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Selection of Indicators and Benchmarking of the European Printing Industry

EMSPI: Energy Management Standardization in Printing Industry

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A. Introduction

This document is the second report delivered in the EMSPI (Energy Management Standarization In Printing Industry) project. It belongs to the Work Package 3 (WP3), in which the main objective is to define Energy Performance Indicators which can help companies assess their energy performance. Furthermore, this document includes as well a discussion of the European benchmarking indicators, which establishes the baseline for future comparisons between companies at the European level. Due to the actual lack of data on energy consumption in the printing industry, it is not viable at the moment to establish the benchmarking values, but it is possible to determine the indicators that may be suitable for it. At the end of the project, once the work with the printing companies is conducted, there will be more information available to establish the European benchmark.

The purpose of defining indicators is to efficiently monitor and manage a certain process with the intent of maintaining a specific level for the process or to change the process. For an indicator to be characterized as being suitable, it needs to weigh the following often conflicting demands:

- The indicator shall provide precise information about the performance.
- The indicator shall be based on data that is easily accessible.

These demands are also present when listing energy indicators and the meaning of these in the context of the graphic industry will be described in this document.

When the suitability of defined energy indicators is to be evaluated, the experience from the Work Package 2 (WP2) of the EMSPI project should be taken into consideration. A significant identified barrier for the work with energy management in graphic companies is the lack of intern prioritization, which is closely connected to the companies' ability to monitor and analyse the energy consumption.

In this context, the energy indicators play an important role, since the precondition for a company to work with continuous improvements is the company being capable of monitoring the performance according to the principles for PDCA[1] under the frame of a management standard such as ISO 50001. Therefore, the basis for working with definition of energy indicators should be that it is preferable for a company to have indicators that are not the most suitable than not to have indicators at all.

This document provides an analysis and selection of energy performance indicators for the printing industry, as well as an outline of the proposed European benchmarking. It starts with the definition of what indicators are, focusing next on energy indicators in particular. Given the topic of this project, the most important indicators to be included are those related to the direct energy consumption in the companies. However also indicators which address other aspects of the energy consumption are included as well such as indicators for energy costs and indicators for indirect energy consumption.

Furthermore, not only are the indicators described and analysed, their suitability as internal use and benchmarking indicators is assessed as well in the last section of the document, selecting those indicators which may be more suitable for these purposes.

[1] Plan Do Check Act (PDCA) is a four-step management method for continual improvements.

B. Definition of Energy Performance Indicators

According to the standard ISO 50001, an indicator can be defined as:

> ***3.13 Energy performance indicator (EPI)***
>
> *Quantitative value or measure of energy performance, as defined by the organization.*
>
> *NOTE EPIs could be expressed as a simple metric, ratio or a more complex model.*

According to the definition of ISO 50001, indicators can both be based on raw data of the energy consumption and also be key figures for the energy performance, where the energy consumption is normalised to a fixed reference to compensate for the variation in production and climate conditions. Since the production in the graphic industry often varies, this document will primarily focus on energy performance indicators consisting of key figures where the energy consumption is normalised in relation to relevant references.

An indicator is a variable that provides information on the state or level of a parameter. As stated in the introduction, in this section, the different types of indicators which could be useful for the printing industry are defined. These indicators can be categorized as follows:

- Energy indicators for the production process
- Energy indicators for general space heating
- Energy indicators for general space cooling
- Energy costs indicators
- Other energy related indicators

A theoretical ideal energy indicator provides stable information about the energy performance of a specific process without the indicator being affected by other conditions than the actual process. However, such an indicator is hardly realistic in the real world, since the majority of indicators can be affected by external conditions and at times to such a degree that it makes the indicator unstable and unsuitable as management tool.

When evaluating the possibility of defining suitable indicators, the reference can pose a challenge for energy indicators, since the traditional ways to calculate the size of production not necessarily have a direct connection with the energy consumption, or they are not calculated with the wanted frequency. On the contrary, the energy consumption is often easily accessible at the overall company level, but more difficult to obtain if energy consumption of single production processes at a more detailed level is needed. A specific condition that must be addressed is the synchronization of the data capture, which underlies the indicator (consumption and reference) and which can have a large impact on how suitable the indicator is.

The most relevant conditions for the suitability of energy indicators are described in the following section.

C. Conditions influencing Energy Performance Indicators

Energy Performance Indicators can be a very powerful tool for printing industries to evaluate their performance. However, their calculation and correct use can be influenced by several factors which affect the results obtained. In this chapter, an analysis of the conditions which may affect the indicators that will be proposed in the next section for the printing industry is included.

C.1. Size of production

There are a number of conditions that can affect the reference data for the size of the production, and with it make an energy indicator unstable:

Variations in the efficiency of production

If there are variations in some of the production parameters that are included in the process, it can influence the energy indicator even though the energy efficiency of the process in principle is unchanged. This can, for example, be changes in the quality of the used materials or changes in the size of print jobs, which means that the process possibly will be slower or with more breaks due to many changeovers. Changes in the total production amount will have the same influence.

Variations in the efficiency of the production will affect the majority of indicators no matter how suitable the indicators may be. It is possible in some cases to compensate for the variations in the produced amount by analyzing the indicators. More detail on this is provided in section D.2.2.

Distance between data and process

The distance between the process and the data used has a great impact on the indicator and the larger the distance between the data and the process the larger the uncertainty is. This means that an indicator which is based on, for example, the company's turnover or number of employees will make the indicator more unstable than if the data used to a higher degree is related to the physical production such as the amount of raw materials, machine counts, etc.

Variations in data for amount and machine data

There are a number of obvious references for indicators in the graphic industry that are attached to data for the amount of raw material and machine data which all can give variations that can influence the indicators.

In the graphic industry, the amount of substrate in tonnes is often used as a reference for energy indicators. Since the substrate used in production can vary in thickness, it can affect the indicator and make it unstable. Moreover, for some companies, it can be difficult to make a division of the tonnage on different machines which can make this reference unsuitable for monitoring of the performance of the single machines.

Another method is to use the number of square meters printed material as the starting point. As with the use of the weight of substrate, a factor to consider is that the area of substrate in the printing machine can vary. Since the printing machine pretty much will use the same amount of energy no matter how large the area of substrate is, the indicator can be significantly affected if the area of substrate varies a lot. Likewise, with the use of the weight of substrate as reference, it can be difficult to make a specific division of the area on several machines.

Finally, it is possible to use the number of prints on the printing machine as the basis. If the point of reference is the number of prints and the energy consumption at the same time is summarized for several machines, it can be necessary to normalise the number of print compared to the sizes of the machines. For example, if a company has both a 16 page print machine and an 8 page print machine, the counting values for the 8 page machine can be divided by 2 and thus be converted into the number for the 16 page print. This is naturally an estimation method because linear proportionality cannot be expected between printing machines of different sizes.

Variations in input and output amounts

An indicator will give different results depending on whether it is based on input or output amounts. If the waste that occurs during the production process varies, it will directly make an indicator based on output amounts more unstable than if it is based on input amounts. The instability is increasing the later in the process the waste occurs. However, an indicator based on output amounts can be more relevant if comparing products or when benchmarking.

Working hours

Another important factor to evaluate when analyzing the indicators is the number of working hours per year, which may differ from company to company. Some are in operation continuously, 7 days a week and 24 hours per day, others only during the day and on working days, based on the type of production. Therefore, the number of working hours is a correction factor to consider in some cases because it may help understand the real time within a year that the company uses for its production and the differences between companies.

C.2. Energy consumption for the manufacturing process

There are several conditions related to making up the energy consumption that can influence the stability of the indicators.

Separation or summarization of energy sources

If all energy sources in the company are summarized to a common indicator, it can be difficult to use the indicator as a management tool, because the indicator typically both will include energy consumption to the production and energy consumption for heating and/or cooling of the facilities. Therefore, separate indicators should as far as possible be listed for the different energy sources and as a minimum with a separation of energy consumption for production and energy consumption for heating and/or cooling of the facilities. However, an indicator based on summarized energy consumption can be relevant when comparing products or when benchmarking.

Separation or summarization of production processes

Just as with the energy sources, definition of indicators for the different production processes will give more stable indicators rather than if the listed indicators cover several or all production processes. However, the challenge by listing indicators for the single production process is often that data for the single process does not exist or is difficult to obtain.

In fact, the existence of secondary meters for the single production process and the electricity consumption is not common in the graphic industry. As a result, companies often just measure total energy consumption at the company level. The companies that use natural gas in the production may have secondary meters related to the single production process, but the physical accessibility of these can be difficult.

C.3. Synchronization of the data capturing

It is very important for the stability of an indicator to have synchronized data capturing of consumption and the reference to the same period. The importance of this will increase, when the frequency of the indicator increases. If a company e.g. lists a weekly indicator for gas consumption on a printing machine, where the consumption of gas and the number of production hours on the machine are calculated with a deviation of 1-2 days, it will probably make the indicator unstable and unsuitable as a management tool. If the same indicator is listed on a monthly basis, a deviation of 1-2 days will have a much smaller influence and thus the indicator will be more suitable.

For indicators that are listed yearly, the synchronization of the periods of captured data is generally of less importance, but some specific conditions for the graphic industry that should be taken into consideration exist. When data for the consumption of substrate is used as reference for indicators, it should be considered whether the data for input amount shows the purchase of substrate or the consumption of substrate. Since some printing houses purchase large amounts of substrate at a time, storage deviation can have a great impact, and therefore the consumption of substrate should be always used as the reference.

The same is applicable for indicators based on the company's output amounts, where waste is substracted. Since substrate waste is typically delivered for recycling when containers and cages are full, this can cause displacements of the period and thus make the indicator unstable.

C.4. Degree days

The influence of climate conditions on energy consumption for space heating and space cooling is another factor to consider when evaluating the indicators. Both for days that are warmer and cooler than the usual, there are parameters which help establish the differences between the average baseline and the daily conditions.

It should be noted that the use of these concepts varies from country to country. On the one hand, while in some countries, mainly those with colder climate conditions, the Heating Degree Day (HDD) term is widely understood, in others, it is unknown for the general population. On the other hand, the Cooling Degree Day (CDD) term is not very common, even in countries where the use of space cooling is widespread. Furthermore, since both parameters use a reference temperature, if different references are used by every country, the comparability of the indicators which include these parameters may be limited.

Heating degree day is a measurement designed to reflect the demand for energy needed to heat a building. It is derived from measurements of outside air temperature. The heating requirements for a given structure at a specific location are considered to be directly proportional to the number of HDD at that location.

Heating degree days are defined relative to a base temperature—the outside temperature above which a building needs no heating. The most appropriate base temperature for any particular building depends on the temperature that the building is heated to, and the nature of the building (including the heat-generating occupants and equipment within it). The base temperature is usually an indoor temperature of 18°C or 19°C which is adequate for human comfort (internal gains increase this temperature by about 1 to 2°C).

HDD are often calculated using simple approximation methods that use daily temperature readings. One popular approximation method is to take the average temperature on any given day, and subtract it from the base temperature (e.g. 18°C or 19°C). If the value is less than or equal to zero, that day has zero HDD. But if the value is positive, that number represents the number of HDD on that day. E.g., when the outside temperature is 10°C on a certain day, this means 8 HDD for that particular day (based on an 18°C base temperature).

Cooling degree day (CDD) is a measurement designed to reflect the demand for energy needed to cool a building. Basically, it is calculated and expressed in the same way as that of the HDD but, instead of using a base temperature that is influenced by the temperature for heating comfort, it considers a base temperature for cooling comfort. In general, the temperature is usually an indoor temperature adequate for human comfort of around 25 ºC.

In this case, for the calculation, the average temperature on any given day is taken, and subtracted from the base temperature (e.g. 25°C). If the value is less than or equal to zero, that day has zero CDD. But if the value is positive, that number represents the number of CDD on that day.

C.5. Space utilization

Due to the different uses of the areas that compose printing companies, it is common to have different heating and cooling requirement depending on the area. As such, for instance, the heating or cooling requirements of offices and storage spaces are usually different, because storage spaces have lower occupation rates.

In a similar way, the functioning of the machines in the production area may cause a higher temperature in that zone due to the dissipated heat, and this may cause a lower need for space heating during the winter and a higher need for space cooling during the summer.

C.6. Height of indoor spaces

Not only do the area and the space utilization influence the heating and cooling needs, but the height of indoor spaces needs to be considered as well. Therefore, a more accurate basis for comparison would be total volume to be heated, as there may be differences in ceiling heights between different areas, but question whether this would be available. The height of the indoor space could be taken as a correction factor.

D. Development of Energy Performance Indicators for the Printing Industry

D.1. Methodological approach

In this section of the document, a number of potential indicators for the performance in the production will be analysed and evaluated according to the suitability as monitoring and management tool internally in graphic companies.

The suitability of the possible indicators will be evaluated from the following scale:

- High
- Good
- Acceptable
- Bad
- Useless

A long list of the proposed indicators will not be suitable for use as indicators in most companies. Therefore, the list should not be seen as a catalogue of possible indicators, but should be basis for selection of the most suitable indicators as foundation for the work that will be carried out in upcoming Work Packages. In fact, in section E, a further discussion of the indicators is included, proposing the most suitable indicators for the internal use of the companies and the sectorial benchmarking.

D.2. Energy indicators for the production process

D.2.1. Analysis of possible indicators

The indicators that are analysed and evaluated in this section will be based on the specific energy sources, which were identified in WP2 of the EMSPI project. Regarding the energy consumption in the production, the primary and often only energy source is electricity. Some printing houses also use natural gas in the production. Please note that the indicators that are analyzed in this section make reference solely to the use of energy related to production purposes. Indicators addressing the use of energy for other purposes such as space heating or space cooling are analysed in sections D.3 and D.4. The specific conditions that are applicable for indicators where the energy sources are summarized are described in a separate table below.

An indicator for the energy performance of the production is in general normalised to compensate for the variation in production in the following way to compensate for the variation in production:

$$Energy\ indicator = \frac{Consumption = Energy}{Reference = Size\ of\ production}$$

When listing the indicators below, kWh is used as the unit for electricity, Nm3 as the unit for natural gas and ton as specification of weight. However, the use of other units such as e.g. GJ for electricity or kWh for natural gas does not change anything, and it is only in benchmarking necessary with conversion factors to make re-calculation to the same units.

The importance of frequency for the suitability is attempted evaluated on respectively an annual basis as a monthly basis as examples. However, other frequencies can be relevant in other connections such as e.g. day, week, and quarters.

Table 1: Potential indicators for specific energy consumption in production. Source: Developed by the authors.

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	**Monthly**
1.1	$\frac{Electricity\ [kWh]}{Consumed\ paper\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Consumed\ paper\ [ton]}$	Variation in substrate thickness.	Good	Acceptable
1.2	$\frac{Electricity\ [kWh]}{Purchased\ paper\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Purchased\ paper\ [ton]}$	Variation in substrate thickness. Purchase of substrate might not reflect the actual consumption due to substrate in stock.	Acceptable	Useless

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	**Monthly**
1.3	$\frac{Electricity\ [kWh]}{Produced\ paper*\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Produced\ paper*\ [ton]}$ ** Produced substrate = <u>Consumed</u> substrate – Waste substrate*	Variation in substrate thickness. Waste substrate might not cover the same period due to waste substrate in stock.	Acceptable	Useless
1.4	$\frac{Electricity\ [kWh]}{Produced\ paper*\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Produced\ paper*\ [ton]}$ ** Produced substrate = <u>Purchased</u> substrate – Waste substrate*	Variation in substrate thickness. Purchase of substrate might not reflect the actual consumption due to substrate in stock. Waste substrate might not cover the same period due to waste substrate in stock.	Useless	Useless

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
1.5	$\frac{Electricity\ [kWh]}{Number\ of\ prints *\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Number\ of\ prints *\ [ton]}$ ** Number of prints = Number of sheets or number of cylinder rotations.*	Variation in size of machines influences, if the indicator covers more than one machine.	Good	Good
1.6	$\frac{Electricity\ [kWh]}{Normalised\ number\ of\ prints *\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Normalised\ number\ of\ prints *\ [ton]}$ ** Normalised number of prints = Number of sheets or number of cylinder rotations adjusted to a common machine size.*	If the difference in the size of the machines is significant it might influence the indicator since linear proportionality cannot be expected.	High	High

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
1.7	$\frac{Electricity\ [kWh]}{Number\ of\ employees}$ or $\frac{Natural\ gas\ [Nm^3]}{Number\ of\ employees}$	Long distance between reference data and process. The number of employees might remain the same even though that the physical production varies. The variation will be larger if the frequency increases. Not adequate for individual machines.	Bad	Useless
1.8	$\frac{Electricity\ [kWh]}{Production\ hours}$ or $\frac{Natural\ gas\ [Nm^3]}{Production\ hours}$	Variations in the size and the type of the orders might not influence on the number of production hours.	Acceptable	Acceptable
1.9	$\frac{Electricity\ [kWh]}{Turnover\ [EUR]}$ or $\frac{Natural\ gas\ [Nm^3]}{Turnover\ [EUR]}$	Long distance between reference data and process. There is a general increase in the activities towards electronic media in the printing companies not related to production machines which might influence the indicator. Variations in costs of raw materials. The variation will be larger if the frequency increases. Not adequate for individual machines.	Bad	Useless

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
1.10	$\frac{Electricity\ [kWh]}{Added\ value\ [EUR]}$ or $\frac{Natural\ gas\ [Nm^3]}{Added\ value\ [EUR]}$	Long distance between reference data and process. There is a general increase in the activities towards electronic media in the printing companies not related to production machines which might influence the indicator. The variation will be larger if the frequency increases. Not adequate for individual machines.	Acceptable	Useless

<u>Indicators for summarized energy sources</u>

As stated at the beginning of this section, the previous table contained indicators which address solely the use of energy for production purposes. Nevertheless, since, in some cases, there is no availability of data for the calculation of other than summarized energy sources indicators, in Table 2 a list of proposed EPI for summarized energy sources is proposed.

While in Table 1, the energy data included solely the consumption for production processes, the data in this table would be a sum of energy consumed for production, for heating and/or cooling purposes and for any other uses the company may have. The use of this kind of indicators is recommended uniquely for those companies that do not have any possibilities to determine the energy consumption of the different sources and/or the different uses in the companies.

When an indicator is based on summarized energy sources it makes the indicator less suitable as an internal management tool, particular when the energy consumption for production and the energy consumption for heating and/or cooling of facilities are summarized (See section C.2). An indicator for summarized energy sources will therefore generally have a lower suitability. This especially applies to indicators that are defined with a frequency on a monthly basis, since the energy consumption for heating facilities in this case will interfere even more.

Table 2: Potential indicators for summarized energy sources. Source: Developed by the authors.

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
1.11	$\frac{Energy\ consumption\ [GJ]}{Consumed\ paper\ [ton]}$	Variation in substrate thickness.	Acceptable	Useless
1.12	$\frac{Energy\ consumption\ [GJ]}{Purchased\ paper\ [ton]}$	Variation in substrate thickness. Purchase of substrate might not reflect the actual consumption due to substrate in stock.	Bad	Useless
1.13	$\frac{Energy\ consumption\ [GJ]}{Produced\ paper * \ [ton]}$ ** Produced substrate = <u>Consumed</u> substrate – Waste substrate*	Variation in substrate thickness. Waste substrate might not cover the same period due to waste substrate in stock.	Bad	Useless
1.14	$\frac{Energy\ consumption\ [GJ]}{Produced\ paper * \ [ton]}$ ** Produced substrate = <u>Purchased</u> substrate – Waste substrate*	Variation in substrate thickness. Purchase of substrate might not reflect the actual consumption due to substrate in stock. Waste substrate might not cover the same period due to waste substrate in stock.	Useless	Useless
1.15	$\frac{Energy\ consumption\ [GJ]}{Number\ of\ prints * \ [ton]}$ or ** Number of prints = Number of sheets or number of cylinder rotations.*	Variation in size of machines influences, if the indicator covers more than one machine.	Acceptable	Acceptable

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
1.16	$\frac{Energy\ consumption\ [GJ]}{Normalised\ number\ of\ prints * \ [ton]}$ ** Normalised number of prints = Number of sheets or number of cylinder rotations adjusted to a common machine size.*	If the difference in the size of the machines is significant it might influence the indicator since linear proportionality cannot be expected.	Good	Good
1.17	$\frac{Energy\ consumption\ [GJ]}{Number\ of\ employees}$	Long distance between reference data and process. The number of employees might remain the same even though that the physical production varies. The variation will be larger if the frequency increases. Not adequate for individual machines.	Useless	Useless
1.18	$\frac{Energy\ consumption\ [GJ]}{Production\ hours}$	Variations in the size and the type of the orders might not influence on the number of production hours.	Bad	Bad
1.19	$\frac{Energy\ consumption\ [GJ]}{Turnover\ [EUR]}$	Long distance between reference data and process. There is a general increase in the activities towards electronic media in the printing companies not related to production machines which might influence the indicator. Variations in costs of raw materials. The variation will be larger if the frequency increases. Not adequate for individual machines.	Useless	Useless

#	Potential indicators for specific energy consumption in production	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
1.20	$\frac{Energy\ consumption\ [GJ]}{Added\ value\ [EUR]}$	Long distance between reference data and process. There is a general increase in the activities towards electronic media in the printing companies not related to production machines which might influence the indicator. The variation will be larger if the frequency increases. Not adequate for individual machines.	Bad	Useless

D.2.2. **Utilization of correction factors**

It is possible for some indicators to make a dynamic analysis of the energy consumption by including the variations in the production in the analysis. This is especially relevant for indicators based on data close to the production process and which at the same time are listed with a high frequency e.g. on monthly or weekly basis. Figure 1 below shows an example of key figures for the consumption of natural gas in a case company.

Figure 1: Example on consumption of natural gas. Source: Developed by the authors

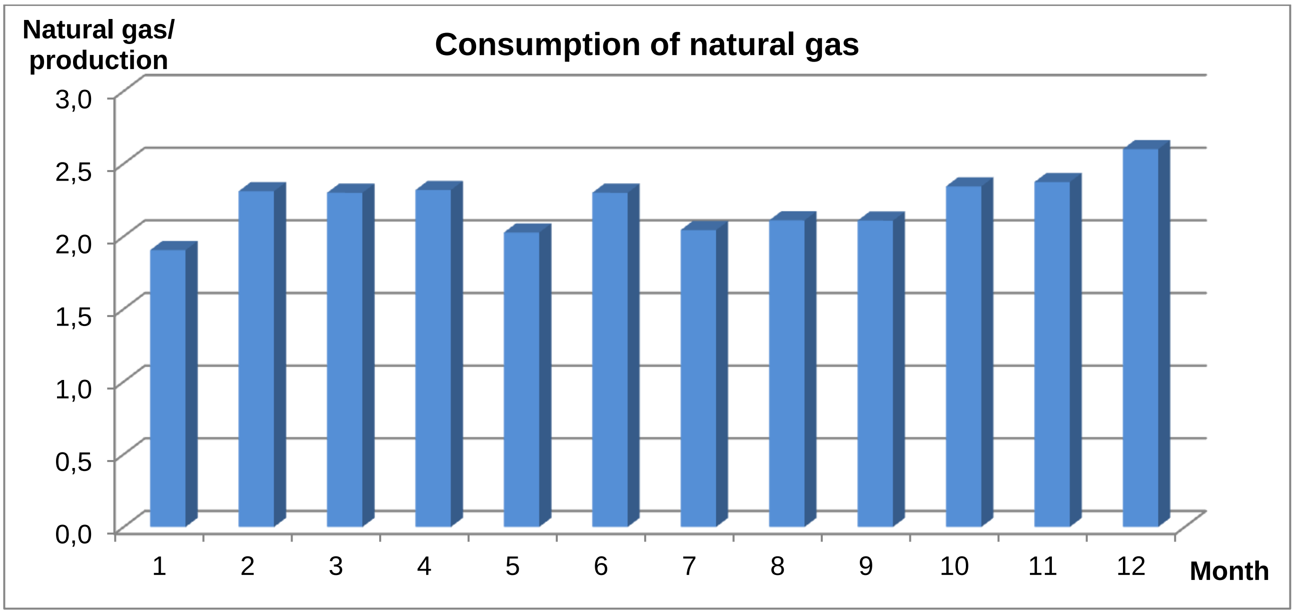
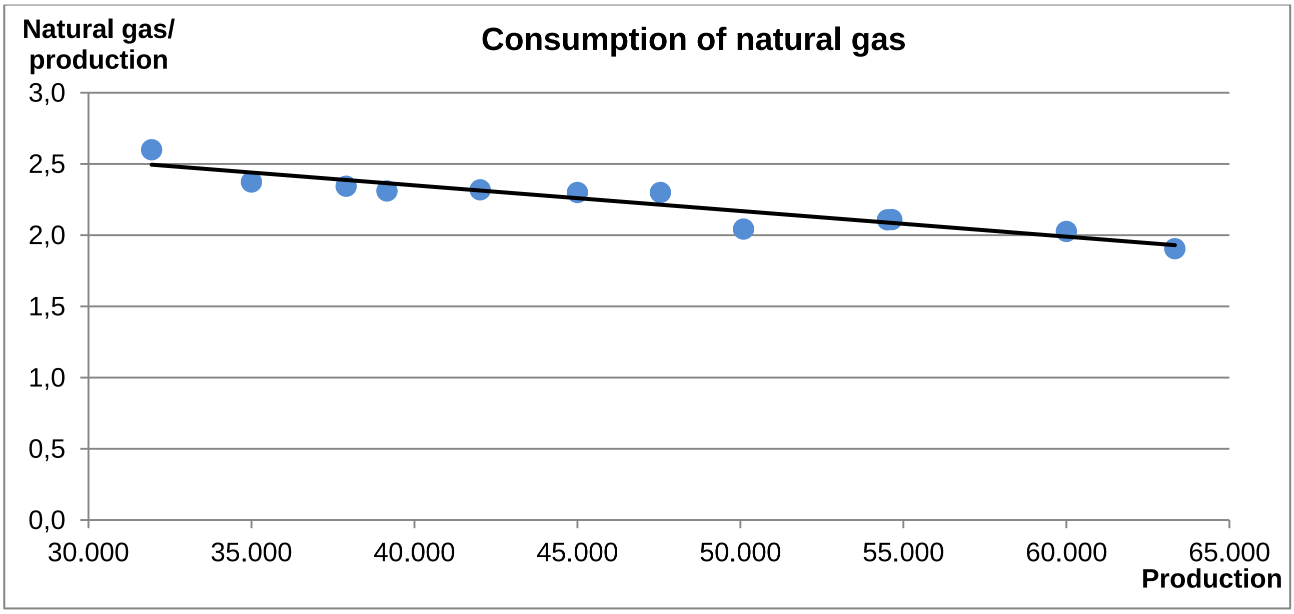


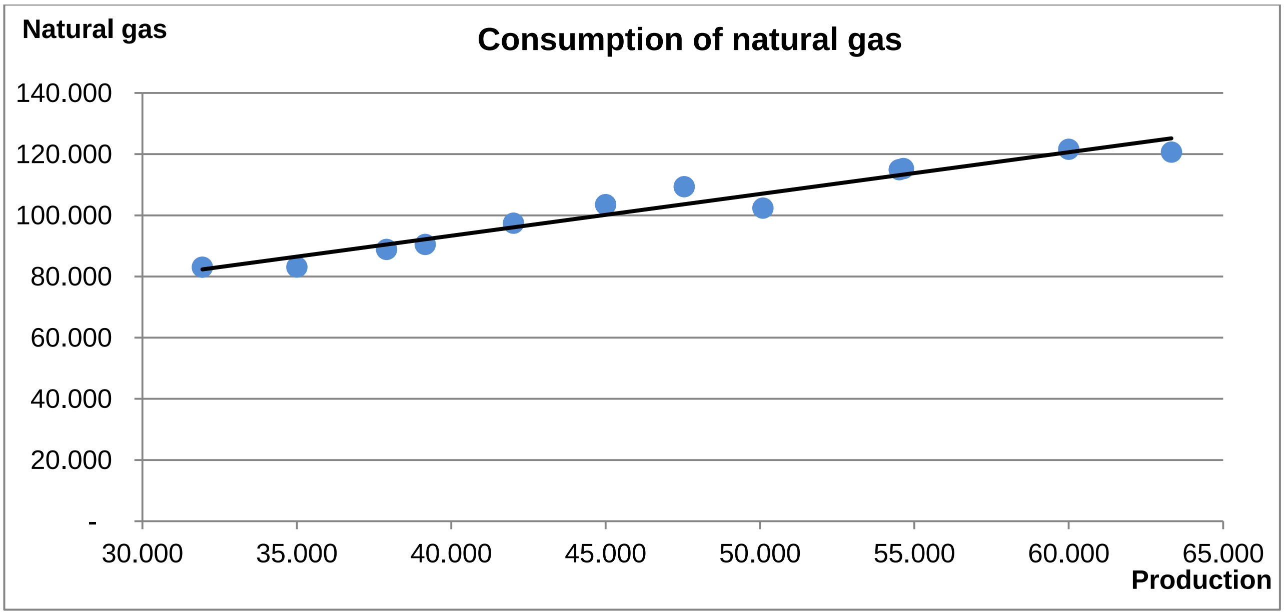
Figure 1 shows that the key figure indicator varies, which probably is caused by variation in the production. This can be corrected by putting the key figure in correlation with the production size as shown in Figure 2

Figure 2: Example on ratio of natural gas and production corrected with production. Source: Developed by the authors



If the energy consumption that relates directly to the production is analysed, there will often be a linear relation between the key figure for energy consumption and the size of production. Naturally, the same relation is also present between the direct energy consumption and the size of the production as shown in Figure 3.

Figure 3: Example on consumption of natural gas corrected with production. Source: Developed by the authors



The lines in FFigure **2** and Figure 3 represent the normal energy consumption (baseline) for the specific activity in the company.

Based on this baseline, it is easy to conclude if the energy consumption deviates from the normal as shown in Figure 4. Furthermore, it is an efficient tool for monitoring planned improvements for the process as shown in Figure 5.

Figure 4: Example on deviations in the consumption of natural gas corrected with production. Source: Developed by the authors

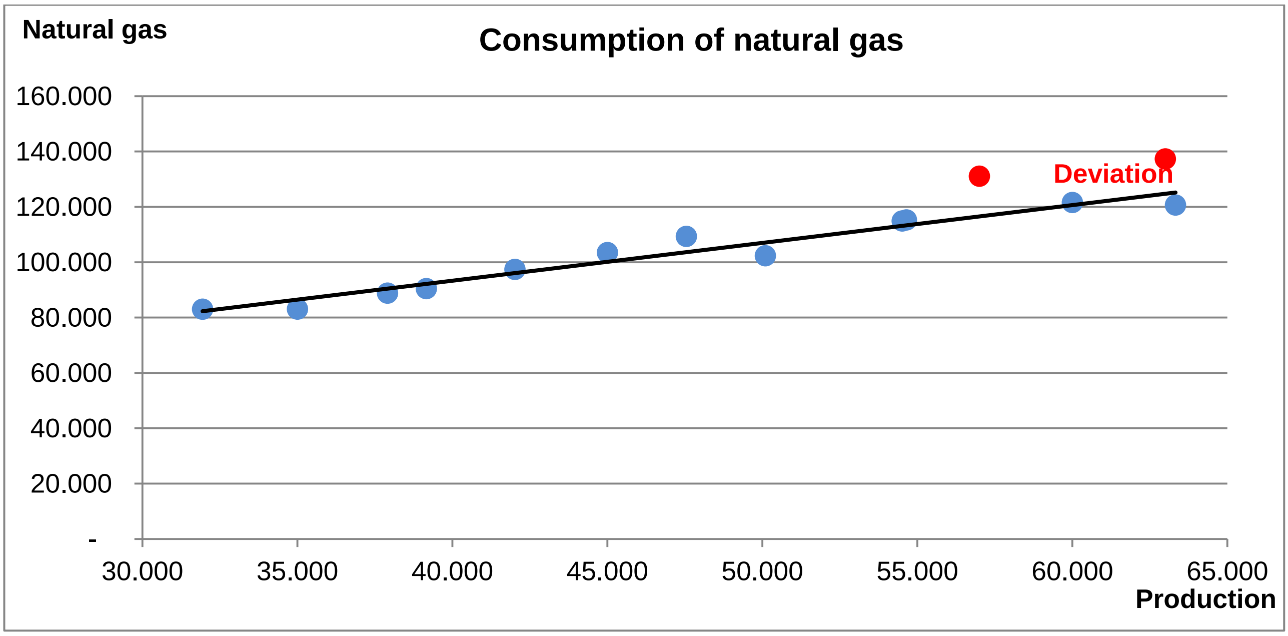
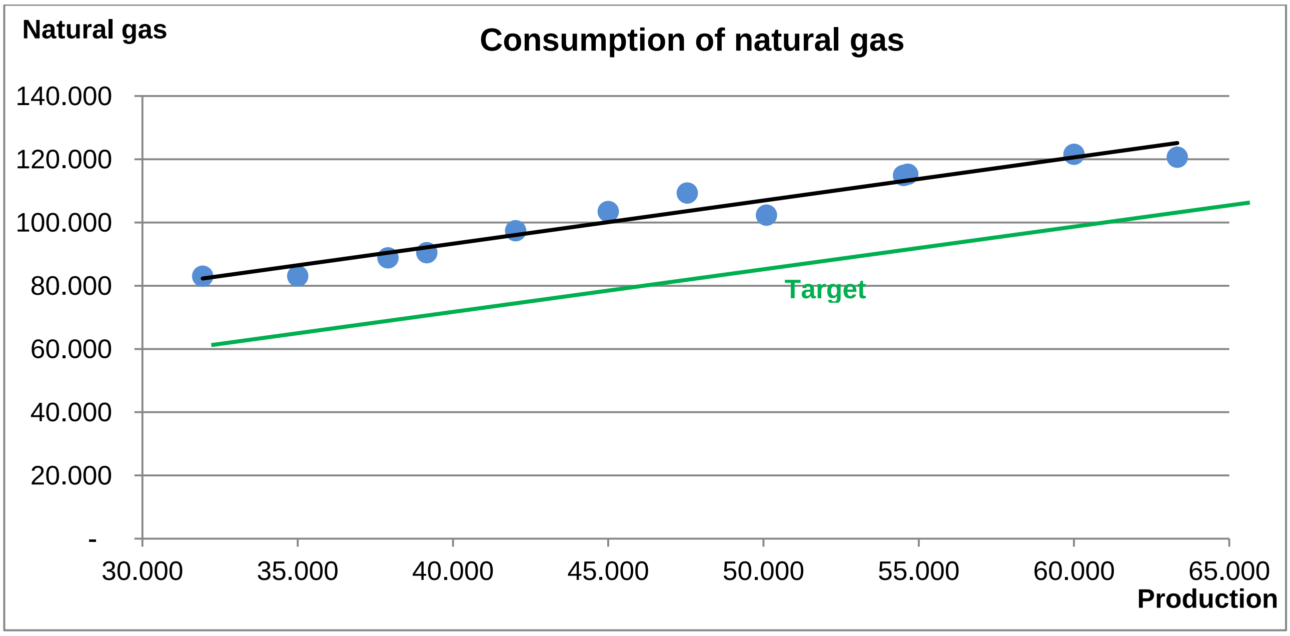


Figure 5: Example on target for the consumption of natural gas corrected with production. Source: Developed by the authors



D.3. Energy indicators for space heating

D.3.1. Analysis of possible indicators

Space heating in the printing industry sector is primarily used for heating of production halls, storage halls and offices. According to statistical data gained from the EEEI project, the share of space heating in the total energy consumption of printing companies is:

- 31% in the Czech Republic

- 31% in the Netherlands
- 22% in Germany

Based on these figures for the region Western Europe / Central Europe it can be stated that a share of 20-30% of space heating in the total energy consumption. While, for Northern Europe this share could be higher, for Southern Europe this figure will be lower. But in Southern Europe, significant consumption for space cooling can be expected.

General indicators developed by the IEA (International Energy Agency) used in services and/or industrial sector for space heating are:

- Space heating energy consumption per value added
- Space heating energy consumption per floor area
- Space heating energy consumption per unit of activity

Given the importance of space heating in the total energy consumption of printing companies, the use of space heating indicators can be key to understand and improve their energy use. The table below shows the potential indicators for space heating:

Table 3: Potential indicators for space heating. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space heating	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
2.1	$Heat\ [GJ]$ or $Natural\ gas\ [Nm^3]$	Strongly influenced by heating degree days Production activities could influence.	Acceptable	Acceptable

#	Potential indicators for specific energy consumption for space heating	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
2.2	$\frac{Heat\ [GJ]}{Size\ of\ production *}$ or $\frac{Natural\ gas\ [Nm^3]}{Size\ of\ production *}$ ** The size of the production can be measured in different ways as described in Table 1 in section D.2.*	Space heating demand not much influenced by actual production, more depending on insulation of building Strongly influenced by heating degree days Conditions related to the size of the production are described in Table 1 in section D.2.	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2
2.3	$\frac{Heat\ [GJ]}{Total\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]}{Total\ floor\ area\ [m^2]}$	Difference in heating demand between types of areas, some may not be heated at all Strongly influenced by heating degree days	Acceptable	Useless
2.4	$\frac{Heat\ [GJ]}{Heated\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]}{Heated\ floor\ area\ [m^2]}$	Difference in heating demand between types of areas (e.g. offices, production areas, storage areas) Strongly influenced by heating degree days *Could be useless in the summer period with a monthly frequency	Good	Acceptable*

#	Potential indicators for specific energy consumption for space heating	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
2.5	$\frac{Heat\ [GJ]}{Total\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]}{Total\ building\ volume\ [m^3]}$	Difference in heating demand between types of areas, some may not be heated at all Strongly influenced by heating degree days	Acceptable	Useless
2.6	$\frac{Heat\ [GJ]}{Heated\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]}{Heated\ building\ volume\ [m^3]}$	Difference in heating demand between types of areas (e.g. offices, production areas, storage areas) Strongly influenced by heating degree days *Could be useless in the summer period with a monthly frequency	Good	Acceptable*
2.7	$\frac{Heat\ [GJ]}{Value\ added\ [€]}$ or $\frac{Natural\ gas\ [Nm^3]}{Value\ added\ [€]}$	Space heating demand not much influenced by actual production, more depending on insulation of building Strongly influenced by heating degree days	Acceptable	Useless

D.3.2. **Utilization of correction factors**

The most important correction factor for energy indicators for general space heating is the correction for the Heating Degree Day (HDD). This is described in detail in section C.4. Due to the importance of the HDD correction, the indicators in Table 3 above are all analysed and rated in the table below taking a HDD correction into consideration.

Table 4:Potential indicators for space heating including Heating Degree Day correction. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space heating	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	**Monthly**
2.8	$Heat\ [GJ]^{HDD}$ or $Natural\ gas\ [Nm^3]^{HDD}$ *HDD: Heating Degree Day energy consumption.*	Production activities could influence.	Good	Good
2.9	$\frac{Heat\ [GJ]^{HDD}}{Size\ of\ production\ *}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Size\ of\ production\ *}$ *HDD: Heating Degree Day energy consumption.* ** The size of the production can be measured in different ways as described in Table 1 in section D.2.*	Space heating demand not much influenced by actual production, more depending on insulation of building Conditions related to the size of the production are described in Table 1 in section D.2.	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2

#	Potential indicators for specific energy consumption for space heating	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
2.10	$\frac{Heat\ [GJ]^{HDD}}{Total\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Total\ floor\ area\ [m^2]}$ *HDD: Heating Degree Day energy consumption.*	Difference in heating demand between types of areas, some may not be heated at all	Good	Useless
2.11	$\frac{Heat\ [GJ]^{HDD}}{Heated\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Heated\ floor\ area\ [m^2]}$ *HDD: Heating Degree Day energy consumption.*	Difference in heating demand between types of areas (e.g. offices, production areas, storage areas) *Could be useless in the summer period with a monthly frequency	High	Good*

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#	Potential indicators for specific energy consumption for space heating	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	**Monthly**
2.12	$\frac{Heat\ [GJ]^{HDD}}{Total\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Total\ building\ volume\ [m^3]}$ *HDD: Heating Degree Day energy consumption.*	Difference in heating demand between types of areas, some may not be heated at all	Good	Useless
2.13	$\frac{Heat\ [GJ]^{HDD}}{Heated\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Heated\ building\ volume\ [m^3]}$ *HDD: Heating Degree Day energy consumption.*	Difference in heating demand between types of areas (e.g. offices, production areas, storage areas) *Could be useless in the summer period with a monthly frequency	High	Good*

#	Potential indicators for specific energy consumption for space heating	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
2.14	$\frac{Heat\ [GJ]^{HDD}}{Value\ added\ [€]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Value\ added\ [€]}$ *HDD: Heating Degree Day energy consumption.*	Space heating demand not much influenced by actual production, more depending on insulation of building	Good	Useless

The Heating Degree Day correction of the energy consumption for space heating can be carried out in two different ways:

- Normalisation by using historic HDD data
- Defining a baseline for the company based on HDD data

<u>Normalisation by using historic HDD data</u>

The energy consumption for space heating can be normalised by comparing the actual HHD data to historic HDD data representing a period which is considered to be normal. The historic data can either be HDD data for a period, for which the company wish to compare, or more official generic HDD data for the area where the company is situated. This method is useful when making budgets for energy consumption and when analysing and evaluating the benefits of energy efficiency projects.

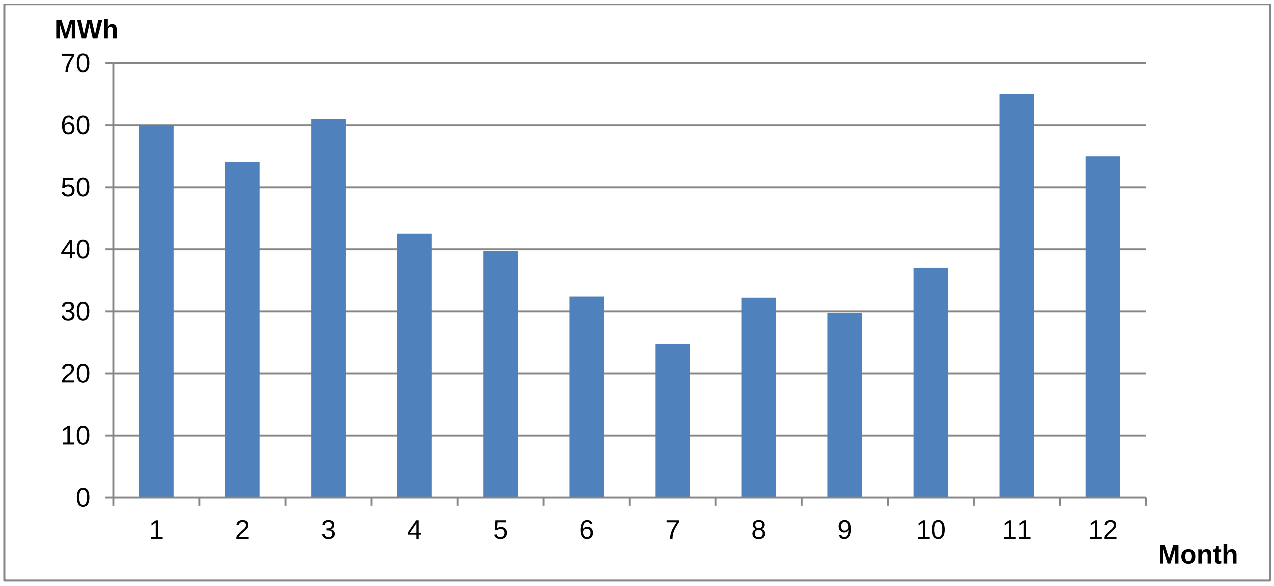
An example of this method is shown below:

$$Energy\ consumption\ (HDD\ corrected) = \frac{HDD\ for\ normal\ period}{HDD\ for\ actual\ period} \times Energy\ consumption\ (measured)$$

<u>Defining a HDD baseline for the company</u>

If the company has sufficient data, it is relevant for the company to define a baseline for the correlation between HDD and the energy consumption for space heating. This is especially relevant, if the company has data for HHD and energy consumption with a monthly or weekly frequency basis like shown in the example in Figure 6.

Figure 6: Example on energy consumption for space heating. Source: Developed by the authors.



The baseline is defined by making a diagram where the energy indicator for space heating (not HDD corrected) is correlated to data for HDD representing the same period. Examples of the definition of baselines for two different indicators are shown in Figure 7 and Figure 8.

Figure 7: Example on baseline for energy indicator for space heating in MWh correlated to HDD. Source: Developed by the authors.

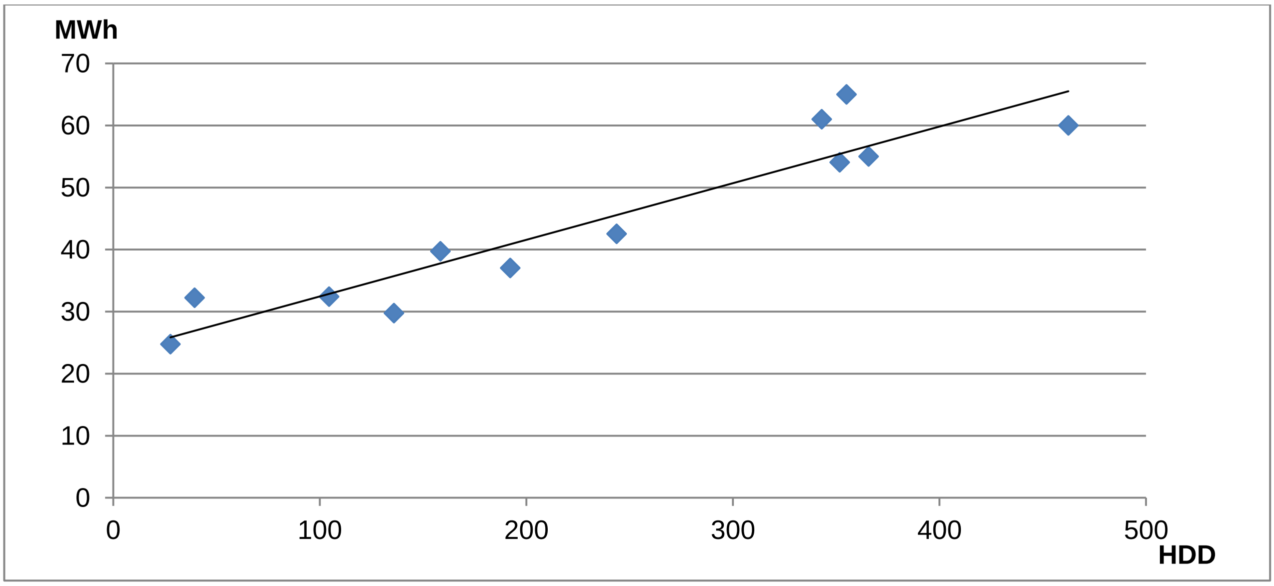
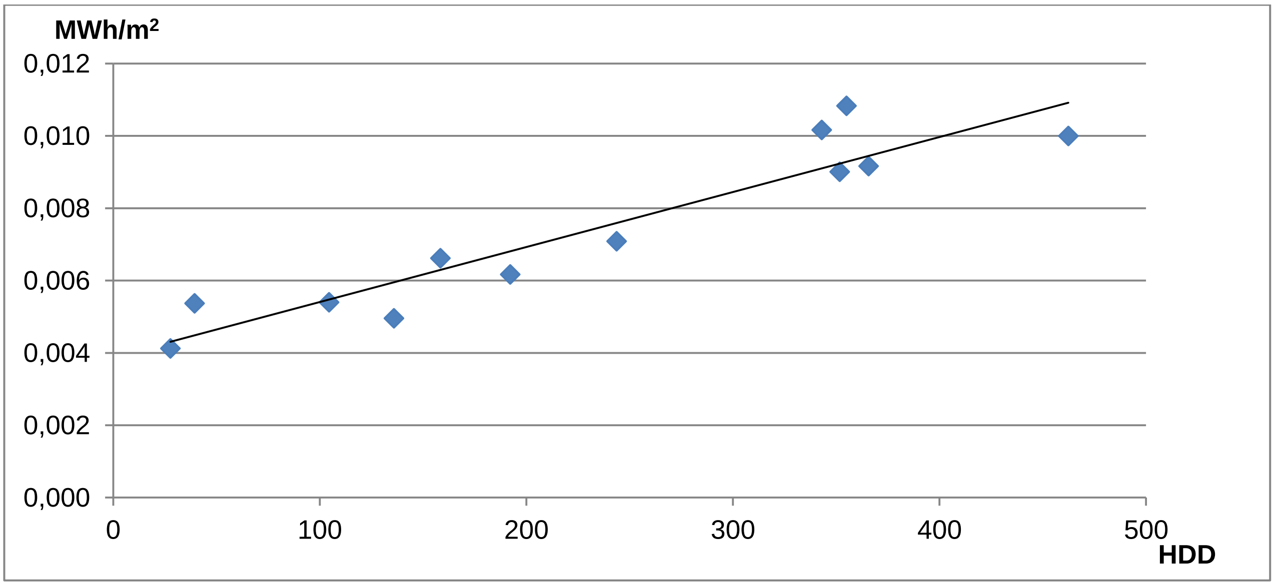


Figure 8: Example on baseline for energy indicator for space heating in MWh/m2 correlated to HDD. Source: Developed by the authors.



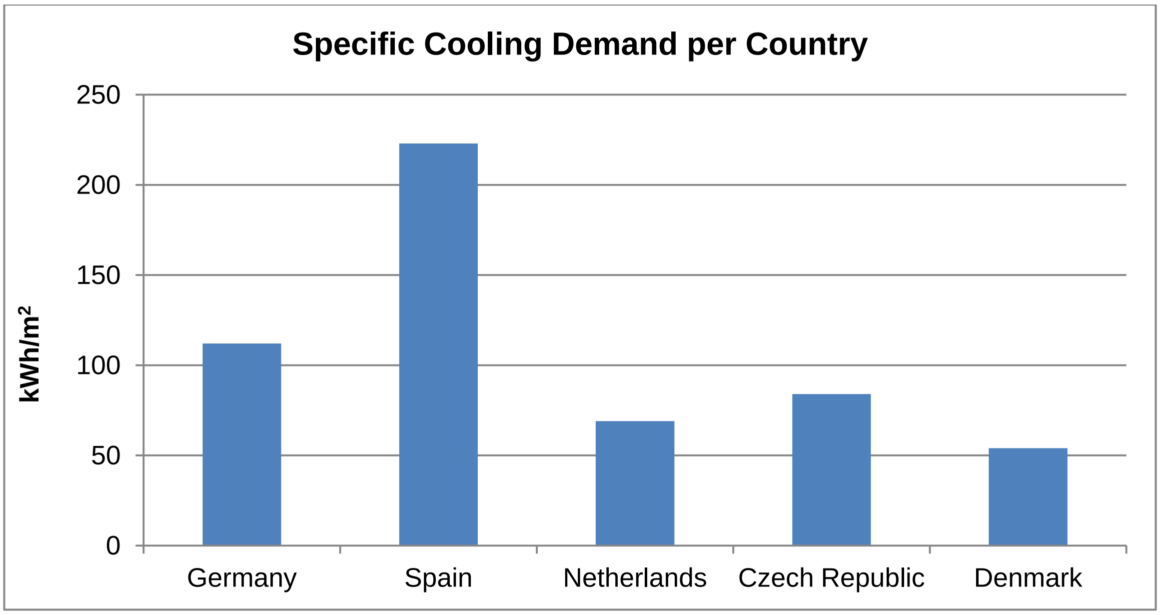
The use of the baseline as management tool for monitoring and setting targets are described in Figure 4 and Figure 5 in section D.2.2

D.4. Energy indicators for space cooling

D.4.1. **Analysis of possible indicators**

The need for space cooling in the printing industry is primary relevant for those companies located in warm countries. The scarce data on energy consumption for cooling purposes at the European level makes it difficult to quantify the particular cooling needs for the printing industry. However, aggregated data for housing and services sectors can provide a reasonable approach to the energy uses for cooling in European Countries. According to the data of the IEE funded Ecoheatcool Project, the cooling demand per cooled area of the countries analysed in the EMSPI projects is shown in the graph below:

Figure 9: Specific cooling demand for the countries included in the EMSPI project. Source: Ecoheatcool Project.



This graph portraits clearly the influence of the climate on cooling demand. Given its climatic features, Spain would be the country with a higher demand per square meter, followed by Germany and the Czech Republic. The Netherlands and Denmark would, on the contrary, be the countries with lower demands.

Due to the differences between countries displayed above for the services and residential sectors, a similar situation could be expected for the printing industry. Unfortunately, the lack of reliable data makes it impossible to estimate the percentage of energy used for space cooling.

General indicators developed by the IEA (International Energy Agency) used in services and/or industrial sector for space cooling are:

- Space cooling energy consumption per value added
- Space cooling energy consumption per floor area
- Space cooling energy consumption per unit of activity

Additionally, in the case of space cooling, another relevant factor to consider is the efficiency of the cooling equipment. If compared with space heating, the efficiencies of space cooling equipment are usually lower and have an important influence on the final consumption of energy for cooling. Therefore, indicators considering this factor can be evaluated as well. When analysing the efficiency of the equipment, there usually are three parameters that can be used and express the ratio of cooling provided to electrical energy consumed:

- COP: Coefficient of Performance. It is a non-dimensional factor that calculates the ratio of the heat removed from the reservoir to the work used to remove that heat. It is limited by the fact that it is highly influenced by the conditions under which the cooling equipment is operated.
- EER: The Energy Efficiency Ratio (EER) of a particular cooling device is the ratio of output cooling energy to input electrical energy at a given operating point. Therefore, it is also limited by the influence of the conditions under which the device is operating.

- ESEER: The European Seasonal Energy Efficiency Ratio (ESEER) is calculated by combining full and part load operating EER, for different seasonal air or water temperatures, and including for appropriate weighting factors. As such, it reduces the influence of the conditions under which the device is operating because it considers different operating conditions and not a unique possibility like the COP and EER.

Preferably, the ESEER would be the best parameter to monitor the efficiency of the cooling equipment. Nevertheless, since in some cases it can be difficult to obtain ESEER data for some cooling devices, EER or COP parameters can be used for the efficiency indicators. In Table 5, the EPI for energy efficiency of cooling devices are described using the ESEER parameters. However, if ESEER data is not available, these indicators can be reformulated using EER or COP data.

Table 5:Potential indicators for space cooling. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space cooling	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
3.1	$Electricty\ consumption\ [kWh]$	Strongly influenced by cooling degree days Production activities could influence Does not account for the efficiency of the devices	Acceptable	Acceptable
3.2	$\frac{Electricty\ consumption\ [kWh]}{Size\ of\ production}$	Space cooling demand not much influenced by actual production, more depending on insulation of building Strongly influenced by cooling degree days Conditions related to the size of the production are described in Table 1 in section D.2. Does not account for the efficiency of the devices	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2
3.3	$\frac{Electricty\ consumption\ [kWh]}{Total\ floor\ area\ [m^2]}$	Difference in cooling demand between types of areas, some may not be heated at all Strongly influenced by cooling degree days Does not account for the efficiency of the devices	Acceptable	Useless
3.4	$\frac{Electricty\ consumption\ [kWh]}{Cooled\ floor\ area\ [m^2]}$	Difference in cooling demand between types of areas (e.g. offices, production areas, storage areas) Strongly influenced by cooling degree days Does not account for the efficiency of the devices	Good	Acceptable

#	Potential indicators for specific energy consumption for space cooling	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
3.5	$\frac{Electricty\ consumption\ [kWh]}{Total\ building\ volume\ [m^3]}$	Difference in cooling demand between types of areas, some may not be heated at all Strongly influenced by cooling degree days Does not account for the efficiency of the devices	Acceptable	Useless
3.6	$\frac{Electricty\ consumption\ [kWh]}{Cooled\ building\ volume\ [m^3]}$	Difference in cooling demand between types of areas (e.g. offices, production areas, storage areas) Strongly influenced by cooling degree days Does not account for the efficiency of the devices	Good	Acceptable
3.7	$\frac{Electricty\ consumption\ [kWh]}{Value\ added\ [€]}$	Space cooling demand not much influenced by actual production, more depending climate conditions Strongly influenced by cooling degree days Does not account for the efficiency of the devices	Acceptable	Useless
3.8	$\frac{\sum_i^n ESEER_i[adim] \cdot Elect.Power_i[kW]}{\sum_i^n Elect.Power_i[kW]}$	Does not quantify cooling demand, solely efficiency Does not consider the differences in use between devices	Acceptable	Useless
3.9	$\frac{\sum_i^n ESEER_i[adim] \cdot Elect.cons._i\ [kWh]}{\sum_i^n Elect.cons._i\ [kWh]}$	Does not quantify cooling demand, solely efficiency	Good	Useless

D.4.2. **Utilization of correction factors**

As in the case of HDD for space heating, the most important correction factor for energy indicators for general space cooling is the correction for the Cooling Degree Day (CDD). This is described in detail in section C.4.

Due to the importance of the CDD correction, the indicators in Table 3 above are all except 3.6 and 3.7 analysed and rated in the table below taking a CDD correction into consideration.

Table 6:Potential indicators for space cooling including Cooling Degree Day correction. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space cooling	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	**Monthly**
3.10	$Electricy\ consumption\ [kWh]^{CDD}$ *CDD: Cooling Degree Day energy consumption.*	Strongly influenced by cooling degree days Production activities could influence Does not account for the efficiency of the devices	Good	Good
3.11	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Size\ of\ production\ *}$ *CDD: Cooling Degree Day energy consumption.* ** The size of the production can be measured in different ways as described in Table 1 in section D.2.*	Space cooling demand not much influenced by actual production, more depending on insulation of building Conditions related to the size of the production are described in Table 1 in section D.2. Does not account for the efficiency of the devices	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2
3.12	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Total\ floor\ area\ [m^2]}$ *CDD: Cooling Degree Day energy consumption.*	Difference in cooling demand between types of areas, some may not be heated at all Does not account for the efficiency of the devices	Good	Useless

#	Potential indicators for specific energy consumption for space cooling	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
3.13	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Cooled\ floor\ area\ [m^2]}$ *CDD: Cooling Degree Day energy consumption.*	Difference in cooling demand between types of areas (e.g. offices, production areas, storage areas) Does not account for the efficiency of the devices	High	Good
3.14	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Total\ building\ volume\ [m^3]}$ *CDD: Cooling Degree Day energy consumption.*	Difference in cooling demand between types of areas, some may not be heated at all Does not account for the efficiency of the devices	Good	Useless
3.15	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Cooled\ building\ volume\ [m^3]}$ *CDD: Cooling Degree Day energy consumption.*	Difference in cooling demand between types of areas (e.g. offices, production areas, storage areas) Does not account for the efficiency of the devices	High	Good
3.16	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Value\ added\ [€]}$ *CDD: Cooling Degree Day energy consumption.*	Space cooling demand not much influenced by actual production, more depending climate conditions Does not account for the efficiency of the devices	Good	Useless

As Seen with the HDD correction, the CDD correction of the energy consumption for space heating can be carried out in two different ways:

- Normalisation by using historic CDD data
- Defining a baseline for the company based on CDD data

<u>Normalisation by using historic CDD data</u>

The energy consumption for space cooling can be normalised by comparing the actual CDD data to historic CDD data representing a period which is considered to be normal. The historic data can either be CDD data for a period, for which the company wish to compare, or more official generic CDD data for the area where the company is situated. This method is useful when making budgets for energy consumption and when analysing and evaluating the benefits of energy efficiency projects.

An example of this method is shown below:

$$Energy\ consumption\ (CDD\ corrected) = \frac{CDD\ for\ normal\ period}{CDD\ for\ actual\ period} \times Energy\ consumption\ (measured)$$

<u>Defining a CDD baseline for the company</u>

If the company has sufficient data, it is relevant for the company to define a baseline for the correlation between CDD and the energy consumption for space heating. This is especially relevant, if the company has data for CDD and energy consumption with a monthly or weekly frequency. The principals for defining the baseline and the use of the baseline as management tool are described in section D.3.2 and section D.2.2.

D.5. Energy costs indicators

D.5.1. Analysis of possible indicators

Energy costs indicators can be important tools for the top management, when prioritising the energy management activities of the company.

For continual monitoring of the energy costs, it might be relevant in some companies to define energy costs indicators separately for both the total energy consumption of the company and for the energy consumption of the production. From an economic perspective, it might be relevant for the management of the company to have an energy cost indicator for the total consumption of the company even though the costs for energy consumption for heating and/or cooling facilities will interfere with the indicator and causing difficulties when comparing one year to another.

The most useful energy cost indicator for many companies will often be the total costs of energy and the distribution of these costs on different energy sources and energy consuming activities in the company. But in some countries there are differences in energy taxes for different types of activities in the companies. For instance, in Denmark, energy for heating has a higher tax rate than energy for use in the production. The complexity of the taxes causes a lack of knowledge in the companies about the real cost of energy for different kinds of activities in the companies, which might make the analysis of pay back time difficult for the companies and set up barriers for the implementation of energy management activities.

Table 7: Potential energy cost indicators. Source: Developed by the authors.

#	Potential energy costs indicators	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
4.1	$\frac{Production\ energy\ costs\ [EUR]}{Number\ of\ employees}$ or $\frac{Total\ energy\ costs*\ [EUR]}{Number\ of\ employees}$	There is a general increase in the activities towards electronic media in the printing companies not related to production machines, which might influence the indicator. The number of employees might remain the same, even though the physical production varies. The variation will be larger, if the frequency increases. *Variations in climate conditions will interfere with the indicator	Useless	Useless
4.2	$\frac{Production\ energy\ costs\ [EUR]}{Turnover\ [EUR]}$ or $\frac{Total\ energy\ costs*\ [EUR]}{Turnover\ [EUR]}$	Variations in costs of raw materials. There is a general increase in the activities towards electronic media in the printing companies not related to production machines, which might influence the indicator. The variation will be larger, if the frequency increases. *Variations in climate conditions will interfere with the indicator	Bad	Useless
4.3	$\frac{Production\ energy\ costs\ [EUR]}{Total\ added\ value\ [EUR]}$ or $\frac{Total\ energy\ costs*\ [EUR]}{Total\ added\ value\ [EUR]}$	There is a general increase in the activities towards electronic media in the printing companies not related to production machines, which might influence the indicator. The variation will be larger, if the frequency increases. *Variations in climate conditions will interfere with the indicator	Acceptable	Useless

#	Potential energy costs indicators	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	Monthly
4.4	$\frac{Production\ energy\ costs\ [EUR]}{Profit\ [EUR]}$ or $\frac{Total\ energy\ costs *\ [EUR]}{Profit\ [EUR]}$	There is a general increase in the activities in the printing companies not related to production machines, which might influence the indicator. The variation will be larger, if the frequency increases. *Variations in climate conditions will interfere with the indicator	Acceptable	Useless

D.6. Indirect energy related indicators

D.6.1. Analysis of possible indicators

According to section 5.7 of ISO 50001, a company can choose to include the supply chain in the scope of the energy management system of the company and work with the indirect energy consumption as well.

In a holistic approach it is very relevant for printing companies to include the indirect energy consumption, since the indirect energy consumption represents approximately 80% of the total energy consumption in the life cycle of a printed product. The most important indirect energy consumptions are related to the production of substrate, printing plates and inks. For further information please refer to WP2: Energy Diagnosis of European Printing Industry, section C.2.

In this section the potential indicators related to different methods for working with the indirect energy consumption will be analysed and discussed, including:

- Indicators for carbon footprint
- Indicators for material efficiency

<u>Indicators for carbon footprint</u>

One method to map and monitor the indirect energy consumption of a company is to calculate the carbon footprint of the supply chain. It can be a complicated task to develop a carbon footprint of a company, unless the company takes the advantage of all already existing standardised systems for the printing industry.

When calculating the carbon footprint of the company particular attention should be brought to the following issues:

a. The boundaries or the scope of the carbon footprint calculation are of significant importance due to the fact that indirect energy consumption related to the raw materials represents approximately 80% of the total energy consumption in the life cycle of a printed product. For further information please refer to WP2: Energy Diagnosis of European Printing Industry, section C.2.

b. To be able to calculate the carbon footprint the company will need to obtain emission factors for consumed energy and raw materials. The emissions factors related to the energy consumption (Scope 1 and 2) can be easily obtained, but the emissions factors of raw material (Scope 3) emissions require specific databases, which may imply economic costs for companies.

The scope and the emission factors for a carbon footprint calculation are not that important as long as the carbon footprint indicator is only used internal in the company. However, if the company wishes to benchmark or use the carbon footprint as a marketing tool and publicise its results, the scope and the emission factors are detrimental for a suitable comparison of companies and products.

To ensure a comparable scope the carbon footprint must be calculated using the internationally recognised standards for calculation. Particularly, it is recommended that, within the same sector, a sectoral standard is used, to enhance comparability. The only existing specific standard for the printing industry is the INTERGRAF recommen-dations on CO_2 emissions calculation in the printing industry: http://www.intergraf.eu/printing-and-the-environment/carbon-footprint.

It can be very difficult to achieve a harmonised use of emission factors between companies and countries, mainly because of the existence of different methods for the definition of the emission factors for electricity consumption. To ensure a comparable calculation based on uniform emission factors for consumption of energy and raw materials, companies can refer to international calculation systems like e.g. www.climatecalc.eu.

Due to the complexity of the indicators for carbon footprint, the analysis of potential carbon footprint indicators in this document will be limited to only one general indicator.

Indicators for material efficiency

The production of substrate, printing plates and inks for use in the printing company represents the majority of the indirect energy consumption of the company with substrate as far most important. Due to this fact the material efficiency in the production of the printing company has a detrimental impact on the indirect energy consumption of the company.

A printing company can have many different indicators related to the material efficiency in the production. For consumption of substrate the company can have indicators based on the amount of substrate, number of prints for making ready, OEE data etc. For the consumption of inks and printing plates the variety of potential indicators are similar.

From an energy management perspective, it is important to stress that all suitable indicators for material efficiency of substrate, printing plates and inks used in the company can also be considered as suitable as indicators for the indirect energy consumption.

In the analysis of the potential specific indicators for material efficiency the analysis will be limited to indicators for substrate efficiency commonly used in the printing industry.

Table 8: Potential indicators for material efficiency and indirect energy consumption. Source: Developed by the authors.

#	Potential energy costs indicators	Conditions influencing the stability of the indicator	Suitability for internal use	
			Annual	**Monthly**
5.1	$\frac{Carbon\ footprint\ [t\ CO_2e]}{Size\ of\ production\ *}$ ** The size of the production can be measured in different ways as described in Table 2 in section D.2.*	Conditions related to the size of the production are described in Table 2 in section D.2. Differences in the scope or the emission factors for the carbon footprint calculation	Good, acceptable, bad or useless, depending on the reference described in Table 2 in section D.2	Good, acceptable, bad or useless, depending on the reference described in Table 2 in section D.2
5.2	*Any suitable indicator in the company related to the material efficiency of:* ***Consumed substrate*** ***Consumed printing plates*** ***Consumed inks***	Only known by the company	High	High
5.3	$\frac{Waste\ paper\ [ton]}{Consumed\ paper\ [ton]}$	Waste substrate might not cover the same period due to waste substrate in stock.	Good	Acceptable
5.4	$\frac{Waste\ paper\ [ton]}{Purchaed\ paper\ [ton]}$	Waste substrate might not cover the same period due to waste substrate in stock. Purchase of substrate might not reflect the actual consumption due to substrate in stock.	Acceptable	Useless

E. Selection of Energy Performance Indicators for the Printing Industry

After having analysed in previous sections the suitability of different types of Energy Performance Indicators for the internal use of printing companies, in this final section of the document, the analysis focuses on determining which indicators may be useful for internal use and for the benchmarking between different companies.

When using indicators for internal use, the main purpose is to extract information which may help control and reduce the internal energy use. However, when the indicators are used for benchmarking, the purpose is to obtain a comprehensive and reliable image of the whole sector, obtaining information to compare the features of different companies and assessing the situation of the sector in general. Therefore, the indicators used for benchmarking need to assure comparability between different companies, without being too influenced by factors that may hinder it.

In fact, the tables below include the information necessary to determine whether the indicators proposed may be suitable solely for internal use or both for internal use and benchmarking. While, in previous sections, an assessment of the indicators for internal use was performed, in this section, on the one hand, the results of that assessment are evaluated and the best indicators for internal use are included, because only those indicators that obtained a mark higher than “acceptable” in the suitability for internal use are displayed. On the other hand, the evaluation of the use of indicators for benchmarking is carried out as well, including the tables below the results obtained for every indicator which was deemed suitable as an internal indicator when its suitability for benchmarking is being considered.

Following the same scheme used in previous sections, the energy indicators are classified by categories: energy indicators for the production process, energy indicators for space heating, energy indicators for space cooling, energy costs indicators and other energy related indicators. In each one of the tables, included below, the suitability of these indicators for internal use is included, as well as the conditions influencing the stability of the indicator for benchmarking purposes and the suitability of its use as a benchmarking indicator. Furthermore, a table in which the indicators recommended for benchmarking are summarized is included at the end of this section for a better understanding of the results of the analysis.

E.1. Energy indicators for the production process

This section includes the internal use and benchmarking analysis of the specific energy consumption in production indicators. Additionally, since the need to consider summarized energy sources is not solely limited to internal use indicators but might be relevant for benchmarking indicators, a evaluation of summarized energy source indicators is performed as well.

Table 9:Internal use and potential benchmarking indicators for specific energy consumption in production. Source: Developed by the authors.

#	Potential indicators for specific energy consumption in production	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
1.1	$\frac{Electricity\ [kWh]}{Consumed\ paper\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Consumed\ paper\ [ton]}$	Good	Acceptable	Variation in substrate thickness between companies.	Good
1.2	$\frac{Electricity\ [kWh]}{Purchased\ paper\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Purchased\ paper\ [ton]}$	Acceptable	Useless	Variation in substrate thickness. Variation in substrate in stock between companies.	Bad
1.3	$\frac{Electricity\ [kWh]}{Produced\ paper*\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Produced\ paper*\ [ton]}$ ** Produced substrate = <u>Consumed</u> substrate – Waste substrate*	Acceptable	Useless	Variation in substrate thickness between companies. Variation in waste substrate in stock between companies.	Bad

#	Potential indicators for specific energy consumption in production	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
1.5	$\frac{Electricity\ [kWh]}{Number\ of\ prints * \ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Number\ of\ prints * \ [ton]}$ ** Number of prints = Number of sheets or number of cylinder rotations.*	Good	Good	The reference is company specific and makes benchmark impossible	Useless
1.6	$\frac{Electricity\ [kWh]}{Normalised\ number\ of\ prints * \ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Normalised\ number\ of\ prints * \ [ton]}$ ** Normalised number of prints = Number of sheets or number of cylinder rotations adjusted to a common machine size.*	High	High	The reference is company specific and makes benchmark impossible	Useless

#	Potential indicators for specific energy consumption in production	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
1.8	$\frac{Electricity\ [kWh]}{Production\ hours}$ or $\frac{Natural\ gas\ [Nm^3]}{Production\ hours}$	Acceptable	Acceptable	Variation in size and activities of companies makes benchmark impossible	Useless
1.10	$\frac{Electricity\ [kWh]}{Added\ value\ [EUR]}$ or $\frac{Natural\ gas\ [Nm^3]}{Added\ value\ [EUR]}$	Acceptable	Useless	Variation in size and activities of companies has a significant influence	Acceptable

Table 10: Internal use and potential benchmarking indicators for summarized energy sources. Source: Developed by the authors.

#	Potential indicators for summarized energy sources	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
1.11	$\frac{Energy\ consumption\ [GJ]}{Consumed\ paper\ [ton]}$	Acceptable	Useless	Variation in substrate thickness between companies.	Acceptable
1.15	$\frac{Energy\ consumption\ [GJ]}{Number\ of\ prints*\ [ton]}$ or ** Number of prints = Number of sheets or number of cylinder rotations.*	Acceptable	Acceptable	The reference is company specific and makes benchmark impossible	Useless
1.16	$\frac{Energy\ consumption\ [GJ]}{Normalised\ number\ of\ prints*\ [ton]}$ ** Normalised number of prints = Number of sheets or number of cylinder rotations adjusted to a common machine size.*	Good	Good	The reference is company specific and makes benchmark impossible	Useless

E.2. Energy indicators for space heating

This section includes the internal use and benchmarking analysis of the space heating indicators. Since climate conditions can have a significant influence on these indicators, the analysis of the suitability of the use of the indicators for internal use and benchmarking is performed first without considering the HDD correction and last considering it.

Table 11: Internal use and potential benchmarking indicators for space heating. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space heating	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
2.1	$Heat\ [GJ]$ or $Natural\ gas\ [Nm^3]$	Acceptable	Acceptable	Variation in size and activities of companies makes benchmark impossible	Useless
2.2	$\frac{Heat\ [GJ]}{Size\ of\ production *}$ or $\frac{Natural\ gas\ [Nm^3]}{Size\ of\ production *}$ ** The size of the production can be measured in different ways as described in Table 1 in section D.2.*	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	The reference is company specific and makes benchmark impossible	Useless

#	Potential indicators for specific energy consumption for space heating	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
2.3	$\frac{Heat\ [GJ]}{Total\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]}{Total\ floor\ area\ [m^2]}$	Acceptable	Useless	Variation in heated floor area and climate conditions influences significantly.	Useless
2.4	$\frac{Heat\ [GJ]}{Heated\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]}{Heated\ floor\ area\ [m^2]}$	Good	Acceptable	Variation in climate conditions influences significantly on international level.	Useless
2.5	$\frac{Heat\ [GJ]}{Total\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]}{Total\ building\ volume\ [m^3]}$	Acceptable	Useless	Variation in heated floor volume and climate conditions influences significantly.	Useless

#	Potential indicators for specific energy consumption for space heating	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
2.6	$\frac{Heat\ [GJ]}{Heated\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]}{Heated\ building\ volume\ [m^3]}$	Good	Acceptable	Variation in climate conditions influences significantly on international level.	Useless
2.7	$\frac{Heat\ [GJ]}{Value\ added\ [€]}$ or $\frac{Natural\ gas\ [Nm^3]}{Value\ added\ [€]}$	Acceptable	Useless	Variation in activities of companies Variation in climate conditions influences particular on international level.	Useless

Table 12: Internal use and potential benchmarking indicators for space heating, HDD corrected. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space heating, HDD corrected	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
2.8	$Heat\ [GJ]^{HDD}$ or $Natural\ gas\ [Nm^3]^{HDD}$ *HDD: Heating Degree Day energy consumption.*	Good	Good	Variation in size and activities of companies makes benchmark impossible	Useless
2.9	$\frac{Heat\ [GJ]^{HDD}}{Size\ of\ production *}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Size\ of\ production *}$ *HDD: Heating Degree Day energy consumption.* ** The size of the production can be measured in different ways as described in Table 1 in section D.2.*	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	The reference is company specific and makes benchmark impossible	Useless

#	Potential indicators for specific energy consumption for space heating, HDD corrected	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
2.10	$\frac{Heat\ [GJ]^{HDD}}{Total\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Total\ floor\ area\ [m^2]}$ *HDD: Heating Degree Day energy consumption.*	Good	Useless	Variation in heated floor area and climate conditions influences significantly particular at the international level.	Useless
2.11	$\frac{Heat\ [GJ]^{HDD}}{Heated\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Heated\ floor\ area\ [m^2]}$ *HDD: Heating Degree Day energy consumption.*	High	Good	Variation in climate conditions influences particular on international level.	Acceptable

#	Potential indicators for specific energy consumption for space heating, HDD corrected	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
2.12	$\frac{Heat\ [GJ]^{HDD}}{Total\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Total\ building\ volume\ [m^3]}$ *HDD: Heating Degree Day energy consumption.*	Good	Useless	Variation in heated building volume and climate conditions influences significantly particular at the international level.	Useless
2.13	$\frac{Heat\ [GJ]^{HDD}}{Heated\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Heated\ building\ volume\ [m^3]}$ *HDD: Heating Degree Day energy consumption.*	High	Good	Variation in climate conditions influences particular on international level.	Acceptable

#	Potential indicators for specific energy consumption for space heating, HDD corrected	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
2.14	$\frac{Heat\ [GJ]^{HDD}}{Value\ added\ [€]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Value\ added\ [€]}$ *HDD: Heating Degree Day energy consumption.*	Good	Useless	The reference is company specific and makes benchmark impossible	Useless

E.3. Energy indicators for space cooling

This section includes the internal use and benchmarking analysis of the space cooling indicators. Since climate conditions can have a significant influence on these indicators, the analysis of the suitability of the use of the indicators for internal use and benchmarking is performed first without considering the CDD correction and last considering it.

Table 13: Internal use and potential benchmarking indicators for space cooling. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space cooling	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
3.1	$Electricy\ consumption\ [kWh]$	Acceptable	Acceptable	Variation in size and activities of companies makes benchmark impossible	Useless
3.2	$\frac{Electricy\ consumption\ [kWh]}{Size\ of\ production}$	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Variation in size and activities of companies makes benchmark impossible	Useless

#	Potential indicators for specific energy consumption for space cooling	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
3.3	$\frac{Electricy\ consumption\ [kWh]}{Total\ floor\ area\ [m^2]}$	Acceptable	Useless	Variation in cooled floor area and climate conditions influences significantly, particularly at the international level.	Useless
3.4	$\frac{Electricy\ consumption\ [kWh]}{Cooled\ floor\ area\ [m^2]}$	Good	Acceptable	Variation in climate conditions influences significantly at the international level.	Useless
3.5	$\frac{Electricy\ consumption\ [kWh]}{Total\ building\ volume\ [m^3]}$	Acceptable	Useless	Variation in cooled floor area and climate conditions influences significantly, particularly at the international level.	Useless
3.6	$\frac{Electricy\ consumption\ [kWh]}{Cooled\ building\ volume\ [m^3]}$	Good	Acceptable	Variation in climate conditions influences significantly at the international level.	Useless
3.7	$\frac{Electricy\ consumption\ [kWh]}{Value\ added\ [€]}$	Acceptable	Useless	Variation in size and activities of companies makes benchmark impossible	Useless
3.8	$\frac{\sum_i^n ESEER_i[adim] \cdot Elect.Power_i[kW]}{\sum_i^n Elect.Power_i[kW]}$	Acceptable	Useless	Variations in the hours of use of different cooling devices not considered Variations in use of space cooling not considered, it can vary significantly at the international level	Useless

#	Potential indicators for specific energy consumption for space cooling	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
3.9	$\frac{\sum_i^n ESEER_i[adim] \cdot Elect.cons._i\,[kWh]}{\sum_i^n Elect.cons._i\,[kWh]}$	Good	Useless	Variations in use of space cooling not considered, it can vary significantly at the international level	Acceptable

Table 14: Internal use and potential benchmarking indicators for space cooling, CDD corrected. Source: Developed by the authors.

#	Potential indicators for specific energy consumption for space cooling, CDD corrected	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
3.10	$Electricy\ consumption\ [kWh]^{CDD}$ *CDD: Cooling Degree Day energy consumption.*	Good	Good	Variation in size and activities of companies makes benchmark impossible	Useless
3.11	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Size\ of\ production *}$ *CDD: Cooling Degree Day energy consumption.* ** The size of the production can be measured in different ways as described in Table 1 in section D.2.*	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Good, acceptable, bad or useless, depending on the reference described in Table 1 in section D.2	Variation in size and activities of companies makes benchmark impossible	Useless

#	Potential indicators for specific energy consumption for space cooling, CDD corrected	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
3.12	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Total\ floor\ area\ [m^2]}$ *CDD: Cooling Degree Day energy consumption.*	Good	Useless	Variation in cooled floor area and climate conditions influences significantly.	Useless
3.13	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Cooled\ floor\ area\ [m^2]}$ *CDD: Cooling Degree Day energy consumption.*	High	Good	Variation in climate conditions influences significantly at the international level.	Acceptable
3.14	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Total\ building\ volume\ [m^3]}$ *CDD: Cooling Degree Day energy consumption.*	Good	Useless	Variation in cooled floor area and climate conditions influences significantly.	Useless
3.15	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Cooled\ building\ volume\ [m^3]}$ *CDD: Cooling Degree Day energy consumption.*	High	Good	Variation in climate conditions influences significantly at the international level.	Acceptable

#	Potential indicators for specific energy consumption for space cooling, CDD corrected	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
3.16	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Value\ added\ [€]}$ *CDD: Cooling Degree Day energy consumption.*	Good	Useless	Variation in size and activities of companies makes benchmark impossible	Useless
3.17[2]	$\frac{\sum_i^n ESEER_i[adim] \cdot Elect.Power_i[kW]}{\sum_i^n Elect.Power_i[kW]}$	Acceptable	Useless	Variations in the hours of use of different cooling devices not considered Variations in use of space cooling not considered, it can vary significantly at the international level	Useless
3.18[3]	$\frac{\sum_i^n ESEER_i[adim] \cdot Elect.cons._i\ [kWh]}{\sum_i^n Elect.cons._i\ [kWh]}$	Good	Useless	Variations in use of space cooling not considered, it can vary significantly at the international level	Acceptable

[2] Please note, this indicator is the same as indicator 3.8.

[3] Please note, this indicator is the same as indicator 3.9.

E.4. Energy costs indicators

This section includes the internal use and benchmarking analysis of the energy costs indicators.

Table 15: Internal use and potential benchmarking indicators for space cooling. Source: Developed by the authors.

#	Potential energy costs indicators	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
4.3	$\frac{Production\ energy\ costs\ [EUR]}{Total\ added\ value\ [EUR]}$ or $\frac{Total\ energy\ costs*\ [EUR]}{Total\ added\ value\ [EUR]}$	Acceptable	Useless	Variation in activities of companies Variation in energy costs between companies	Bad
4.4	$\frac{Production\ energy\ costs\ [EUR]}{Profit\ [EUR]}$ or $\frac{Total\ energy\ costs*\ [EUR]}{Profit\ [EUR]}$	Acceptable	Useless	Variation in activities of companies Variation in energy costs between companies The profit varies significant	Useless

E.5. Indirect energy related indicators

This section includes the internal use and benchmarking analysis of other energy related indicators.

Table 16: Internal use and potential benchmarking indicators for material efficiency and indirect energy consumption. Source: Developed by the authors.

#	Potential other energy related indicators	Suitability for internal use		Conditions influencing the stability of the benchmarking indicator	Suitability as benchmarking indicator
		Annual	Monthly		
5.1	$\frac{Carbon\ footprint\ [t\ CO_2e]}{Size\ of\ production\ *}$ ** The size of the production can be measured in different ways as described in Table 2 in section D.2.*	Good, acceptable, bad or useless, depending on the reference described in Table 2 in section D.2	Good, acceptable, bad or useless, depending on the reference described in Table 2 in section D.2	Variation in size and activities of companies makes benchmark impossible. Differences in the scope or the emission factors for the carbon footprint calculation	Useless (unless standardised calculation systems are used)
5.2	*Any <u>suitable</u> indicator in the company related to the material efficiency of:* ***Consumed substrate*** ***Consumed printing plates*** ***Consumed inks***	High	High	The indicators are company specific and makes benchmark impossible	Useless
5.3	$\frac{Waste\ paper\ [ton]}{Consumed\ paper\ [ton]}$	Good	Acceptable	Variation in size and activities of companies	Acceptable

E.6. Summary of Benchmarking Indicators

In the table below, a summary of the indicators that are considered to be the most suitable ones for the sectoral benchmarking is included.

Table 17:Summary of potential benchmarking indicators. Source: Developed by the authors.

#	Indicator category	Indicator	Suitability as benchmarking indicator
1.1	Energy consumption in the production	$\frac{Electricity\ [kWh]}{Consumed\ paper\ [ton]}$ or $\frac{Natural\ gas\ [Nm^3]}{Consumed\ paper\ [ton]}$	Good
1.11	Energy consumption in the production (summarized energy sources)	$\frac{Energy\ consumption\ [GJ]}{Consumed\ paper\ [ton]}$	Acceptable
2.11	Space heating	$\frac{Heat\ \ [GJ]^{HDD}}{Heated\ floor\ area\ [m^2]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Heated\ floor\ area\ [m^2]}$ *HDD: Heating Degree Day energy consumption.*	Acceptable
2.13	Space heating	$\frac{Heat\ \ [GJ]^{HDD}}{Heated\ building\ volume\ [m^3]}$ or $\frac{Natural\ gas\ [Nm^3]^{HDD}}{Heated\ building\ volume\ [m^3]}$ *HDD: Heating Degree Day energy consumption.*	Acceptable

#	Indicator category	Indicator	Suitability as benchmarking indicator
3.9	Space cooling	$\frac{\sum_i^n ESEER_i[adim] \cdot Elect.cons._i\ [kWh]}{\sum_i^n Elect.cons._i\ [kWh]}$	Acceptable
3.13	Space cooling	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Cooled\ floor\ area\ [m^2]}$ *CDD: Cooling Degree Day energy consumption.*	Acceptable
3.15	Space cooling	$\frac{Electricy\ consumption\ [kWh]^{CDD}}{Cooled\ building\ volume\ [m^3]}$ *CDD: Cooling Degree Day energy consumption.*	Acceptable
5.1	Indirect energy consumption	$\frac{Carbon\ footprint\ [t\ CO_2e]}{Size\ of\ production *}$ ** The size of the production can be measured in different ways as described in Table 2 in section D.2.*	Useless (unless standardised calculation systems are used)
5.3	Indirect energy consumption	$\frac{Waste\ paper\ [ton]}{Consumed\ paper\ [ton]}$	Acceptable