Energy efficiency projects deliver! An analysis of 6,500 industrial energy efficiency projects

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Abstract

The success of energy efficiency projects is often reported on an anecdotal basis relying on successful case studies. That information is important, in particular to show technological progress. Still, those highlight projects do not represent the vast majority of energy efficiency projects implemented by the market.

Within the publicly available database DEEP, technological and economic data from over 10,000 energy efficiency projects has been collected by a project consortium on behalf of the European Commission. Half of them are production related industry projects. The other half comprises building projects of which a third has been implemented in the industry, too. The database covers projects from the European Union as well as the United States.

In our paper, we will present an analysis of the industrial projects in the DEEP database, showing payback, avoidance costs and savings of the implemented energy efficiency measures. We will consider influencing factors such as company size, sector, type of measure and country. With our analysis, we can show in detail that cost-efficient measures exist for a broad technological scope.

Introduction

The Energy Efficiency Financial Institutions Group (EEFIG) was established by the European Commission's Directorate-General for Energy (DG Energy) and United Nations Environment Program Finance Initiative (UNEP FI), in 2013. It created an open dialogue and work platform for public and private financial institutions, industry representatives and sector experts on how to overcome the challenges of obtaining long-term financing for energy efficiency [EEFIG 2015].

Since its establishment, EEFIG has managed to engage over 120 active participants from 100 organizations.

In close coordination with the Commission's Clean Energy for all Europeans package, EEFIG supported the launch of largest Pan-European energy efficiency data platform called the De-risking Energy Efficiency Platform or 'DEEP', (deep.eefig.eu). The development and implementation of the platform has been funded by the European Commission.

DEEP is an open source database for energy efficiency investments performance monitoring and benchmarking, which supports the assessment of related benefits and financial risks. The main rationale behind the DEEP database is to allow financial institutions to assess those benefits, risks and performance results of energy efficiency projects. Currently those projects are rather difficult to evaluate for financial institutions. While the investment side of those projects is very much the same as for other investments, the cash flow on the other hand – as it is dependent on saved energy – is uncertain.

The DEEP database is designed to fill this knowledge gap by providing a statistically valid database based on aggregations of successfully implemented projects. It allows a highly customizable comparison of implemented energy efficiency investments for example by country, by measure type, building type and verification method. DEEP provides market evidence from Europe and the United States. The data platform is a new source of operational risk management benchmark, which helps project developers, financiers, and investors to better assess the risks and benefits of energy efficiency investments. It is translated to French, German, Italian, Spanish, and Polish. As of January 2018, DEEP has available data for 10,000+ energy efficiency projects in buildings and industry, contributed by 25+ data providers. By sharing their knowledge, the data providers contribute to the validity of the underlying data and increase the credibility of the database as a whole.

The DEEP database also allows the users to benchmark project performances and identify related opportunities; to receive public acknowledgement and visibility as data contributor; and to connect data to investors and influence the industry best practice. Furthermore, DEEP allows users to enhance their understanding of and access to energy efficiency finance related business opportunities; to streamline underwriting procedures through the EEFIG Underwriting Toolkit (valueandrisk.eefig.eu); decrease due diligence and transaction costs; and improve risks assessment through high quality and credible data framework.

Within this paper, we will give a general overview of the DEEP platform and its underlying data. Afterwards we will provide an analysis of the key indicators of the DEEP related to industrial energy efficiency projects.

The DEEP platform

The database is owned by the European Commission, but the day-to-day operation has been contracted to a Database Administrator from the project consortium. A Database Terms of Use (for Data Users) and Data Privacy Terms (for Data Providers) were developed in dialogue with DG Energy and EEFIG and with inspiration from other databases hosted by e.g. IFC and the EC.

Data providers are requested to deliver data that is anonymized to a level that is in conformity with the legal requirements of their home jurisdiction and any legal agreements entered between them and the underlying projects.

Full sets of Project Data provided by Data Provider are not made visible or otherwise available on an individual project level to Users or any outside entity through the user interface of the Platform or otherwise. Limited subsets of selected Project Data are displayed to Users in aggregated form along with similar data for other projects in graphs, charts and tables for User-selected subsets of projects.

To ensure privacy of personal data, detailed project location (post code, address) and personal information (names and contact details for individuals) provided to the DEEP by the Data Provider are not visible for any other users of the Platform than the Data Provider and the Database Owners and Administrators.

The DEEP platform offers the following services:

- Key Figures: The Key Figures page provides a quick overview of the Buildings and Industry projects in the DEEP. More specifically, this service presents information about the current number of projects, median payback and median avoidance cost for buildings and industry projects for each country visually in a map by hovering above each country.
- Data Overview: The Data Overview page provides a more comprehensive aggregated overview of the energy efficiency projects in the DEEP. The user can choose to see an overview of the energy efficiency projects in Buildings or Industry by clicking on the respective icon at the beginning of the page. In each case, this service presents in simple terms two charts. The first chart presents the distribution of payback time on 10th, 25th, 75th and 90th percentiles per measure types. The chart presents the average (median) payback time (years required for the saving to pay for the investment without any interest costs) for all buildings/industry projects. The second chart in the data overview page is the avoidance cost per measure on 10th, 25th, 75th and 90th percentiles in Eurocent/kWh.
- View Charts: The View Charts functionality allows the user to view and filter a number of predefined charts for Buildings/Industry energy efficiency projects. Through this panel, the user is able to filter the projects that will be included in the charts below based on:
  1. Country
  2. Measure type
  3. Sector
  4. Verification method

This service enables the user to visualize and customize a variety of charts, which are used in the analysis later in this paper.

Analysis Toolbox

The analysis toolbox allows the creation of charts in a dynamic and highly customizable manner. The user can select different variables such as country, measure type, verification method, building type, organization size for the grouping on the x-axis. The metric of interest such as Total investment, Energy consumption (before, after, forecast) can be plotted on the y-axis. The user is able to choose the aggregation function (Average, Sum, Count, Min, Max, Percentiles, Median, and Standard deviation). Other types of graphs, such as pie charts and scatter plots are also available. Moreover, the user is able to create advanced, custom metrics.

Benchmark your Projects

The benchmark service allows to benchmark the projects of the user against the projects in the DEEP. The user selects the category (Buildings/Industry) as well as the benchmark method (Avoidance cost, Simple Payback time, Area cost, Energy saved). This panel allows the user to filter the projects that will be included in the below charts based on Country, Measure Type, Building Type and Verification method.

Moreover, the user is able to choose a discount rate for the calculation of the avoidance cost indicator. The variable discount factors allow to reflect the difference in discount factors (e.g. due to country, sector, individual conditions) as well as factors such as monetarized risk perception. Implicit and generalised discount rates are also used by policy makers when they evaluate which policies to choose and how ambitious they can be [Schleich 2016].

The user is also able to select which projects from its portfolio to use. Based on these parameters this service generates a

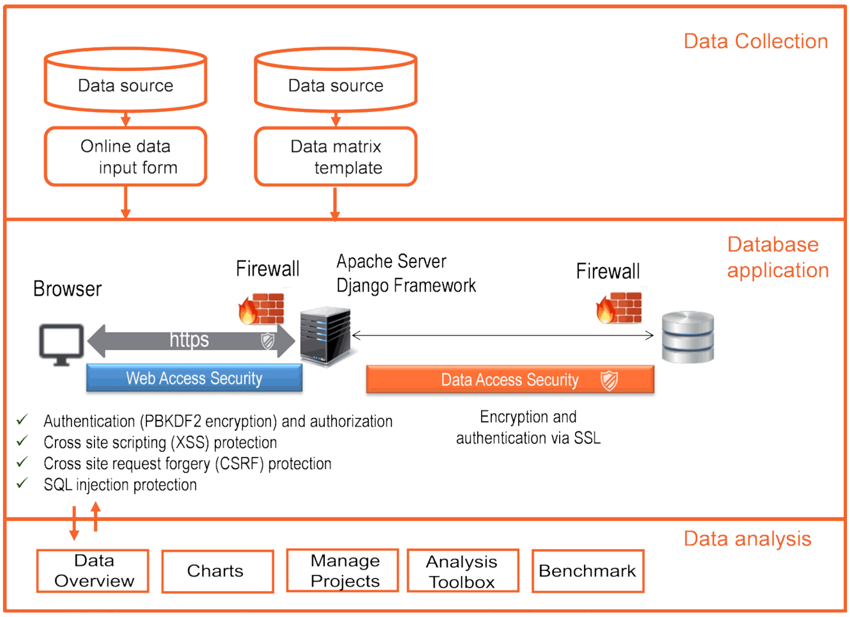

Figure 1. DEEP architecture overview [Glenting 2017].

final chart that compares the benchmark variable selected between the database projects and the user's portfolio on 10th, 25th, 75th and 90th percentiles.

Deep architecture design and security

DEEP ARCHITECTURE DESIGN

DEEP is hosted on a cloud-based provider, based on PostgreSQL. The data is separated into private and public data. Access to the DEEP, upload of data and extractions of analyses and results is facilitated via a web based interface developed with Python/Django Framework. Upload of data is available for users through the interface or as bulk upload where data is provided in an Excel template. The database is a secure and high-performance, energy efficiency data warehouse encompassing the entire workflow, including collection, sharing, and archiving of data. Figure 1 represents the overall DEEP architecture.

Data Overview

The analysed data has been collected in 2016 and 2017 but covers a longer time span. Most projects have been implemented in 2014–2016.

The following graphs shows the number of datasets in the DEEP database aggregated by country. For each country, the number of projects with each of the following three indicators is given:

- Projects with total investment
- Projects with energy cost saving
- Projects with energy savings

The total investment is a mandatory indicator for the analysis, though only either energy savings or energy cost savings is needed for a very basic analysis. The DEEP platform currently does not allow the use of user defined energy prices; therefore, no energy cost savings are derived from the energy savings.

For each graph in this paper we indicate the date, when the data was gathered from the database as well as the number of analysed projects in the graph compared to the overall dataset.

The major share of projects originates from Germany, followed by the UK and Poland. Seven more countries still have a total count of more than 250 projects represented in the database. Despite the dominance of German projects in the database, the main indicators have proven to be stable during the first population of the database with projects from various countries.

Analysis

In the following analysis, a set of main KPIs is used for the analysis. Apart from the indicators directly taken from the project's datasets, two major metrics are used:

- Avoidance costs
- Payback time

AVOIDANCE COSTS

The avoidance cost can be compared to the energy price of the investor and allows a direct assessment of the profitability of the measure. Within DEEP the user has the flexibility of using an individual discount rate for the assessment. The avoidance cost is one of the main indicators for economic performance in DEEP. To calculate the avoidance costs (equivalent annual cost), the following formula has been used.

$$AC_{i,n} = C \cdot \frac{(1+i)^n \cdot i}{(1+i)^n - 1} \quad (1)$$

C: investment
i: interest rate
n: calculation lifetime

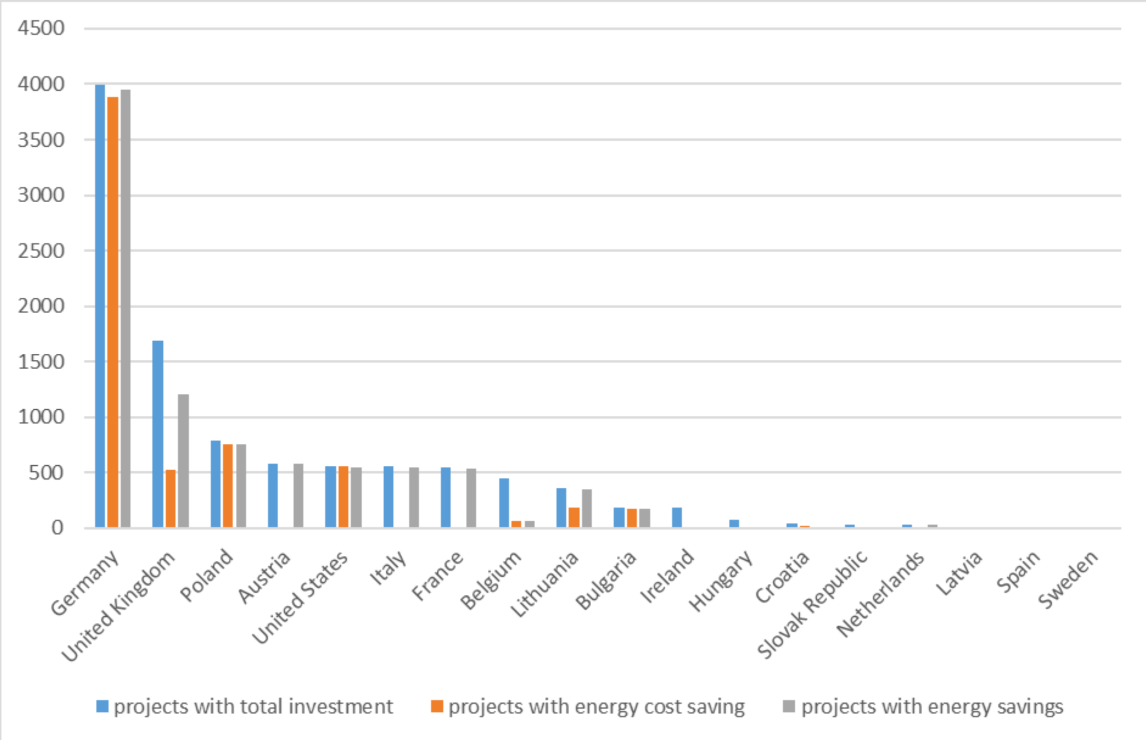

Figure 2. Data availability (by measure type). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 10,099 from a Database total of 10,166.

PAYBACK TIME

The payback time, defined as the average (median) number of years required for the saving to pay for the investment without any interest costs.

The static payback time is calculated directly from the underlying data. If no energy cost data is available, no payback time can be calculated. In contrast to the avoidance cost, which is independent of the actual energy price of the individual project, the payback time reflects the individual energy price of each analysed project. The payback time is the main indicator of the financial return in DEEP. The indicator can be analysed for clusters of projects with sufficient statistical coverage. The generic threshold for projects in a single analysis is 30. A lower threshold of 10 is possible, but not recommended for analysis. To calculate the payback time, the following formula has been used:

$$PT = \frac{C}{p_E} \qquad (2)$$

C: investment

p_E: annual energy savings

The use of more sophisticated metrics would be preferable but is restricted by the availability of the data in the database.

The analysis is presented in box-plot graphs showing the 10 %, 25 %, 50 % (median), 75 % and 90 % percentiles of the analysed data.

Industrial Buildings

DEEP includes 1,454 industrial building projects (1,385 for the EU 28) with a median payback time of 3,16 years and a median avoidance cost (undiscounted) of 1.81 Eurocent/kWh.

Industrial building projects represent nearly 29 % of the non-residential projects uploaded in DEEP. The following graph reflects the distribution of the total investments of all industrial buildings.

INVESTMENT SIZE

Lighting projects can be very small-scale projects if only a low number of lamps is covered by the measure. Therefore, lighting projects are the projects with the smallest investments, although 10 % of the projects have investments of more than €100,000. Building fabric measures usually have higher investments as they often require scaffolding, which sets a threshold for reasonable investments. Rather unexpectedly, the building fabric measures represented in the database have a median investment of only €10,000 compared to the €16,000 of the HVAC projects. A quarter of the building fabric measures have a total investment of over ~€100.000. The overall range of these projects is nevertheless the largest of all three categories.

All distributions are heavily right skewed, which is not visible in the graph directly due to the logarithmic y-axis scale.

PAYBACK TIME

When a deeper analysis is made of the payback time for building projects it is noted that HVAC and Lighting projects have a median payback time of around 3 years whereas Building Fabric Measures have a median payback time of around 7 years. This reflects not only the fact that most building fabric measures have longer payback periods, but that the industrial sector is more prone to invest in measures with shorter payback.

Looking at the building fabric measures in more detail, an interesting finding is, that a quarter of the projects have a payback time of more than ~22 years; ten percent of the projects have

Figure 3. Total Investment (industrial buildings, by measure type). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 1,446 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

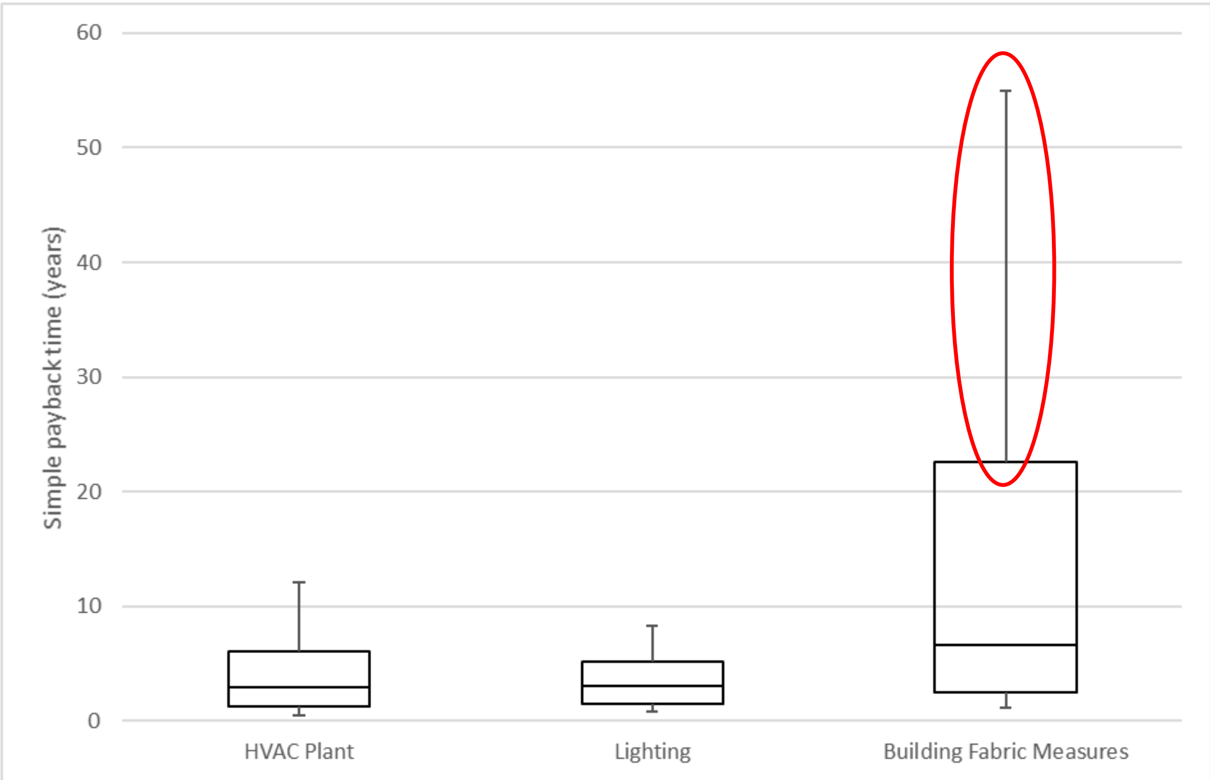

Figure 4. Payback time for industrial building projects in EU28 (per measure type). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 1,445 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

a payback time of more than ~50 years. Those measures are obviously not implemented only for their energy saving benefit as those measures are not economical if only energy saving benefits are considered. Still, building fabric measures usually come with a broad variety of other benefits such as improved indoor climate, noise protection and building conservation.

When looking at the sub-categories of measures (level 2) more in detail, the chart indicates that there are significant differences between the payback time of single measure renovation projects (some HVAC and lighting measures have a median pay-back time of 2 years or less) and building fabric measures in industrial buildings (up to 29 years). The spread of the payback time of those measures is large. Whereas the roof measures distribution is rather right skewed, the distribution of the glazing measures is rather symmetrical. It should be noted, however, that the number of observations in each level 2 single measure category for industrial building is still low and its statistical significance therefore limited (e.g. 28 projects implemented glazing).

AVOIDANCE COSTS

Building Fabric measures by nature have a longer lifetime than HVAC and Lighting measures. This reflects in the avoidance cost of Building Fabric over the lifetime of a measure in comparison with the avoidance cost for HVAC and Lighting as seen in Figure 6.

If the discount factor (time value of money) is increased in the calculation of avoidance cost, so that savings in the distant future are associated with a lower value than savings in the near future, the picture gradually changes. Figure 7 shows how a discount factor of 10 % changes the investability of a situation where Building Fabric measures (3.79 Eurocent/kWh) are more expensive than HVAC (2.55 Eurocent/kWh) but still cheaper than Lighting over the lifetime of the measures (5.05 Eurocent/kWh). This implies that measures for which the savings are discounted over a longer lifetime are more sensitive to an increased risk perception represented by the higher discount rates. This is also backed by the longer payback time of these measures.

Regarding the comparison of lighting and HVAC it should be noted, that the energy saving through lighting measures is electricity compared to a mix of fuels and electricity saved with HVAC measures. When associated with the shorter payback time for HVAC and Lighting, this implies Building Fabric measures are more attractive from a society (macroeconomic?) point of view than from the point of view of an individual investor.

Verification

The verification status is unknown for 98 % of the industrial projects uploaded in DEEP (1,354 out of 1,385). Only 16 industrial building projects in the database indicated that they were submitted to third-party verification.

Multiple benefits of renovation

Finally, the DEEP also includes data on additional value triggered by the project for 1,344 building projects, but no information is available on this point for industrial buildings.

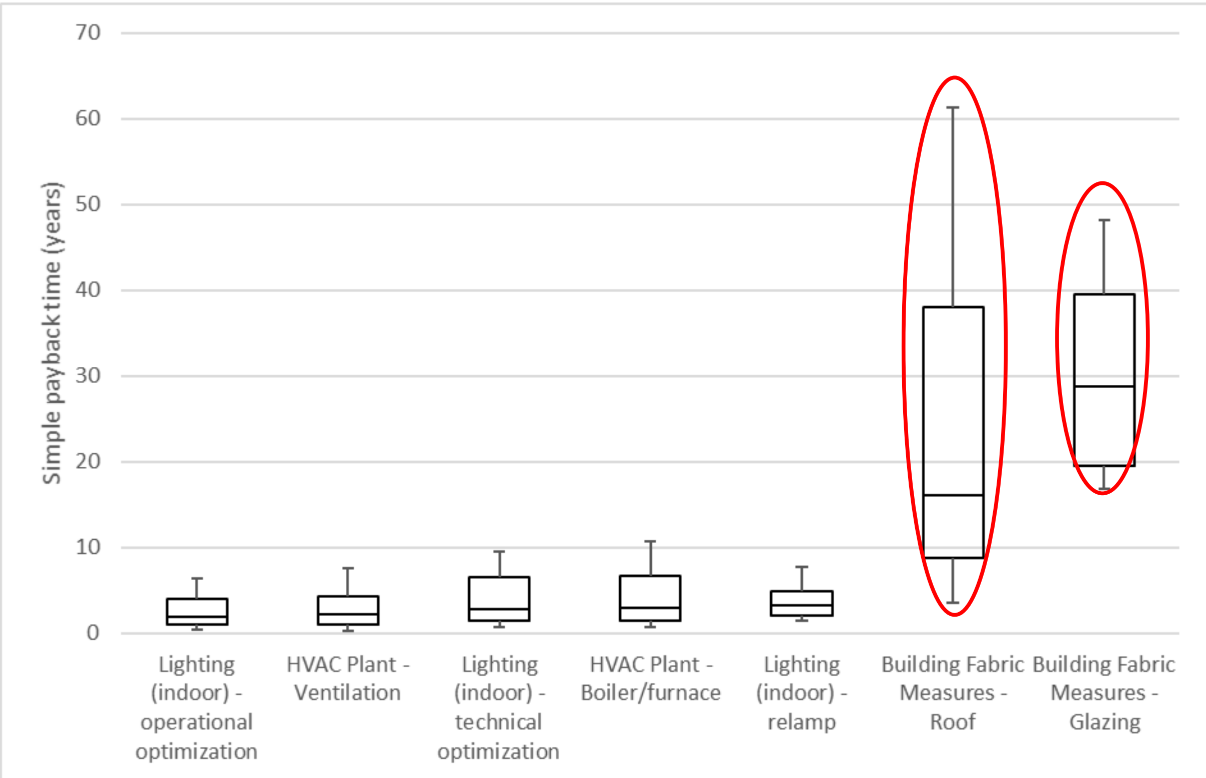

Figure 5. Payback time for industrial building projects in EU28 (level 2 measures). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 631 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

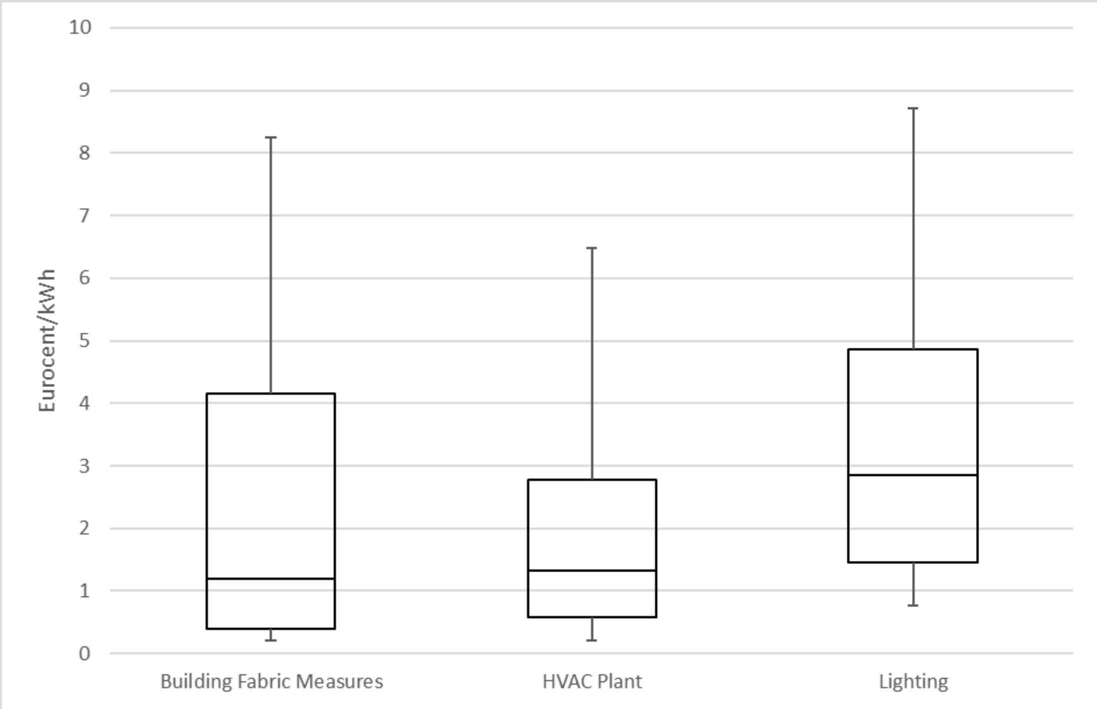

Figure 6. Avoidance cost per measure in industrial building projects in EU28 (no discounting). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 1,376 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

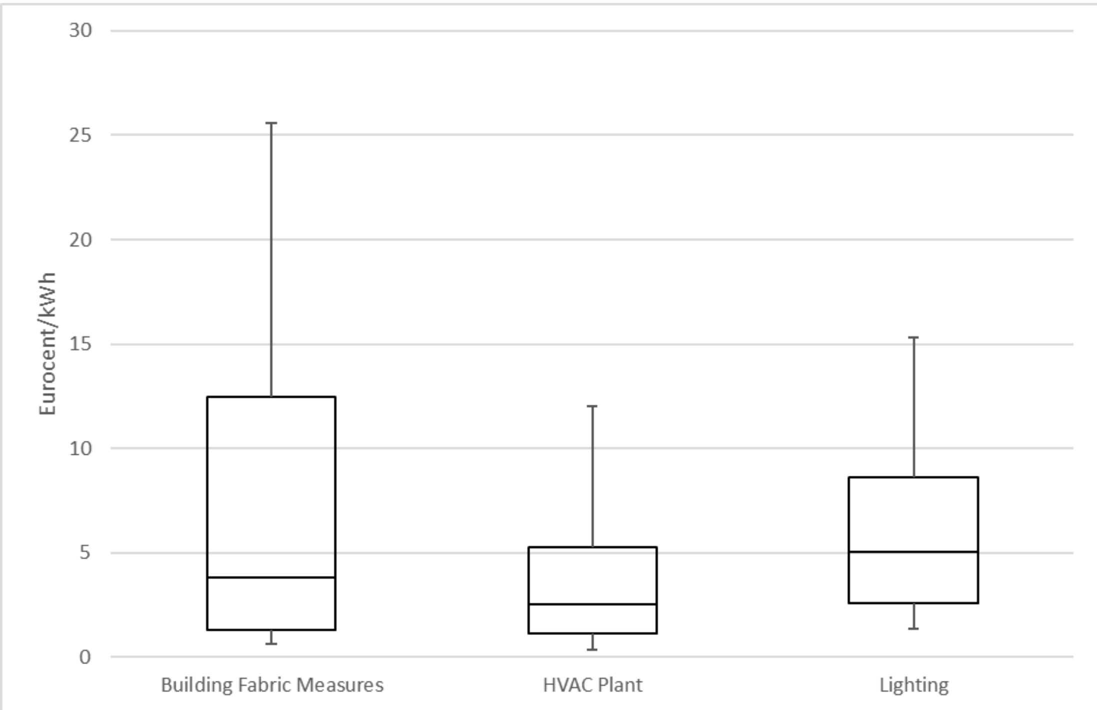

Figure 7. Avoidance cost for building projects in EU28 (10 % discounting). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 1,376 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

While many project owners see other benefits to renovation other than energy and cost savings (e.g. carbon emission reductions, reduced maintenance, health benefits and employee satisfaction), most of the industrial building projects collected under DEEP do not provide this information. This is a major shortcoming of the underlying data. As we have shown before, a significant share of the building fabric measures tends to be uneconomical if energy savings are considered as the only (monetary) benefit. The consideration of multiple benefits of energy efficiency measures can broaden the scope of economically feasible measures in that domain.

Industrial Cross-Cutting and Process Technologies

DEEP includes 5,014 industrial projects. As for building projects, the total investment is among others an important enabler (or barrier) for energy efficiency investments in industry projects. Lack of credible data, joint underwriting procedures, well prepared projects as well as the fact that EE investments are not on the strategic agenda and are regarded as being the major obstacles towards a widespread implementation of energy efficiency measures. This lack of capital provided and requested for energy efficiency projects results from these barriers [EEFIG 2015].

TOTAL INVESTMENTS

Most of the projects represented in the database have rather low overall investments with the median of the investments being below €9,000. Furthermore, 25 % of the projects have an overall investment of below €2,000. Still, 10 % of the projects have an overall investment of more than €100,000.

Figure 8 shows the total investments and breaks the result down to the individual measure types of the industry projects. As expected, measures targeting motor systems are rather low in their total investment, whereas power systems and waste heat projects require rather high upfront investments.

PAYBACK TIME

Payback time is more a risk than an economic indicator. It does not provide any information about the economic benefits of the project but only shows the time in which the revenue from the energy savings will cover the initial investment. Even measures with rather long payback times may be highly profitable if their technical and operational lifetime exceeds the payback time.

Still, payback times are most prominent among the indicators. In all categories, the median payback time of the projects in the database is below 4 years. For motors, it is below two and for compressed air systems about 1 year. Generally, the level of payback times in low, but for many projects, it is above the usually accepted time of 2 years.

Street lighting projects are an exception as their payback is higher than 5 years. The risk associated to the installation of street lighting is rather low, though. The lifetime of street lighting measures is rather long, so the risk associated to these measures is low.

ECONOMIES OF SCALE

Due to economies of scale, but also due to the decision-making mechanisms, one would expect large companies to have shorter payback times than smaller companies. This is backed by the data. Small and micro enterprises tend to implement projects with longer payback times than lager enterprises. The large en-

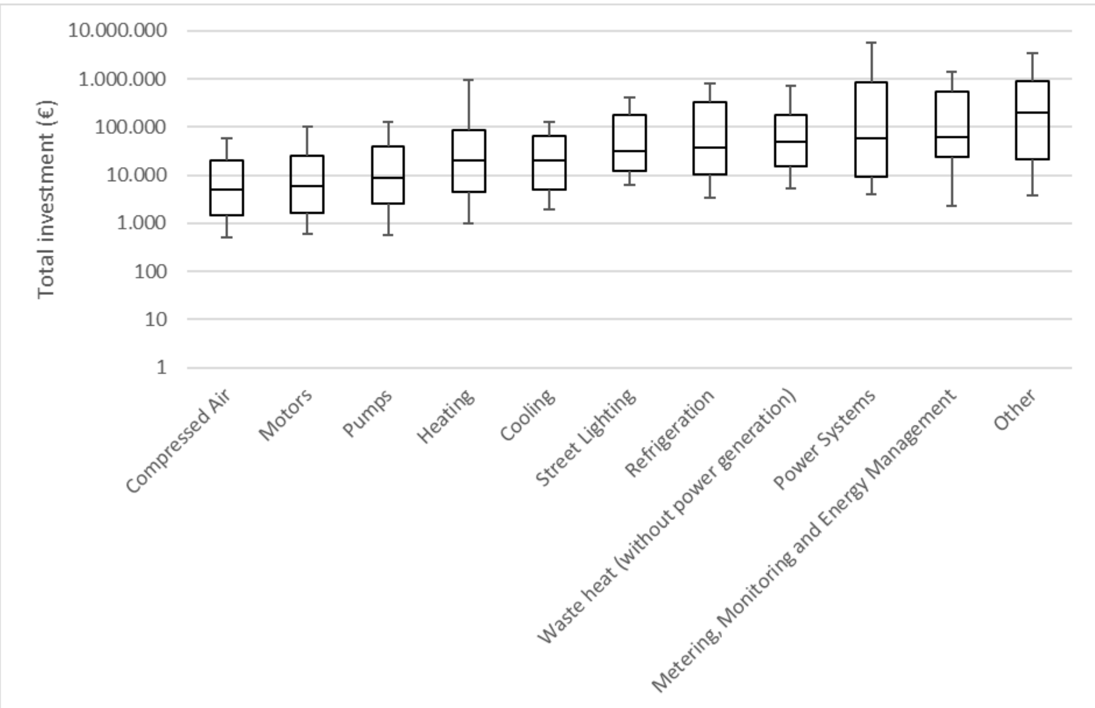

Figure 8. Total investment for industrial projects (per measure type, logarithmic scale). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 5,008 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

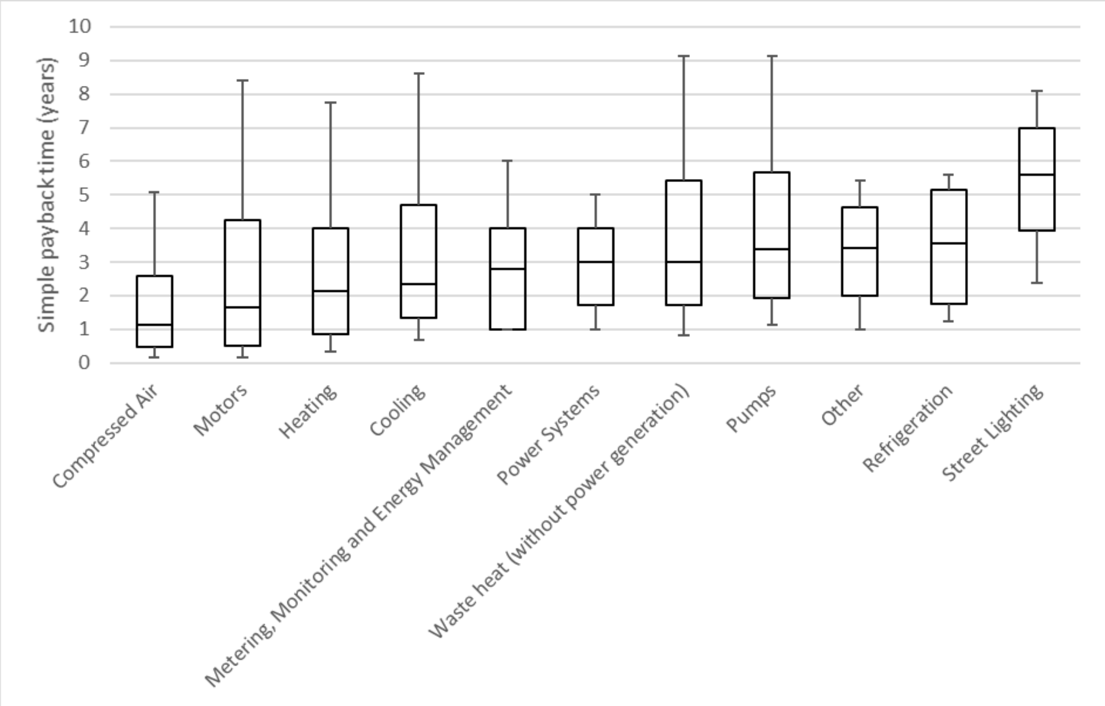

Figure 9. Payback time for industrial projects in EU28 (per measure type). Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 2,733 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

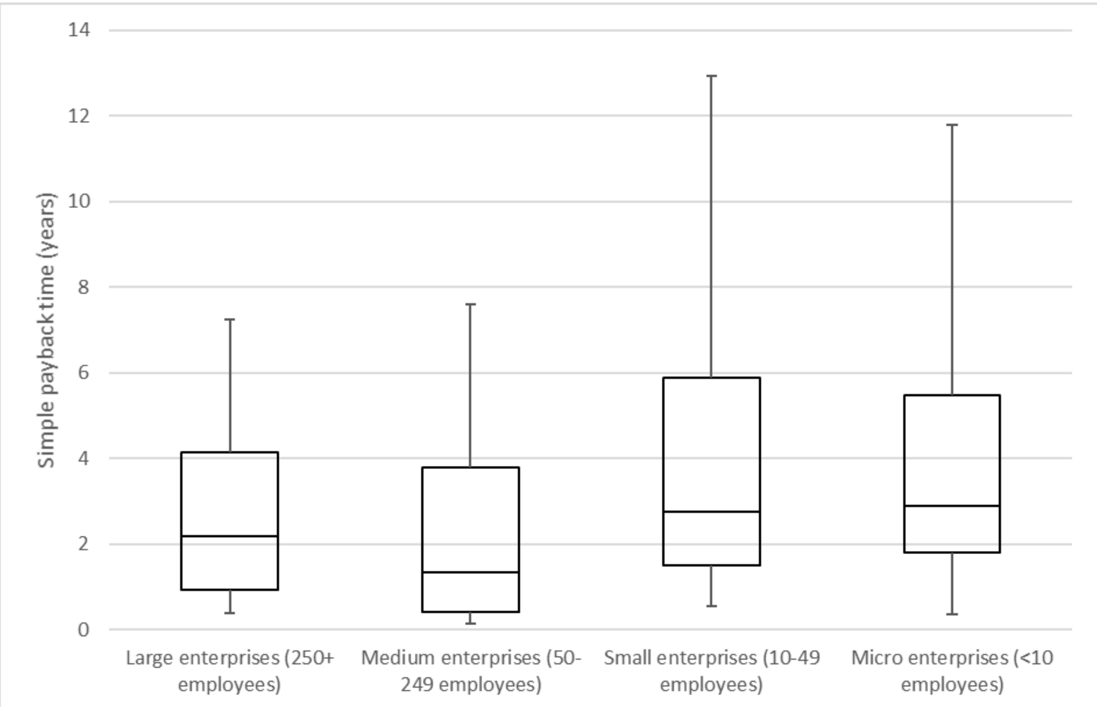

Figure 10. Distribution of payback time of industry projects by company size. Source: DEEP Output data on 19/01/2018.

Sub-set of projects shown in Chart = 2,467 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

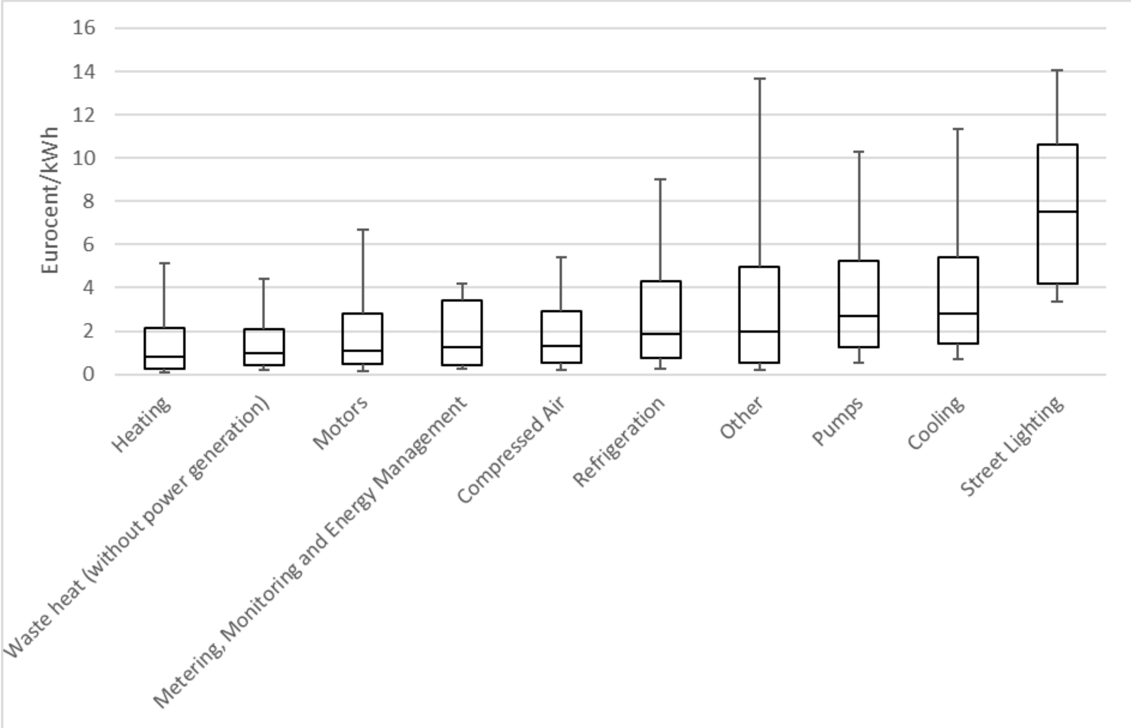

Figure 11. Avoidance cost per measure for industrial projects in EU28 (no discounting). Source: DEEP Output data on 19/01/2018. Sub-set of projects shown in Chart = 4,857 from a Database total of 10,166. 10 %, 25 %, 50 %, 75 % and 90 % percentiles are shown in the boxplot.

terprises' projects have a median payback time of 1.75 years, whereas the small and micro enterprises' projects have and median of 2.25 years. In addition, the 75th percentile value is much higher for the smaller companies.

AVOIDANCE COSTS

In the following graph, the avoidance costs are shown by measure type. The two (usually) fuel related measure categories (heating, waste heat) have the lowest median avoidance costs of ~1 ct per kWh. Compressed air and motor systems also have avoidance costs well below 2 ct per kWh. Cooling, pumps and other applications have median avoidance costs of ~3 ct per kWh. Compared to common energy prices in industry those values are extremely low and show the high cost effectiveness of these investments. These measures are highly attractive for investments as their avoidance cost is well below the related energy prices. As the 90 % percentiles of the measures are still below the energy price for each category the associated financial risk for investments in these technologies is low.

Conclusions and Outlook

With the DEEP database, the most comprehensive publically available database of energy efficiency projects has been created. The objective of the creation of the database was to build an evidence base related to the technical and economic performance of energy efficiency projects in order to evaluate the associated risks. This objective has been achieved with some limitations.

The database is currently the most comprehensive collection of data publically available in Europe. The underlying data is consistent and the indicators are stable when new data is added. Still, the geographical and technological coverage needs improvement in order to be "the" benchmarking platform for energy-efficiency projects.

The database allows the user a detailed analysis of the underlying data. As shortly outlined in this paper, this data proves the overall effectiveness of energy efficiency measures in delivering profitable energy savings. In industrial buildings as well as in industrial processes and cross-cutting technologies a broad variety of economically attractive energy efficiency measures are available.

Still, the current state of the database as it is does have some shortcomings. The database contains implemented projects, which increases the credibility of the underlying figures.

Linked to this asset, the database does not allow estimating the potential for further applications of the energy efficiency measures. Market actors willing to address new market segments cannot identify the size of these markets with the data currently represented in the database.

The number of projects in the database is large and covers a broad range of countries and technologies but only limited economic data is available for the individual projects. This results in a rather limited range of economic indicators. Currently, for most project the payback and/or avoidance costs are calculated. In a future development, the database could allow the calculation of other indicators such as IRR based on variables (energy prices etc.) defined by the user. In addition, payback times are currently based on the energy prices of the actual projects. Therefore, they are strongly dependant on the local energy prices, which heavily vary among countries, sectors and company sizes.

Despite these potentials for further development, the DEEP database is already a powerful tool to analyse industrial energy efficiency measures on a statistically sound basis.

References

EEFIG 2015: Energy Efficiency Finance Institutions Group (2015): "Final report covering Buildings, Industry and SMEs", Brussels, February 2015.

Glenting 2017: Carsten Glenting, Ivo Georgiev, Peter Sweatman, Steven Fawkes, Spyros Mouzakitis, Clemens Rohde, Mariangiola Fabbri (2017): EEFIG de-risking energy efficiency investments – Final Report, Brussels, December 2017.

Schleich 2016: Joachim Schleich, Xavier Gassmann, Corinne Faure, Thomas Meissner (2016): "Making the implicit explicit: A look inside the implicit discount rate"; Energy Policy, Volume 97, 2016, Pages 321–331, ISSN 0301-4215.

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