A comprehensive indicator set for measuring multiple benefits of energy efficiency

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Keywords

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Abstract

In this paper, we develop a quantitative indicator approach to measure multiple benefits of energy efficiency (MB-EE). The MB-EEs are classified into three groups: environmental, economic, and social-related MBs. The first group contains most relevant and direct aspects of energy efficiency such as energy savings and reduced GHG emissions. The second group comprises, among others, positive macro-economic impacts on economic growth, for innovation and competitiveness as well as import dependency. The third group of impacts covers aspects such as health benefits, poverty alleviation and employment. Quantitative knowledge on these MB-EE is, however, scattered and not easily accessible for the actors in the policy field. Spreading information on these benefits in an easily accessible way will contribute to the capacity building of the actors on these additional benefits. In order to achieve this goal, we develop a comprehensive quantitative indicator set consisting of 20 indicators covering the different aspects of MB-EE. We discuss the methodological approach to the indicators set, the underlying data sources and limitations. This indicator set is planned to be applied for 31 countries (EU28 plus Norway, Switzerland and Serbia) to provide a comprehensive tool of MB-EEs. This allows an in-depth comparison of developments and differences across Europe. The indicator set also supports the design of well-suited energy policies by taking into account, on an informed basis, more of the beneficial aspects of energy efficiency in future.

Introduction

In the last decade energy efficiency became a more and more relevant topic. Today energy efficiency is commonly seen as essential to all of the major objectives of climate and energy policies and is denoted as the "first fuel" in the EU 2030 climate and energy policy framework (Saheb, Ossenbrink 2015) and by the International Energy Agency as well (IEA 2013).

A large share of energy efficiency is not considered cost-effective when only energy savings are accounted as benefits. Including co-benefits like reduction of emissions, health and economic benefits are significantly higher than the cost of energy measures (Zhang et al. 2016).

The environmental impacts of energy efficiency on primary and final energy consumption as well as emissions related to energy conversion are evident. Also, the economic impacts are well studied over the last years. Recently the social impacts, i.e. effects on living conditions, were focus of a rapidly increasing number of studies. To unify these different aspects and give a more holistic view on the benefits of energy efficiency in a single framework Ryan, Campbell (2012) presented the multiple benefits approach, which was further refined by IEA (2014). Ürge-Vorsatz et al. (2016) proposed several methods for the quantification of multiple benefits or 'multiple impacts' of energy efficiency in a green economy context developed as part of the COMBI project[1].

To transfer these approaches to an easily accessible tool within the project ODYSSEE-MURE[2], we developed a framework to quantify different aspects of energy efficiency with a compre-

1. http://combi-project.eu/
2. http://www.odyssee-mure.eu/

hensive set of indicators. This aims to support a detailed comparison between countries across the EU and to help the design of future energy policies in a well-suited manner.

In this paper, we introduce our general approach followed by an overview of a sub-set of indicators from our framework with definition and data sources. Then we present first results for selected indicators followed by a discussion of our approach and conclusions with a short outlook upcoming work within the project.

General approach

For our approach for a comprehensive measurement of multiple benefits we designed a set of indicators, which should allow examining the most important aspects of energy efficiency. These indicators are also grouped into 8 sub-categories, which cover a certain aspect of energy efficiency (see Table 1). The total set contains 20 indicators divided in three different main categories, namely environmental, social and economic.

Environmental impacts include the direct effects of energy efficiency on primary and final energy consumption and the mediation of GHG and other emissions by reducing final energy consumption and thus lowering the primary energy consumption of the energy conversion sector for heat and electricity generation. Primary energy consumption and the related emissions are also directly impacted by the penetration of electricity and heat generation by renewable energy sources.

Social impacts in our measurement framework are defined as direct effects on aspects such as alleviation of energy poverty, health and well-being (including improved living comfort) and disposable household income.

Economic impacts comprise issues like improved GDP, employment, competitiveness and energy security, which are characterised as positive multiple benefits of energy efficiency.

These categories – especially economic and social – might overlap due to direct or more indirect linkages between their different aspects. However, some aspects like disposable household income, which clearly could also be labelled as economic have high immediate impacts on the well-being of those affected and are therefore categorised as social aspects. This categorisation is naturally not fully distinct due to the several interconnections between the aspects, but as we are only considering effects individually and do not aggregate different indicator or categories our categorisation should also not raise issues due to overlaps and linkages, like double counting.

For our analysis, we consider the time period from 2008 to 2015 – if possible – as these years are strongly impacted by the Energy Efficiency Directive (EED) and the national programmes and measures it triggered in the Member states of the EU.

Due to restriction regarding the length for this paper, our analysis will be limited to an in-depth presentation of a sub-set of indicators, at least one from each sub-category, which will cover all three main categories, economic, environmental and social impacts of energy efficiency, in an appropriate manner. The selected indicators presented in this paper are highlighted in Table 1.

Impact analysis: Definitions and data

ENVIRONMENTAL IMPACTS

Annual energy savings

For a number of our indicators the energy savings calculated from the ODYSSEE database (top-down savings) or the MURE database (bottom-up savings) are important starting points. In ODYSSEE, energy savings are calculated based on the unit consumption at the level of up to 30 sub-sectors or end-uses. Savings from international air transport and ETS sectors in industry are included as well. In industry and freight transport, savings may be negative for some years due to a deterioration of energy efficiency; this is due to capacity effects in industry and freight transport in times of economic recession. They are derived from the ODEX, an indicator that measures the energy efficiency progress by sector. For each sector, this index is calculated as a weighted average of sub-sectoral indices of energy efficiency progress. Such sub-sectors are branches of the sectors industry or service, end-uses for households or modes for transport (ODYSSEE-MURE 2016).

The bottom-up savings provided by the MURE database originate from policy evaluation studies on a national level and National Energy Efficiency Plans (NEEAP) as well as Article 7 notifications published by each Member state. For the indicators in our framework we use, if suitable, both top-down and bottom-up energy savings, as they provide different but equally interesting perspectives.

The main difference between energy savings from ODYSSEE and NEEAPs is that ODYSSEE in contrast to the NEEAPs also accounts for international air transport and ETS. Negative savings are also included in ODYSSEE, which is generally not the case in NEEAPs, and ODYSSEE savings include all types of savings whereas NEEAP savings, which are often calculated using bottom-up methods, will be restricted to policy related savings.

Local air pollution

Lelieveld et al. (2015) estimate that outdoor air pollution, mostly by PM2.5[3], lead to 3.3 million premature deaths per year worldwide, predominantly in Asia, with over 34,000 premature deaths in Germany in 2010. According to the study, in Germany about 20 % of these deaths are related to energy conversion in power plants and the residential sector.

For our measurement approach, we use data on annual energy saving by end-use (e.g. space heating, appliances, etc.) from the ODYSSEE database and calculate – based on a typical break-down by energy source per end-use – the local pollutants using end-use and fuel specific emission factors (see Figure 1). The data necessary is on one hand provided by the ODYSSEE-MURE project and on the other hand through national emission factors as for example provided by the German Environment Agency (UBA).

3. Fine airborne particulate matter with a diameter < 2.5 µm, which is linked to respiratory diseases and cardiovascular diseases (see Dockery et al. 1993).

Table 1. Set of indicators for the quantification of multiple benefits of energy efficiency.

Category	Sub-category	Indicator
	Energy and Resource Management	
Environmental	**Energy savings**	Annual energy savings
Environmental	Saving of fossil fuels	Saving on fossil fuels; extension of range of fossil fuels
Environmental	Impacts on RES targets	Lowering of RES target; replacement of RES capacity; reduced need for interconnectors
	Global and Local Pollutants	
Environmental	GHG savings	Annual CO_2 savings linked to energy savings
Environmental	**Local air pollution**	Emission factors for avoided local pollutants (incl. electricity)
	Energy poverty	
Social	**Alleviation of energy poverty**	Impact of savings on energy cost shares in household income
	Living comfort	
Social	**Health and well-being**	Externalities linked to health impacts
Social	Disposable household income	Shares of energy costs in household income
	Innovation and Competitiveness	
Economic	**Innovation impacts**	Patent indicators
Economic	Competitiveness	Indicators on foreign trade with EE products
Economic	Turnover of energy efficiency goods	Production statistics
	Economy (Macro)	
Economic	Impact on GDP	Impact of energy savings on GDP growth
Economic	**Employment effects**	Input-Output (I/O) analysis
Economic	Impact on energy prices	Price elasticities
Economic	Public budgets	State income from employment based on energy savings
	Economy (Micro)	
Economic	Industrial productivity	Semi-quantitative classification of impacts
Economic	**Asset value**	Valuation of buildings and companies for different end-uses according to energy efficiency benefits
	Energy Security and Energy Delivery	
Economic	**Energy security (A)**	Import dependency (conversion to primary energy necessary)
Economic	Energy security (B)	Impact on supplier diversity (Herfindahl-Hirschman-Index)
Economic	Impact on integration of renewables	Demand-response potentials by country

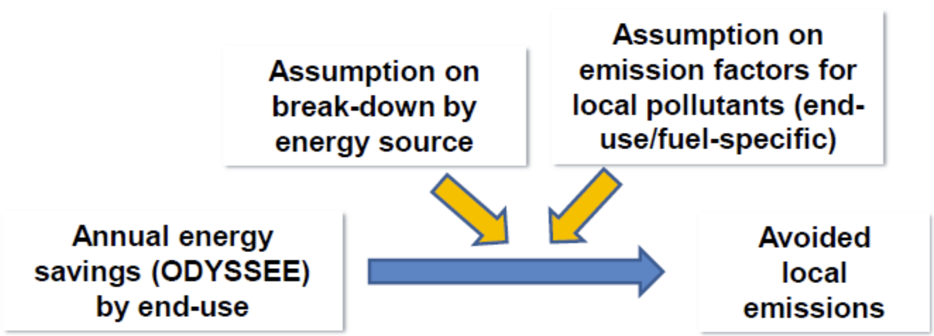

Figure 1. Schematic process of the calculation of avoided local emissions.

SOCIAL IMPACTS

Alleviation of energy poverty

Tackling energy poverty is explicitly stated as a policy objective in the European Commission's Communication on the Energy Union Package (European Commission 2015a). In the European Union, the problem of energy or fuel poverty is not limited to colder climates or particularly poor Member states as one might expect. It exists also in the south of the EU like in Spain, Portugal, Italy, Greece and Cyprus, as well as in relatively well-situated Member states like the UK and Ireland. BPIE (2014) estimates that between 50 and 125 million people in the EU are currently suffering from energy poverty and are unable to afford proper indoor thermal comfort. At the same time energy efficient renovation of buildings in the EU holds a large potential for energy savings. Fraunhofer ISI et al. (2009) identified an overall energy efficiency potential in residential heating of 16 Mtoe to 45 Mtoe in the European Union. To achieve the targets, it set for itself these potentials are essential for the EU. To unlock these potentials, it is necessary to address all types of households in the residential sector. This emphasizes the importance of targeting low-income and energy poor households in energy efficiency policy.

The definition of energy poverty differs from country to country and over time (see (Maxim et al. 2016) or (Robić et al. 2015). For example, in the United Kingdom, a household is described as 'fuel poor' when more than 10 percent of its total income is spent for heating on an acceptable level (Bird et al. 2010). France has recently formulated a similar definition of 'energy precariousness' based on a household spending more than 10 percent of its income to meet its energy needs (Bouzarovski 2013).

Thus, we represent this issue in our measurement framework with an indicator measuring the impact of energy measures on the share of energy costs in total household income, as this is one common basis of definition.

Assuming a constant level of energy consumption, the share of energy cost in income depends on one hand on the price of energy and on the other hand on the level of income. While energy efficiency measures might have an impact on energy prices (Chernick, Plunkett 2014), taxes and duties as well as other cost elements strongly reduce this effect on the energy prices for final consumers. Also, household income is impacted directly only by energy efficiency through reduced energy cost (indirectly also through employment effects and others). Thus, we only consider the impact of energy efficiency on the energy consumption of household (including fuel consumption for heating and electricity consumption) assuming constant prices and household income. We also assume a uniform distribution of energy savings among all groups of income in households.

This approach might lead to an overestimation of the effects of energy efficiency on low income households, which are more prone to energy poverty, as they do not benefit as much from energy efficiency policies as higher income groups.

Health and well-being

Health benefits represent a more indirect effect of energy efficiency. On the one hand, these impacts on health are strongly related to (local) emissions from power plants, district heating and local residential heating systems as well as emissions from transport and industry. Electricity and heat generated by these facilities lead to increasing air pollution such as NO_x, SO_2, small particle matters (PM2.5) and CO_2. By reducing the energy consumption, a part of this air pollution can be avoided. Also, energy efficiency policies targeting industrial processes have a strong positive effect on health by reduction of emissions of PM2.5. Zhang et al. (2016) give an extensive example regarding the effects of energy efficiency measures on the emissions China's cement industry and the related premature deaths.

On the other hand, better indoor climate has positive effects on the health of residents. Willand et al. (2015) gives several examples of benefits from energy efficiency in household including mental health, autonomy and social status of residents. Especially low-income households see significant improvements in health following energy efficiency measures (Maidment et al. 2014). This emphasises the importance of energy efficiency measures as part of a strategy to tackle social issues like fuel poverty and health inequity.

As the latter aspects of energy efficiency, such as those regarding improved life quality beyond direct health impacts are quite difficult to assess, we restrict to measure those impacts related to air pollution, i.e. avoided premature deaths by energy efficiency. This indicator can be calculated by extension of the indicator regarding *local air pollution* in combination with premature mortality rates from studies such as Lelieveld et al. (2015).

IEA (2014) gives some examples for possible indicators used in measuring health and well-being impacts of energy efficiency. However, those are mainly based on (in situ) measurements, which should be performed before and after certain energy efficiency measures were carried out in a household. Thus the data base for those indicators is every limited.

ECONOMIC IMPACTS

Innovation impacts

Innovation is a driver for economic growth and is referred to as important indicator for the transition towards a sustainable for competitive, secure and sustainable energy system in the 2030 Climate and Energy Framework (European Commission 2014a). For a measurement regarding the innovation impacts of energy efficiency, first we identify relevant energy saving technologies from the ODYSSEE, which provides diffusion data showing the share of stock and sales for energy efficient technologies (i.e. appliances of a certain energy efficiency class, efficient heating systems, etc.).

These energy saving technologies and the technological details related to energy efficiency are identified and then linked to suitable classes and sub-classes of the International Patent Classification (IPC) system. This strategy is supported by the search of certain energy efficiency related keywords in the abstract and title of patents.

For the patents found by this strategy, which are available for example from the PATSTAT[4] database, the relative patent share (RPA) is calculated by putting the patent share of the country

4. PATSTAT database provided by the European Patent Office (EPO) (see https://www.epo.org/searching-for-patents/business/patstat.html).

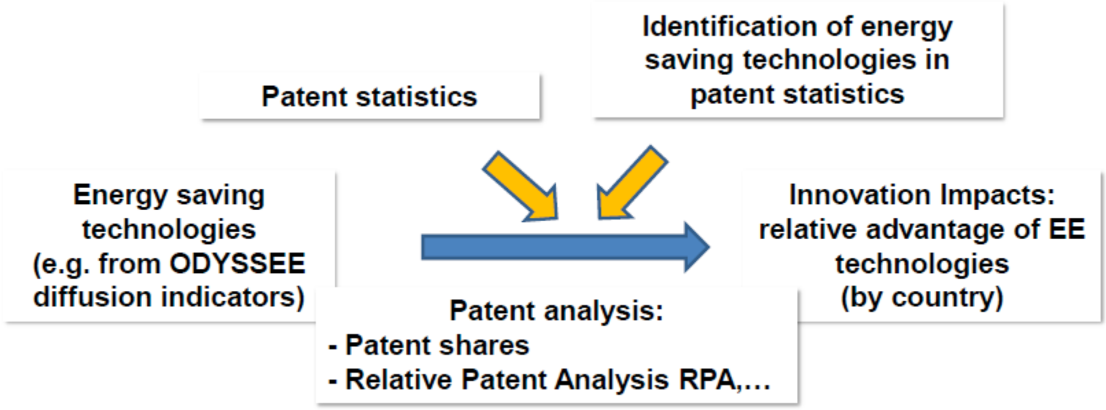

Figure 2. Schematic of the calculation of innovation impacts.

for the given energy efficiency technology of scope in relation to patent shares of the country in all fields.

For each country *i* and each technology *j* the RPA is calculated with following equation (Eichhammer, Walz 2009):

$$RPA_{ij} = 100 * \tanh \ln \left[\frac{\left(p_{ij} / \sum_i p_{ij}\right)}{\left(\sum_j p_{ij} / \sum_{ij} p_{ij}\right)} \right]$$

where p_{ij} represents the number of patents for a certain technology *j* from a country *i*. If the patent share for a technology is over-proportionally large then the RPA takes a positive value. This implies that – compared to other technologies – there is more national innovation activity. However, if a country is generally strong in patents, it is more difficult for a technology to achieve a positive RPA value.

Calculation of employment effects – Input-Output-Analysis

The calculation of employment and GDP effects of energy efficiency investments is based on Input-Output-Modeling[5] using latest available version of the comprehensive IO table (IOT) for Germany from EUROSTAT presenting empirical economic data of inter-industrial flows of goods and services in current prices within one year.

At first, we set the focus of our IO-analysis on the effects of energy efficiency in the residential building sector in Germany, as for these many different easy accessible evaluating studies of high quality exist. This allows an evaluation of our results and assures the quality of our method when expanding the measurement to other countries.

As the IO tables we use are show a high level of aggregation our focus on residential buildings requires a couple of qualifications. First of all, a distinction between the two main industries that are affected by the programmes under investigation must be made.

First, large shares of the triggered investments flow into the construction industry. However, renovations and energy efficiency measures in new buildings in the residential area only make up approx. 1 percent of the entire output of the construction industry (destatis 2015a). Therefore, coefficients for the relevant sectors must be developed in order to adapt the VA changes accordingly, that were identified in the IO analysis. Constructive measures for improving energy efficiency in residential buildings require primarily insulating material, plastering, heat-absorbing glazing etc. Thus, the actual impact on particular sectors is different to what changes in the overall consumption of the construction industry would indicate. For instance, inputs from industries producing insulating materials are likely to be underestimated by our analysis, while inputs from industries, that are relevant for other sub-categories of the construction industry, such as road building, are likely to be overestimated.

Second, these programmes lead to investments in renewing heating equipment in existing buildings and the installation of modern heating technology in new buildings. They are represented by an increase in consumption of sector "Machinery and equipment" in the IO model. Nevertheless, they account only for approx. 0.9 percent of the total output of machinery and equipment industry. For an appropriate estimation of the macroeconomic impact of these measures, we must consider – analog to the analysis of the construction sector – the variation of inputs to the different sub-sectors. Obviously, manufacturing heating equipment requires different parts than manufacturing machine tools, for example. Hence, for an appropriate calculation of VAs in particular sectors correction factors must be implemented here as well.

In a next step towards the calculation of gross employment, we investigate the cost per final energy saved for typical energy efficiency measures in the household sector regarding buildings. These are extracted from the MURE database, which also includes financial data on programmes related investments besides the bottom-up savings for measures implemented in the EU, and other national studies such as BPIE (2015) and IWU, Fraunhofer IFAM (2016) for Germany. This investment per final energy saving is then used to estimate total investments, which are then split into economic sectors by energy efficiency technology (e.g. insulation material, heating systems etc.).

These values are finally used as inputs for the IO-Analysis (see Figure 3), which results in changes in value added in related economic sectors. These changes are then translated to additional gross employment using country and sector specific employment coefficients, which are for example provided by the German Federal Statistical Office (destatis). Another source

5. For detailed information on Input-Output-Modeling see e.g. Miller, Blair 2009.

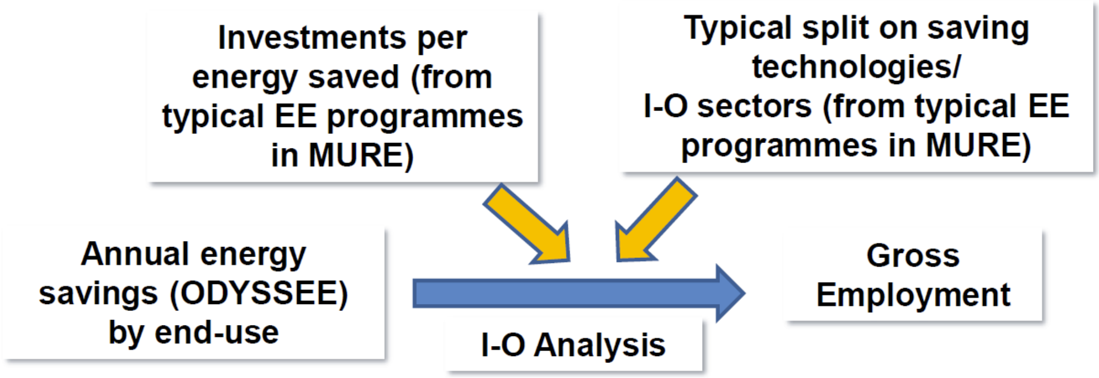

Figure 3. Schematic for the process of calculating employment effects in the framework.

for energy savings as an input for the indicator is the ODYSSEE database, which provides top-down energy savings by end-use and sector.

Impact on asset value

Eichholtz et al. (2010) found, that buildings with a certification of high energy efficiency generate a rent about 7 percent higher than otherwise identical buildings and realize an increase of selling prices by 16 percent. Another more recent study by Eichholtz et al. (2013) found that for buildings in the US rated as energy efficient by the LEED[6] or 'Energy Star' standard, a USD 1 saving in energy costs per square-foot on average results in a 3.5 % higher rent and a 4.9 % premium in market valuation. For office buildings in the US the EPA (2006) reports that a USD 0.50 per square-foot annual reduction in energy costs results in an asset valuation increase of USD 5.90 per square-foot.

However, these values differ significantly between countries and even regions, as tighter housing markets do tend to recognize energy efficiency to a lesser degree. This makes it difficult to find an easily applicable indicator that is suitable for all countries we are considering. National evaluations of the effects of certain energy labels or building standards on rent per m² or selling price can help to establish a first starting point for the development of this indicator.

Energy security (A) – Import dependency

Many countries in the European Union are highly depended on a few suppliers of fossil fuels, like oil and natural. Such dependence leaves them vulnerable to supply disruptions, whether caused by political or commercial disputes, or infrastructure failure. For example, the dispute about gas transports between Russia and the transit-country Ukraine in 2009, left many EU countries with severe shortages. As a reaction the European Commission released its Energy Security Strategy in 2014, which among others states an increase of energy efficiency (with a focus on industry and buildings) and achievement of the proposed 2030 energy and climate goals as a long-term measure against the energy import dependency of the EU (European Commission 2014b).

Energy import dependency shows the extent to which a country relies upon imports in order to meet its energy needs.

6. "Leadership in Energy and Environmental Design": building certification standard developed by the U.S. Green Building Council.

It is calculated based on the following formula also used by statistics institutes such as Eurostat:

$$\frac{net\ imports}{(gross\ inland\ consumption + bunkers)}$$

A negative dependency rate indicates a net exporter of energy, while a dependency rate in excess of 1 indicates that energy products have been stocked (European Commission 2015b).

To estimate the impact of energy efficiency on the import dependency of a country we calculate in a first step the final energy consumption by energy carrier (i.e. electricity, fossil fuels, etc.) avoided by energy efficiency. Final energy savings by end-use and sector are available from the ODYSSEE-database. These are translated to energy savings by fuel based on typical energy carrier breakdown per end-use. Ensuing we calculate the resulting avoided primary energy supply by energy carrier using national primary energy factors, which is then used to calculate a counterfactual import dependency (for the sum of actual imports and calculated avoided imports). The difference between this counterfactual value and the actual import dependency (e.g. provided by Eurostat) represents the estimated effect of energy efficiency on the import dependency of a country.

Results

In this chapter, we present first results for selected indicators from our framework. These results are based on preliminary data. In particular, the time periods considered here will be extended in future work for a variety of these indicators.

ANNUAL ENERGY SAVINGS

Table 2 shows the final energy savings by energy carrier for Germany calculated from data available from the ODYSSEE database. These are the basis for several other indicators in our framework.

Compared to energy savings from the NEEAP of Germany the ODYSSEE savings are in the case of Germany significantly smaller (about 40 %).

ALLEVIATION OF ENERGY POVERTY

Total final savings by energy efficiency in households in Germany amounted to about 3900 GWh in 2014 (ODYSSEE 2016). Assuming an equal distribution of these savings over all households this lead to a saving of about 96 kWh per household for

Table 2. Final energy savings for Germany from 2008 to 2012 by energy carrier (Source: ODYSSEE).

Energy carrier [PJ]	2008	2009	2010	2011	2012
Coal	7.1	10.7	18.4	24.7	25.9
Oil products	57.6	100.5	135.8	169.4	185.0
Gas	35.5	62.4	93.1	110.4	121.5
Heat	7.3	13.1	18.7	21.6	26.7
Renewables	8.5	16.2	27.4	33.8	35.2
Electricity	30.4	52.4	75.1	96.4	103.8
Total	146.5	255.3	368.4	456.3	498.1

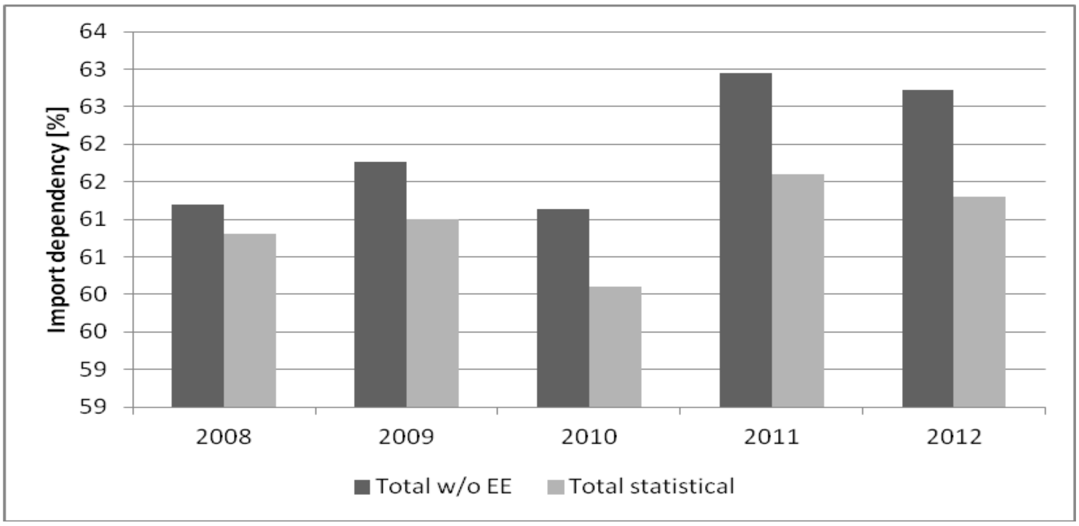

Figure 4. Comparison of import dependency (own calculations, based on ODYSSEE and Eurostat).

this particular year. This equals to 0.6 % of the average final energy consumption of a household in Germany.

For the impact of energy efficiency on energy poverty, these energy savings resulted in an average reduction of the share of energy cost in the net household income by 0.05 %p. For 'energy poor' households fulfilling the criterion of an expenditure of at least 10 % of the net household income for energy this reduction equals to 0.13 %p or 1.5 % of the household's energy cost. This group is represented in the first decile of the distribution of net equivalent household income. Households among the bottom 5 % of net household income face an expenditure for energy of almost 12 % of the household income (Schumacher et al. 2016). However, as energy poor households usually do only benefit from energy efficiency measures to a lesser degree than average households this estimated effect might be overestimated (Ugarte et al. 2016).

IMPORT DEPENDENCY

Our analysis of the effect of energy efficiency for Germany shows a difference in energy import dependency of 1 %p in average for the years 2008 to 2012 (see Figure 4). The highest impacts can be observed in import dependency of coal (0.6 %p in 2008, 1.4 %p in 2012) and the lowest on the import dependency of oil products (0.04 %p to 0.2 %p). This difference in impact is mainly due to the high net imports of oil products (about 4,500 PJ in 2012 or over 50 % of total net imports) and the relatively small energy savings regarding this energy carrier. Thus, the effect of these savings on the import dependency of oil is only of minor extent.

EMPLOYMENT EFFECTS

In 2015, investments triggered by the KfW programme "Energy-efficient Refurbishment" amounted to €6,368 M. In total, they led to estimated final energy savings of about 5 PJ (IWU, Fraunhofer IFAM 2016). In line with the evaluation of this programme, for our analysis we assumed that 80 % percent of the investments are consumed by finishing and installation works, which equals to €5,094.4 M.

Our IO analysis is based on a symmetric product-product table at basic prices. Therefore, to use the identified investments from the KfW programme as an input variable for the IO analysis, the German value added tax of 19 % percent must be deducted to get basic prices.

Taking this into account, the original investments of €5,094.4 M in the finishing and installation industry are represented as an increase in demand of the constructions by €4281 M. As a result of the IO analysis, the value added of the construction works rises by net €2,472 M. Thus, multiplied with the employment coefficient of 17.45 employees per M€ GVA for the finishing and installation works provided by destatis (2015b) this investment lead to a direct employment effect of approx. 51,000 workplaces in this sector, which corresponds to approx. 59,000 person years[7]. Moreover, we can draw the conclusion, that approx. 10,200 work places per PJ saved are created.

In contrast to our results, evaluations of the KfW programme "Energy-efficient Refurbishment" estimate the creation of 54,000 person-years in the sector construction (IWU, Fraunhofer IFAM 2016).

For the KfW programme "Energy-efficient Construction" we estimate that approx. 240,000 work places as a direct effect are created, while the KfW evaluation of the programme expects the creation of 254,000 person-years. In this calculation, we use the average employment coefficients of the finishing and installation industry and the general building construction (16.36 employees per M€ GVA).

Furthermore, we have also analysed the impact of the Home Energy Efficiency Scheme (HEES) in the UK, which targeted energy improvements in residential buildings, particularly for low-income households. Within its first phase from 1991 to 1996 it led to annual average expenditures in energy efficiency measures of £104 M/a (Wade et al. 2000). Analogue to the assessment of the KfW programmes, the IO analysis indicates that the HEES programme directly created an annual employment of approx. 1,145 person-years, with an adjusted employment coefficient of 22.21 employees per M£ GVA for the UK construction sector. In comparison, the programme evaluation of the Association for the Conservation of Energy suggests an annual job creation of 1,300 person-years (ACE 2000).

Discussion

As a result of our analyses we presented first results for an indicator framework to multiple benefits. These show the effects of energy efficiency in Germany as final energy savings, reduction of import dependency and additional employment in the construction sector.

In this section, we focus on the discussion of methodological approaches within our framework. First of all, availability of data in general is a problem regarding certain aspects of our approach, especially for health and living comfort and also impacts on asset values, which constitutes a starting point for efforts to collect data on these topics on a national level.

Also, Table 1, which is giving an overview of the indicators we use in our framework, shows a seemingly unequal distribution of indicators over the three main categories environmental, social and economic. Especially social aspects seem to be inadequately represented. This is, on one hand, due to the limitations regarding implementation of indicators with justifiable effort for these aspects and, on the other hand, the strong interconnection of social impacts with economic impacts. So, for instance, employment, competiveness and energy prices, which are classified as economic aspects in our framework, have strong relations to disposable household income and thus to energy poverty as well as health and well-being.

Some other aspects of energy efficiency are not yet covered neither in other approaches (e.g. by the IEA) nor in our framework. For instance, one missing aspect would be the other less-known impacts of air pollution in addition to health impacts, as there are impacts on crops and forests by both lower atmosphere ozone and acidifying emission. These are, however, outweighed in monetary terms by health impacts at least by a couple of orders of magnitude. Yet one more aspect not covered would the risks of destruction 'cultural heritage' by soiling and corrosion of historic buildings and monuments. This would be an extension to the asset values, which are already included in our MB approach. However, data collection - especially for all countries considered – would require too much effort.

In our framework we use data on final energy savings from two sources, namely ODYSSEE for top-down savings and MURE for bottom-up savings. Bottom-up data is often more reliable, because it is more based on actual monitoring data and comprehensive evaluations. Top-down data also may indicate zero savings or even negative savings while, at the same time, bottom-up can confirm that even large savings have actually taken place. However, bottom-up evaluations often do not distinguish the types of energy carrier in which the savings occur, which is essential for the calculation of emissions (CO_2 and pollutants). This makes further research on a national level regarding a reliable break-down method of bottom-up saving necessary.

In a way top-down savings also show how other impacts are "destroying" bottom-up savings of energy efficiency policies, and this message is also valuable. We aim to reflect these "dialectics" of savings in our MB approach with appropriate communication.

Another challenge is to enable the correct interpretation of the indicators, which may require additional knowledge on methods and coherences between indicators. We aim to provide such knowledge in an easily usable way in the form of an online web tool in incorporating our framework.

Thus, our indicator approach still needs further development to assure consistent and comprehensive results for all countries of the EU28 (plus Norway, Switzerland and Serbia).

Outlook and conclusion

At this point our indicator set covers a decent share of the aspects of the multiple benefits of energy efficiency. However, further research and development will be necessary in the future to expand our measurement approach to all countries we would like to include in a consistent and comparable way. Also, collection of data that is not available at the moment in a reliable quality or sufficient coverage will require large effort. However, more reliable data on some aspects will be available in near future: e.g. data on demand response potentials by country will be available from the current project REFLEX[8]. Furthermore, more detailed national data on certain aspects of our framework will be provided by national partners within the ODYSSEE-MURE project to enrich the data base of our indicator set.

In a next step an extension of our IO analysis to GDP effect and also indirect employments effects will be included and also applied to other types of energy efficiency programmes than those focusing on buildings. Furthermore, this analysis will be

7. Assuming an estimated employment effect of 13.8 person years per M€ net revenue (IWU, Fraunhofer IFAM 2016)

8. http://reflex-project.eu/

carried out for all countries considered in our framework based on the IO tables provided by Eurostat.

We aim to transfer all information we collected and approaches we developed in a comprehensive and easily accessible online web tool within the project website of ODYSSEE-MURE.

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