors are also different for the regarded countries. The outdoor factors increase from Norway, over Germany and France to Spain (meaning a decrease of correction). The indoor factors also increase in this direction with the difference, that the German factor is slightly bigger than the French factor. This increase is more important when indoor use is regarded compared to outdoor use, where the correction factors are not as sensitive to the regarded country.

The increase of the factors represents the climatic differences between the regarded countries. The colder the climate of the specific country is, the bigger is the effect of the both regarded effects. The warmer the climate is, the smaller are space heating losses or credits and the smaller are the advantages for the condenser drier with respect to decreasing temperature. The exception of the German indoor factors is a result of differences in space heating supply.

The large reduction in the Norway indoor scenario can be explained by the fact, that in contrast to the other countries the CED of electricity generation is smaller than the CED of space heating supply. Thus the space heating credits for condenser driers lead to a quite large reduction of the total CED.

8.3 Sensitivity analyses

8.3.1 Average loading

When regarding average loading (3.2 kg per cycle) instead of ideal loading, the correction factors are calculated in the same way as in the base case scenarios. Figure 8.13 and 8.14 show the standard electricity demand, the total CED and the corrected electricity demand of the drier technologies in the sensitivity analysis with average loading for *Germany indoor* and *Germany outdoor scenario*. It basically shows the same picture as figure 8.5 and 8.6. The main difference is, that the total energy demand under real life conditions is higher than in the base case scenarios. This results from the increasing specific electricity demand (per kilogramme) due to lower loading (see chapter 4 *parameters*). Therefore with reduced loading more electricity is needed to dry the same amount of laundry. This effect is not considered in the electricity calculation under standard conditions and thus increases the difference between standard and real life energy demand.

Nevertheless the correction factors in the indoor and in the outdoor sensitivity scenarios are the same as in the base case scenarios resulting in identical corrected energy demands as in the base case scenarios.

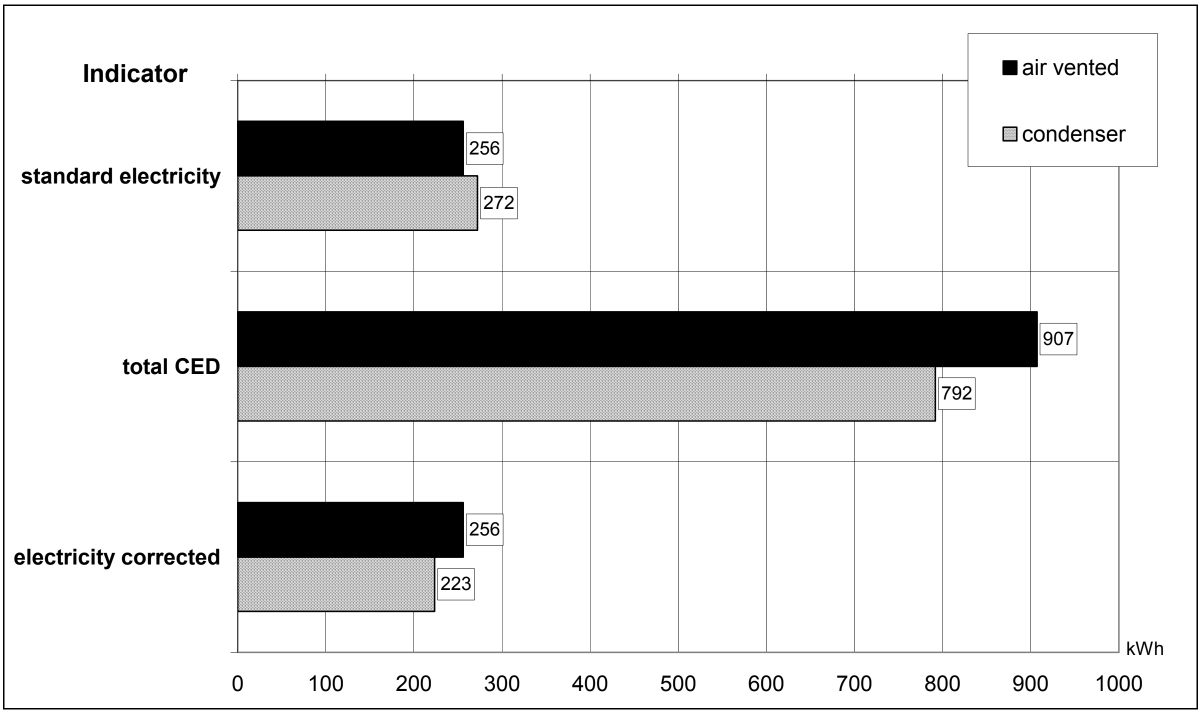


Fig. 8.13 standard electricity demand, CED and corrected electricity demand (*Germany* indoor average loading)

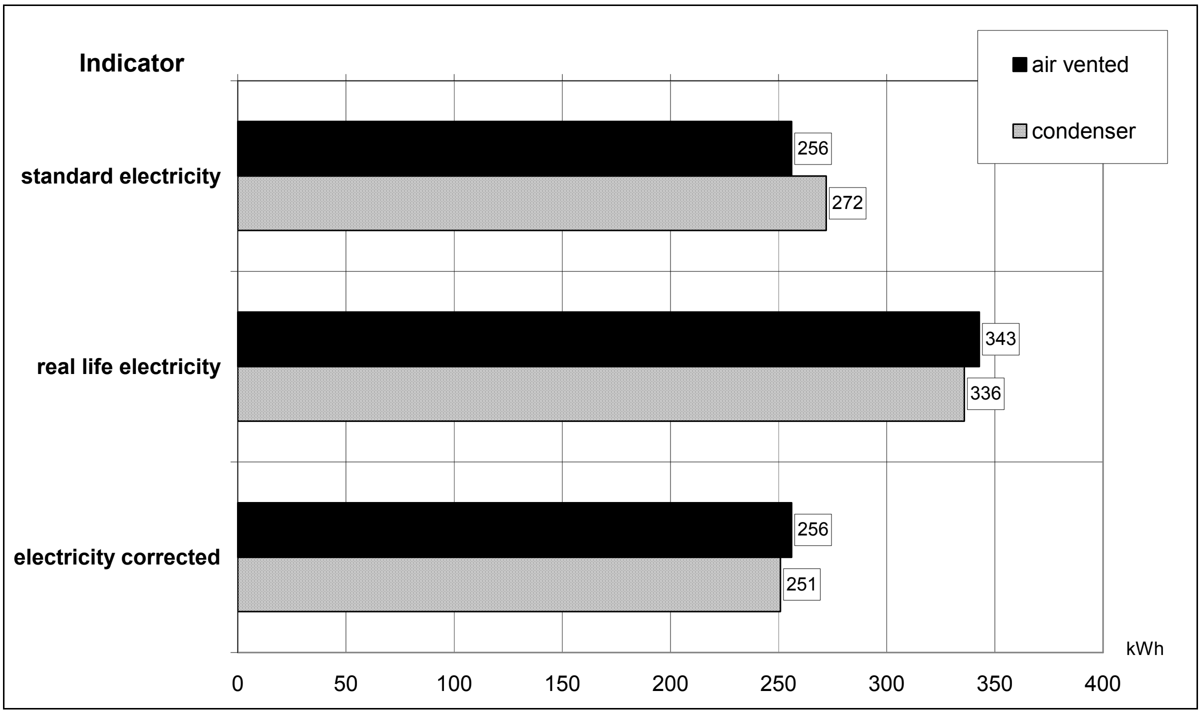


Fig. 8.14 standard electricity demand, real life electricity demand and corrected electricity demand (*Germany outdoor average loading*)

Table 8.2 gives an overview about the correction factors in the sensitivity scenarios for both indoor and outdoor use and for all countries. For easier comparison with the base case correction factors these are copied into the table (italic column, see table 8.1).

Table 8.2: correction factors of the sensitivity scenarios *average loading*

	Indoor		Outdoor	
	5 kg	3.2 kg	*5 kg*	3.2 kg
Norway	*0.471*	0.471	*0.890*	0.890
Germany	*0.821*	0.821	*0.922*	0.922
France	*0.798*	0.798	*0.931*	0.931
Spain	*0.902*	0.902	*0.966*	0.966

The correction factors both when the driers are used indoors and outdoors are the same as in the base case scenarios for all regarded countries.

8.3.2 Use only during heating period

When regarding use only during the heating period instead of whole year use, the correction factors are calculated in the same way as in the base case scenarios. Figure 8.15 and 8.16 show the standard electricity demand, the total CED and the corrected electricity demand of the drier technologies in the sensitivity analysis with use only during the heating period for Germany indoor and outdoor use.

As in figure 8.5 and 8.6 the standard electricity demand of air vented driers is lower than that of condenser driers. The main difference is, that the absolute demand figures are smaller than in the base case scenario resulting from a lower total number of drying cycles during the year. Compared to the base case scenarios, the advantage of condenser driers when considering total CED is much stronger. This is represented in the correction factors. For the indoor case the correction factor is 0.666 (base case scenario: 0.821), for the outdoor scenario the correction factor is 0.886 (base case scenario: 0.922).

This can be explained by the fact that the space heating and ambient temperature effects that are both advantageous for the condenser drier mainly apply during the heating period. Regarding also the summer period, where the use of an air vented drier might be better (under energetically aspects), levels out the advantages of the condenser drier during heating period.

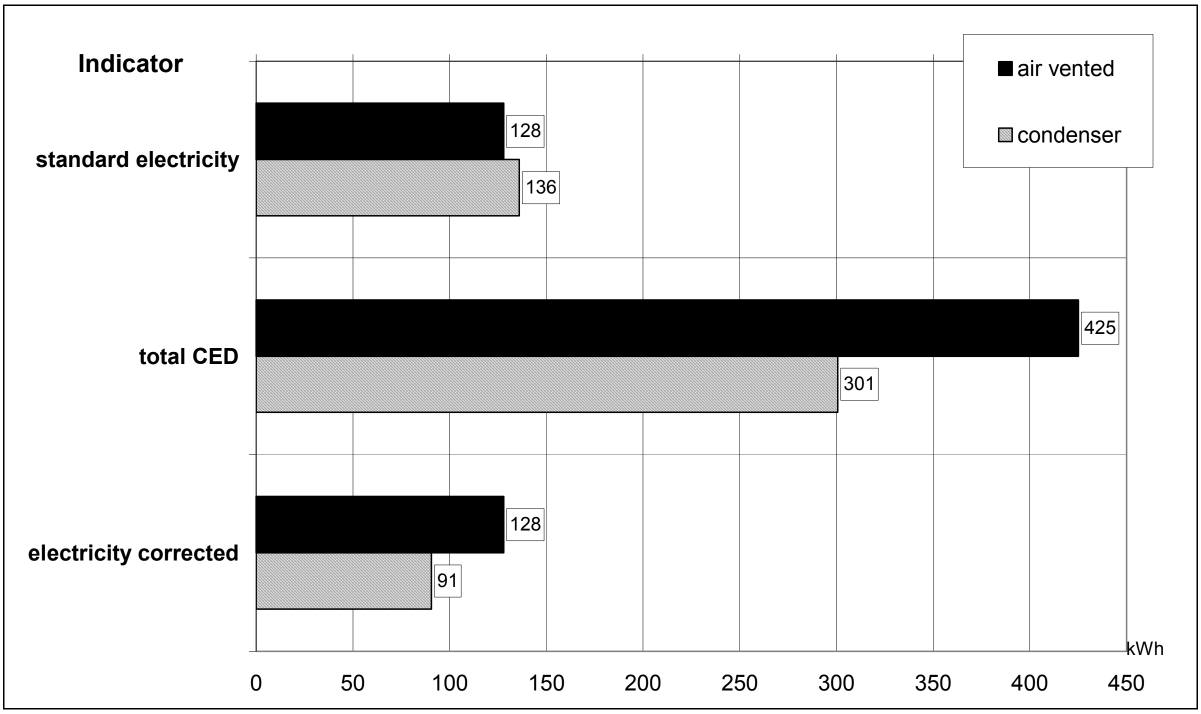


Fig. 8.15 standard electricity demand, CED and corrected electricity demand (*Germany indoor heating period*)

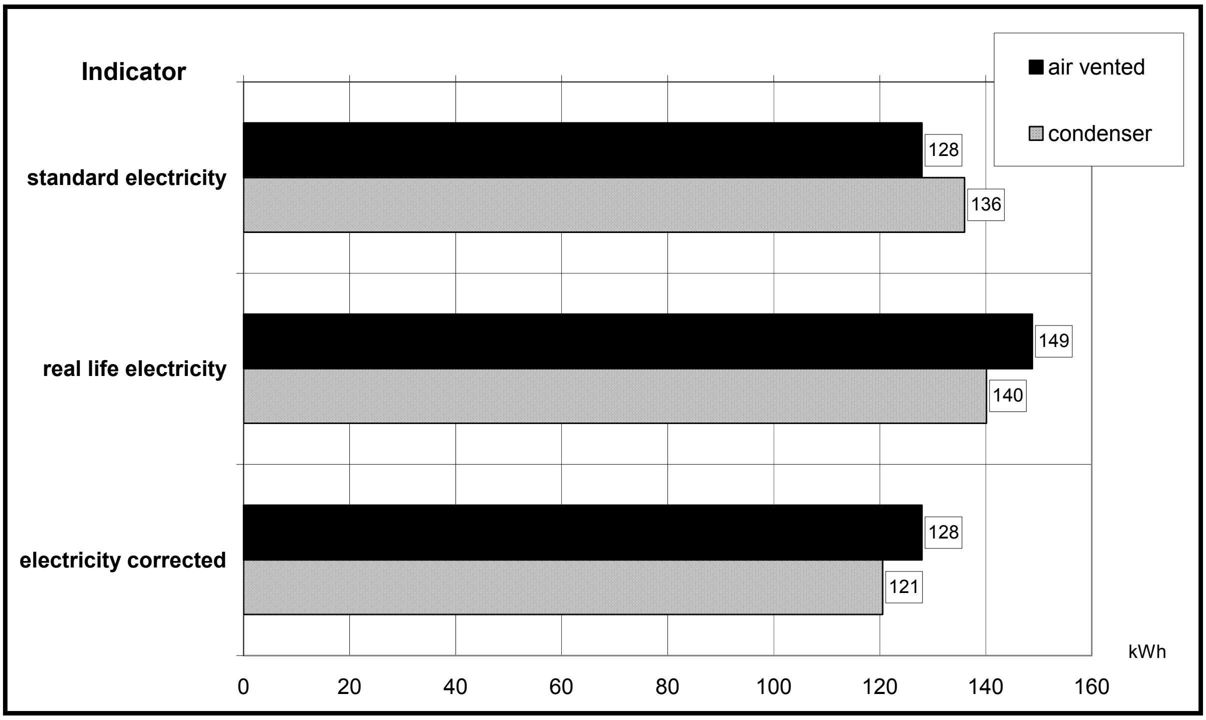


Fig. 8.16 standard electricity demand, real life electricity demand and corrected electricity demand (*Germany outdoor heating period*)

Table 8.3 gives an overview about the correction factors in the sensitivity scenarios for both indoor and outdoor use and for all countries. For easier comparison with the base case correction factors these are copied into the table (italic column, see table 8.1).

Table 8.3: correction factors of the sensitivity scenarios heating period

	Indoor		**Outdoor**	
	whole year	only heating period	*whole year*	only heating period
Norway	*0.471*	0.337	*0.890*	0.883
Germany	*0.821*	0.666	*0.922*	0.886
France	*0.798*	0.620	*0.931*	0.896
Spain	*0.902*	0.568	*0.966*	0.921

It can be seen that in all scenarios the correction factors are smaller compared to the factors in the base case scenarios. This means the reduction of the standard electricity demand of the condenser driers is greater when regarding use only during the heating period. The indoor factors are more sensitive to this parameter. They change more than the outdoor factors.

8.3.3 Remaining water after spin

The following table (table 8.4) shows the calculated correction factors for the different percentages of remaining water after spin. Again for easier comparison with the base case correction factors (remaining water after spin: 70%) these are also copied into the table (italic column see table 8.1).

Table 8.4: correction factors of the sensitivity scenarios *remaining water after spin*

	Indoor			**Outdoor**		
	70%	60%	50%	*70%*	60%	50%
Norway	*0.471*	0.471	0.471	*0.890*	0.890	0.890
Germany	*0.821*	0.821	0.821	*0.922*	0.922	0.922
France	*0.798*	0.798	0.798	*0.931*	0.931	0.931
Spain	*0.902*	0.902	0.902	*0.966*	0.966	0.966

It can be seen that the factors both when the drier is used inside and outside heated rooms don't change with decreasing percentage of remaining water after spin.

8.3.4 Air extraction rate of the air vented drier

As the air extraction rate of air vented driers can't be determined exactly, next to a rate of 120 m^3/h also a rate of 150 m^3/h is regarded. The calculation with an air extraction rate of 150 m^3/h only changes the correction factors for indoor use as the air extraction rate changes the space heating effect when an air vented drier is used inside heated rooms (see also sensitivity analysis for space heating credits below).

Table 8.5 shows the correction factors for both indoor and outdoor use. The outdoor factors are the same as in the base case. For easier comparison the base case correction factors of indoor use (120 m^3/h) are also shown (italic column, see table 8.1).

Table 8.5: correction factors of the sensitivity scenarios *air extraction rate*

	Indoor		**Outdoor**
	120 m^3/h	150 m^3/h	*120 m^3/h*
Norway	*0.471*	0.449	*0.890*
Germany	*0.821*	0.807	*0.922*
France	*0.798*	0.786	*0.931*
Spain	*0.902*	0.897	*0.966*

The correction factors slightly decrease when an air-extraction rate of 150 m^3/h is assumed (meaning a greater reduction of electricity demand of condenser drier). This can be explained by the fact, that through a higher air-extraction rate of air vented driers the amount of air, that is blown to the outside, has to be replaced by cold air and then has to be reheated by the space heating system, increases. This results in a higher space heating energy demand of the air vented driers whereas at the same time the parameters for condenser driers don't change compared to the base case scenarios. This results in a further decline of the performance of the air vented driers compared to condenser driers in relation to the base case scenarios.

8.3.5 Length of cycle times

The length of the cycle time determines (among other parameters) the total amount of extracted air of air vented driers. This only has an effect when air-vented driers are used indoors as the amount of extracted air only influences the space heating energy demand.

In the base case scenarios it is assumed that the cycle time is 90 minutes. As some air-vented driers have a longer cycle time, the correction factors were also calculated with cycle times of 120 and 240 minutes.

Table 8.6 shows the correction factors for both indoor and outdoor use. The outdoor factors are the same as in the base case. For easier comparison the base case correction factors of indoor use (90 minutes) are also shown (italic column, see table 8.1).

Table 8.6: correction factors of the sensitivity scenarios length of drying cycle

	Indoor			**Outdoor**
	90 min	120 min	240 min	*90 min*
Norway	*0.471*	0.442	0.357	*0.890*
Germany	*0.821*	0.803	0.737	*0.922*
France	*0.798*	0.783	0.725	*0.931*
Spain	*0.902*	0.895	0.869	*0.966*

The correction factors with longer cycle times are smaller than in the base case, meaning a bigger reduction of the electricity demand of condenser driers. Longer cycle times mean a larger amount of extracted air and thus more space heating energy is required. As the energy demand of condenser driers stays constant this means a relative decrease of the performance of air vented driers compared to condenser driers. The effect is stronger in countries with a colder climate.

8.3.6 Relative humidity of air

The relative humidity of the air influences the energy demand of air vented driers. Under standard conditions the relative humidity is set 65 %. At the standard temperature of 20°C, this means an absolute humidity of 9.45 g/kg.

With lower humidity the energy demand of air vented driers decreases. Lower air humidity lowers the electricity demand and thus also the space heating energy demand of the air vented drier. The energy demand of condenser driers is not affected.

As sensitivity the correction factors are also calculated with a relative humidity of air of 40 % and 25 %.

Table 8.7 shows the correction factors for both indoor and outdoor use for the base case (italic column, see table 8.1) and the two sensitivity analyses with lower relative humidity.

Table 8.7: correction factors of the sensitivity scenarios length of drying cycle

	Indoor			**outdoor**		
	65 %	40 %	25 %	*65 %*	40 %	25 %
Norway	*0.471*	0.486	0.495	*0.890*	0.902	0.966
Germany	*0.821*	0.847	0.863	*0.922*	0.939	0.950
France	*0.798*	0.824	0.839	*0.931*	0.949	1.020
Spain	*0.902*	0.931	0.948	*0.966*	0.991	1.070

It can be seen that the correction factors both indoors and outdoors slightly increase, meaning a smaller reduction of the electricity demand of condenser driers. This is due to the fact that a lower air humidity only lowers the energy demand of air vented driers whilst that of condenser driers stays constant. The energy demand of air vented driers becomes relatively better the lower the relative humidity is.

In those cases where the correction factor in the base case is already close to one (France outdoor and Spain outdoor), a relative humidity of 25 % results in correction factors that are slightly above one. This means that the energy demand of condenser driers has to be increased to represent the total energy demand under real life conditions.

8.3.7 Space heating credits

In the base case scenarios it is assumed that during heating season 50 % of the electricity demand of condenser driers can be credited against the space heating demand, replacing a corresponding amount of space heating energy demand.

To check a more conservative assumption, the correction factors where also calculated when assumed that during the heating period only 25 % of the electricity demand can be credited against space heating energy demand.

This change only applies to condenser driers and only when used indoor heated rooms. Therefore, the correction factors of outdoor use don't change with this sensitivity analysis (see also sensitivity analysis for air extraction rate above).

Table 8.8 shows the correction factors for both indoor and outdoor use. The outdoor factors are the same as in the base case. For easier comparison the base case correction factors of indoor use (50 %) are also shown (italic column, see table 8.1).

Table 8.8: correction factors of the sensitivity scenarios s*pace heating credits*

	Indoor		**Outdoor**
	50 %	25 %	*50 %*
Norway	*0.471*	0.640	*0.890*
Germany	*0.821*	0.876	*0.922*
France	*0.798*	0.869	*0.931*
Spain	*0.902*	0.940	*0.966*

The correction factors when only 25 % of the electricity is credited are bigger than those of the base case scenarios (meaning a smaller reduction of the electricity demand of the condenser drier) as not so much credits for space heating can be given from the energy demand of the condenser driers.

8.3.8 Correction factors calculated with GWP

Differences are only to be expected in the indoor scenarios (see chapter 3). Table 8.9 gives an overview about the potential correction factors. The outdoor factors are the same as in the base case. For easier comparison the correction factors calculated with the CED are also shown.

Table 8.9: correction factors of the base case scenarios calculated with the GWP instead of the CED

	Indoor		Outdoor
	CED-factor	GWP-factor	*CED-factor*
Norway	*0.471*	-0.005	*0.890*
Germany	*0.821*	0.808	*0.922*
France	*0.798*	0.394	*0.931*
Spain	*0.902*	0.906	*0.966*

When regarding the correction factors of the base case scenarios calculated with the GWP instead of the CED, two main questions arise.

1. Why is the 'GWP-factor' in *Norway indoor* around zero (even below) and the factor in *France indoor* also much smaller than the 'CED-factor'?
2. Why is there a difference between the 'CED-factors' and the 'GWP-factors' in *Norway indoor* and *France indoor* and why are there (almost) no differences in *Germany indoor* and *Spain indoor*?

The first question can be explained by the fact that space heating supply in Norway has an approx. 2.7 times higher GWP than electricity supply (due to higher ratio of renewable energy sources in the electricity supply system). In France the GWP of the space heating supply is approx. twice as high as the GWP of electricity supply (due to relatively high ratio of electricity generation by nuclear power).

A condenser drier safes a certain amount of space heating. This means, the GWP of this amount of safed end energy produced by an average space heating system can be subtracted from the GWP caused by the electricity supply for the drier itself. In Norway the heating period is quite long and therefore the assumed proportion of the electricity demand of the drier (25 % or 50 %) can be credited against space heating demand for a quite long period (9 months in total). This results in the fact, that if 50 % of the drier electricity is credited during the heating period 38 % of the annual drier electricity demand can be credited against space heating demand. As the GWP of space heating supply is 2.7 times as high as the GWP of electricity demand, this results in the fact that there is practically no GWP through the use of the condenser drier.

In France the effect is similar but not as strong as in Norway: the GWP of space heating supply is only (but still!) 2.1 times as high as the GWP of electricity demand and the heating period is shorter (only 6 months in total). This means that 25 % of the annual electicity demand can be credited agains space heating supply, resulting in a reduction of the total GWP of some 50 %.

The lower GWP of electricity supply compared to space heating supply in Norway comes from a very high ratio of renewable energies in the electricity generation. In France it comes from a high ratio of electricity generation through nuclear power plants.

In both countries the effect is even stronger when regarding drier use only during the heating period.

The second question can be explained by comparing the differences between the GWP of space heating and the GWP of electricity supply with the differences between the CED of space heating and the CED of electricity supply.

The following table (table 8.10) shows the ratio between space heating supply factors and electricity supply factors. For example, the space heating supply in Germany only needs half the primary energy than the electricity supply system to produce the same amount of end energy.

Table 8.10: ratio between space heating supply factors and electricity supply factors

	CED	**GWP**
Norway	1.11	2.69
Germany	0.47	0.51
France	0.60	2.08
Spain	0.74	0.70

It can be seen that the ratio in Germany and Spain is practically the same for both the CED factors and the GWP factors. In France and Norway they are quite different. This results in only very small changes of the correction factors for Germany and Spain and in the above described large changes in Norway and France.

9 Main results and conclusions

To give an overview about the span of the correction factors table 9.1 to 9.3 give a compilation of the factors derived from the calculations for the base case scenarios and the regarded sensitivity analyses. The tables also show the relative differences of the correction factors of the sensitivity analyses compared to the correction factors of the base case in the respective country.

Table 9.1: correction factors indoor and relative difference to base case indoor (1)

	base case	loading	only heating period	remaining water after spin		air extraction rate
		3.2kg		60%	50%	150 m3/h
Norway	**0.471**	0.471	0.337	0.471	0.471	0.449
Germany	**0.821**	0.821	0.666	0.821	0.821	0.807
France	**0.798**	0.798	0.620	0.798	0.798	0.786
Spain	**0.902**	0.902	0.568	0.902	0.902	0.897
Norway	**-**	-	-29%	-	-	-5%
Germany	**-**	-	-19%	-	-	-2%
France	**-**	-	-22%	-	-	-1%
Spain	**-**	-	-37%	-	-	-1%

Table 9.2: correction factors indoor and relative difference to base case indoor (2)

	cycle time		relative humidity of air		credits for space heating	GWP-factor
	120 min	240 min	40%	25%	25%	
Norway	0.442	0.357	0.486	0.495	0.640	-0.005
Germany	0.803	0.737	0.847	0.863	0.876	0.808
France	0.783	0.725	0.824	0.839	0.869	0.394
Spain	0.895	0.869	0.931	0.948	0.940	0.906
Norway	-6%	-24%	+3%	+5%	+36%	-101%
Germany	-2%	-10%	+3%	+5%	+7%	-2%
France	-2%	-9%	+3%	+5%	+9%	-51%
Spain	-1%	-4%	+3%	+5%	+4%	0%

Table 9.3: correction factors outdoor and relative difference to base case outdoor

	base case	loading	only heating period	remaining water after spin		relative humidity	
		3.2kg		60%	50%	40%	25%
Norway	0.890	0.890	0.883	0.890	0.890	0.902	0.966
Germany	0.922	0.922	0.886	0.922	0.922	0.939	0.950
France	0.931	0.931	0.896	0.931	0.931	0.949	1.020
Spain	0.966	0.966	0.921	0.966	0.966	0.991	1.070
Norway	-	-	-1%	-	-	+1%	+9%
Germany	-	-	-4%	-	-	+2%	+3%
France	-	-	-4%	-	-	+2%	+10%
Spain	-	-	-5%	-	-	+3%	+11%

The results can be interpreted as follows:

- Almost all calculated correction factors are below 1. This mean that in almost all cases the corrected electricity demand of condenser driers is smaller than the standard electricity demand, when the relation between real life energy demand of the two systems should be represented. An exception is the sensitivity calculation with a relative humidity of the air of 25% with outdoor use. Here in France and Spain the correction factors are slightly above 1.
- As shown in table 8.1 the calculated potential correction factors are smaller (meaning a bigger correction) for the indoor scenarios than for the outdoor scenarios. This means that the effect of lower ambient temperature is smaller than the consideration of space heating demand and credits. This difference is the biggest for Norway (90 %). It is smaller for France, Germany and Spain (17 %, 10 %, 7 %).
- The potential correction factors are not sensitive to the parameters:
    - loading of the drier,
    - remaining water after spin.
- The factors are sensitive to the parameters:
    - credits for space heating substitution,
    - air extraction rate,
    - cycle time,
    - relative humidity of air,
    - use pattern: whole year use vs. use only during heating period,
    - the way of modelling the correction factors: CED or GWP as “common currency” to make different end energies comparable.

    The extend of deviation from the base case correction factors is different for the different parameters (see the last four rows in tables 9.1 to 9.3)
- The CED-correction factors have the greatest effect in Norway, due to its quite cold climate and lower CED of electricity supply compared to space heating supply.
- The correction factors increase (meaning a smaller correction of the electricity demand of condenser driers) as the climate becomes warmer.
- The GWP-correction factors have a very big effect in Norway (due to cold climate and lower GWP of electricity supply compared to space heating supply) but also in France (also due to lower GWP of electricity supply compared to space heating supply).
- The span of the correction factors is quite big:
    - in Norway the span is the largest. Here the calculated correction factors vary between 0.89 (base case outdoor) and –0.005 (GWP-factor indoor). In Spain the correction factors are quite constant between around 0.9 and around 1

with the exception of the factor in the sensitivity calculation with use only during heating period (correction factor: 0.568).

- In the base case indoor scenarios the factors vary between 0.471 (Norway) and 0.902 (Spain).

Against these results the main conclusions are:

- As the span of the correction factors is quite big, it might be difficult to define a correction factor that fits for all countries and drying situations.
- It might be difficult to communicate “corrected electricity demand values” to retailers and consumers.

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