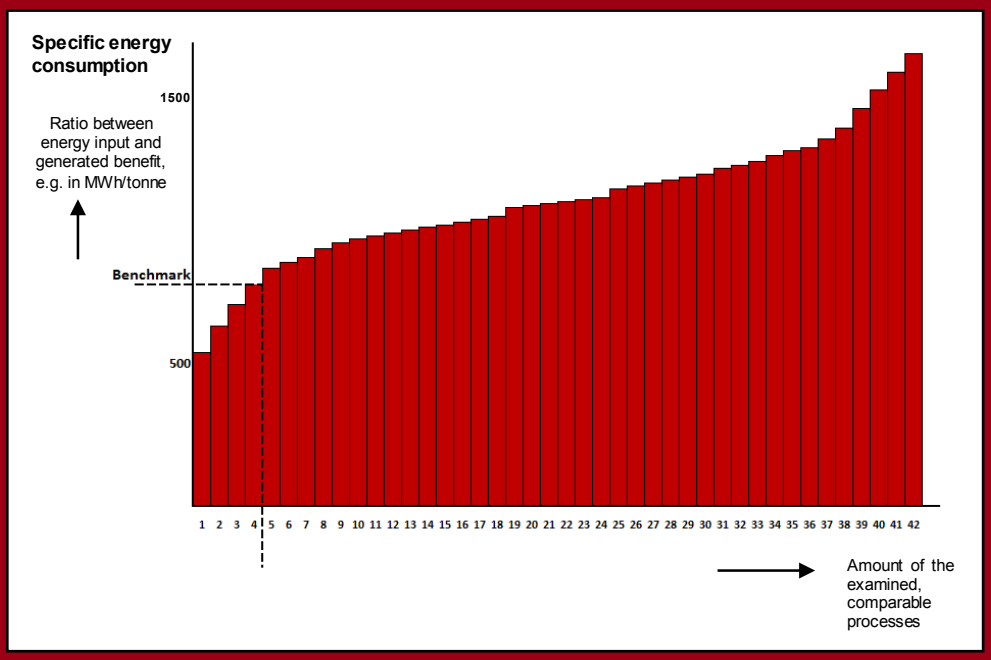

Energy Efficiency Benchmarking

Methodological foundations for the development of energy efficiency benchmarking systems pursuant to EN 16231

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Summary Report

Content

1 Introduction

Energy efficiency measures often constitute very profitable investments. However, they are only slowly implemented. One of the main obstacles is the great effort the identification of potential savings in companies involves. Especially small and medium-sized enterprises (SMEs) find it difficult to uncover energy deficiencies in systems and buildings. In order to assess whether plants or entire organisations are energy-efficient, benchmark values are needed. Companies have to carry out mutual comparisons in order to evaluate whether their economic activities are comparatively energy-efficient or not. Energy efficiency benchmarking provides a way to assess the energy efficiency by comparing the specific energy demand of comparable processes as well as entire production processes.

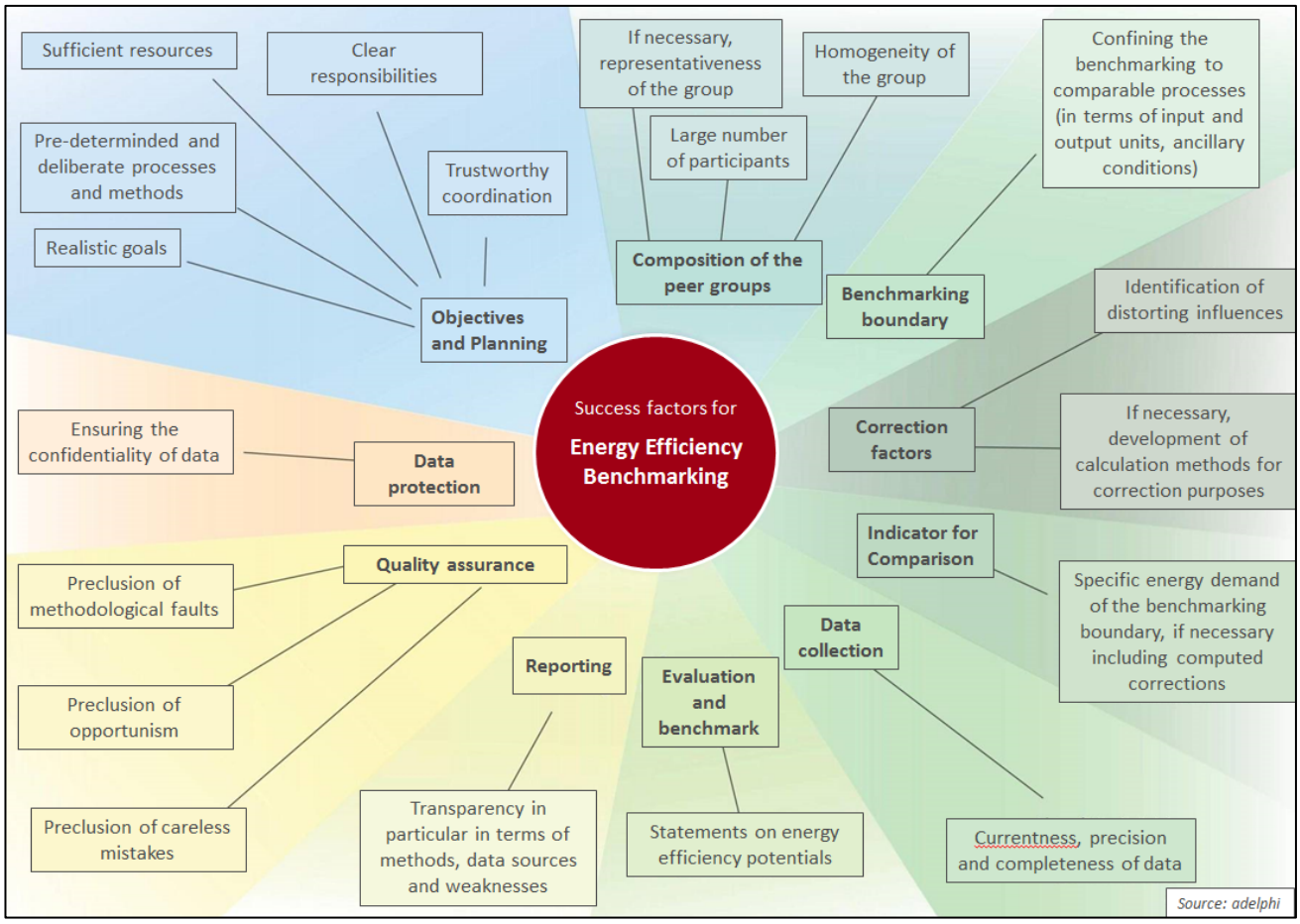
The study “Energy Efficiency Benchmarking: Methodological foundations for the development of energy efficiency benchmarking systems pursuant to EN 16231” intends to establish a methodological framework for the creation of online-based energy efficiency benchmarking systems and thereby especially illustrate the key challenges. The summary report summarises the results of the study. First, the success factors for energy efficiency benchmarking pursuant to EN 16231 are visualised and supplemented by recommendations. The importance of energy efficiency benchmarking for operational energy management is illustrated in a separate chapter. Subsequently, the key challenges for energy efficiency benchmarking that were identified in the context of the exemplary development of benchmarking systems for 10 technology areas and on the basis of the considered benchmarking for production processes in 30 industrial and commercial sectors will be discussed. On this basis, the potential of future benchmarking systems will be taken into consideration. The concrete recommendations, which are discussed in detail in the final report, will be summarised.

2 Energy efficiency benchmarking pursuant to EN 16231: a ten-point plan

The benchmarking standard EN 16231 provides the first universal and uniform catalogue of requirements for the collection and analysis of operational energy data in terms of energy efficiency benchmarking. The requirements of the standard were structured in ten steps. Together they form the first action plan for the practical implementation. Completed benchmarking projects and studies from related topics are considered in more detail on the basis of this standard. At the end of each step, recommendations for action are provided.

The short version of the study does not give detailed explanations of the standard requirements and the considered projects and studies. Instead, the requirements are visualised and some supplementary recommendations are provided subsequently.

2.1 Requirements of the EN 16231



Success factors for Energy Efficiency Benchmarking

Quelle: own image (adelphi)

2.2 Supplementary recommendations

Supplementary recommendations concerning objectives and planning

At the beginning of a benchmarking project, the initiators should ensure that the project's objective is clear: if financial benefits of participants depend immediately on the performance in the benchmarking, the requirements with regard to the significance are higher than for benchmarking systems that serve an initial self-assessment. The more significant and precise the expected results are meant to be, the higher the cost of data collection and benchmarking coordination, and the higher the necessary resources that need to be made available for the project. The project planning should be aligned with the requirements of benchmarking. It must be clear from the beginning what the benchmarking should achieve for the user - and what aspects it cannot fulfil. Regardless of the complexity of the benchmarking system, a coordinator should always be provided for. He takes care of the benchmarking, is in touch with the parties involved and ensures the proper implementation of the project. In order to fulfil his duties, he should be well acquainted with the processes that are to be compared in the benchmarking.

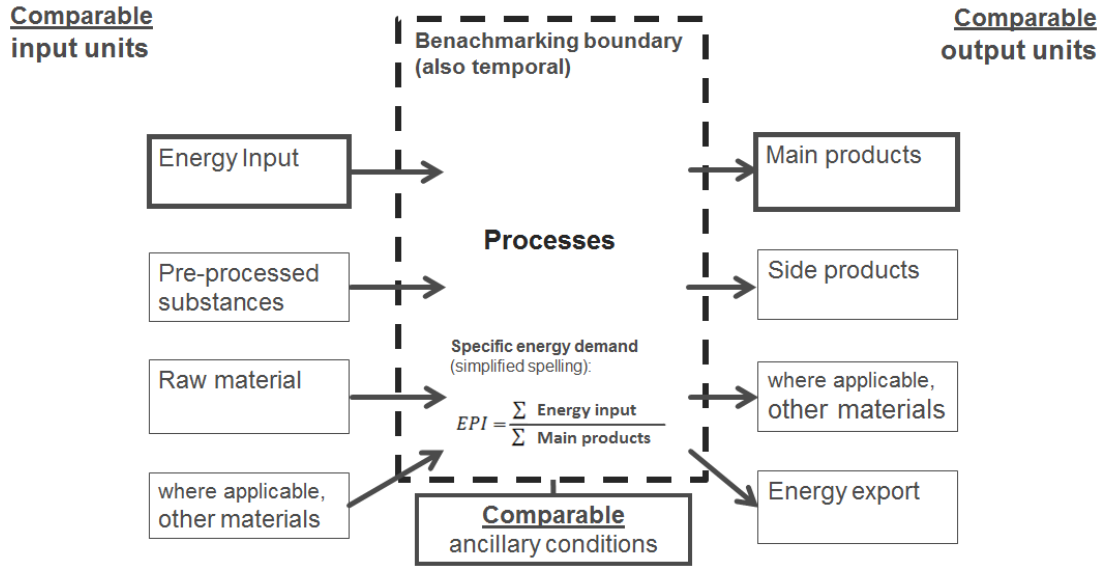
Supplementary recommendations concerning the composition of the peer group

In order to include a representative number of companies in the benchmarking system, the target group should be analysed in advance:

- Is it possible to compile homogeneous groups? (according to products, manufacturing levels etc.)
- If so, how many processes would be represented in a homogeneous group? Does the number suffice to ensure anonymity and provide valid results?
- Are potential participants willing to share sensitive data with a coordinator?
- How can this group be convinced to participate in the benchmarking?
- How can pilot companies that are willing to provide their data for the collection of benchmarks be identified and be the first to be saved in the system?
- What financing options are there for the benchmarking?

The requirements with regard to the homogeneity of the target group may be different, depending on the orientation of the benchmarking. The demands on the homogeneity can be higher or lower, depending on the goal pursued and the significance sought. In addition to assuring appropriate homogeneity of the comparison groups, it is important to communicate the benchmarking's limits of performance openly to the participants.

Supplementary recommendations concerning the benchmarking boundary



Benchmarking boundary with input and output units and ancillary conditions

Quelle: own image (adelphi)

The establishment and precise definition of benchmarking boundaries is the most important step to ensure the comparability of benchmarking results. In that context it is important to emphasise that the benchmarking does not refer to individual plants or the organisation as such, but to individual processes that are carried out within a plant or an organisation. Thus, the comparability of input and output units of the process and the conditions that affect it are decisive for the determination of the respective benchmarking boundary. The benchmarking boundary can cover both individual processes at the level of systems technology and process chains as well as the entire production process within organisations. The required accuracy of the benchmarking boundary depends on the objective and desired significance of the benchmarking.

Provided that a high degree of accuracy is required, the benchmarking boundaries have to be set narrowly and clearly (maximum comparability in input units, output units and ancillary conditions). Yet if the benchmarking is merely meant to provide an initial, rough evaluation, the comparability requirements are also lower; benchmarking boundaries can be softened if necessary and larger differences can be permitted. This has to be communicated clearly and transparently. An important comparative dimension refers to the place of production. If a company carries out all stages of production at its own production site, its entire energy consumption incurs at this particular location. However, other operations may obtain semi-finished products in order to process the final product. If the benchmarking figure is defined as "energy consumption per quantity produced", the company that obtained the semi-finished product will have a lower specific energy consumption than the company that performs all production steps at its own site.

Supplementary recommendations concerning correction factors

Correction factors should be avoided. In case of a very differentiated choice of benchmarking boundaries, benchmarking can, ideally, do without any correction factors. However, in practice it will never be possible to guarantee an exact adherence to the defined benchmarking boundary by all benchmarking participants (same proportion of energy consumption through by-products, same manufacturing levels etc.). These uncertainties can either be accepted or corrected. Developing sound correction factors is essentially a question of available funds. The metrological examination or rather the exact physical derivations of the effects of all features on the specific energy consumption involves high costs. When determining correction factors it is crucial to ensure that areas or methods in which or through which energy savings can be achieved are taken into consideration. It is therefore important to assess, for example, whether the production of certain goods at places where only relatively poor resources are available (e.g. degree of purity of natural gas) makes sense, or whether systems that operate mainly at partial load could in fact achieve a higher capacity utilisation if certain processes were optimised. If such conditions are excluded, certain aspects are deemed to be immutable although they are not necessarily invariable. In this context, an approach like that adopted in the BESS project is recommended. In that case, the user can choose individually whether the developed correction factors should be considered in the evaluation or whether it should contain uncorrected results. The correction factors have to be updated regularly due to the fact that influencing conditions are not static but may change over time. If the funds for a repeated and sound re-calculation of the correction factors are insufficient, correction factors should not be represented at all. In such cases, the alternative is to accept the uncertainty and point the uncertainty out to the benchmarking users.

Supplementary recommendations concerning the reference value

In theory and practice, the specific energy consumption has established itself as the measurand for energy efficiency and is also required by the EN 16231 as an Energy Performance Indicator. All evaluated projects enable the development of an energy index, which reflects the energy consumption per product.

The resulting Energy Performance Indicator (EPI) for benchmarking is:

$$EPI\ (simplified\ spelling) = \frac{\sum Energy\ Input\ (\ Primary, Final, or\ Usable\ Energy)}{\sum Main\ Products\ (Products, Services, or\ \ Usable\ Energy)}$$

The Main Products as such do not describe the usefulness of a process. As already stated, the input values are equally important, therefore in order to ensure the comparability of benchmarking also the input units at which the process starts should be defined clearly by the benchmarking boundaries. Also differences in side products should be considered. If correction factors are to be included they should be designed so as to flow into the EPI as an additional factor.

Supplementary recommendations concerning the collection of data

When formats for data collection are developed, great importance should be attached to user friendliness. The desire to carry out a survey that is as comprehensive as possible and thus be able to provide more accurate findings should be weighed against the risk of deterring users due to an abundance of input options. The same applies to the querying of sensitive data (sales volume, total and energy costs etc.). Practice has shown that entrepreneurs do not normally like to disclose such information and especially not online. In general, sensitive data such as information concerning sales volumes, profits, total costs or energy costs should therefore not be queried. In sum this means that data querying should comply with the following rule: “as much as necessary and as little as possible.” It is advisable to query the consumption values of the sources of energy in the same way as they are available to the users of the benchmarking. Natural gas, for example, may not be indicated in kWh on the energy bill, but in m³. If wood is used as an energy source, the amount is usually calculated in cubic metres.

Supplementary recommendations concerning the quality assurance

The testing of plausibility and reliability is an important element of a benchmarking in order to detect errors at an early stage. In that regard, the scope and accuracy of the test is highly dependent on the available funds. Lean systems that provide a result immediately after data has been entered can be subject only to an automated rapid test in which the limits of what is possible are defined.

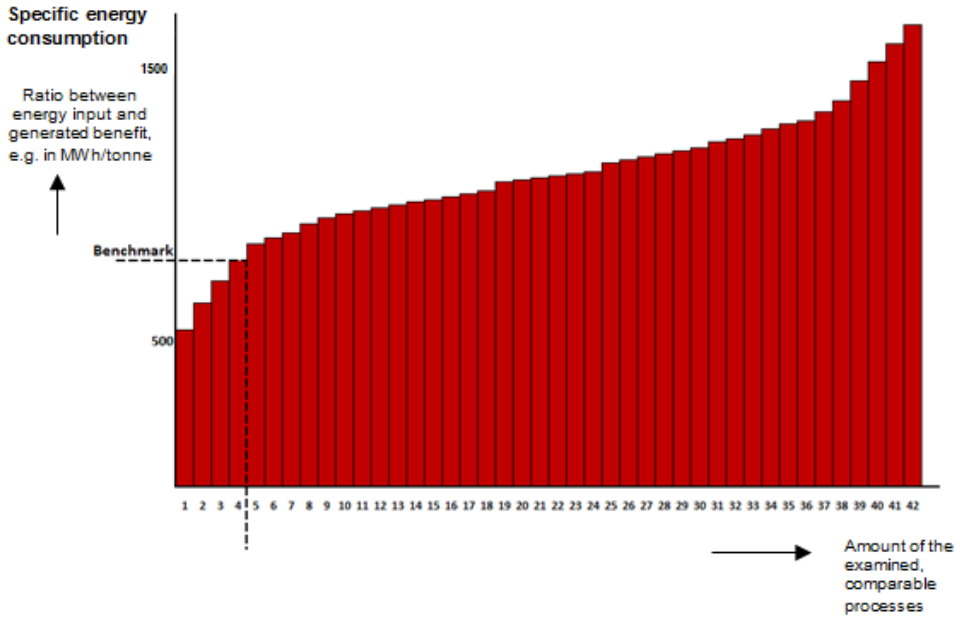
However, if erroneous data is to be excluded reliably, an automated testing is insufficient. In that case, the data collection should adhere to minimum standards such as, for example, the “Monitoring & Verification procedure in the context of ISO 50001” or the criteria of EN 16247 “Energy Audits”. Independent energy auditors need to verify the entered data in the course of regularly conducted energy audits. Existing systems like those existing or considered in Germany, for example, in the context of obligatory energy management for companies should be used.

The highest possible degree of reliability is required as soon as specific competitive factors depend on the benchmarking results (like in the case of benchmarking in emissions trading in terms of the allocation amount of free certificates). In such a case, the verification should be carried out by a certified evaluator.

Supplementary recommendations concerning data protection

Due to his technical skills and impartiality, the coordinator must be trustworthy and perceived as trustworthy by the target group. All users of the benchmarking should be confident that data is processed professionally and sensitive data is handled responsibly. Furthermore, in accordance with standard requirements, the data should be made anonymous as it has been done, for example, in the BESS project. Provided that the coordinator should have the opportunity to submit further enquiries, the anonymous form should be implemented only upon the publication of the results rather than by the time the data is entered. If specific regulations depend on the results of the benchmarking – for example the respective allocation of emission allowances to a company, the anonymisation of the data becomes more difficult. This same problem would arise in any other case in which the participation or the performance in the benchmarking provides a proof for certain facts. If the granting of tax benefits, for example, was linked to participation in an energy efficiency benchmarking system, the coordinator would have to know the identity of the companies in order to be able to attribute the respective results correctly to the individual company. Considering the phishing attack on the emissions trading it is important to emphasise that online-based systems require a great deal of attention when it comes to IT security. This is particularly important with regard to systems that store comprehensive information about the company.

Supplementary recommendations concerning the evaluation and benchmark



Example of a benchmarking curve

Quelle: own image (adelphi)

As far as clarity, significance and analysis possibilities are concerned, the evaluation should be displayed as a benchmarking curve. Outliers can be identified immediately. The interpretation is facilitated if the curve is supplemented by information that appears, for example, when clicking on data points and provides information on operational characteristics and the scope of corrections. Furthermore, the results should be presented in a table.

An atypical course of the benchmarking curve can indicate that the benchmarking boundary was not defined sufficiently selective or deviations could not be adjusted accurately.

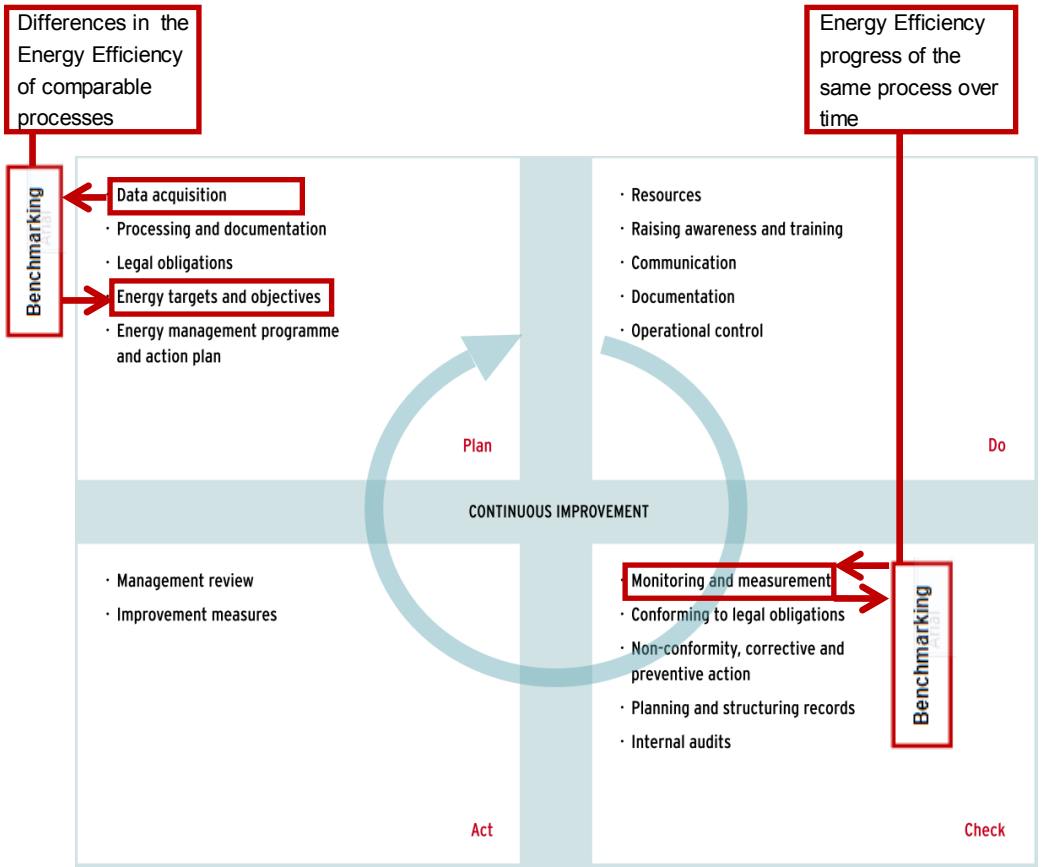
In view of the acceptance of the results it is important that they are confirmed by the benchmarking participants. According to the standard, correction factors can be added if differences between the compared processes that were not considered initially arise retrospectively. However, this possibility entices the benchmarking participants to polish up their results artificially and exert pressure on the coordinator (especially when energy managers within the participating organisations are interested in demonstrating a high level of energy efficiency to the top management). The coordinator may not give in to the pressure to carry out improper corrections and must proceed very carefully. If the number of required corrections is too high, the established benchmarking boundaries should be reconsidered or refined. This shows that the coordinator needs to have another characteristic trait: assertiveness.

Supplementary recommendations: reporting

The documentation of the benchmarking is a very important aspect of a benchmarking project. All cards have to be put on the table. Only a transparent reporting that addresses the weaknesses of the benchmarking allows for an adequate interpretation of the results and the achievement of learning effects for further benchmarking projects. Quite often, the budget planning neglects the reporting. Yet the necessary resources must be budgeted from the outset. All collected data and its evaluation are subject to confidentiality and should at this point be made accessible only to the benchmarking participants. Therefore, it is not always possible to publish the results - not even after they have been anonymised. At the beginning of the benchmarking, the participants should reach an agreement in terms of whether or not

the results should be published. The reporting does not have to be provided in paper form. This could even be impractical in the case of online-based benchmarking. It is recommended to make the benchmarking report available for download. In addition, possible uncertainties and weaknesses should be indicated.

3 Implications of energy efficiency benchmarking for energy management systems



Benchmarking as an instrument in Energy Management Systems

Source: own image (adelphi) on basis of adelphi 2012a: 20

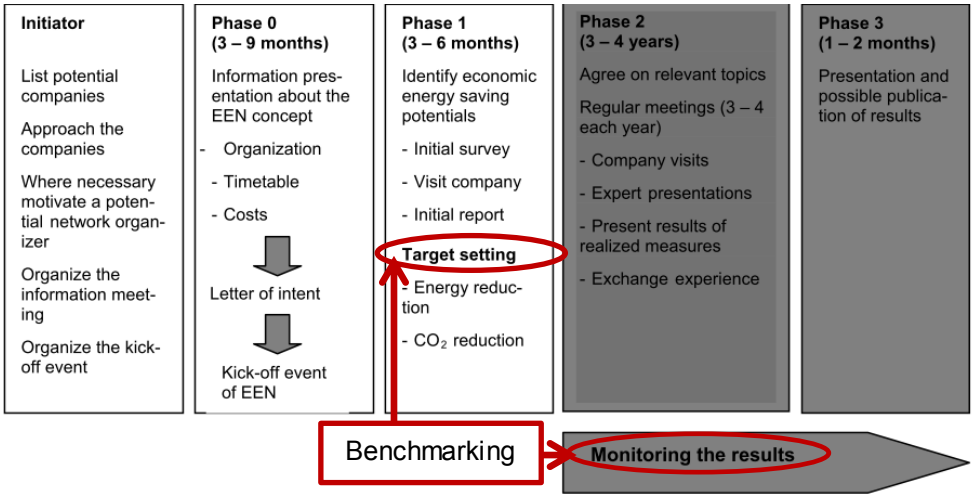
There are several connecting factors between energy management and energy efficiency benchmarking. The principles of EN 16231 can be embedded in the energy management as an integral element. For that purpose, it is listed as an instrument in the energy management systems standard ISO 50001.[1] Energy efficiency benchmarking can assist the planning of energy targets and the review of energy efficiency progress.

[1] Cp. DIN ISO 50001:2011: 23

3.1 Realistic planning of energy targets

In the context of planning the energy management system, the development of energy targets is of great importance. Energy targets should be realistic and therefore aligned with the actually existing potentials to increase energy efficiency. The formulation of energy targets must be preceded by a comprehensive assessment of the initial energy situation. Energy efficiency benchmarking can provide information on potential savings in connection with individual processes or the entire production process. This requires references to similar processes within the same organisation or other organisations.[2]

Usually, small and medium-sized enterprises (SMEs) do not have comparable internal systems. Therefore, they have to rely on external benchmarking, i.e. a comparison of their processes with those of other organisations. If energy efficiency benchmarking is to be used as the basis for the definition of energy targets, the operational energy management becomes a cross-organisational task. Due to the fact that the coordinator needs to have insight into information on energy parameters and passes them on to the benchmarking participants in an anonymous form, trust in the coordinator and amongst the companies is essential. For that reason, a promising approach is to implement energy efficiency benchmarking in existing inter-organisational networks that have been set up the collective goal to increase their energy efficiency. In those cases, trust amongst each other and in the coordinator has already been established.



Placement of Benchmarking in the network cycle of the LEEN-system

Source: own image (adelphi) on basis of LEEN o.J.: 2

These structures can be found, for example, in the Learning Energy Efficiency Networks (LEEN). Since LEEN constitutes an organisational and cross-sectoral approach to energy management there are good reasons to compare especially the processes within the cross-sectional technologies. The system technology in LEEN companies is assessed locally by energy experts. Thus, a high grade data quality and a correct definition of the benchmarking boundaries within these companies are warranted.

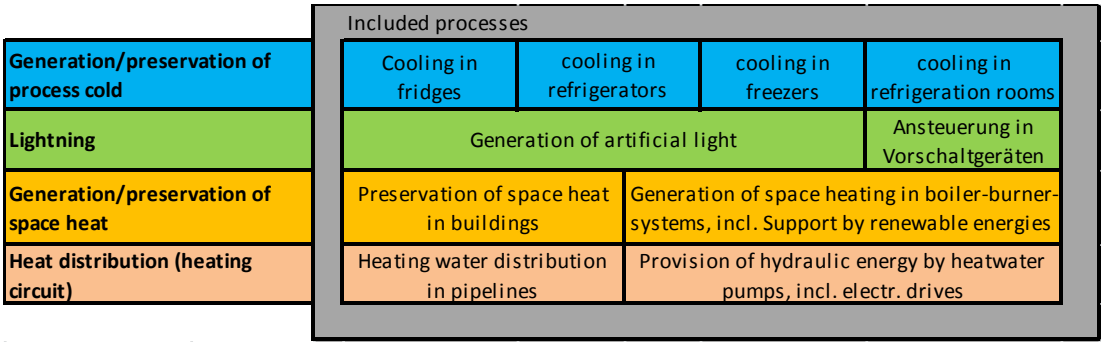
[2] Cp. DIN EN 16231:2012: 21

3.2 Significant evaluation of the energy efficiency progress

The principles of energy efficiency benchmarking pursuant to EN 16231 are appropriate tools to assess the increase in energy efficiency in the course of the monitoring. In this case, the energy relevant data of a process is compared along the time axis. A continuous monitoring and comparison with the baseline (baseline situation in the defined reference year) are already integral components of energy management systems according to ISO 50001. However, the energy management systems standard hardly addresses the question of comparability. Therefore, a monitoring approach that is based solely on the specific energy consumption is very common. In those cases, a linear dependence of the energy use on the production volume is presumed. In practice, however, many other factors affect the energy use (changing weather conditions, changes in manufacturing depth etc.). Failure to take these influences into account can lead to false conclusions.

In some cases, the energy performance indicator has to be adjusted with the help of correction factors in order for it to be able to provide significant results on the energy efficiency of a process in the case of (traceable) deviations in ancillary conditions and input and output units. If the principles of EN 16231 are taken into account in addition to the ISO 50001, the significance of the monitoring in the context of an energy management system increases significantly.

4 Summary of energy efficiency benchmarking of processes in individual systems



Selection of examination areas for the development of benchmarks in processes

Source: own image (adelphi)

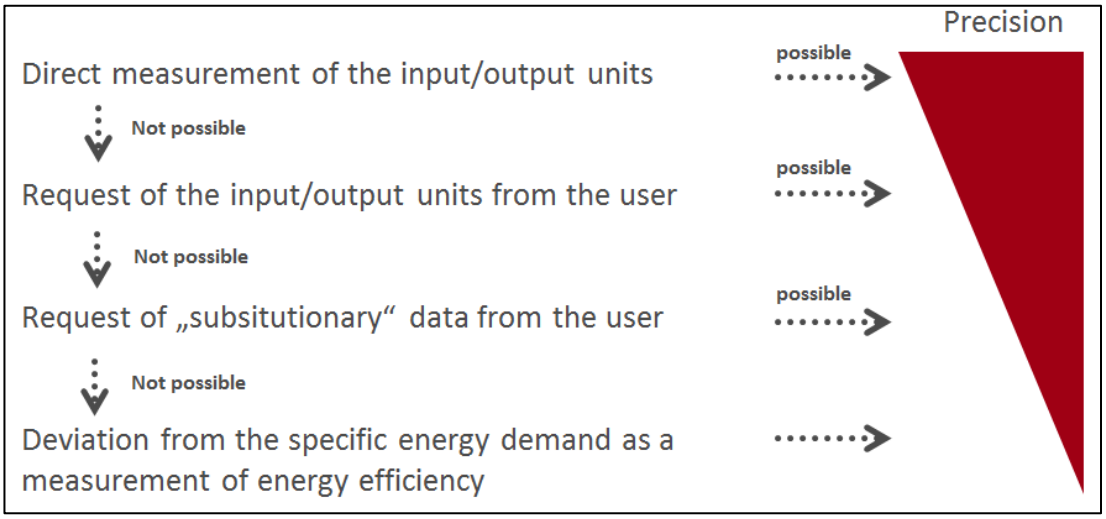
The opportunities to develop online-based benchmarking systems for individual processes in system technologies were identified with the help of examples. Typical challenges and difficulties were also identified. The benchmarks should not be determined in the benchmarking itself, but calculated on the basis of the best available technology pursuant to eco-design. The calculations have the purpose of illustrating the general approach, the complexity and the challenges of energy efficiency benchmarking. In the context of the analyses, procedures for online-based benchmarking of selected processes and process chains were described and difficulties arising throughout the calculation were demonstrated exemplarily. In addition, uncertainties were identified. Some of the difficulties are discussed below in order to allow for learning effects with regard to benchmarking for other processes.

4.1 Challenges

Use of benchmarks provided in literature

During the investigations, which are not explained in the short version of the report, the benchmarks were not established in the benchmarking as such, but calculated on the basis of eco-design. This entails the general problem that in eco-design, energy efficiency classes are measured under uniform laboratory conditions. As a result, the benchmarking boundary between the benchmarks pursuant to eco-design does not sufficiently coincide with the systems in the benchmarking. If a benchmark is not determined in the benchmarking as such, it has to be ensured that it coincides with the benchmarking boundary or the deviations must be accurately traceable.

Data query regarding the numerator and denominator of the EPI



Effect of the data collection method on the precision in benchmarking (simplified)

Source: own image (adelphi)

The energy performance indicator reflects the specific energy consumption. The energy use is compared to the benefit generated within a process. The quality of the indicator depends on the precise definition of the output and input units and the accuracy of the data collection.

- direct measurement of the input/output units

The direct measurement is ideally suited for an accurate and comprehensive data query. The structuring of the energy performance indicator does not require comprehensive calculations if the benchmarking boundary does not allow for deviations. Simple ratios are formed for the relation between the energy use and the generated benefit. The benchmarking systems developed here exemplarily for the online usage are only partially able to determine data needed for the energy performance indicator through measurement.

- request of the input/output units from the user

Due to the lacking possibility to carry out measurements, the benchmarking relies on user input. The origin and accuracy of the data the user inputs in online-based benchmarking systems are based on is unknown – and so are the users themselves. It cannot be assumed that measurement techniques other than electricity meters etc. are available. Correct reading by the user cannot be presupposed either. Thus, the data accuracy is uncertain.

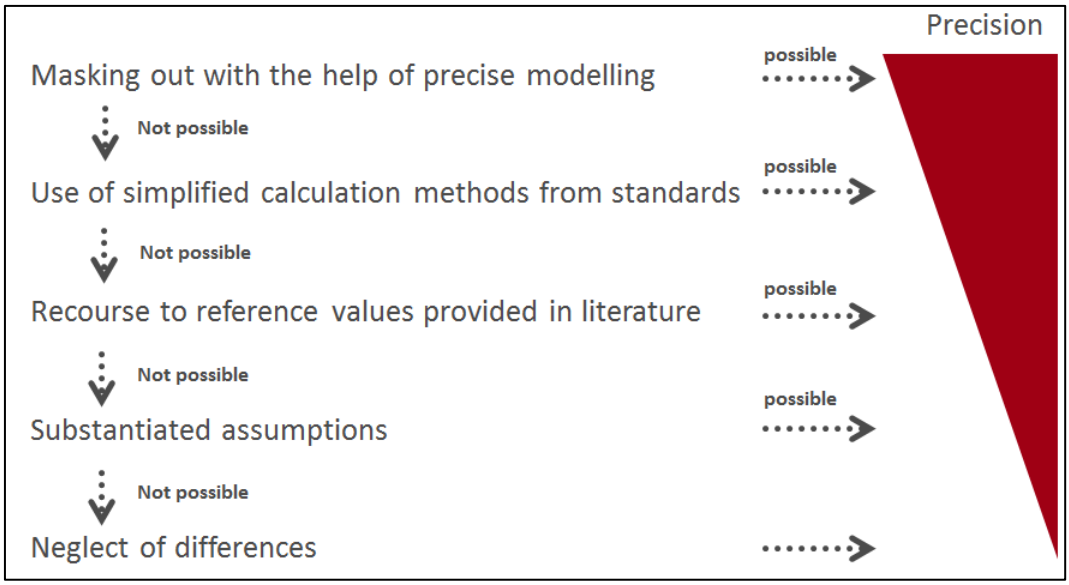
- request of “substitutionary” data from the user

Information on the useful heat demand is required for the development of benchmarking systems for the generation and preservation of space heating and the heat distribution. Since the existence of heat meters and the knowledge of the user as regards the useful heat demand were not presupposed initially, the climate-adjusted, specific heating demand has instead been retrieved from energy performance certificates. Using the effective climate factors as well as requested information on the building’s useful area, this is then used to determine the useful heat demand. This method already implies a correction and is inaccurate in so far as climatic factors are over-simplified and the data given in energy certificates merely constitute snap-shots that also presume standardised user profiles. Due to this problem, a revised version of this chapter requested the installation of heat meters.

- deviation from the specific energy consumption as a measurand of energy efficiency

In the case of cooling units it was not possible to refer to the actually appropriate reference value (the mass of the substances cooled in a cooling unit, taking into account the heat capacity and initial temperature) due to the lacking measurability of the data. Thus, the maximum filling volume of the refrigeration unit was used alternatively. However, this reference value does not reflect with sufficient precision the food refrigeration’s value and presupposes congenerous loading. As far as the lighting is concerned it was necessary to consider the installed capacity due to the fact that it was not possible to retrieve the useable energy light. Furthermore, there was no feasible “second best” energy-related reference value available. Comparisons referring to the installed capacity are unsuitable for benchmarking as they fail to provide information on the energy efficiency in case of practical applications.

Achieve comparability with correction factors



Effect of the correction method on the precision in benchmarking (simplified)

Source: own image (adelphi)

Corrections are accurate if the deviations from the benchmarking boundaries can be traced precisely. In the ideal case it is not necessary to resort to corrections because all compared processes are in accordance with the defined benchmark boundary (input and output units, boundary conditions). The following alternatives are available in case corrections are to be undertaken:

- blinding out with the help of precise modelling

Corrections are most accurate if the particular differences that are to be corrected are clearly identified and their impact on the energy use can be reconstructed on the basis of an accurate modelling. In the developed benchmarking system for the provision of heating energy, the energy export of a CHP was individually traced and adjusted on the basis of a very simple modelling. Depending on the respective case of application, the modelling can become rather complex (for example, if the developed benchmarking system for heating water had not determined the pressure loss in the distribution network on the basis of the building dimension, but on the basis of the hydromechanics).

- use of simplified calculation methods from standards

In cases in which differences cannot be modelled easily and resources for complex modelling cannot be provided, it is often possible to resort to simplified calculation methods from standards. The simplified efficiency procedure of the DIN 18599 was used in the benchmarking system developed for illumination. The benchmarking on heating water distribution was also based on simplified calculation methods of the DIN 18599 as an alternative to modelling. Simplified calculation methods from standards are based, inter alia, on approximate values. Their use is, however, generally accepted.

- recourse to reference values provided in literature

In some cases it was necessary to resort to reference values provided in literature (e.g., load profile for heating pumps from eco-design) to carry out the corrections. In the end, reference values are mean values that deviate from the individual case.

- well-founded assumptions

In case literature fails to provide values it is possible to make assumptions. These need to be well-founded, which means that they should be based on experience and professional expertise. This approach was chosen for the benchmarking system for heating water distribution for the annual operating time of heating circulation pumps. Assumptions, however, are the worst possible basis for the correction of differences.

- neglect of differences

Often it was neither possible to resort to the user's data, reliable reference values nor to assumptions. In such cases, a consideration of the individual case was dispensed with and homogeneity was presupposed. In the case of the benchmarking boundary building this applies to, for example, the internal heat gains. In the case of refrigeration units, differences in the ambient temperature were not considered.

4.2 Potentials

The studies on benchmarking of individual processes regarding system technologies have shown that the use of user inputs is not feasible if the requirements of EN 16231 are to be complied with. Without measurements, a considerable amount of required information is not available to the user. The exemplary development of benchmarking systems for processes in individual technologies has shown that the results will be inaccurate if the benchmarking allows for compromises in terms of quality and is tailored to the data provided by the user. If the benchmarking is intended to compare a large number of processes from different regions, an individual metrological on-site examination by experts is too costly.

For an extensive, accurate and cost-effective benchmarking, the data collection should be carried out with the help of permanently installed, automated measurement systems that can be read from a distance. This averts the use of generalised reference values that distort the significance. Furthermore, automated measurement is capable of solving the problem of cumbersome and inaccurate manual user inputs. Another great advantage of using permanently installed, automated measurement systems is that benchmarking can take place continuously and constantly provide updated results.

In the context of space heating generation, such a system can be implemented already (inexpensive heat meters available). However, for other areas of technology, appropriate measuring systems have yet to be developed. The development and dissemination of such measuring systems is supported by the fact that the operator can benefit from the benchmarking opportunities as well as several other positive effects. In that regard, the condition monitoring possibility is the most important benefit. It facilitates the prediction of defects in equipment technologies and thus reduces the likelihood of production losses. Furthermore, permanently installed measuring technology can be used for energy controlling, the control of technical systems according to demand or in the context of demand side management.

If the requirements for automated remote measurement of all required data are given, benchmarking has the potential to be a powerful tool for accurate, uncomplicated identification of energy efficiency potentials on the level of the individual process.

4.3 Recommendations for action

In order to implement in the medium term automated benchmarking systems that provide precise statements on energy efficiency potentials in technologies, the respective have to be created. In that regard it is advisable to take measures that accelerate the innovation of automated measuring systems and their dissemination in the market:

- **establish an interdisciplinary research network to stimulate an integrative exchange of experience gained in the different application areas of permanently installed measuring systems**
- **establish an automated energy efficiency benchmarking system in the public housing stock for demonstration purposes**

5 Summary of energy efficiency benchmarking of entire production processes

In the past, online-based benchmarking systems for the entire product manufacturing at the company level have already been established in many ways. In the context of the study, recommendations for benchmarking in 30 trade and industry sectors were provided. Furthermore, available reference values were collected for benchmarks. Considering the indicated benchmarking of entire production processes (company level) in sectors, the following statements can be made:

- It was possible to provide information on reference values that are appropriate for benchmarking in the respective sector. The benchmarking refers to the relation of energy use to the created benefit.
- Structuring the peer group on the basis of the German economic sectors seems appropriate. In order to ensure the best possible comparability, the respectively finest branch of the economic sectors (or PRODCOM) should be chosen as a basis for the benchmarking boundaries in terms of the output units (end product).
- Furthermore, the comparability of input units (raw products) should be ensured with the help of an appropriate definition of the benchmarking boundary in order to reflect the actual production process.
- The mentioned benchmarks were derived from different sources. The project documentation does not always indicate how the benchmarks were determined.
- It was not possible to verify the existence of a comprehensive documentation of the mentioned benchmarks. It is not immediately apparent, by whom the data was collected, whether they are based on measurements, in which year they were collected and how corrections were carried out. A complete documentation is an essential success factor for benchmarking to ensure that the significance of the data can be assessed.
- It should be emphasised that the development of the mentioned benchmarking was not yet based on a uniform standard. Therefore, the respective coordinators were not able to use a uniform “code”.

5.1 Challenges

The biggest challenge when benchmarking entire production processes concerns the different manufacturing depths of companies, even if they belong to the same industrial sector. Although the same sector sufficiently ensures the production of the same main product, this does not necessarily also mean that the same by-products are produced and the same starting materials (input units: raw materials, semi-finished products) are used. Simple benchmarking systems that are meant to motivate can ignore this problem if necessary.

Where accurate results are required, by-products and starting materials must be considered in addition to the main products. The analysis of benchmarking projects in sectors did not sufficiently determine whether these aspects were taken into account, or whether the benchmarking boundaries are based solely on the economic sector.

In principle, the challenges of benchmarking processes that are formulated in chapter 4, also apply to the benchmarking of entire production processes in companies.

5.2 Potentials

Linking energy efficiency benchmarking to the data collection in energy audits can increase the quality of benchmarking the entire production process in companies significantly. This approach is already adopted, for example, in the Austrian SME initiative (similar to the German program "Energy consultancy in SMEs" of the KfW). The reporting is carried out via online forms by the energy auditors. Subsequently, the data is used for the development of benchmarks. If energy auditors gathered information about the company's main products as well as the input units (raw materials, semi-finished products), it would be easier to consider the production depth and define the benchmarking boundaries more accurately. Furthermore, recurring audits would prevent obsolescence of the determined benchmarks.

After developing the benchmarks from the energy audit reports, the comparison can be carried out on the basis of user input. User input provided by the company itself serves only the evaluation of the data by the company in question and does not influence the benchmark.

In general, the data collection benefits from the fact that the data needed in order to develop the benchmark can be accessed relatively easily by the energy auditor. Important data can be retrieved directly from the accounting reports of a company (for example the amount and type of purchased energy, raw materials and semi-finished products).

In addition, the potential that results from the improved remote reading of required data for the online-based benchmarking of individual processes in the medium to long term, applies also to benchmarking of entire production processes. If input and output units and the boundary conditions of individual processes are captured accurately, their configurations and entire production process can be considered, too. If all required data was collected automatically, the user would receive both reliable estimates of the energy efficiency of the entire production process and the energy efficiency of relevant individual processes of the technology.

5.3 Recommendations for action

In order to create the preconditions for the use of benchmarking to give more accurate statements on energy efficiency potentials at the level of the whole company, the following measures should be adopted:

- **Develop online forms for reporting through energy auditors to ensure that collected data can be used for energy efficiency benchmarking in the future.**
- **Instruct energy auditors to collect data on the manufacturing depth (main products, by-products, used raw materials and semi-finished products) in the context of energy audits in order to sharpen up the benchmarking boundaries.**
- **Continuous development of benchmarks on the basis of the energy audit reporting**
- **Provide input forms for companies (including selection possibilities for production depth) allowing for a comparison with the benchmark**