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Conception And Implementation of Energy Controlling Instruments According to ISO 50006:2014

Bachelor Thesis
Umwelttechnik

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Hamburg
March the 23th, 2016

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The bachelor thesis was written in cooperation with the company Envidatec GmbH

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List of Abbreviations

BAFA	Bundesamt für Wirtschaft und Ausfuhrkontrolle
EEA	Energy Efficiency Analysis
EM	Energy Monitoring
EnB	Energy Baseline
EnMS	Energy Management System
EnPI	Energy Performance Indicator
GHG	Greenhouse Gas
GNP	Gross National Product
HDI	Human Development Index
ISO	International Organization for Standardization
SEU	Significant Energy Use
TOE	Tones of Oil Equivalent

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1 Introduction

Expand and increase of the energy consumption are a historical reality which has accompanied the development of our civilization. Nowadays, the problem of an essential increase in energy efficiency takes on special significance more than ever. This is occuring due to following reasons: a high exhausting rate of energy resources such as oil and gas, which have a large share in the global supply-demand balance; the negative impact of the power consumption growing on the environment, leading to a significant deterioration of the ecological situation.

The increase of the energy resources consumption, on the one hand, will be transformed into the global energy crisis, on the other hand, may lead to an ecological disaster unless urgent measures will be taken. Among the measures that significantly affect the reduction of energy consumption, there is energy efficiency, which is the ratio of the effective fuel and power resources consumption.

Improving the energy efficiency strongly depends on the management level of energy resources consumption, which is formed on the basis of modern ideas, principles, methods, techniques and management theory. Applying these basic theories to the management of the energy consumption process creates a special discipline - energy management.

Energy management implies the control of energy resources, taking into consideration technical as well as organisational, motivational, informational, marketing and investment aspects. At the same time to control the consumption of energy resources it is necessary to manage the techniques and application methods of technical facilities for improving the fuel, heat and electricity efficiency [1].

The mankind has come a long way with the application and development of energy: from the energy of burning fires up to nuclear power reactors. This path is characterized by the expanding use and increasing consumption, resulting in two alternative tendencies.

The first trend is characterized as follows. In its development, mankind is constantly increasing consumption of fuel and energy resources. Energy consumption in the world over the past century has increased more than seven times, exceeding its end with 350 Exajoules (see Figure 1.1).

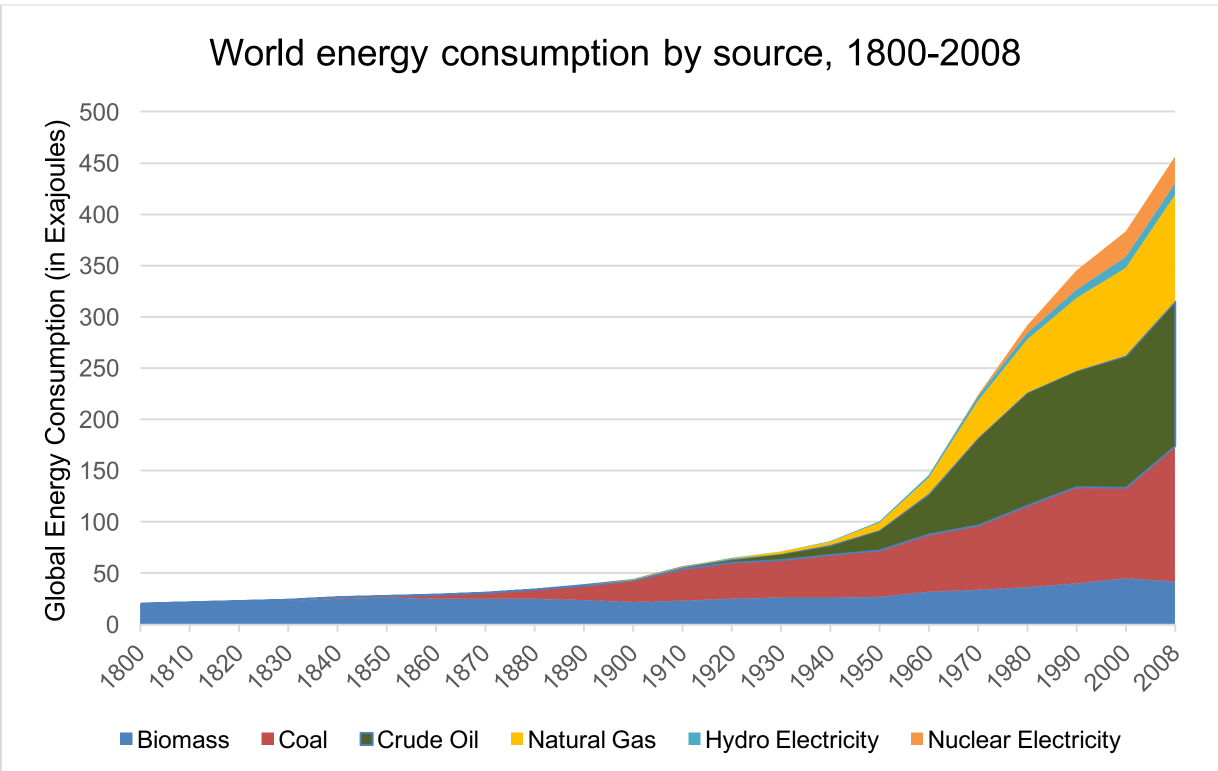


Figure 1.1: World energy consumption by source, 1800-2000 [2]

The development of particular countries on the planet is inextricably linked with its level of energy consumption. Energy use is a prerequisite for economic progress. The prosperity of economic development stimulates demand for better quality energy services, which empower basic needs of humanity, such as food and shelter. They also are the contribution of social development by improving and public health and education.

Energy itself is not sufficient for setting up the conditions for economic growing, but it is undoubtedly necessary for this process. It is impossible to manage a store, grow harvest, operate a factory or deliver goods and wares to consumers without using different form of energy [3]. For better understanding the relationship between the development and energy consumption, it is helpful to analyse the UN Human Development Index (HDI) and energy consumption per capita of a certain country as illustrated in Figure 1.2.

The HDI is a composite statistical index which envelops such spheres as life expectancy, education, and income, and is used to classify countries into four categories (see Table 1.1) of human development [4].

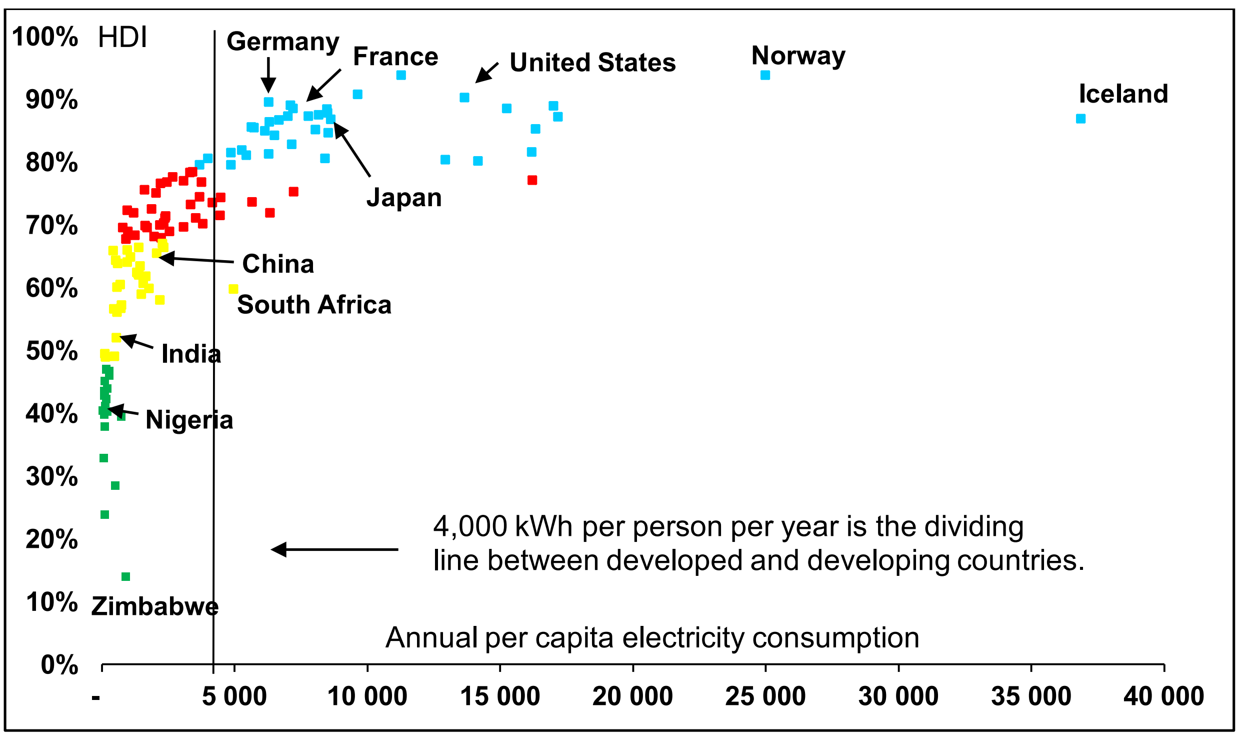


Figure 1.2: Correlation between HDI and per capita electricity consumption, 2007 [5]

The figure above clearly illustrates that a higher HDI goes hand in hand with increased per capita energy use.

Table 1.1: HDI country classification [4]

HDI	Development stage	Country	Color (Figure 1.2)
90 – 100 %	Very high	Germany, Japan, United Kingdom	Blue
80 – 89,9 %	High	Russian Federation, Turkey, Kazakhstan	Red
50 – 79,9%	Medium	China, India, Morocco	Yellow
0 – 49,9 %	Low	Nigeria, Zimbabwe	Green

The second trend is characterized by the following alternative. Increasing of energy consumption leads to negative consequences for the human environment, the depletion of fossil energy resources - coal, oil, gas and related to this process CO_2 discharge into the atmospare (see Figure 1.2).

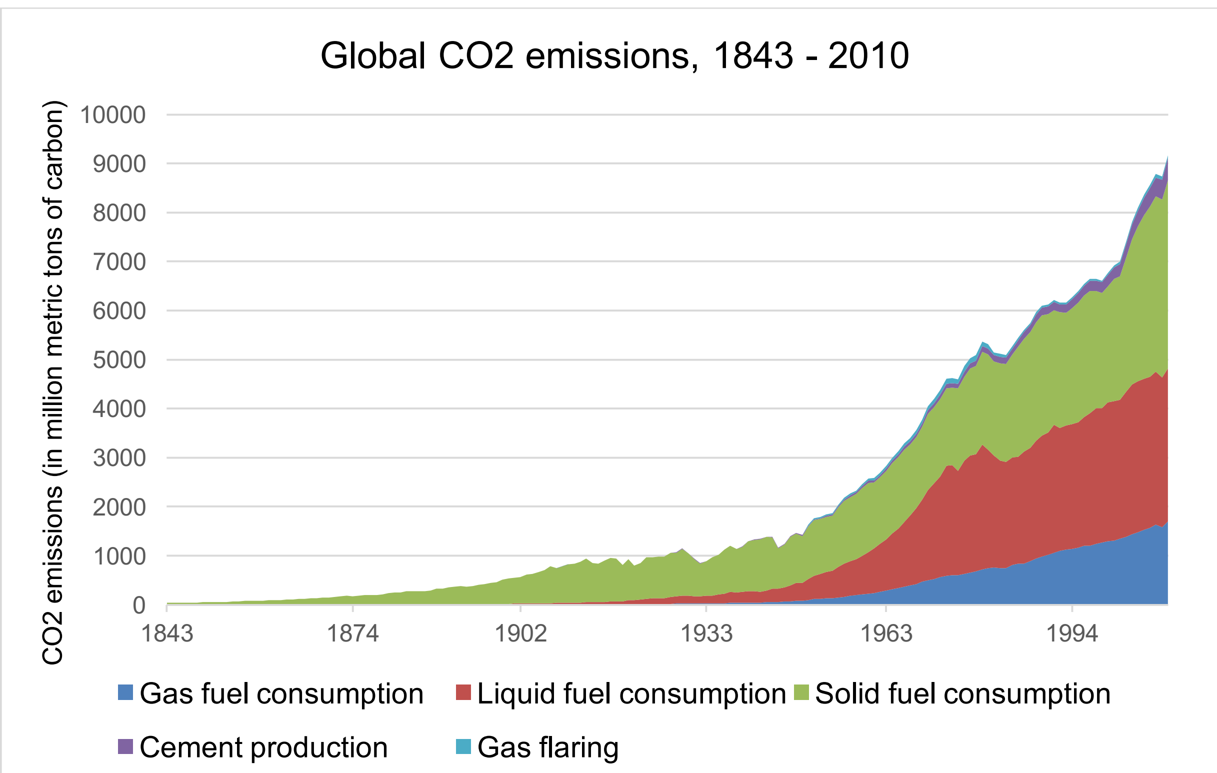


Figure 1.3: Global CO_2 emissions, since 1843 [6]

It is essential and possible to reach a compromise between these mutually competing trends, consisting of substantially increasing of energy efficiency, reducing of fossil fuels consumption, replacing it with renewable resources: hydropower, wind energy, solar energy, woodworking industry waste, field crop cultivation and organic waste.

So far, the control issues of energy consumption and improving the energy efficiency were considered primarily as a technical problem, with clearly insufficient application of modern theories of management. For this reason, most companies do not have significant results in terms of energy savings.

In this context, the role of management practices is of fundamental importance in improving the energy efficiency of enterprises. The modern concept of the energy resources controlling should be based on the provisions of the theory and methods of energy management.

2 Background

In line with global trends, there are an increasing number of standards, regulations and incentives regarding energy management, which energy intensive companies in particular must be conform to and aware of. The standards on energy management systems (EnMS) such as ISO 50001 provides a framework and enables a systematic approach for a company to continuously improve its energy usage. The process of improvement impacted upon by all levels within the organisation.

2.1 Envidatec GmbH

This work was written in cooperation with the company Envidatec GmbH. Since it was founded in 2001 the team operates in the field of energy management systems and energy monitoring.

The company combines expertise from the fields of energy services, energy and operational data management and energy efficiency. With years of experience in the areas of hardware, software and services is the Envidatec GmbH a competent customer-orientated partner. In addition, the long-standing contacts with reputable energy suppliers, institutions, networks and services expand the firm capabilities.

Envidatec aim is to detect energy saving potentials based on experience with close collaboration with the clients. This ensures that each customer organisation is analyzed according to the individual needs to find optimal solutions.

Since 2008, the Envidatec GmbH is dedicated to new tasks that are defined by the laws and standards in the area of energy management systems. Energy efficiency analyses that are in accordance with energy saving regulations or necessary for the refund of the so called in Germany ecotax provision, are part of the repertoire of internal audits and can be certified accordingly.

The new requirements of ISO 50001 will be the main concern of the Envidatec GmbH. Thus, the implementation of operational energy management, the accompanying monitoring hardware and software, and in addition the supervision of energy related projects will accompany Envidatec in the near future [7].

2.2 ISO 50001

ISO 50001:2011 «Energy management systems - Requirements with guidance for use» which was released in June 2011, is a specification established by the International Organization for Standardization (ISO) for an EnMS. The standard determines the requirements to establish, implement, maintain and improve the system of energy controlling, whose objective is to permit an organisation to attend a systematic approach in reaching continuous improvement of energy performance (Figure 2.1), covering the components of efficiency and security of energy, its use and consumption. The standard intends to assist organisations, independent of its size, branch or location, continually decrease their energy use, and corresponding to this process costs and GHG (greenhouse gas) emissions [8].

The main aim of ISO 50001 is to improve energy-related performance and efficiency and to indicate opportunities for reduction of energy consumption. The methodical and systematic approach will provide organisations with establishment of required systems and processes. Consecutive energy management helps in realization of untapped energy efficiency potential. As a result the organisation will turn the observance of

EnMS requirements to advantage like cost savings and make a essential contribution to environmental and climate protection by the reduction of CO_2 emissions [9]. ISO norm should alert employees and the management level not only to the immediate but alos to long-term energy management gains which can be made. The organisation can find out possible potential savings and competitive advantages. Moreover, a significant image encouragement of the company can be reached [10].

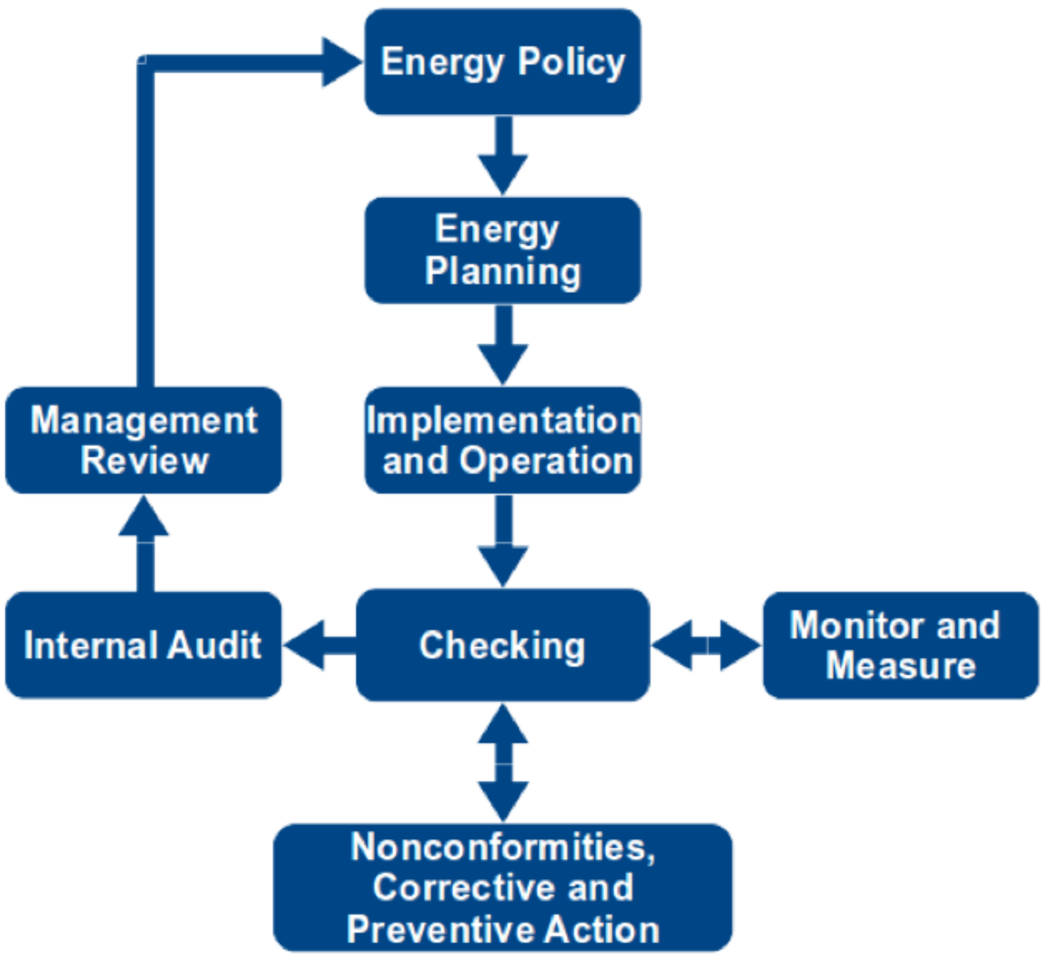


Figure 2.1: Continuous improvement process according the ISO 50001 [7]

Particular relevance has the introduction of an EnMS for energy-intensive businesses in Germany. Since 1st January 2012 an amendment to the Renewable Energy Sources Act is in force, according to which energy-intensive businesses can benefit under extended terms of a compensation scheme. Federal Office of Economics and Export Control (BAFA) can reduce the cost of the promotion of electricity from renewable sources for electricity-intensive manufacturing industries.

The operational energy management follows the Plan-Do-Check-Act-Cycle (PDCA) as is shown in see Figure 2.2, which provides a framework for continuous improvement of processes or systems. It is a dynamic model - the results of a step form the basis for the next run. This structure allows to evaluate the current energy consumption repeatedly, and to optimize and reduce costs progressively [11].

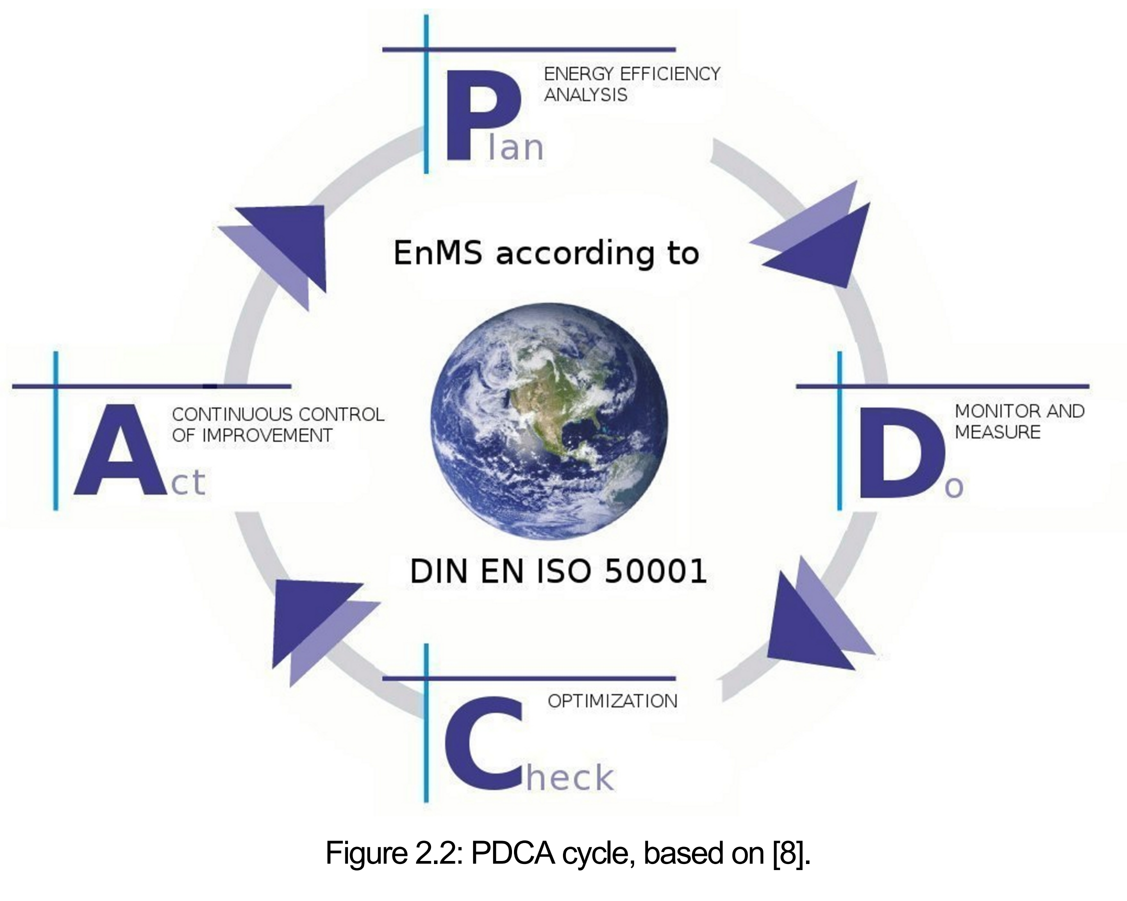


Figure 2.2: PDCA cycle, based on [8].

The ISO standard specifies requirements appropriate to energy consumption and use, and involving in the process measurements, documentation, reporting and alarming, design and procurement practices for equipment, processes, systems, and staff which stimulate energy performance improvement. It applies to all variables related to energy performance that can be influenced and monitored by the organisation and is appropriate to any organisation requesting to guarantee the conformity of its established energy policy and to demonstrate results to others. Such conformity can be confirmed either by means of self-evaluation and self-declaration, or by certification of the EnMS by an external company.

According to ISO 50001 an organisation has to establish a plan of energy performance improvement utilizing quantitative energy performance indicators (EnPIs); that is not a prescription but a standard that helps the organis
ation to set its own EnPIs providing flexibility. Different indicators that range from simple to complex due to energy consumption and intensity or engineering models are considered by standard in related guidance documents.

Managing energy causing difficulty for organisations by reason of the notion that energy performance is single presented and must consequently be measured using a simple, universally applied EnPI. Energy performance can only in rare instances be accurately represented by a single measure or value. It is better to pay attention on organisation’s energy performance represented by a set of measures providing related information to the variety of management levels and staff within the organisation that control and influence it.

For a multi-level company, where every layer of management has specific responsibility and a particular sphere of control, a tiered range of EnPIs will need to be developed for the provision the organisation with the applicable information so that effective management and improvement of energy related performance can be reached. At any given level, it is important to divide the performance of equipment individually and systems as a whole from the operational effectiveness of the personnel that manage or use it [12]. Chapter five provides the example of EnPIs that can be appropriate for different levels of management in an organisation and for different types of planned improvements.

2.3 ISO 50006

After the development of the ISO 50001 standard, there was substantial discussion over the advantages of simple versus more complex EnPIs which approaches the release of a new ISO 50006 standard. ISO 50006:2014 «Energy management systems - Measuring energy performance using energy baselines and energy performance indicators - General principles and guidance» provides organisations with practical guidance and methodology for meeting the requirements of ISO 50001 in particular establishment, use and maintenance of EnPIs and EnBs by measuring energy performance and energy performance changes. EnPIs and EnBs are crucial interrelated components of ISO 50001 that are integral part of the measurement, and therefore enable management and improving of energy related performance in an organisation. Energy performance is a extensive concept which includes consumption, use and efficiency of energy. The ISO 50006 is a standard with guideline character. It does not contain mandatory provisions, instead of this, it provides assistance over the definition of energy indicator and energy baseline. It is noticed in ISO 50006, by which procedure the plans can be implemented efficiently and how the targets can be tracked and quantified.

Energy savings technics, for more than four decades, has been developed by the innovating energy efficient products. The norm ISO 50001 introduced a new and timely concept called “energy performance”, which is similar to “key performance indicators” known by many business managers. It is also essential as it defines that, energy savings can be achieved by following means: energy use, energy consumption, and energy efficiency.

Energy performance represents measurable results connected to energy efficiency, energy use and energy consumption, which in the context of energy management systems can be measured against the organisation's energy policy, objectives and targets [8]. It is necessary for an organisation to know the way and amount of energy used and consumed to manage the energy performance effectively using appropriate systems, facilities, processes and equipment. The result related to energy efficiency in these systems, facilities, processes and equipment is expressed with energy performance indicator and used to define improvement made by an organisation. The energy performance in an organisation during particular period is characterized by a reference called Energy baseline. It allows an organisation to measure changes in energy performance during defined periods. Another use of the EnB is a reference before and after application of improvement measures to assess energy savings. Organisations define targets for energy performance as part of the energy planning process in their energy management systems. The organisation needs to consider the specific energy performance targets while identifying and developing EnPIs and EnBs. The relationship between energy performance, EnPIs, EnBs and energy targets is illustrated in Figure 2.3 [13].

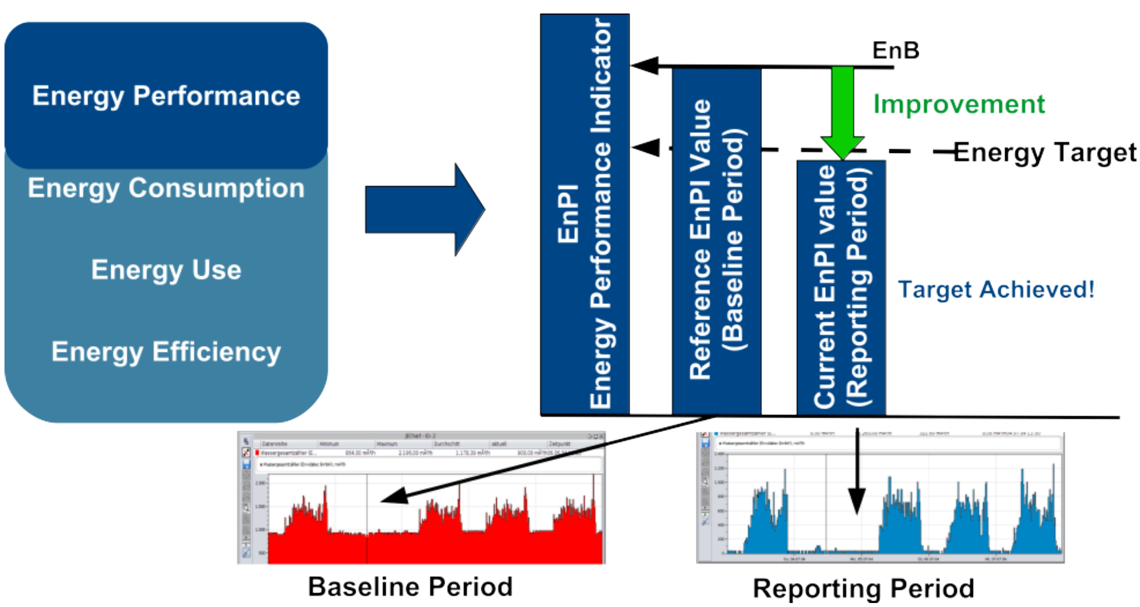


Figure 2.3: Relationship between energy performance, EnPIs and EnBs [10]

In order to gain value from the ISO 50006 standard it is not necessary to implement ISO 50001. The norm also suggests examples and practical cases, shares ideas and approaches in the field where an organisation can establish, monitor, measure and review EnB and energy performance. In case the baseline and energy performance indicators are conform, statistically significant and repeatable, they can be used for forecast of the future energy consumption, monitoring the energy performance and applying of appropriate corrective and preventive actions – an importnant requirement of ISO norm.

3 Energy Performance Indicators

An energy performance indicator is best defined as a point of reference against which comparisons can be made. Energy performance indicators are a valuable tool for assessing energy performance, allowing an enterprise to compare the performance of similar activities and determine the scope for improvement. The primary goals of energy performance indicators are to enhance energy consumption understanding, increase energy efficiency and decrease energy intensity. At a national level, energy performance indicators find application as a useful instrument for measuring the progress of sectoral CO_2 emission reduction efforts [14].

As it is described in ISO 50006, EnPI represents quantitative value or measure of energy performance, which is defined by the organisation and could be expressed as a simple metric, ratio or a complex model. The indicators should provide relevant energy performance information to enable various users within an organisation to understand its energy performance and take actions to improve it.

The EnPIs can be applied at facility, system, process or equipment levels to provide various levels of focus. According to ISO 50006 organisation should set an energy target and an energy baseline for each EnPI [13].

Energy target represents quantifiable and detailed energy performance requirement, applicable to the part of organisation or organisation at a whole, that arises from the energy objectives and that needs to be set and met for achieving this objective. Energy baseline provides a basic information for comparison of energy performance, which reflects a specific period of time [8].

3.1 Types of EnPIs

An appropriate selection of EnPI is one that, at the minimum investment and effort necessary, provides feedback and direction on the progress which is being made and if the energy policy is on the path to achieving its goals and meeting its targets.

Perhaps the simplest and most used EnPI is metering of the energy consumption. Such indicator works successfully for facilities, whose inputs do not change seasonally and whose processes are not dependent on external factors such temperature. In the general case, energy consumption is responsive to such factors as use, occupancy and weather. For industrial operations, production levels are essential factors. Thus energy per occupant might be significant to building managers while consumption per unit of production could be a helpful EnPI for industrials.

Substantial data and information to assess the energy situation and to develop the first indicators are already available to the companies in various forms (for example energy bills, plans, etc.). Among other things, indicators can include: number of employees, annual turnover, operating surface, layer system, production hours, products, energy consumption (electricity, gas, oil). The simplest EnPIs are represented in Table 3.1.

If not used appropriately, EnPIs can provide confusing or misleading information. In a number of cases, when an EnPI is established to measure the performance at one particular level of the organisation or of a whole system, or activity and then applied to measure performance at a higher or lower level, the wrong, incorrect conclusion can be reached.

Table 3.1: The simplest EnPI with description [15]

Indicator	Description	Unit
Energy consumption (entire)	Absolute	kWh, MWh, Euro, Dollar
Energy consumption (specific)	$\frac{\text{Entire Energy Consumption}}{\text{Production amount}}$	kWh/kg kWh/m^3
Shares of energy source	$\frac{\text{Energy Source Share}}{\text{Entire Energy Consumption}} \cdot 100\ \%$	%
Energy intensity	$\frac{\text{Energy of process or area}}{\text{Entire Energy Consumption}} \cdot 100\ \%$	%
Efficiency	$\frac{\text{Useful Output Power}}{\text{Supplied Power}} \cdot 100\ \%$	%
Utilization rate	$\frac{\text{Useful Output Energy}}{\text{Supplied Energy}} \cdot 100\ \%$	%
Industry-oriented indicator	$\frac{\text{Entire Energy Consumption}}{\text{Turnover}}$	kWh/Dollar, kWh/Euro

As it was mentioned earlier, where production ratio changes – raises or decreases unexpectedly and drastically, an energy indicator which was designed for measuring energy consumption as a ratio to product output would correspondingly indicate that in whole, the energy consumption of company has increased relative to its output. However, assessing the efficiency improvement in organisation’s system would not be useful unless the Energy performance indicator was transfigured to consider operating rates’ differences. A company producing three similar products that demand different energy amount is an example of EnPI use. When a company changes the relative amounts of production, an uncompensated or single indicator can cause further discrepancies. The next example is a company where the energy consumption depends on the quality of the input materials: as if a material in the dry state requires less energy than in a wet state and the producer cannot adjust the moisture level. In this case, the company needs several specific performance indicators to understand the energy performance completely: the first EnPI shows the overall energy consumption; the second EnPI shows the energy output pro unit not considering the state of input materials; the third one shows the energy output pro unit considering the state of input materials. The whole set of indicators can describe the energy performance more accurately including its variety of use, levels and purposes.

3.2 EnPI Development

An overview of the process for developing, use and update of the EnPIs (Annex I) is illustrated in ISO 50006 and it consists of three big steps as mentioned in following:

1. Relevant information which should be acquired includes:
   1.1 Boundaries;
   1.2 Energy flow;
   1.3 Relevant variables;
   1.4 Static factors;
   1.5 Data.
2. The energy performance indicators should identify:
   2.1 Users;
   2.2 Specific characteristics.
3. Establishing of energy baselines:
   3.1 Suitable period;
   3.2 Testing of EnB.

3.2.1 Acquiring of Relevant Information

To measure energy performance, the scope of the analysis first for each EnPI has to be precisely defined. By defining the boundaries the following should be considered:

– organisational responsibilities in relation with energy management;

- the ease of isolating the EnPI boundary by quantifying energy and relevant variables;
- the EnMS boundary;
- the significant energy use (SEU) or group of SEUs the organisation designates as a priority to control and improve;
- specific equipment, processes and sub-processes which should be isolated and managed [13].

The primary boundary levels of EnPIs are individual, system and organisational as described in Table 3.3

Table 3.2: EnPI boundary levels [13]

EnPI boundary levels	Description and examples
Individual facility/ equipment/ process	Physical perimeter of one facility/equipment/process for control and improvement.
	Example: the steam production equipment.
System	Physical perimeter of a group of facilities/ processes/equipment interacting with each other.
	Example: the steam production and use equipment.
Organisational	Physical perimeter of facilities/processes/ equipment also taking into account the responsibility in energy management of individuals, teams, groups or business units designated by the organisation.
	Example: steam purchased for a factory or department.

Boundaries are location-related and refer to facilities, installations and energy flows. Once an EnPI boundary is defined, the organisation should identify energy flow across the boundary. The organisation can use a Sankey diagram like the one in Figure 3.3 or fence diagram to determine the energy information required to establish EnPIs. Fence diagram is used for representing data in three dimensions, Sankey diagrams show the proportionality of the flow with the different width of the arrows. These diagrams or energy maps visually show the flow of energy within and across the EnPI boundary.

For energy analysis and the establishment of performance indicators they can include additional information, such as metering points and product flow.

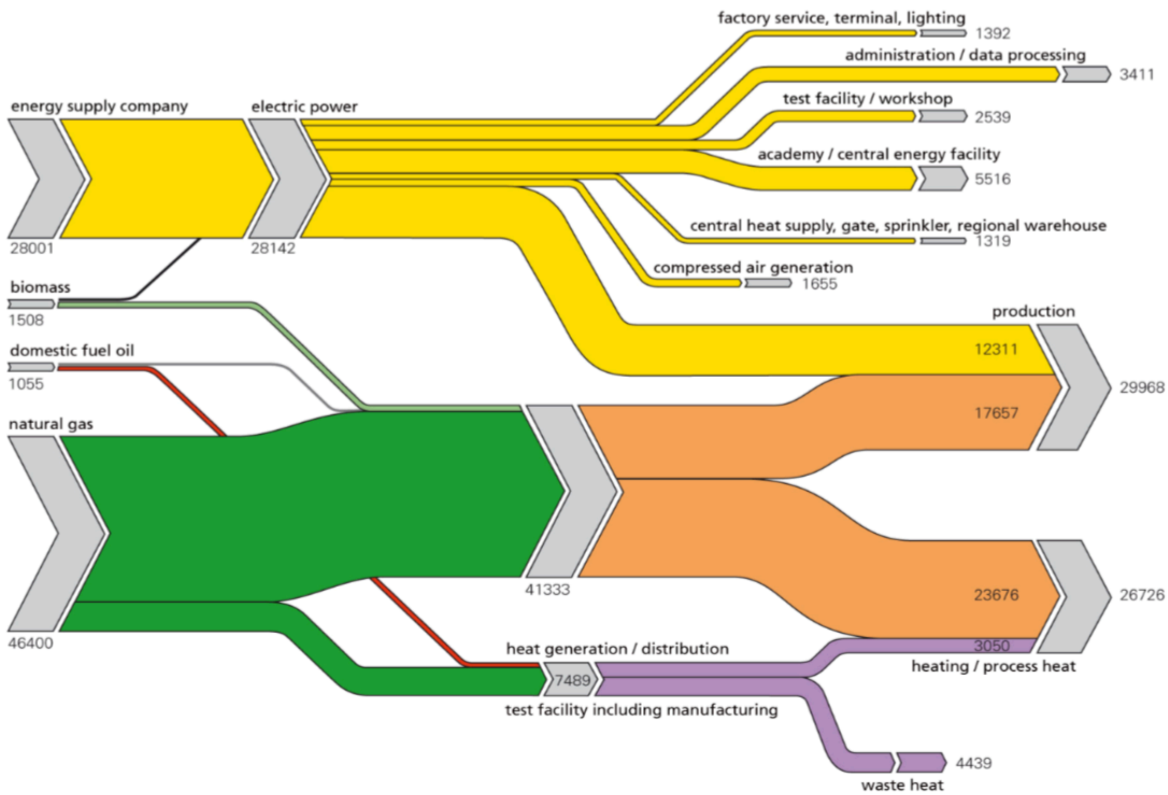


Figure 3.3: Example of energy flow chart, Sankey diagram [16]

Depending on the needs of the company and its EnMS, meaningful variables, that may have an influence on energy performance, should be characterised and quantified at each EnPI boundary. It is essential to isolate those variables that are important regarding energy performance from the variables which have small or zero influence. Data analysis is often required to define the significance of relevant variables.

The relevance of some variables can be higher to energy consumption than by the others. For example, where energy consumption per unit of production is being measured, counting the number of final products may provide a misleading result if there are intermediate outputs produced, and whether these intermediate outputs are wasted, value added, or recycled. Once the relevant variables have been isolated, further modelling methodes can be used to determine the precise nature of the relationship. For the organisations it is often challenged to understand the magnitude of the relationship of variables and energy consumption. ISO 50006 gives a method to assess whether a variable significantly affects energy consumption.

In the first place, it is essential to understand any trends in energy consumption and in potentially relevant variables, which can be plotted over time in a trend chart. This process will represent the organisation evidence of seasonality or evidence of variables changing at similar times as energy consumption. For example, if energy consumption is due to heating, the consumption will increase during the cooler winter months. If the load is related to cooling, consumption will increase during the summer months, as shown in Figure 3.2.

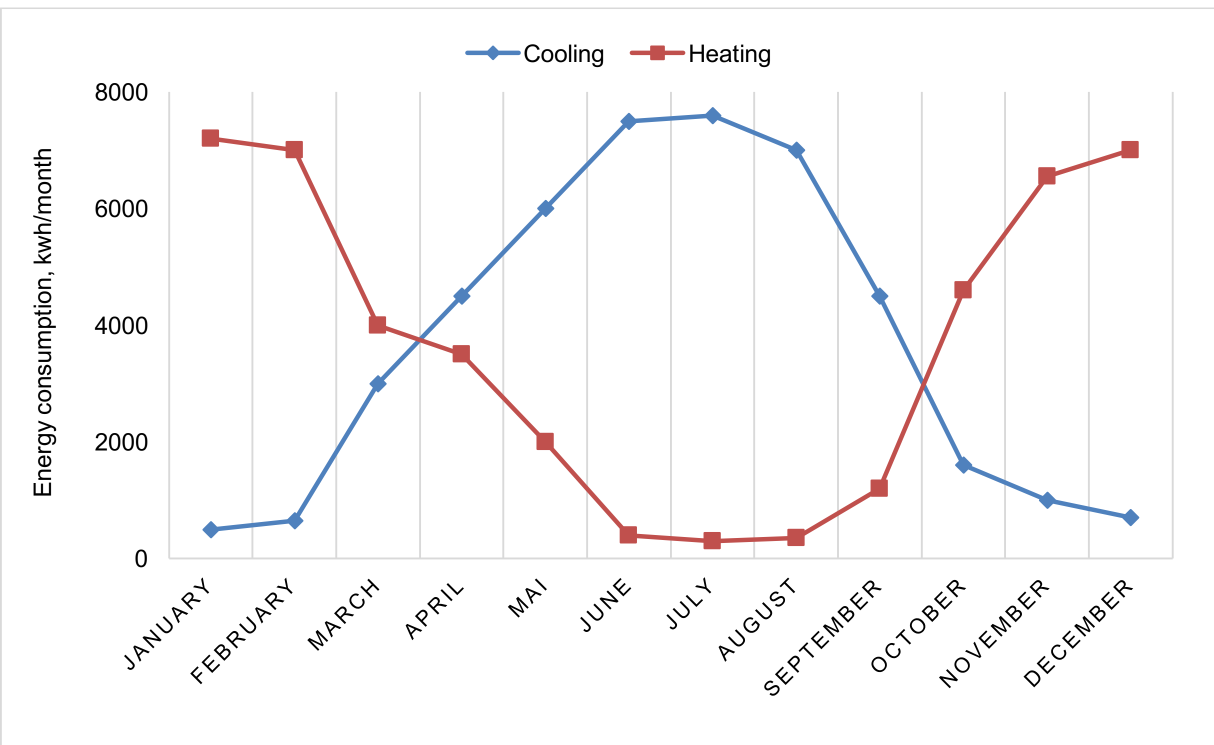


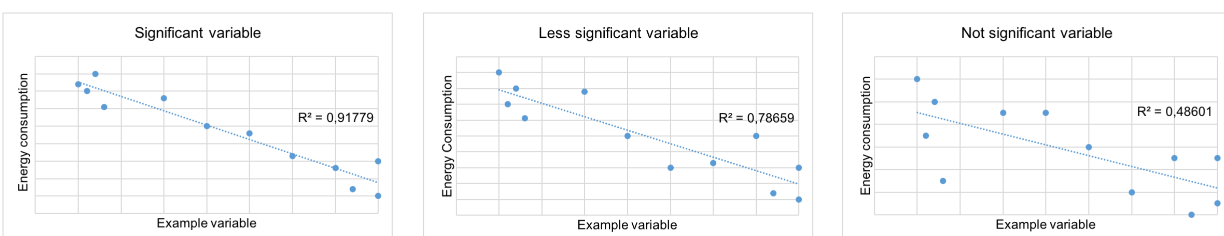
Figure 3.4: Trend chart example showing seasonality, own depiction.

After estimating the tendency of energy consumption and variables, the organisation should assess the significance of the relationship. For this process, a variable against energy consumption can be mapped using an X-Y diagram. The relationship in the scatter of points will show the relevance of each variable. This relation can be described with the coefficient of determination R^2, which gives the divergence proportion of the variable that is predictable from the other one. It is a measure that allows to determine the precision of predictions from a certain model or method. For example, if R^2 = 0,85, which means that 85% of the total variation in *y* can be explained by the linear relationship between variables *x* and *y.* The other 15% of data remains unexplained [17].

Table 3.3: Levels of significance

Coefficient of determination, R^2	Significance
0,9 – 1	Significant variable
0,75 – 0,89	Less significant variable
< 0,75	Not significant variable

If the points appear to be scattered around a mathematical function, shown as a trend line then this is indicative of the presence of relevant variables (see Figure 3.3 a) and b)). If the points appear as a random cloud with no evident relationship, the variable is likely, not relevant (Figure 3.3) and can not be used for further analysis [13].



a) Significant variable b) Less significant variable c) Not significant variable

Figure 3.5: Example variables with differing levels of significance, based on [13]

The factors affecting energy performance are often not constant and change in value. They should be analysed to see if they are best considered as a relevant variable or as a static factor. For example, a manufacturing plant may have a routinely changing production level that is a relevant variable and non-routinely changing product mix that is a static factor.

It is important to make a record of the static factors condition at the time when EnPIs and EnBs are being established. The company should evaluate these static factors over the time, to ensure that the EnPIs and EnBs remain appropriate and to record any major changes that could have an influence on the energy performance.

Although static factors do not differ significantly between the reporting period and the baseline period, if conditions change the static factors could change and the organisation should maintain related EnPIs or EnBs.

It can be difficult to understand when static factors need to be maintained to related EnPIs or EnBs. The following describes a few helpful steps.

- Change in product type - after an introduction of a new product, maintenance may be required for the new product type.
- Change in shifts per day – number of shifts increases or decreases, this may require maintenance.
- Change in building occupancy - the number of occupants significantly increases or decreases due to new leases, then this may require maintenance.
- Change in floor area - the organisation significantly expands the building, and then this may require maintenance.

Since the organisation has defined boundaries, related to them energy flows, relevant variables and static factors it is necessary to specify the data to be collected for each EnPI and its related EnB. Due to this information an organisation may discover that some of the EnPIs that were identified previously as significant may not be measurable due to data limitations or other barriers. In this case, it is needful to assess, and consequently refine the EnPIs or introduce additional meters or measurement methods.

3.2.2 Identifying the Energy Performance Indicators

By developing an EnPI, the organisation should understand its energy consumption characteristics such as base load as well as variable loads due to occupancy, production, weather and other factors. Organisations define targets for energy performance as part of the energy planning process in their EnMS. Energy performance targets should be characterised by EnPI values.

By comparing EnPIs over time, they should allow to determine if the energy performance has changed and whether it is meeting its targets. By selecting appropriate EnPIs, organisations should consider the users of the information and their needs as key factors. EnPIs should be easily understandable by their users. The type and complexity of the indicators should be adapted to the different final users' needs (Table 3.2). For this process multiple EnPIs may be required [10].

Table 3.2: Organisational levels and their needs, based on [13]

User	Users' needs
Top management	Consideration of the energy performance in long-term planning, to ensure that all requirements are met and to ensure that results are measured and reported at determined intervals.
Management representative	Understanding of both planned energy performance and any deviation from desired performance in terms of energy performance and in financial terms.
Plant or facility manager	Control and assurance of the efficient operation of taking corrective actions for deviations in energy performance, eliminating waste and undertaking preventive maintenance to reduce energy performance degradation.
Operation and maintenance personnel	Control and assurance of the efficient operation of taking corrective actions for deviations in energy performance, eliminating waste and undertaking preventive maintenance to reduce energy performance degradation.
Process engineer	Plan, execution and evaluation of an energy performance improvement action using suitable EnPI for the action and its evaluation method.
External users	Energy actions and performance improvements.

To meet the user needs and the complexity of the application the organisation should choose the type of EnPI. The main types of EnPIs, which are represented in Table 3.4 with examples, are:

- measured energy value: consumption of an entire site or one or more energy uses measured by a meter;
- ratio of measured values: expression of the energy efficiency;
- statistical model: relationship between energy consumption and relevant variables using linear or nonlinear regressions;
- engineering based model: relationship between energy consumption and relevant variables using engineering simulations.

Table 3.4: Energy performance indicators types with examples [13]

EnPI type	Examples
Measured energy value	Energy consumption (kWh) for lighting in company
	Fuel consumption (GJ) of boilers
Ratio of measured values	kWh/tonne of production
	GJ/unit of product
Statistical model	Energy performance of a production facility with two or more product types
	Relationship between the energy consumption and the flow rate
Engineering model	Industrial or power generation systems where engineering calculations or simulations enable accounting for changes in relevant variables and their interactions
	Whole building models that account for hours of operation, centralized versus distributed HVAC systems, and varying tenant needs

3.2.3 Energy Baselines Establishing

Information collected by measuring a building's energy performance for a minimum of 12 months (36 months preferred by ISO 50006) will establish a baseline for energy consumption. This interval can serve as a basis point for setting goals for energy efficiency improvement as well as a comparison instrument for evaluating future efforts and analysing the trend of overall performance.

The energy baseline is described by the value of the EnPI during the baseline period. A comparison between the EnB and reporting period EnPIs can be used to evaluate the progress towards meeting energy objectives and energy targets and illustrates improvements in energy performance.

The following steps should be taken to establish an EnB:

- to determine the specific objective which the EnB will be used;
- to determine a suitable period;
- to gather the data;
- to determine and test the EnB.

By establishing the EnBs the organisation should determine a suitable data period in consideration of the specific of its operations. The baseline period and reporting period should be long enough to ensure that the variability in operating patterns is accounted for by the EnB and EnPI. Normally these periods are 12 months long to account for seasonality in energy consumption and relevant variables.

The frequency with which an organisation collects data is an important factor in determining a suitable baseline period. It should be of sufficient duration to capture variations in relevant variables, such as seasonality in production, weather patterns, etc. Typical periods to be considered are:

- One year - The most common EnB duration, likely due to adjustment with energy and business objectives (reducing energy consumption from a previous year). This time period also includes the full range of seasons and consequently can capture the impact of relevant variables such as weather on energy use and consumption. It can also capture a full range of business operating cycles where production may vary during the year due to annual market demand patterns.

- Less than one year - suitable in cases without the seasonality in energy consumption or if shorter operating periods capture a reasonable range of operating patterns. Short EnB durations may also be necessary for situations in which there is an insufficient quantity of reliable, appropriate or available historical data (e.g. when changes in the organisation, policies or processes make only current data available).
- More than one year - seasonality and business trends can combine to make a multi-year EnB. Especially, custom multi-year EnB periods are useful for extremely short annual production cycles where a business manufactures products for a few months each year and is relatively inactive for the rest time of the year (e.g. a winery might want to track energy performance only during the crushing and fermentation period of each year, however over multiple years) [13].

Companies need to gather their energy records for the base year selected. The energy records must include a breakdown of the energy used by type, for example electricity, natural gas, oil and coal. Energy use within the boundary may include manufacturing and industrial operations as well as non-manufacturing energy use (e.g., energy consumed in office buildings). These energy data are needed to calculate the energy use baseline.

To establish the EnB, the related EnPI should be measured or calculated using the energy consumption and relevant variable data from the corresponding period. If appropriate, the EnB should be tested for validity using statistical tests such as the P-Value, F-Test or the coefficient of determination to ensure that it is an appropriate reference for comparison. If a model is determined not to be valid, the organisation should consider adjusting the EnB or determine a new model, corresponding EnPI and EnB.

3.3 Application of Energy Performance Indicators

To evaluate the changes in energy performance, EnPIs should be quantified during the reporting period and compared to the corresponding EnBs. There are several common approaches which can be used for all type of energy performance indicators:

– Difference (D)

This is the difference between the baseline period EnPI (A) value and the reporting period EnPI values (B).

$$D = B - A$$

– Percent change (P)

This is the change in values from the baseline period to the reporting period, expressed as a percentage of the EnB.

$$P = \frac{B - A}{A} \cdot 100$$

– Current ratio (C)

This is a ratio of the reporting period value divided by the baseline period value.

$$C = \frac{B}{A}$$

These approaches will be used in the comparison of energy consumption in the report from chapter five.

EnPIs can be used by companies generally for analysis and regulation (Figure 3.3). The regulation function can be divided into the functions planning (development of different indicators) and control (target-performance comparison).

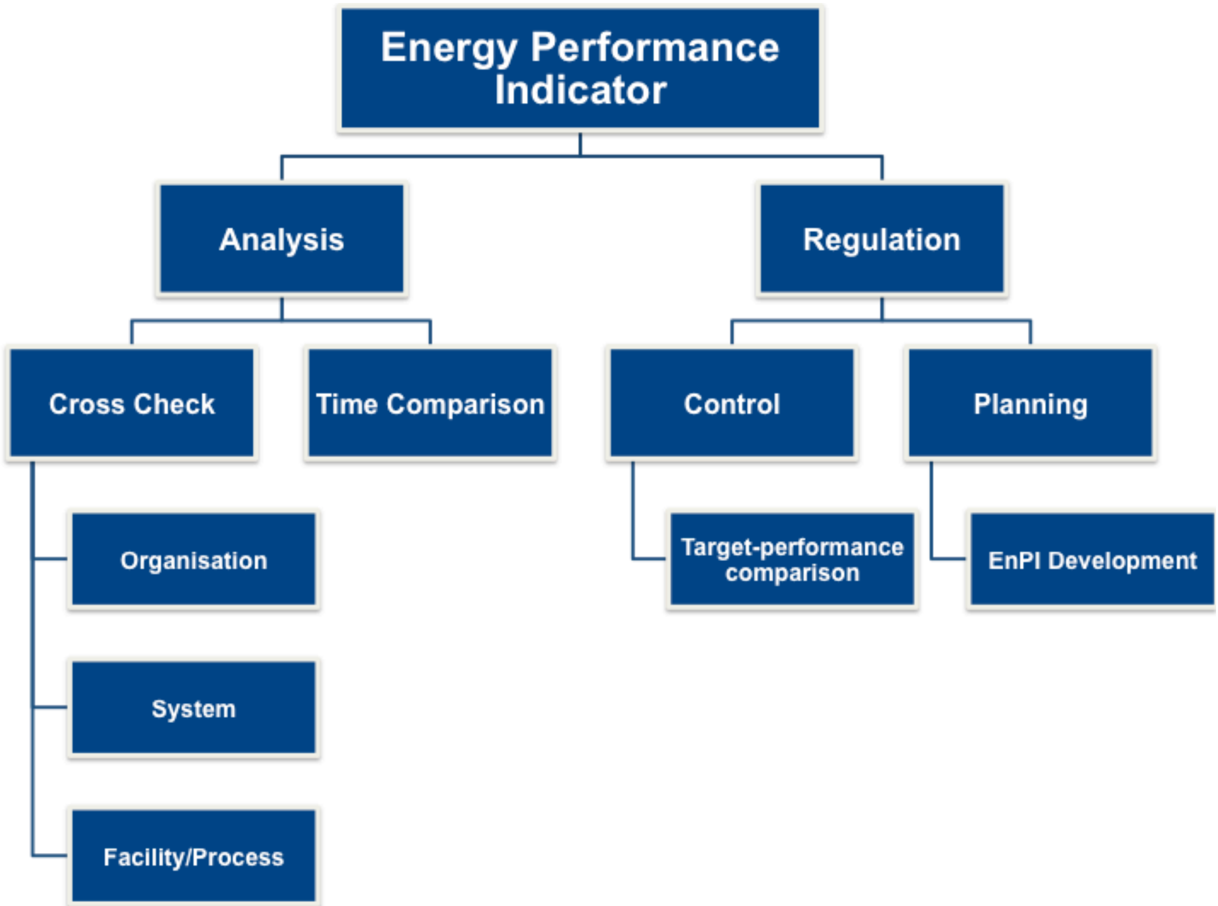


Figure 3.6: Application of the EnPIs [18]

Analyses are based on a comparison of the EnPIs. Through significant deviations between the indicators undesirable developments and / or opportunities for improvement can be identified. Two methods of EnPI comparison are possible:

- Time comparison analysis represents the comparison of the same indicator of an object at different time (e.g. energy consumption of company X during the working day and energy consumption of the company X in rest-day) or comparison of different periods (e.g. energy consumption of company X in the past two years). Such time series analyses have the advantage that the values of the same object (enterprise, division, department, facility) are compared. Changes to the object - product, process, system, organisational changes - are known in the enterprise relatively accurate and can be used for a meaningful interpretation of the figures.

- Cross-check analyses correspond comparisons of the same EnPIs relating to different objects. This shall include:
    - Organisational or benchmarking (e.g. energy consumption of company A and B);
    - Facility comparison (e.g. heating energy consumption per square metre in the warehouse I and warehouse II);
    - System and process comparisons (e.g. energy consumption per cubic metre of compressed air of compressed air systems).

Cross-check comparisons can be carried out either continuously or once. The biggest challenge of this method is to find two or more actually comparable objects (plants, equipment, processes) [18].

4 Informational Support of Energy Management System

The main objective of the informational support in energy management is the development and maintenance of the information system which produces based on the monitoring of energy consumption reports and messages for helping staff (system users) to take effective control decisions and actions for improving the energy efficiency.

It is important to understand that energy management information system operates not only as a technical computerized system for monitoring and control of energy consumption or performance indicators, but also as a system that provides the administrative aspect of their effective use [1].

Consumers of information (information system's user) are the persons involved in the process of consumption and energy control, i.e. key personnel, which takes control of machinery, equipment, generation, transmission and conversion of the energy resources, as well as management staff at all levels (from the head of departments to the CEO of the company). The flexibility of energy management standards in development EnPIs allows an organisation to select such indicators that, taken together, will meet the varied needs of different levels of the organisation.

In this way, energy management information system is an information-controlling system which provides the user with the information, allowing them make decisions about efficient energy consumption.

4.1 Reporting

How it was mentioned before it does make sense to develop level-devided EnPI's monitoring system. Some EnPIs will be of interest to the management (business unit annual energy consumption), while other will provide utility managers with timely feedback so that they can ensure an energy system is operating as expected (e.g., kW/Nm^3 for a compressed air system). EnPIs can answer at least two questions: how well did the organisation the comparison with its target and how well is this system presently performing compared with a target. The latter EnPI provides information to operators who can correct system performance as soon as it is noticed, and thus contribute toward achieving the larger organisational targets. The possible EnPIs for different levels of organisation is listed in Table 4.1

Table 4.1: Possible EnPIs for different organisational levels [18]

User	Possible EnPIs	Unit
Top management and management representative	General energy overview Specific energy consumption Shares of energy source Efficiency	kWh; $/kWh kWh/Prod. output % %
Plant or facility manager	Facility energy consumption Energy intensity of facility Processes consumption overview Efficiency of the facility	kWh, $ % kWh, $ %
Process engineer	Process energy consumption Process intensity Specific EnPI of the process/system Efficiency of the process/system	kWh % kWh/m^2 %
Extern	Energy efficiency and improvements	%

For each level the information should be identified in a valid form (table, graph diagram, chart), provide them with the knowledge of the energy consumption state in real time, allows them to make the decision to sustain the energy consumption at the appropriate level, to improve energy efficiency of production.

In the management reports, meaningful information is needed, that make it possible to take strategic decisions. Depending on company size, however, the expression of the reports can be very different (Figure 4.1).

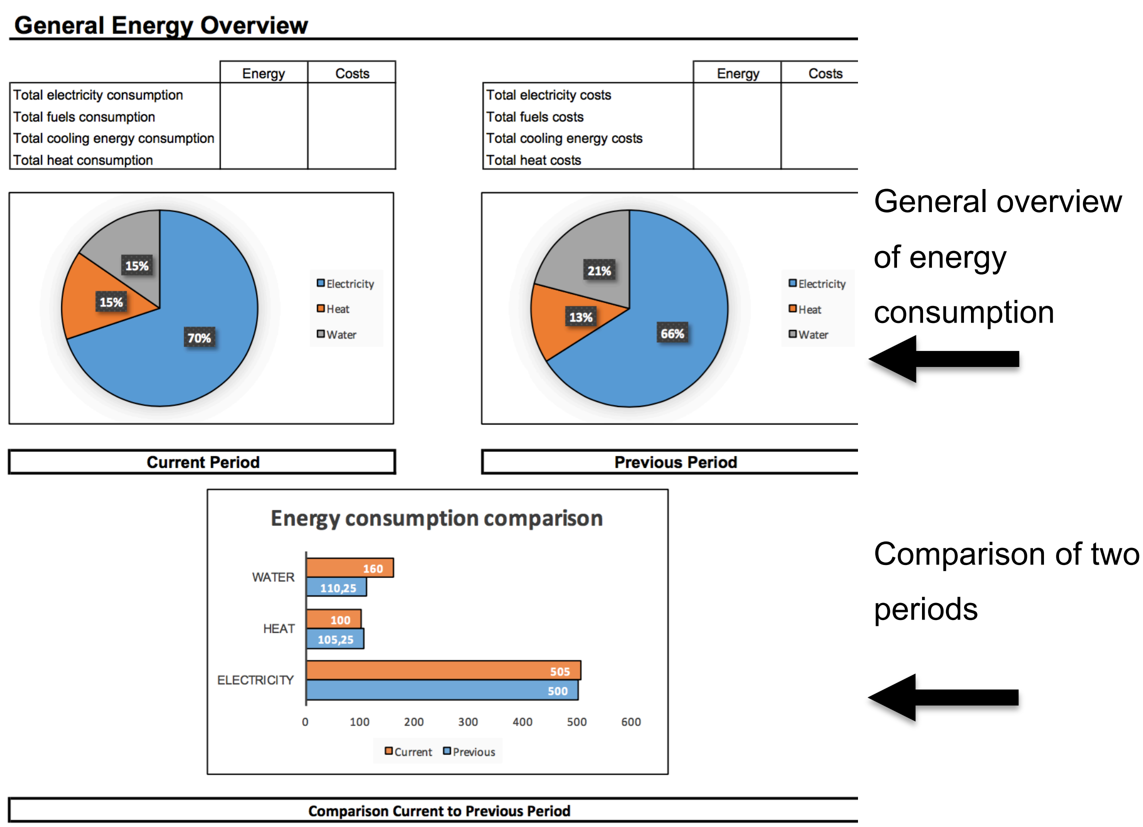


Figure 4.1: Report example for CEO, own depiction

The report above represents the energy consumption and costs from two periods: reporting and previous and the comparison between them. It gives a simple outlook for top management of the energy state in organisation.

At the level of plant / facility management and / or technical management and their subdivisions is necessary to get the information with a much higher level of detail (see Figure 4.2). Measuring results that are not plausible, can have very different backgrounds. The question is to clarify whether a probe was measured incorrectly or whether the affected technical system or component has a problem.

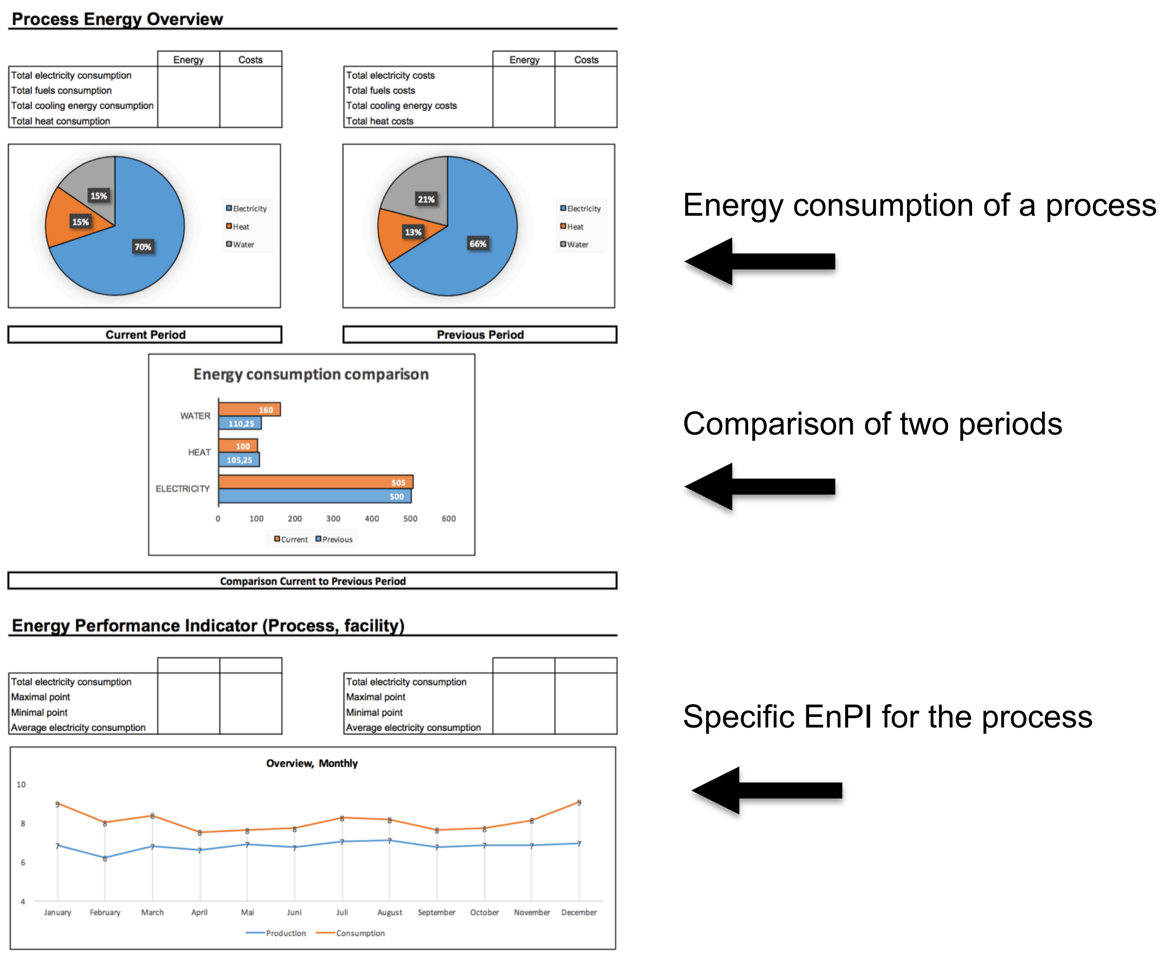


Figure 4.2: Facility manager report example, own depiction

For external users information should be presented digestible. The targeted and purely informative presentation of the activities and results in the field of energy consumption are in an absolute priority. Many companies use this for their image-building in the public.

According to ISO 50006 the organisation can use a variety of reports and reporting methods for energy performance, including:

- comparison of current performance with targer performance (chart);
- trend chart of EnPIs (and other relevant variables);
- X-Y chart (e.g. energy consumption and production);

– assessing variance;
– cumulative summation chart (CUSUM);
– vizualisation using various analytical tools (e.g. JEVis System);
– multidimensional graphics with internal benchmarking.

4.2 Alarming

Along with reporting the alarming system should be integrated in energy management system as an informational support component. During normal work operation it is always likely that unforeseen behaviors occur which indicate the misbehavior of a system. In order that escape long periods of malfunctioning irregularities should be detected as fast as possible.

An alarm is an announcement to the operator initiated by a process variable (or measurement) passing a defined limit as it approaches an undesirable or unsafe value. The announcement includes audible sounds, visual indications (e.g., flashing lights and text, background or text color changes, and other graphic or pictorial changes), and messages. The announced problem requires operator action.

The main objective of alarms is to indicate that something unfavorable may have occurred. The purpose of the alarm system is to bring a potentially abnormal process condition to the attention of the operator in time for appropriate remediation and with appropriate guidance for success. In the event that the operator suspects or is already aware of the possible existence of an abnormal situation or condition, the alarm system shall provide confirmation for those concerns. It offers a productive way to appropriately support the enterprise [19].

4.3 JEVis System

Nowadays many energy services companies offer informational support systems. The JEVis system is a solution for energy monitoring provided by Envidatec GmbH. It is an open source program which is based on computer language Java. To be in compliance with the standard ISO 50001 JEVis was certified in 2012 by the international certification institute DQS. The system can be applied as hosting solution My-JEVis or as standalone in-house installation, but is generally applicable to all branches of trade. The JEVis system is specially developed for the analysis and evaluation of the energy relevant variables. JEVis is completely flexible and meets the individual requirements. The structure of JEVis system is illustrated in Figure 4.3 [20]

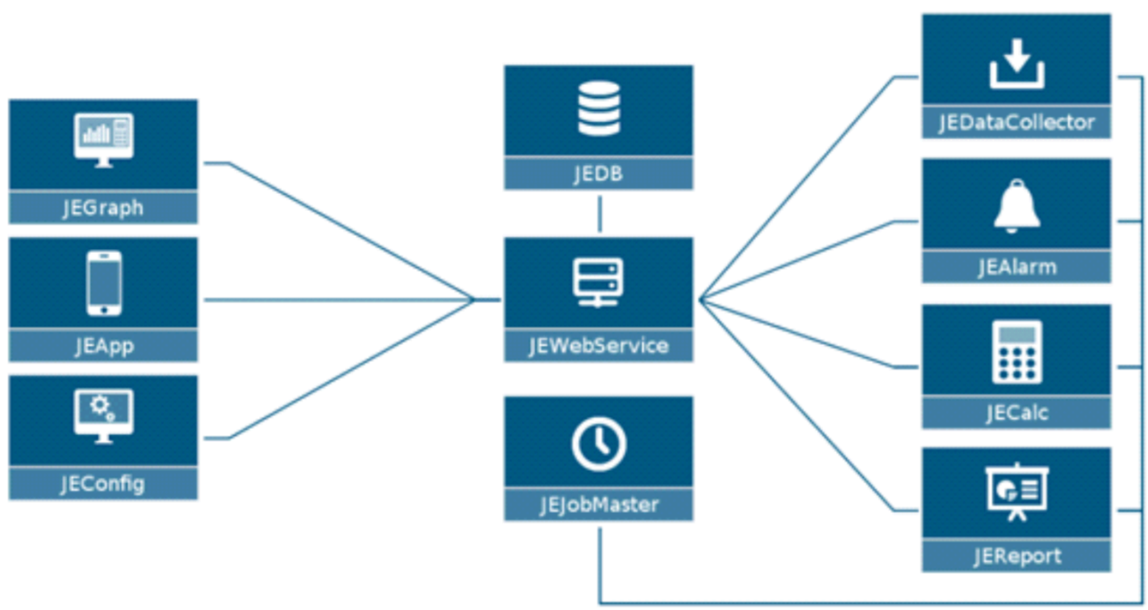


Figure 4.3: JEVis system structure [21]

In this chapter will be presented back-end service of the JEVis system - the generation of reports – JEReport and how to work with it.

The JEReport is a reporting tool for the JEVis system within the organisation can get required visualized informations about data. The function JEReport supplies standardized adjusted messages on energy data at fixed time intervals. The report can be configured depending on customer personal requirements and contain only selective information. The daily / weekly / monthly reports give an opportunity to detect the energy losses or essential negative changes on time.

4.3.1 Template creation

For the creation of the report firstly a template should be created. The template in this thesis will be developed with Microsoft Excel. All common Excel commands, formulas and markups are supported by the template. For the transformation of the generated template into a report the Java library - jxls is used (see Figure 4.5). Jxls uses a special set of markups in templates to indicate the structural or logical relation of output formatting and data layout.

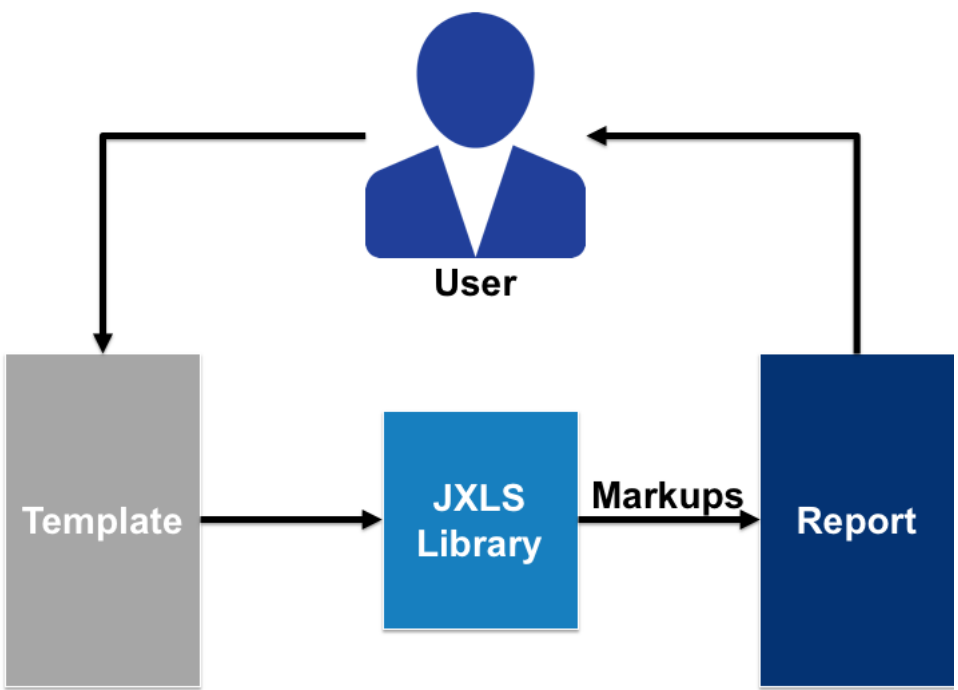


Figure 4.5: Process of report producing, based on [22]

The first step of template producing is to understand the form of the collected data or established EnPI. This information is the result of the created structure in the JEConfig. The shape of the data represents a map with various entries which include a key and a value as illustrated in Figure 4.6. Each command in the template indicates a specific data. After a template command found the appropriate data, the transformation process replaced the command with the correct information.

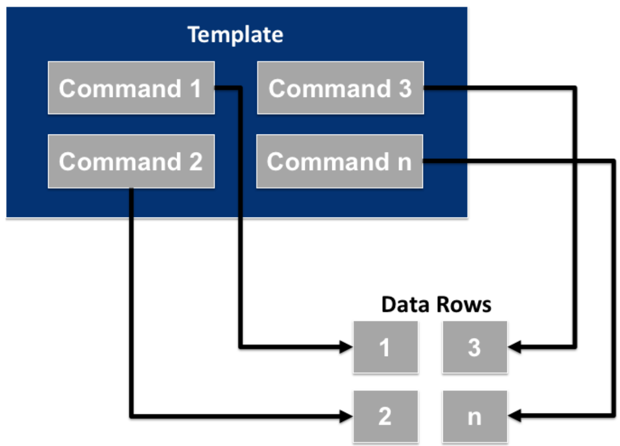


Figure 4.6: Connection between commands and data in JEVis, based on [22]

As the second step we should consider all parameters which will be used. In our case we have 3 essential parameters:

- object;
- object attribute;
- value of the attribute.

The object name can include the whole organisation, special part of it or particular facility. Object attribute describes the appropriate characteristic of the object: address, year, location etc. Finally, the third parameter indicates the real value of attribute which can include time, value and unit. The examples of all three parameters are shown in Table 4.3.

Table 4.3: Examples of JEReport parameters

Object	Attribute	Value
Office	Location	Hamburg
	Address	Veritaskai 2
Electricity meter	Value	320
	Unit	kWh
	Time	01.01.2016 14:32:00

So let us consider an example with two links in report. The first link relates to the specific EnPI, the second one links to an example company ABC. Each object in JEVis includes several attributes and each attribute several samples or data row as represented in Figure 4.7.

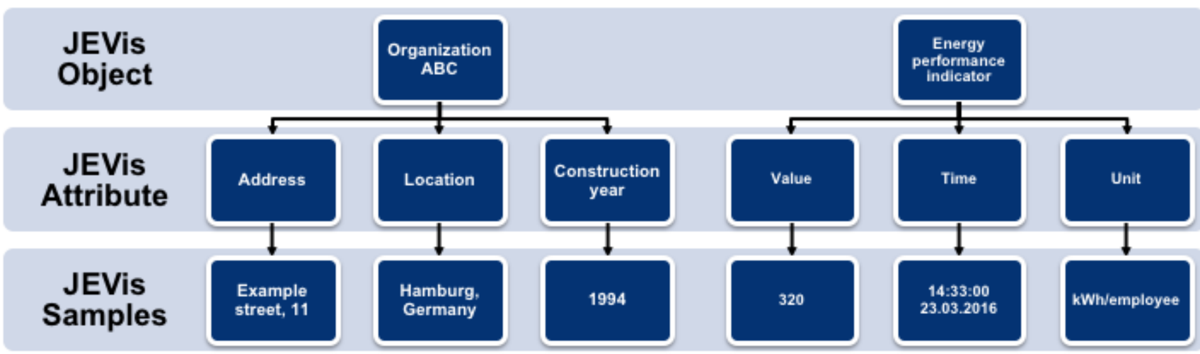


Figure 4.7: Example of JEReport parameters, based on [22]

The collected data by the JEReport is now organized in different logical layers based on the configurations of the JEConfig. We have a command in template ${OrganisationABC.location.value}: on the first level we have the mapping from the link of all JEVis data and get all information below our JEVis Object 'OrganisationABC'. The second level represents all attributes of an object. In our case they include location, address and construction year of an object 'Organisation ABC'. The real values appears on the third level. With this command we can either get the timestamp or the value from the JEVis database (Figure 4.8).

The commands in the template have to be enclosed by the special area markup by comments in the template file. Consequently the process of transformation determines exactly which part should be transformed and which one should not be enabled.

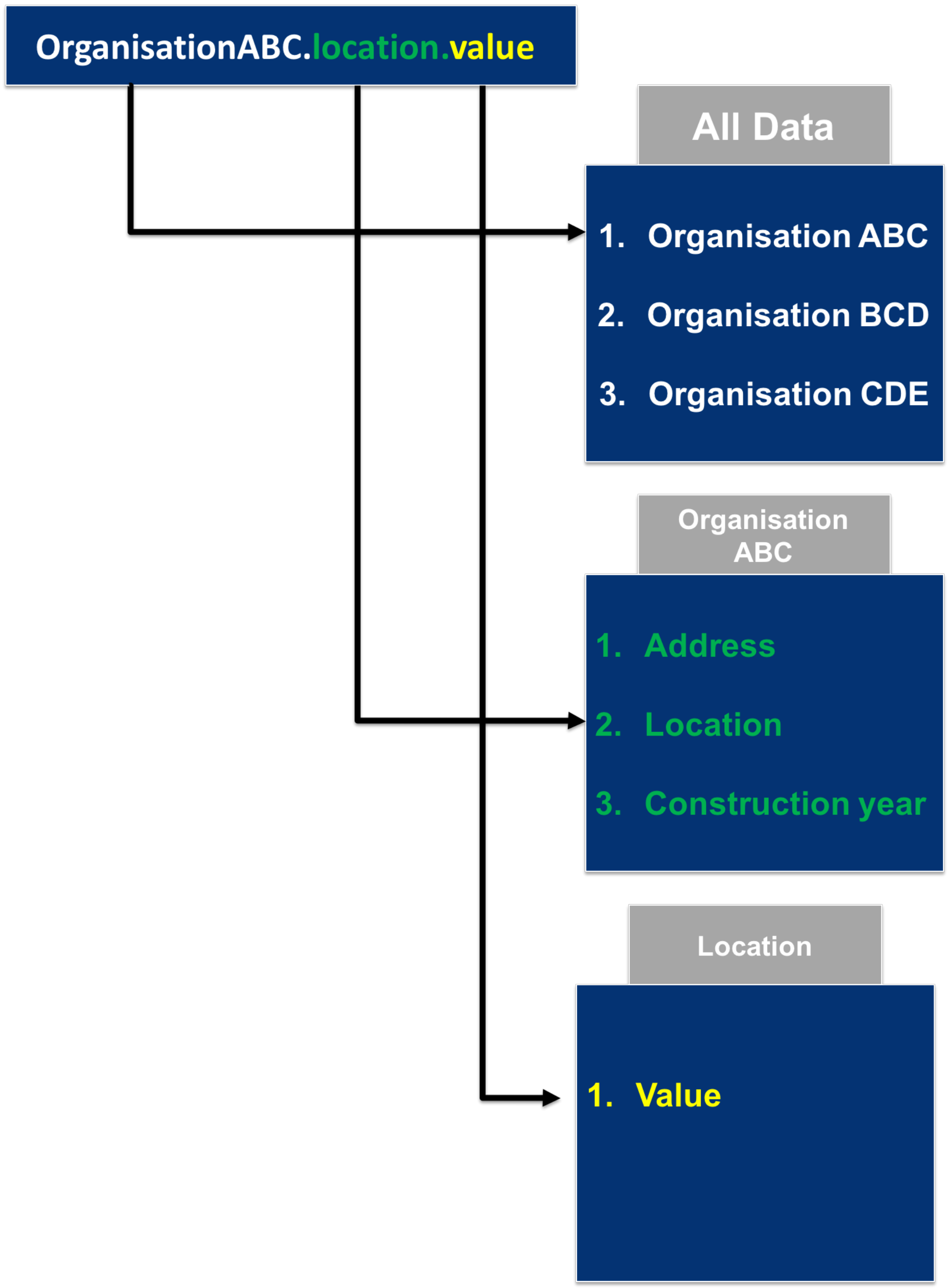


Figure 4.8: Logical structure of JEVis data, based on [22]

5 Implementation

Implementation of energy controlling instruments is not limited to energy consumption around the physical product. It does not matter if we consider the production of a manufacturing organisation, services or knowledge as a product.

The chapter five will illustrate the establishing of the energy performance indicators for business processes in the office building and implementation of the reports with a real values and EnPIs with the JEReport service and database.

Envidatec GmbH has a head office in Hamburg, Germany. The office is equiped with the three main meters which are measuring the electricity and heat consumption and water volume, the data is collected, stored and analyzed with the JEVis system.

In order to develop an appropriate EnPI we will consider the achievements of the business processes through the products of the company: energy efficiency analysis (EEA), implementation of EnMs and energy monitoring (EM), as an output we have project days per every product. The products will present a measurement boundary, for which the indicators are defined.

As a second step the relevant variables should be defined. They include the amount of project days per baseline period, number of employees involving in each process and overall, area of the office and the project income. After analysing and combining the available variables the following energy indicators (see Table 5.1) for the evaluating the energy performance can be used.

Table 5.1: Examples of developed EnPIs

EnPI	Unit
$\frac{\text{Electricity consumption}}{\text{Project day * Employee}}$	$\frac{\text{kWh}}{\text{day} \cdot \text{employee}}$
$\frac{\text{Income}}{\text{Electricity consumption * Employee}}$	$\frac{\text{Euro}}{\text{kWh} \cdot \text{person}}$
$\frac{\text{Electricity consumption}}{\text{Area * Employee}}$	$\frac{\text{kWh}}{m^2 \cdot \text{employee}}$

The first indicator represents the energy demand per one project day and one employee who is involved (Figure 5.1). It shows the energy demand of each product.

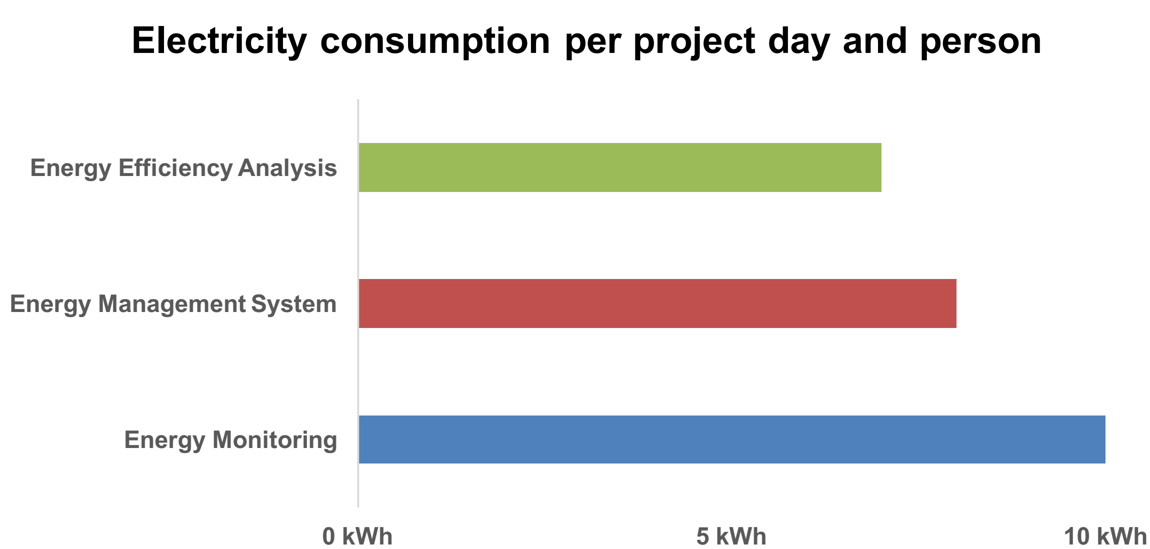


Figure 5.1: Electricity consumption per project day and employee

The second EnPI (Figure 5.2) presents the income per one unit of energy and employee. It will give an outlook of the income per person from every spent kilowatt-hour or shows how profitable the product is. At the figure the points are located according to the amount of project days and energy and the area of the circle represents an income.

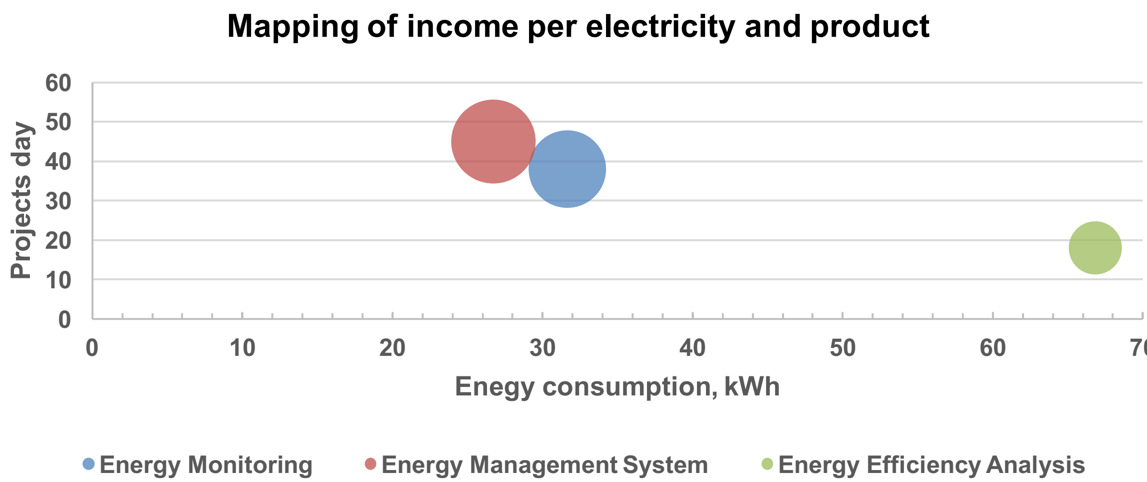


Figure 5.2: Income per project day and electricity consumption

The third indicator represents a simple overview of electricity consumption per area and employee of the office, which can be used for benchmarking.

The established energy indicators should be relevant to all organisational levels of the company and be allotted to different users: top management, department managers and external customers. The indicator categorisation makes the comparison process easier. For the top management level representing of the whole organisation is essential, department leaders will profit by data across their boundary and by comparison between all three departments. For the external users or customers, it is important to show, that the EnPIs can be easily understandable and they can develop use the indicators for their needs. The report for the established EnPI's is attached in appendixes.

As a last step the energy baseline for a comparison and improvement processes should be established. The JEReport allows to get data with various length and aggregation: day, week, month or year. For example, we can get the data for every day over the time of one month or year (see Table 5.2). As an example, the daily aggregation and month duration will be used.

Table 5.2: Example of period and aggregation in JEReport

Period	Aggregation	Example
Month	Day	1, 2, 3 … 30
Year	Month	1, 2, 3 … 12
Year	Week	1, 2, 3 … 52

Finally, the established EnPIs clearly show the energy demand for each product of the Envidatec activities, and as was mentioned EnPI can represent not only the relationship between the physical product and its energy amount, the correlation can be made in each business sector.

6 Conclusion

The aim of this thesis was the development of methodology for establishing the energy performance indicators according to ISO 50006 for improving the energy efficiency of enterprises. The most common EnPIs and steps for their development are discribed with practical examples and advices. It is suggested for company to develop multi-level indicators to simplify the decision making process on every organisational level.

The objective was also the designing of appropriate reporting tools, to make the understanding more convenient and simpler for all levels of organisation. The energy monitoring system JEVis provided by Envidatec GmbH was presented as an effective way to collect all required information and to present it in appropriate way. The thesis also specifies the simplest methods of EnPI’s application for both situations inside the company borders and on the outside of them.

Finally, as an example, the EnPIs for Envidatec office in Hamburg were developed. The JEReport software was used for the report creation. All the steps for JEReport using are described in the thesis.

The process of energy performance indicators developing from ISO 50006, in general, fits to every organisation from every sector, but the EnPIs can differ markedly, and individual approach is advisable.

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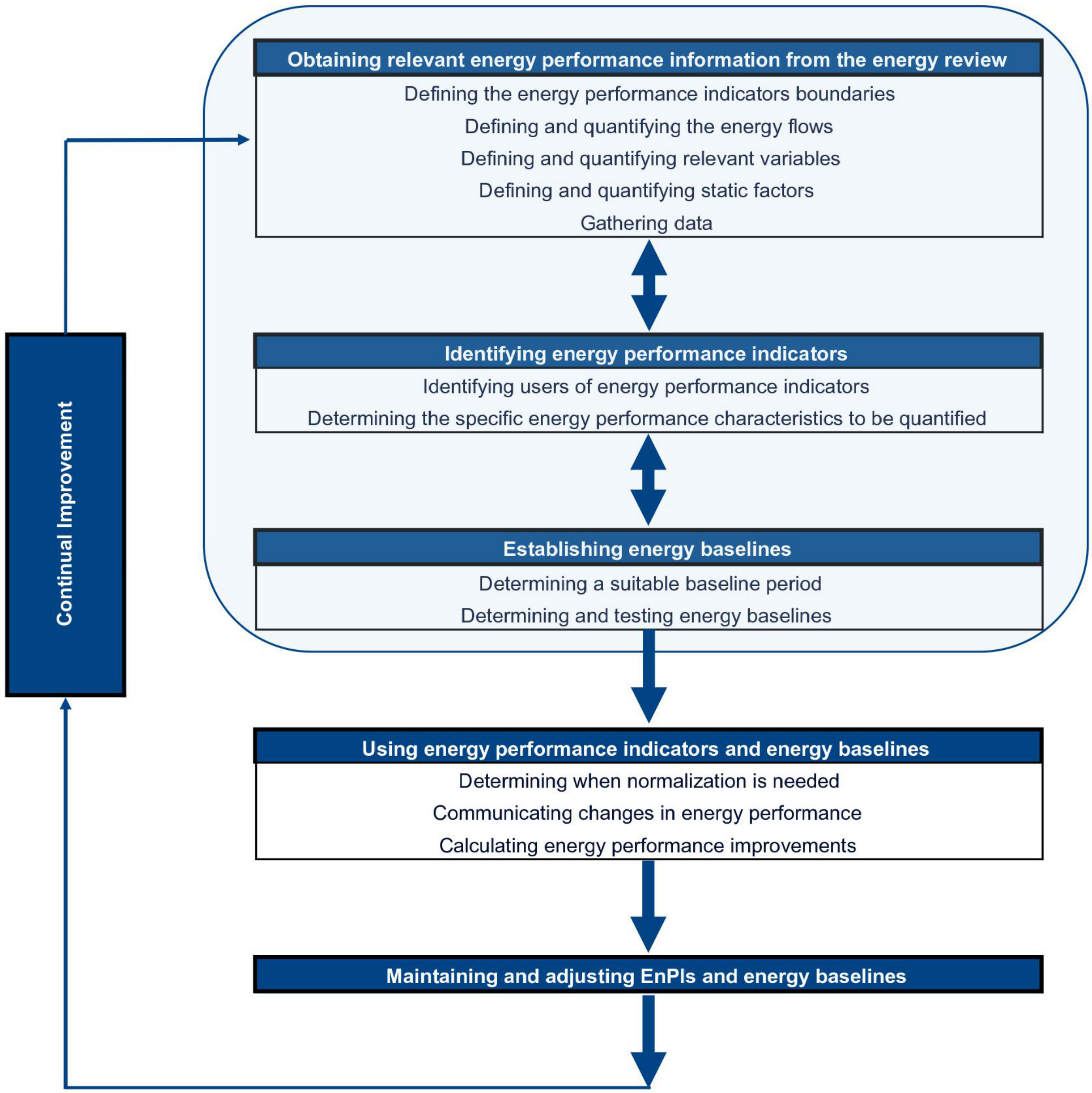
Appendixes

EnPI's developing process



JEVis Report

ENVIDATEC
ENERGY EFFICIENT INTO THE FUTURE

Date	15.02.16

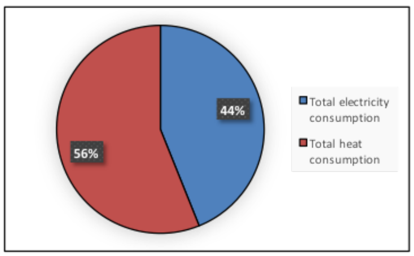
Organisation name	Envidatec GmbH
Object name	Office
Address	Veritaskai 2
Staff	25
Area, m2	150

Monthly Report

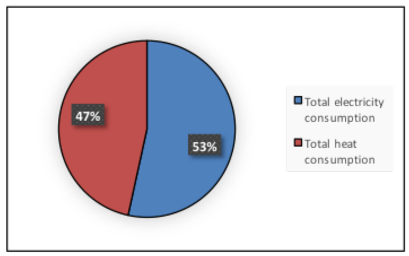
General Energy Overview

	Energy
Total electricity consumption	1 233 kWh
Total heat consumption	1 575 kWh

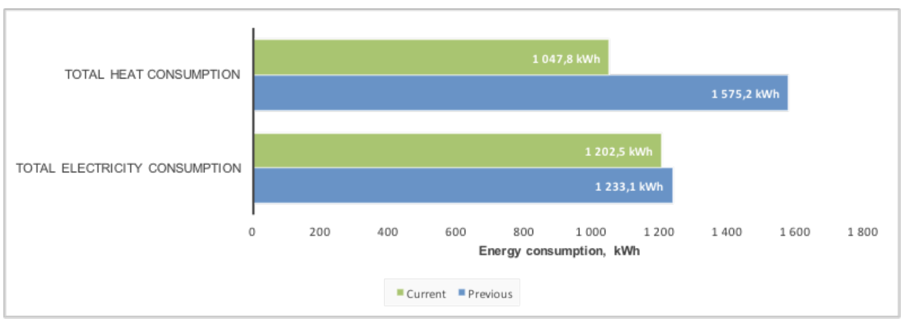
	Energy
Total electricity consumption	1 203 kWh
Total heat consumption	1 048 kWh



Previous Period



Current Period



Comparison Current to Previous Period

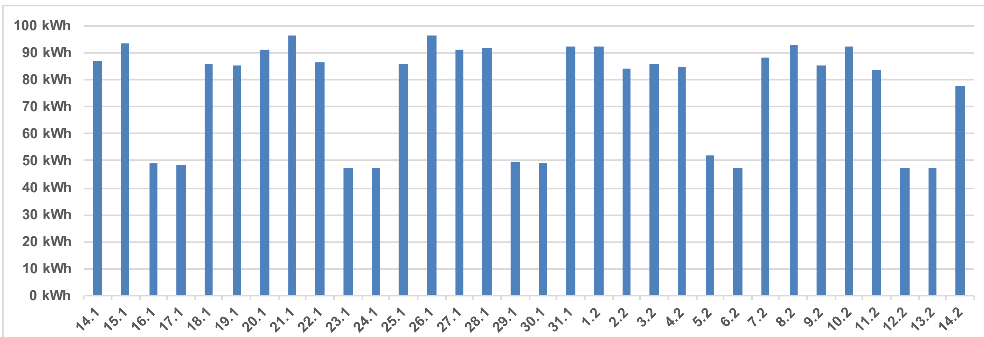
ENERGY EFFICIENT INTO THE FUTURE

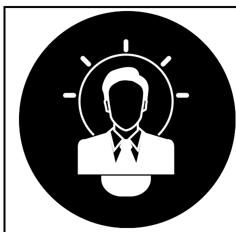
Date	**15.02.16**
Organisation name	Envidatec GmbH
Object name	Office
Address	Veritaskai 2
Staff	25
Area, m2	150

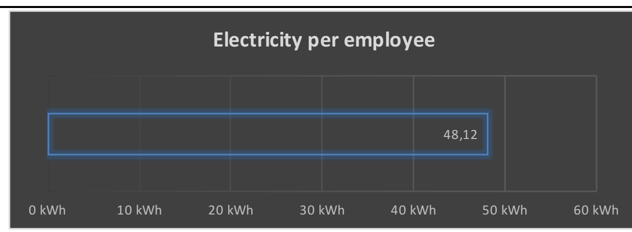
Electricity

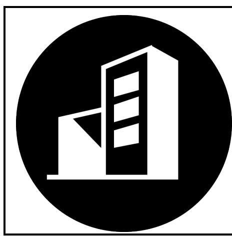
	Energy	Unit
Total electricity consumption	1203	kWh
Electricity per employee	48,12	kWh/empl
Electricity per square meter	8,02	kWh/m2
Average electr. consumption	80,20	kWh

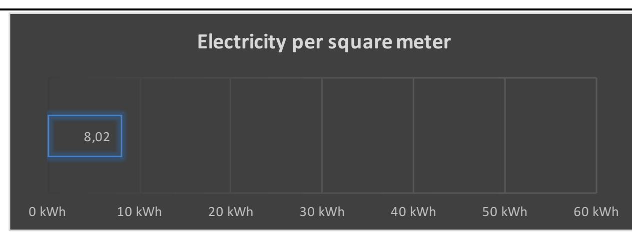
	Energy	Unit
Total electricity consumption	1233	kWh
Electricity per employee	49,3	kWh/empl
Electricity per square meter	8,2	kWh/m2
Average electr. consumption	82,2	kWh











ENVIDATEC
ENERGY EFFICIENT INTO THE FUTURE

Date	15.02.16
Organisation name	Envidatec GmbH
Object name	Office
Address	Veritaskai 2
Staff	25
Area, m2	150

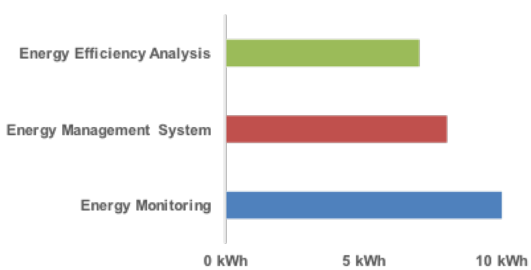
Current Period

Product Oriented EnPI

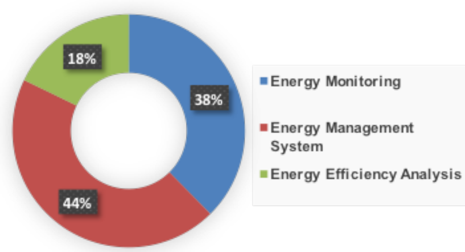
	Energy	Unit
Electricity per project day	11,9	kWh/day
Electricity per product A	31,7	kWh/A
Electricity per product B	26,7	kWh/B
Electricity per product C	66,8	kWh/C

	Product	Days
Energy Monitoring	Product A	38
Energy Management System	Product B	45
Energy Efficiency Analysis	Product C	18

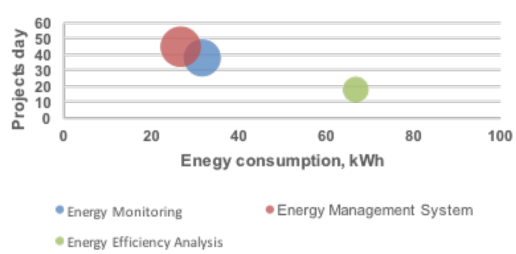
Electricity consumption per day per person



Project day percentage



Mapping of electricity per product and output



Mapping of electricity per product, person and output