Identifying current knowledge, suggestions and conclusions from existing literature

Work Package 3 – Task 3.1

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Preface

Several barriers limit energy efficiency policy evaluation. This results in a lack of quantitative data, and impedes evidence-based analysis required to distinguish effective from ineffective energy efficiency policies. EPATEE aims at tackling this problem by raising the capacity of policymakers and implementers. The project provides them both with tools and with practical knowledge to make effective impact evaluation an integral part of the policy cycle. EPATEE makes use of existing evaluation experiences in a range of instruments, such as energy efficiency obligation schemes, regulations, financial incentives and voluntary agreements. Experience sharing is the core of the project. Lessons learnt from other EU initiatives and good practices in how to successfully evaluate the impact and cost-effectiveness of such energy efficiency policies will provide the basis for the development of guidelines and good practice evaluation tools. For further information please visit our website: www.epatee.eu

This report briefly describes the use and content of the Knowledge Base – an accessible online data base on policy evaluation studies. References to certain issues such as free-rider effects are provided in the corresponding review sections. In addition, the report takes up some insights gained from reviewing the evaluation studies listed in the Knowledge Base. One key issue is the purpose of evaluations and the corresponding energy savings assessed. Another key issue is efficiency or cost effectiveness, as this metric relies on the type of costs and energy savings. Finally, the scope of the evaluation is extended to further impacts of energy efficiency measures, with a particular focus on macroeconomic impacts, their meaning and comparability.

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1 | Introduction

1.1 Background of this report

Energy efficiency is one key area of the EU Energy Union's Clean Energy package to achieve the goals of a sustainable, secure, affordable and competitive energy supply and to combat climate change[1]. Promoting energy efficiency is also grounded on the fact that energy efficiency improvements can bring multiple benefits. Further, improved energy efficiency can contribute to various objectives such as reduction in national fossil fuel consumption and greenhouse gas emissions, reduced consumer expenditures for energy services, secure energy supply, economic growth, new jobs and increasing industrial competitiveness (International Energy Agency (IEA) 2014)[2].

However, there are barriers and market failures (Brown 2001; Weber 1997; Paramonova and Thollander 2016; Jaffe and Stavins 1994; Bukarica and Robić 2013) that hinder the diffusion of energy efficient behaviour and technologies across all stages of the energy service supply chain, leading to energy efficiency investments below the social optimum. The gradual diffusion of cost-effective energy efficiency interventions below the social optimum has been termed the "energy efficiency gap" in literature, and the erosion of this gap can be achieved through the identification and remediation of both economic market failures and further economic and non-market/behavioural barriers (Hirst 1990). Economic and behavioural non-market barriers, defined through social approaches, do not explicitly conflict with the market, but are conditions which lead to sub-optimal investment or uptake into energy efficiency (Bukarica and Robić 2013). In contrast, under market failure, the market does not create the conditions for the development and/or access of appropriate technologies for the economy to reach the cost-effective optimum of technology diffusion. The persistence of market failure and non-market barriers necessitates the intervention from public policies (Jaffe and Stavins 1994).

Founded on this line of argumentation, the EU has approved a series of legislations, during the last years the Energy Efficiency Directive in 2012 (EED, 2012/27/EU) with a recast adopted in June 2018[3], the Energy Performance of Buildings Directive (EPBD, 2010/31/EU then 2018/844) in 2010 with a recast in 2018, the Energy Labelling Directive with a recast in 2017, the Renewable Energy Directive (RED, 2009/28/EC) in 2009 with a proposed update in 2016. The key aspect of the EED is the requirement for Member States to implement measures allowing reaching the EU's 20% energy efficiency target by 2020 (even if each EU countries have to set their own indicative national energy efficiency targets in primary or final energy). Member States may implement measures and policies that are most appropriate for their individual resources and needs. However, a key mandatory aspect of the EED is the requirement for Member States to report to the European Commission their results in National Energy Efficiency Action Plans (NEEAPs) every three years, as well as to inform in annual reports more specifically on results about EED Article 7. This includes ex-ante evaluations that present energy savings expected from the measures to be implemented in coming years, as well as ex-post evaluations, including monitoring of actual target achievements.

Lately, 'considerable progress' has been made towards the energy efficiency targets in the EU; as of 2017, there has been a 50% reduction in the consumption of buildings in relation to figures from the

[1] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
[2] See also the results of the COMBI projects: https://combi-project.eu/
[3] For an overview of the recast of Directives included in the Clean Energy Package and more details about the objectives beyond 2020, see: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans

1980s and energy intensity has decreased by 16% between 2005 and 2014 (European Commission 2017). The period from 2005 to 2014 showed rapid progress towards energy efficiency targets across Member States, as a result of the development of a diverse and appropriate policy mix (EEA 2017). A review published by the Odyssee-Mure (2015) states that financial instruments are the most implemented and well-developed policy measures to assist the diffusion of energy efficiency improvements within the European Union, and with a focus on the residential and industrial sector. However, the EEA (2017) states that further efforts are required across Member States to abate the effects of more recent increased energy consumption since 2014 in order to meet the 2020 and 2030 targets. With the European Commission (2017) and EEA (2017) stating that there has been unequivocal progress towards an energy efficient system, the implication is that there is a robust understanding on how to achieve the efficiency targets in a cost efficient way. Thus, necessary resources and efforts have to be set aside for implementation and evaluation of energy support policies ensuring that robust, timely and effective evaluation of the policy implementation may improve and strongly contribute to growing efficiency and hence target achievement.

1.2 Expected outputs

The concept of 'evaluation' related to energy efficiency policies and programmes is a diverse and multi-faceted one, but importance attributed to effective evaluations is recognised by the European Commission, as part of the general "better regulation" strategy[4]. In 2017 the Evaluation into Practice to Achieve Targets for Energy Efficiency (EPATEE (https://epatee.eu/)) project was selected within the EU Horizon 2020 programme, after a call for proposals to add further strength to the effectiveness of the energy efficiency policy mix within the EU by engaging and activating public authorities. The project provides policymakers and implementers with tools and practical knowledge to ensure that impact evaluations within the EU become an integral part of the policy process. A review of current evaluation practices aims to deliver practical materials to be used for the development of a toolbox which aims to reduce the inaccessibility of information of energy efficiency evaluations and help to improve policy design and hence effectiveness of policies.

The analysis presented in this report draws on available published literature to develop a collection of studies that outline the features and shortcomings of energy efficiency evaluations. This collection of studies will be referred to as the Knowledge Base henceforth. The goal of this report is to describe the Knowledge Base in a structured manner, point out some distinctive features of the reviewed evaluation studies, discuss gaps and inconsistencies and provide suggestions how to improve the quality and transparency of evaluations.

The partners for the project are as follows: Austrian Energy Agency (AEA); Agence de l'environnement et de la maîtrise de l'energie (ADEME); Association technique énergie environnement (ATEE); Stiching Energieonderzoek Centrum Nederland (ECN)[5]; Energetski Institut Hrvoje Pozar (EIHP); Federazione Italiana per L'uso Razionale Dell'energia (FIRE); Fraunhofer Institute for Systems and Innovation Research ISI; Institute for European energy and climate policy (IEECP); Lietuvos energetikos institutas (LEI); Motiva Oy (Motiva). These organisations will be referred to collectively as the project partners where appropriate throughout the report.

In the following, the approach that was applied to develop the Knowledge Base in line with the EPATEE requirements will be introduced. After the presentation of the formation of the Knowledge Base, the information that is included within the Knowledge Base is provided in the results section. Finally, the

[4] https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en
[5] As of 1 April 2018, ECN is part of TNO

contained information will be synthesised: gaps, suggestions and extensions are summarised in a concluding chapter.

2 | Knowledge Base

2.1 Brief description of the Knowledge Base

In the framework of the project EPATEE, a Knowledge Base is developed and made available in the result section of the EPATEE webpage (https://epatee.eu/). The objective of setting up such a database is to collect and make information available for experience sharing and capacity building, but not to be representative nor exhaustive. As of January 2018, it includes about 180 studies, on which the following literature review and discussion is based.

The Knowledge Base comprises bibliographic as well as other information about the main features of the studies such as on type of study, type of policy instrument, sectors, geographical scope, language, year of publication, type and objective of evaluation, data collection and calculation methods as well as on the baseline scenarios, normalization and adjustments effects and impacts apart from energy savings. The type of studies comprise empirical (evaluation reports and papers) and analytical (guidelines, methodological and meta-evaluation papers) publications. The priority was on collecting studies about ex-post evaluations done in Europe. However publications from outside Europe or about ex-ante evaluations were also included when relevant.

A large bulk of evaluations comes from the United Kingdom. This is grounded on the fact that in the UK, evaluations of policies have been part of the policy packages for many years and that English is the common language of the project team. Evaluations in other languages are indeed more difficult to find, as they might not be well referenced in search engines or might not be available online at all. There might be strong bias towards known publications, country coverage and language. The residential sector, which typically employs financial or fiscal support measures, is largely presented in the Knowledge Base. This can be partly explained by the emphasis put on these policies in Member States' energy efficiency strategy as noted in (Odyssee-Mure, 2015). At the opposite, agriculture gets little notice, which is also reflected by the fewer number of policies for this sector in the NEEAPs. Aiming at a sample of studies representative of evaluations done in EU Member States would have required an extensive survey that was not possible within this project. This limitation restricts the possible quantitative conclusions that may be drawn regarding coverage, usage or practice of evaluations. However, a particular attention was paid to gather studies that enable to cover a broad diversity of situations.

All information of the Knowledge Base will feed an online toolbox, which will be accessible through the EPATEE website. Users can do a direct online-search in the Knowledge Base as well, which is available on the same website. The online search of the Knowledge Base allows searching in both a simple search (Search by categories as indicated in Figure 1) and advanced type of search (see Figure 2).

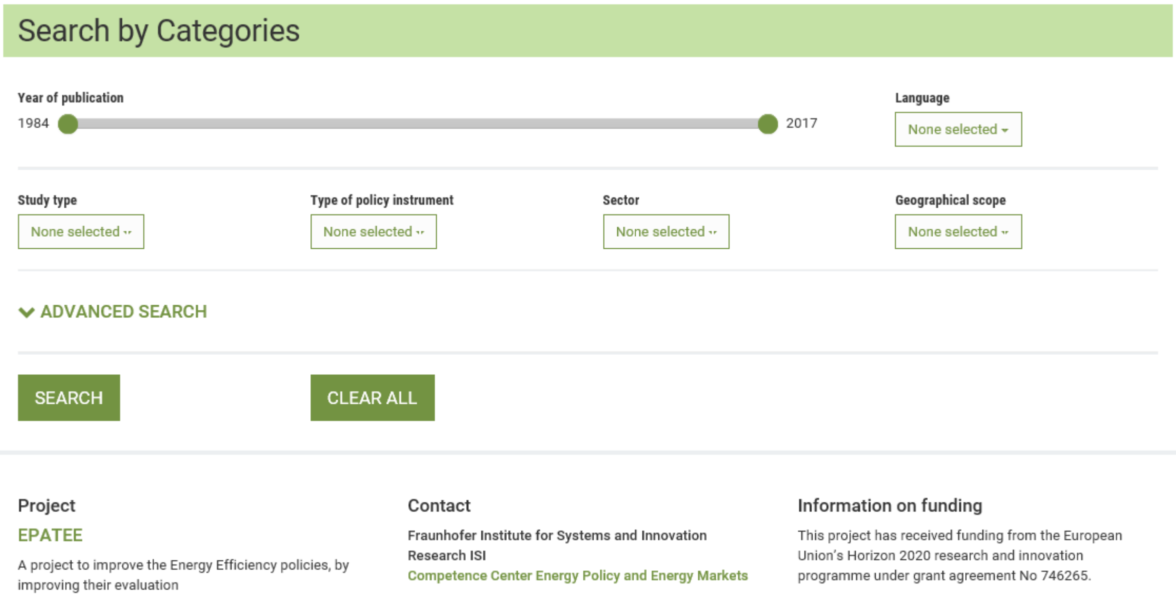


Figure 1: Simple search option in the Knowledge Base

The simple search (Search by Categories as indicated in Figure 1) allows searching by type of study, policy instrument, sector and geographical scope. An advanced search is feasible allowing for searching by all criteria as outlined in the section overview of the current content of the Knowledge Base (see Figure 2). The typologies used to code the references for these criteria are detailed in section 2.3.

Multiple selections within a category are possible. That is, a user can search for more than one policy type or sector. In addition, the studies are linked to the more detailed case studies about particular policy evaluations or evaluation methodologies that were elaborated in the EPATEE project.

The output of the online search contains all information on the criteria that are selected as well as the title of the study, the internet address (if available) and the study as pdf (Portable Document Format) if available and publicly accessible. To keep the Knowledge Base, and hence also the toolbox, updated, it is considered as a living tool. This means that further or new studies, which are recommended by users will be added on an annual basis by the project team. Before the updating, the project team briefly reviews the recommended evaluation studies.

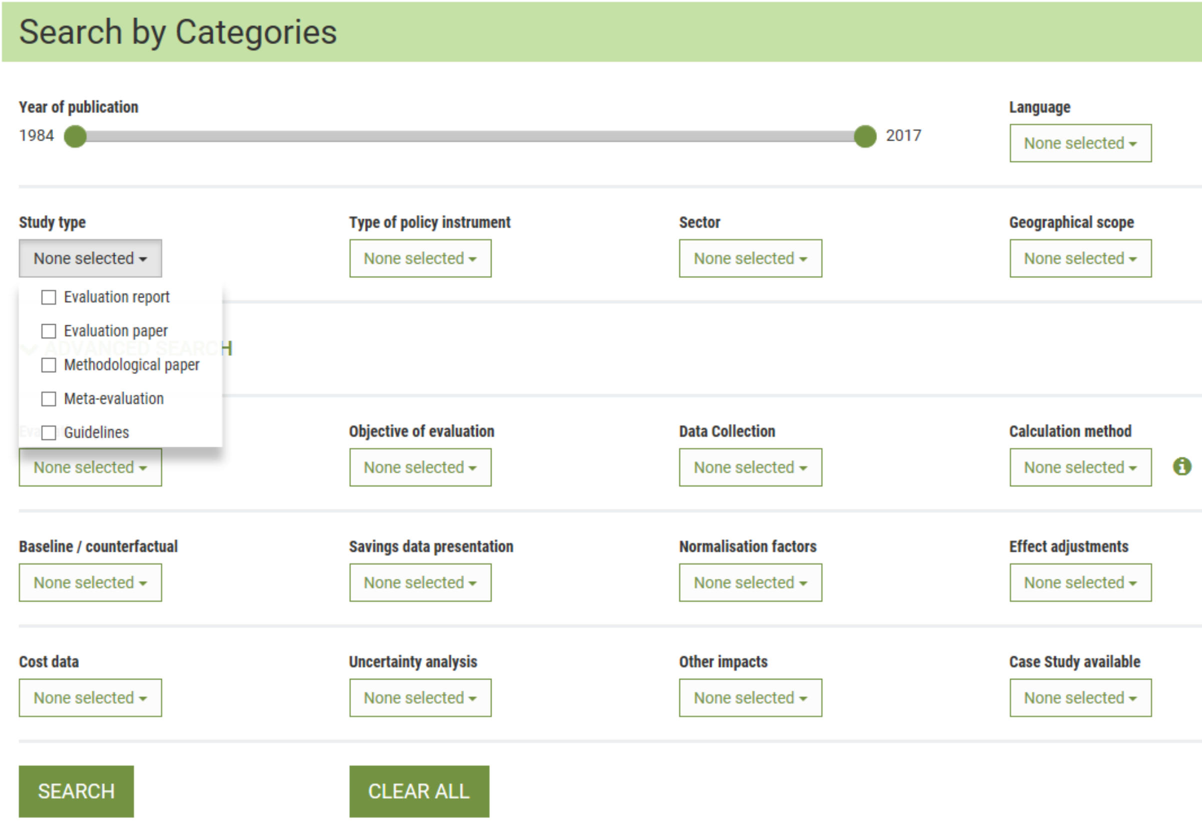


Figure 2: Advanced search option in the Knowledge Base

2.2 Setting up the Knowledge Base

In a first step, research-oriented search engines, i.e. the Web of Science and Google Scholar were used as it was assumed to find good-quality evaluations. In a next step, the sample was complemented by supplementary sources suggested from project partners. The Web of Science research was based on a keyword search such as “energy efficien* evaluation”, “energy efficiency policy evaluation” to select peer-reviewed journal articles and conference proceedings. The search results were subsequently refined by reading the abstract of the papers to ensure relevance to the prescribed literature criteria. Google Scholar was used to complement the Web of Science research as it includes some evaluation reports or guidelines when quoted in scientific papers.

Moreover, evaluations based on the recommendation of project partners are included to ensure a larger coverage of EU Member States and the inclusion of papers in other languages than English. In addition, specific keywords were searched in Web of Science and sorted by the number of citations for specific methodological issues to ensure that a holistic understanding of the constituent aspects of the Knowledge Base was formed (e.g. energy efficiency + rebound effect, energy efficiency + spill-over, energy efficiency + free-rider). After the review of initial literature, a short review of recently released (2015-2017) conference papers from the ECEEE, IEPEC and IEPPEC[6] were reviewed to contextualise the

[6] European Council for an Energy Efficient Economy: http://www.eceee.org ; International Energy Program Evaluation Conference (North America, since 1989): http://www.iepec.org ; International Energy Policy & Programme Evaluation Conference (Europe since 2010, and Asia Pacific since 2017): http://www.ieppec.org

already reviewed literature and add a greater depth of understanding to the framing of energy efficiency evaluations.

A final stage of the review process was carried out within the project team to ensure that key methodological papers and evaluations that had not been initially included within the Knowledge Base would be included. This phase involved scanning the already reviewed evaluation papers to reference check the methodologies that were employed within them and searching for the relevant papers, again using the Web of Science portal. When the final collection process was completed, project partners were requested to check and verify that all reports or papers they consider as crucial were included.

The references were coded in a systematic way to enable searches on homogenous typologies and present the references in a harmonised way. Due to intellectual property rights, full-text files were not included and, subsequently, no full-text search is available. When the literature was collated, the Knowledge Base was proofed to ensure that bibliographic information was correct, and that common errors in data entry were not present.

Because the Knowledge Base is seen as a living tool that will be updated on an annual basis, number, types of evaluation studies, policies included in the database is likely to alter over time. Beyond this, focused searches with general search engines such as Google are planned in a later stage of the project, to get a more extensive view of what is available in the grey literature.

2.3 Scope of information in the Knowledge Base

In the following the main types of information about the studies that are available in the Knowledge Base is presented. When a user makes a search in the base, the first result is a **list of references** (Figure 3).

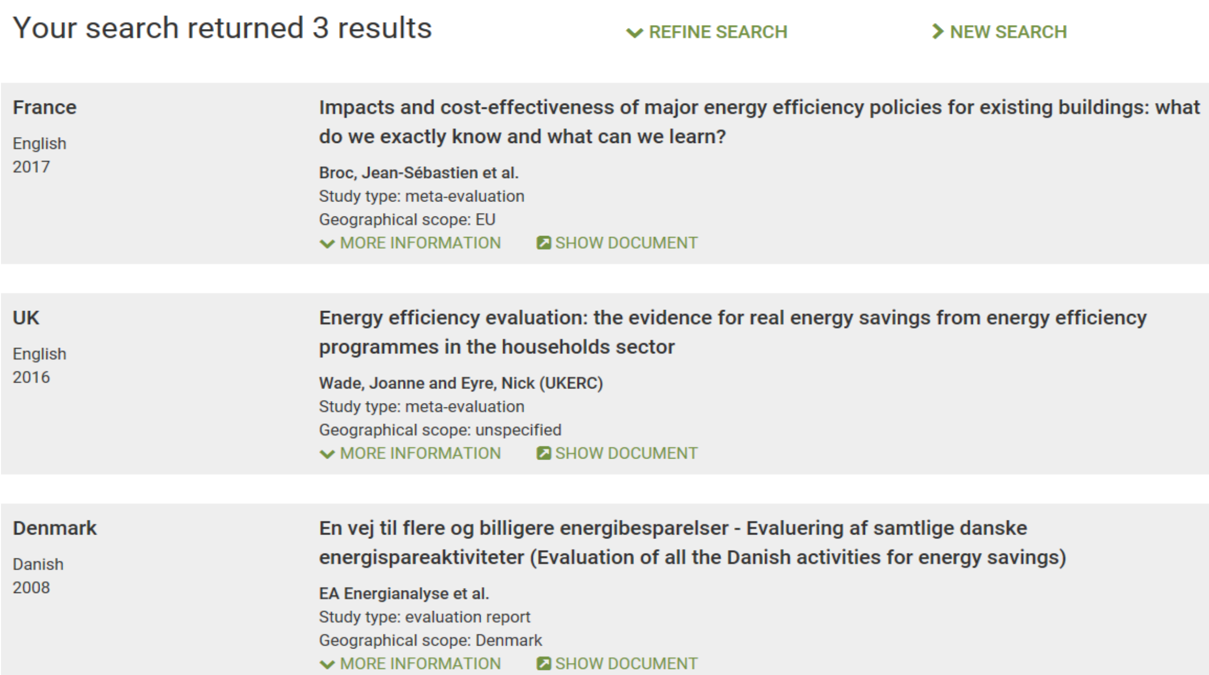
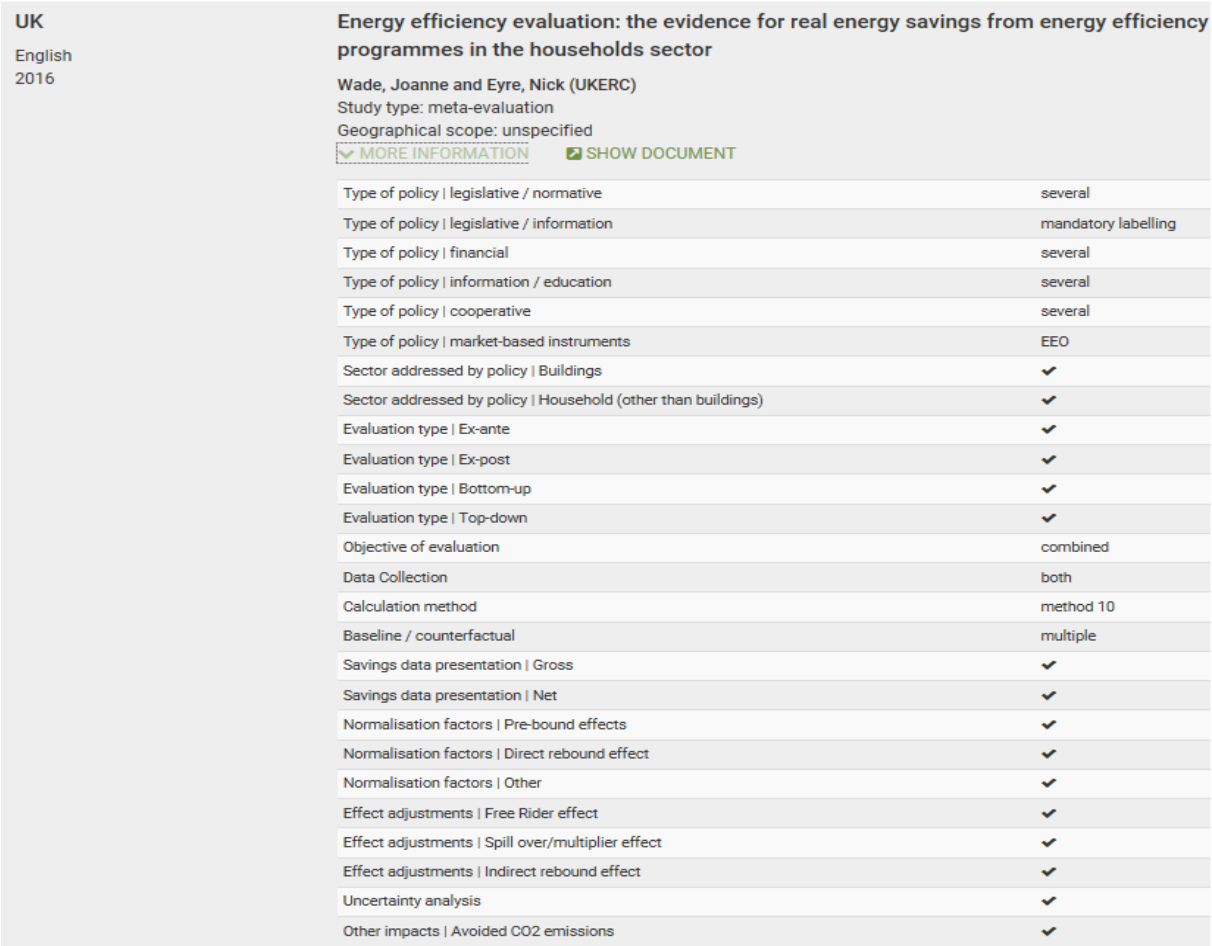


Figure 3: Search results: found references

Then the user can get more details about each reference by clicking on the "**more information**" button of one of the references listed in Figure 4. These details correspond to the information systematically coded for each reference entered in the base, and presented by type of information in the continuation of this section.



UK
English
2016

Energy efficiency evaluation: the evidence for real energy savings from energy efficiency programmes in the households sector

Wade, Joanne and Eyre, Nick (UKERC)
Study type: meta-evaluation
Geographical scope: unspecified
MORE INFORMATION SHOW DOCUMENT

Type of policy | legislative / normative	several
Type of policy | legislative / information	mandatory labelling
Type of policy | financial	several
Type of policy | information / education	several
Type of policy | cooperative	several
Type of policy | market-based instruments	EEO
Sector addressed by policy | Buildings	✔
Sector addressed by policy | Household (other than buildings)	✔
Evaluation type | Ex-ante	✔
Evaluation type | Ex-post	✔
Evaluation type | Bottom-up	✔
Evaluation type | Top-down	✔
Objective of evaluation	combined
Data Collection	both
Calculation method	method 10
Baseline / counterfactual	multiple
Savings data presentation | Gross	✔
Savings data presentation | Net	✔
Normalisation factors | Pre-bound effects	✔
Normalisation factors | Direct rebound effect	✔
Normalisation factors | Other	✔
Effect adjustments | Free Rider effect	✔
Effect adjustments | Spill over/multiplier effect	✔
Effect adjustments | Indirect rebound effect	✔
Uncertainty analysis	✔
Other impacts | Avoided CO2 emissions	✔

Figure 4: Search results: information of selected reference

2.3.1 Bibliographic considerations

Given the objective to make information available and accessible, the inclusion of accurate and relevant bibliographic information is imperative for all types of studies. Thus it is ensured that the listed sources include the source, the author or authoring organisation, origin, geography, year of publication, language and type of study as presented in Table 1.

Table 1: Bibliographic categories within the Knowledge Base

Bibliographic Category	Information Included
Source	If available and possible a direct link to evaluation reports, guidelines or conference papers; for journal paper the digital object identifier (DOI), if available.
Author or organisation	Name of first author or the organisation that carried out the evaluation
Origin	Country of origin of first author/organisation
Year of publication	The year when the study is published
Language of publication	

Bibliographic Category	Information Included
Geography	Country(ies) in which the efficiency policy/programme is evaluated
Type of study	Evaluation paper, evaluation report, methodological paper, meta-evaluation, or guidelines

The framework of EPATEE has a focus on the state of knowledge within the European Union, and therefore evaluation sources from within the European Union are of highest priority for inclusion. It is desirable for sources from each Member State to be considered, however limits on resources (or the geographical coverage of project partners) mean that language and expertise of sources from all EU Member States is not possible within the context of this report. As far as possible, sources from a diverse range of EU countries should be included. Nevertheless, there is still a certain lack of evaluations in Central/Eastern European regions in the Knowledge Base.

The EU-centrism of the project does not exclude relevant examples from outside of the European Union. This is sensible as there are established evaluation practices within the USA that have high relevance to the evaluation practices within the European Union. Therefore, exemplary sources (available in English) from outside of the European Union are included in the review process as well. More specifically about USA, the regulatory framework for energy efficiency programmes makes that most utility programmes are evaluated due to the obligation of utilities to report to Public Utility Commissions in many of the states. Including all these reports would have overwhelmed the Knowledge Base, and thereby its users. To illustrate this, the CALMAC website[7] that gathers evaluations done in California alone includes 1,287 references (when checked on May 2018). Therefore it was decided to include references that provide a synthesis of the US experience, particularly from the Uniform Methods Project[8].

The evaluation studies are grouped into five literature typologies to simplify the search process, to provide information on the type of study and to ensure that the users of the Knowledge Base have preliminary information on the level of robustness of the information. The five groups are:

- **Evaluation reports**: an evaluation of an existing energy efficiency policy or programme (EEP) in a given country or region; commonly carried out by a third party as commissioned by the implementer.
- **Evaluation paper**: a peer reviewed paper included in scientific journals or presented at the IEPEC, IEPPEC or ECEEE conference which discusses specific policy evaluations or methodological approaches.
- **Methodological paper**: a peer-reviewed paper that focusses on methodological issues which may or may not use case-study evaluations to supplement their discussion.
- **Meta-evaluations**: a review of several evaluation studies, generally focussing on secondary data sources.
- **Guidelines**: evaluation guidebooks, manuals and protocols describing evaluation methods to assist programme evaluators with their work.

Papers which are henceforth defined as **empirical papers** are evaluation papers and evaluation reports on energy efficiency evaluations. Their results are specific to a given case. Papers which are henceforth

[7] http://www.calmac.org/search.asp
[8] https://energy.gov/eere/about-us/ump-protocols

defined as **analytical papers** are methodological papers, meta-evaluations and guidelines of energy efficiency evaluations.

2.3.2 Data collection methods

The data collection method present in the Knowledge Base refers to whether the data was directly collected by the evaluator for the purpose of the study; this may or may not be specific measured data, deemed savings or diffusion indicators:

- **Primary data collection methods**: are data explicitly collected for the purpose of the evaluation, this may include surveyed data from participants, metered data from an end use energy service, energy billing data or diffusion indicators such as number of stocks sold.
- **Secondary data collection methods**: are data collected from other sources such as national statistics for diffusion indicators, or modelled or estimated data from readily available sources or other studies.

In case, both, primary and secondary data are used, the option "both" is indicated, whereas not specified is indicated in cases where the evaluation does not explicitly state the data source.

2.3.3 Energy efficiency policies (EEP) and sectors

All types of energy efficiency policies, programmes or measures that support increased uptake of existing efficient technologies, or change the way in which a technology is used, which in turn results in energy savings, were included in the review. The policy instruments were categorised (see Table 2) following the framework of the ODYSEE-MURE project database (http://www.odyssee-mure.eu/; http://www.esd-ca.eu/Media/esdca/files/private/mure-guidelines) to contribute to further homogeneity within the energy efficiency discourse in the European Union and to ensure that a common framework for discussions may be maintained.

Table 2: Policy instruments within the Knowledge Base

Policy Instrument Name	Included measures
Legislative - Normative	Mandatory standards, mandatory demand side management (DSM), regulations on buildings, heating systems, vehicles
Legislative - Informative	Mandatory audits, mandatory energy managers/management systems, building certificates, mandatory labelling
Financial	Grants, subsidised loans, others, several instruments
Fiscal/Tariffs	Eco- or energy taxes, CO_2 taxes, tax exemption or reductions, special depreciations
Information/Educational	Energy billing, information campaigns, voluntary energy audits, regional or local information centres, voluntary labelling
Co-operative measures	procurement, voluntary agreements, voluntary DSM measures, green procurement, ESCOs
Market based instruments	energy efficiency obligations (EEO), energy efficiency auctions/tender systems (EEA), emission trading systems or other similar schemes with allowances (ETS), Joint Implementation (JI) or Clean Development Mechanisms (CDM)

Note: The typology used in the Knowledge Bases is not exactly the same used in the latest version of the MURE database

The purpose of the Knowledge Base is to give a cohesive review of the evaluations that are available targeting all end-use sectors, as well as the energy sector (for measures on CHP, transmission or distribution networks). The sectors were also defined in accord with the ODYSEE-MURE database, as follows: Buildings (residential and non-residential), Households (other than buildings), Services (other than buildings), Industry (other than buildings), Agriculture, Energy Sector, and Transport. Policy instruments may target buildings indiscriminate of the sector, and therefore a separate sector for buildings was individually included to cater for these policies.

2.3.4 Types of evaluation

The broad general methodological approach that is applied for the type of evaluations is defined to be two evaluation types, or none, or a combination of both. These two types correspond to the two main purposes defined in the evaluation literature:

- **Impact evaluation** (summative purpose/accountability): primarily cases where specific energy savings are calculated, or assessments of diffusion indicators of technologies, or broader context impacts of costs.
- **Process evaluation** (formative purpose/learning): primarily bespoke evaluations that examine how and why the policy or programme has achieved the initial objective (or not), if some parts of the policy implementation went differently from what was planned, and how it may be improved using feedback from the perspective of programme administrators, end-users and other stakeholders.

If the evaluation combines or covers both impact and process evaluations, the “combined” is indicated whereas “other” is used in case of evaluation objectives that are not impact or process evaluations; typically, methodological papers that present specific methodological issues without the support of a case study. The focus of the evaluation literature selected for the Knowledge Base is impact evaluations which specifically ascertain actual energy savings, while process evaluations focus on the measure implementation and improvements.

Furthermore, some evaluations report ex-ante energy savings, i.e. assessment of energy savings that are based on expected energy efficiency actions due to planned programmes and policies. Ex-post energy savings report on actually achieved energy savings when having implemented energy efficiency actions. There is a predominant selection of ex-post evaluations, i.e. on studies which evaluate energy savings after the implementation of the measure in the Knowledge Base. Exemplary empirical and analytical sources that present ex-ante evaluations of the energy efficiency within the European Union may be included, but ex-ante studies with a focus outside the European Union are excluded.

2.3.5 Calculation methods

The Knowledge Base aims to give evaluators quick access to information regarding calculation methodologies, and therefore the described energy savings calculation methods have been broken down into **9 separate methodologies**. These methodologies are presented in Table 3 (see guideline of the ODYSEE-MURE project database[9] or Schlomann and Eichhammer (2011)). An additional methodology, ‘Method 10’, is defined to ensure that process evaluations, or impact evaluations which apply diverse, unknown, or not specific methodologies may be effectively included within the data.

[9] http://www.esd-ca.eu/Media/esdca/files/private/mure-guidelines

The distinction between top-down and bottom-up methodologies that is pre-defined within the Knowledge Base draws upon the definitions as presented by Thomas et al (2011). Top-down methods monitor energy efficiency indicators that are defined by sector and/or type of end-use calculated from national averages, while bottom-up approaches use data and assessments at the level of the participants and aggregate it to evaluate the policy measure. The nuances within the bottom-up and top-down methods are diverse and show in some cases diverse combinations of methods. The guidelines included within the Knowledge Base discuss these issues in depth, and present the explicit calculation processes that must be followed in order to calculate energy savings.

Table 3**:** Energy saving methodologies within the Knowledge Base

Calculation Method	Typology
Bottom-up methods	
Method 1	**Direct measurement**: unitary energy savings are directly measured to measure actual energy savings
Method 2	**Unitary energy savings**: **billing analysis** or energy sales data are examined to describe energy consumption
Method 3	**Deemed estimates**: unitary energy savings are assumed to describe energy consumption
Method 4	**Mixed deemed and ex-post estimates**: unitary energy savings are determined by analysis of equipment or sales data, inspection of samples, or monitoring of equipment
Method 5	**Detailed engineering estimates**: complex modelling of a unit (building or company) is undertaken through detailed engineering methods
Mixed bottom-up/top-down methods	
Method 6	Modelling through **stock modelling** or simulation based on indicators
Method 7	Modelling based on **diffusion indicators** which is based on the share of specific equipment or practice in the market
Top-down methods	
Method 8	Monitoring of **energy consumption indicators** for sectors or sub-sectors; or specific indicators for an end-use equipment
Method 9	**Econometric models** or simulation at the aggregated level through the collection of price elasticity indicators
Others	
Method 10	The application of diverse methods, or methods which are not defined as above.

As can be seen from Table 3, the data collection of energy savings is an important factor in the selection of the appropriate methodology. The data collection is therefore implicitly defined through the calculation method criteria or vice versa.

2.3.6 Baselines

Energy savings are by essence a quantity that is defined by a comparison between two situations: the reference situation (or baseline) and the situation after the implementation of the energy efficiency action. An explicit definition of the baseline is therefore essential to the understanding of the calculated energy savings. The baseline is the construction of a hypothetical level of energy consumption, sometimes also called counterfactual when aiming at distinguishing the impacts of a measure or package of measures from changes due to other factors. The counterfactual is the assumption of what would have occurred in the absence of the measure(s). By essence, it has not occurred and is unobservable for exactly the same group under the same circumstances.

Table 4: Types of baselines defined for the Knowledge Base

Type of baseline	Description
Before/after	Metered energy consumption for the site, equipment etc. where an energy efficiency action was implemented before and after the implementation of the action. The “before” situation can also be defined based on stock average about buildings, equipment, etc. or other statistics depending on data availability and evaluation objectives.
Control group	Energy consumption of end-users that are assumed to be comparable with the participants of the measure(s) evaluated. These end-users form the control group. This may be a Randomised Control Trial or Quasi-experimental control group. Comparisons between participants and a control groups, and before and after the measure can be combined, as for example when using difference-in-differences (DiD) methods.
Trend	Using a set of assumptions (for example, extrapolating trends observed in previous years, taking into account effects of policies already in place for many years) to define a business-as-usual scenario.
Minimum or performance standards	This type of baseline can for example be used when the evaluation objective is to assess energy savings beyond minimum energy performance requirements set in current regulations (e.g., national building codes, EU EcoDesign requirements). Thus, only savings exceeding standards are considered.

In addition to the baselines in Table 4, further options are indicated to cover and include a large number of studies in the Knowledge Base. These are:

- Multiple: when a study or evaluation considered more than one method to define the baseline.
- N/a: when a study or evaluation does not explicitly define how a baseline was constructed.

2.3.7 Adjustment factors

Depending on the type of baseline used to calculate the energy savings, evaluators may apply further analysis to consider exogenous factors to separate them from the impacts attributed to the measure(s) under evaluation. Correction and adjustment factors are usually distinguished in literature. While correction factors refer to factors used to normalise energy consumption (weather conditions, occupancy rates, production volumes), adjustment factors are factors used to distinguish gross and net energy savings, e.g. free-rider, spill-over. Gross savings are calculated as the difference in energy consumption with and without the energy efficiency action, normalised by correction factors. Net savings are derived from gross savings adjusted by the gross-net-factors.

The following correction and adjustment factors were prioritised for inclusion within the Knowledge Base and are described herein (see Table 5).

Table 5: Summary of correction and adjustment factors within the Knowledge Base

Correction/Adjustment Factors	Description
Performance gaps	Cases where the observed performance after the measure is installed is lower than the expected performance. E.g. differences in operating conditions or quality issues such as defects from installation or measurement
Non-compliance	Stipulations are not fulfilled by the programme recipient
Pre-bound effects	Cases where end-users consume less energy before the implementation of a measure than was estimated by engineering estimates
Direct rebound effects	Improved EE decreases the effective price of a service and subsequently increases consumption of that service, thus offsetting the reduction in energy consumption achieved by EE investments
Indirect rebound effect	Lower effective price of energy service may lead to changes in demand for other goods and services (e.g. lower energy bills allowing end-users more overseas holiday)
Spill over/multiplier effect	Additional reduction in energy consumption or demand that are due to programme influences beyond those directly associated with the programme participation
Free-rider effects	Users that benefit from the support, but would have implemented the measure even without the support (fully or to some extent)
Additionality	Energy savings that would not have been achieved in the absence of the measure
Double counting	Measures aiming at the same target (group or sector) can interact, either through the overlap of policies/programmes or through technical interactions

Performance gaps are one of the possible reasons of the difference between actual and calculated energy consumption. It may be caused by construction/installation mistakes, improper adjusting of equipment, excessive simplification of simulation models and occupant behaviour (rebound effect). Literature within the Knowledge Base only refers to performance gaps for references about buildings and other actions in the household sector.

Non-compliance is a factor that may be measured within evaluations so as to ascertain whether intended energy savings from mandated policies are actually occurring. Compliance evaluations refer to a set of processes and procedures through which information is provided, assessed and checked to determine whether codes and requirements are met.

Even if all technical conditions were correct, there can be a behavioural component which affects the resulting energy savings, the pre- or rebound effects: **Pre-bound effects** discuss the phenomenon in which occupants of energy inefficient buildings consume less than would be expected in the absence of an energy efficiency intervention (Galvin and Sunikka-Blank 2016). A **direct rebound effect** occurs when improved energy efficiency for a particular energy service will decrease the effective price of a service and will therefore lead to an increase in consumption of that service (Sorrell 2007). This could (partly) offset the expected reduction in energy consumption provided by the EEP. **Indirect or secondary rebound effect** occurs when the lower effective price of energy services as a result of an energy efficiency action will lead to changes in demand for other goods and services (Barker et al.

2007; Greening et al. 2000; Sorrell 2007). Those, indirect or so called economic rebound effects – or economy-wide rebound effects as Greening et al. (2000), Sorrell (2007) and Barker et al. (2007) call it – occur when a fall in the real price of energy services will reduce the price of intermediate and final goods throughout the economy, which in turn, leads to a series of price and quantity adjustments, with energy intensive goods and sectors gaining at the expense of less energy-intensive ones. Some studies argue that energy efficiency improvements may also increase economic growth, which may itself increase energy consumption. A macro-economic rebound effect considers both indirect and direct economic effects, and occurs when energy efficiency leads to economic stimulation through structural change in economic activity and new activities become economically viable (Barker et al. 2007).

Spill-over and multiplier effects are equivalent for Thomas et al. (2012) and arise from energy efficiency actions (EEA) that are realised without any further involvement of authorities, agencies or programmes. They can be unintended consequences of policies (Vine and Sathaye 1999), or as Moser et al. (2012) state, actions implemented outside the energy efficiency policy but initiated or stimulated by the policy itself (particularly in the case policies aiming at market transformation effects). Spill-over effect comprises several types of spill-over, of programme participants and non-participants (PWP 2017). According to Wade and Eyre (2015), participant spill-over represents energy savings that are achieved when a participant installs EE actions or practices outside of the efficiency programme after having participated. Further differentiations of participant spill-over can be found in PWP (2017) and Rathbun et al. (2001). Nonparticipant spill-over are additional savings that are achieved when a nonparticipant implements measures or practices as a result of the programme's influence, but is not accounted for in programme savings (Wade and Eyre 2015). Albeit methodological papers enter sometimes in very detailed distinctions of different sub-types of spill-over effects, they are rarely quantified in evaluations in Europe.

Free-riders are market actors who make use of facilities or support from the intervention, but would have taken energy saving actions anyway (Paramonova and Thollander 2016; Vine and Sathaye 1999). Self-reports or participants surveys are seen as the most common and accessible way to control for free-ridership, but also raise questions about possible bias such as social desirability bias. Rathbun et al. (2001) have elaborated a flowchart summarizing the steps how to quantify free-ridership through interviews. An alternative approach is to use quasi-experimental methods (e.g., comparisons between participants and a control group). This approach holds other risks of bias, for example possible bias in sampling (self-selection bias) and matching participants and control group (Violette and Rathbun, 2017).

Additionality of an energy efficiency action is given, if there are energy savings that are additional to what would have occurred without the energy efficiency intervention according to Bundgaard et al (2013). This can then be transcribed in more practical terms, depending on the context and policy objectives. For example, the European Commission (2016) uses existing EU minimum standards, e.g. EcoDesign requirements for energy-using products and EPBD requirements for new buildings to reference additionality in the context of the Energy Efficiency Directive (EED) (Rosenow et al. 2016; Rosenow et al. 2017). For most of the studies, additional energy savings are defined as gross savings adjusted by free-riders, spill-over effects and double counting (Paramonova and Thollander 2016), although the latter two are rarely assessed.

Double counting as mentioned in Schlomann et al. (2015) and Eichhammer (2008) is considered of high importance within the European Union because Member States might need to implement multiple policy measures to reach their intended energy savings targets. Controlling for double counting aims to ensure that energy savings originating from different policies that may target the same end-user are only counted once. From a practical perspective double counting must be shared between multiple policies through either estimated or known distribution, or energy savings may only be counted in one of the policy measures that may lead to energy savings. Some national energy efficiency schemes were modified to avoid double counting and be in accordance with the EED Annex V.

2.3.8 Other impacts

Energy efficiency evaluations may also include the consideration of other induced impacts from the adoption of policies. There is an increased level of attention that is being paid to non-energy impacts within the sphere of energy efficiency policy but also in the context of climate policy and energy transition. In literature several terms are used to address impacts other than energy savings. While in the US mainly the term non-energy benefits dominate (Freed and Felder 2017) when referring to benefits in addition to energy savings, in Asian regions co-benefits appear as a commonly used term in many papers (e.g. He et al. (2010), Zhang et al. (2018)) in the context of energy savings and emission of air pollutants. Ancillary benefits and co-benefits are employed interchangeably by Jakob (2006), when referring to benefits such as greater comfort or air quality from building renovations. International Energy Agency (IEA) (2014) applies the term multiple benefits for those other benefits. The list of non-energy impacts is diverse and includes economic, social and environmental aspects. And as International Energy Agency (IEA) (2014) explicitly highlights, there is a lack of systematic evaluation of non-energy benefits. The Knowledge Base aims to contribute to the discourse of non-energy impacts with the following considerations (see Table 6 for further impacts or issues included in the Knowledge Base).

Carbon savings as a specific aim of the evaluation cannot always be directly calculated from energy savings, but need to be estimated explicitly, because energy savings might be based on different types of resources, technologies and times, which has implications for emissions. For example, if self-generated electricity that would have been produced at the site is abated, a default emission factor should be applied, which is based on the fuel and emission source being avoided. The emission factor should be selected based upon the respective technologies and time periods of savings. For example, within an industrial setting, the displaced natural gas consumption from an increased efficiency can be calculated. A common practise observed in literature is to apply standard emissions factor to calculate avoided emissions. However, applying standard emission factors does not account for the specific situation under analysis and thus could slightly defer the results.

Peak load or demand savings are terms indicating a shift of load over time due to the energy efficiency policy in force or the energy efficiency action taken. Demand savings are typically more difficult to define than energy savings because a disaggregated time resolution is required as opposed to more simple aggregation of monthly or even annual data that can be used to assess energy savings.

Macroeconomic effects are expressed in terms of economic growth and employment which are stimulated or damped by EE actions. **Distributional effects** analyse what kind of (financial) burdens and benefits selected types of consumer have to bear due to EEP. Some cases also look into regional or spatial distribution of burdens and benefits, or between sectors, industries and consider them as distributional effects. **Industrial competitiveness** stands for the assessment of how energy efficiency improvements deliver substantial benefits within industry in addition to cost savings through enhancing competitiveness, profitability, production quality and improving the work environment. Increasing the awareness of the benefits to industry can help realign energy efficiency as a key business priority and stimulate further participation in energy efficient behaviour.

Energy security is often used in terms of reduced dependency on imports of fossil fuels. However, in a wider sense it may include also risks of origin, system reliability, price volatility and costs.

Table 6: Summary of other impacts

Other impacts	
Carbon savings	Abated carbon emissions from the reduced demand of energy after an intervention
Air pollutants savings	Reduced emissions of air pollution due to reduced energy consumption having a positive impact on health
Peak load/demand savings	The modification of energy demand through the implementation of energy efficiency interventions
Macro-economic development	Energy efficiency investments and less energy consumption might stimulate economic activities, thus growth and employment.
Distributional effects	The impacts and financial burdens on certain groups of final consumers, industries or investors, e.g. energy poverty.
Industrial competitiveness	Firms producing EE technologies for domestic market might get a lead position at the global market as well
Energy Security	Less energy consumption reduces imports of fossil fuels and, thus, reduces import dependency. Lower energy consumption and demand-side management can also reduce the needs in investments for grid infrastructures (for electricity and gas grids).

2.4 Description of literature in the Knowledge Base

Currently, the studies included in the Knowledge Base cover more than 50% of all EU Member States, plus Japan, the US, New Zealand, Switzerland and Norway. Further, the proportion of analytical and empirical evaluation papers is rather balanced. Almost 50% of the studies are empirical evaluation papers, of which evaluation reports dominate, and a bit more than 50% are analytical papers, which are dominated by methodological papers. Given the selection focus, not surprisingly, the majority of the practical and theoretical papers are ex-post evaluations, often with bottom-up calculation methods, although some ex-ante guidelines are present (Schiller et al. 2011; ADEME 2013; Irrek and Jarczynski 2007; Vine and Sathaye 1999). Further to this, the majority of papers employ specific bottom-up calculation methods in both the empirical and the analytical sources. But there is also a significant inclusion of exemplary top-down sources for both empirical and analytical sources.

Guideline sources that are included within the Knowledge Base display relative homogeneity with regards to the energy savings calculation methods that are applied for both gross and net energy savings, with greater depth in the contextualisation and presentation of these methods over time. Guidelines included in the Knowledge Base do not speak about the pre-bound effects, as the term itself has been coined recently (Sunnika-Blank and Galvin, 2012). But some of them deal with uncertainties related to modelling and recommend calibrating the models with metered or measured data of energy consumption, which can help taking into account pre-bound effects. The guidelines typically describe how to conduct impact evaluations, although they do not explicitly apply case study examples to calculate energy savings, they outline the best practice to do so.

Regarding policies and sectors, there is a base of theoretical literature that considers all sectors and policy instruments. For example, Nilsson et al. (2008) Harmelink et al. (2008) Schiller (2007) Eichhammer (2008) consider all policy instruments and all sectors apart from agriculture and energy sectors. Within the empirical evaluation literature there are studies which consider all policy instruments and sectors as well, e.g. Housing Energy Efficiency Agency, (2017)[10]. However, there is a high number of papers related to the residential sector, which typically employs financial or fiscal support measures, while agriculture gets little notice.

A large share of studies is dedicated to impact evaluations due to the focus of the EPATEE project. The process evaluations within the empirical sources do not explicitly or directly focus on energy savings. Instead they add context/information to the future of energy efficiency policies in their respective countries, through ex-ante analysis or ex-post studies bringing a better understanding about how the schemes work. These studies can also bring insights about adjustment effects such as free-rider and spill-over effects. For example, Daussin-Benischou and Mauroux (2014) present the sensitivity of French households to various levels of fiscal incentives, based on data monitored over a period with changes in the incentive rates and conditions. In another paper, Bukarica and Robić (2013) qualitatively discuss how the variety of stakeholders within energy efficiency policies can contribute to the erosion of the energy efficiency gap in Croatia from a social perspective, two empirical papers present adjustments of a programme for retrofits within multi-apartment buildings in Lithuania (e.g. Housing Energy Efficiency Agency, 2017; Bernatonis, 2015[11]); and MTI and Motiva (2006) qualitatively discuss the efficacy of the Energy Efficiency Agreements in Finland that ran from 1997-2005. The analytical literature add value by the contextualisation of methodological issues such as comparability of different calculation methods (e.g. Moser et al. 2012; Andersson et al. 2017), free-ridership (e.g. Grösche et al. 2013) and rebound effects (Greening et al. 2000; Sorrell 2007; Binswanger 2001; Haas and Biermayr 2000).

Regarding calculation methods, there is a slight dominance of bottom-up approaches. While the literature covers all methods, method 10 dominates within the Knowledge Base. It requires special consideration as it is the application of diverse, mixed or undefined methodological approaches. The prescribed definition of method 10 means that meta-evaluations and guidelines are typically ascribed as “method 10”, but there are exceptions, for example, Haas and Biermayr (2000) and Galvin and Sunikka-Blank (2016). The guidelines applied directly to the DSM programmes in the Netherlands focussed explicitly on method 4, using mixed deemed and ex-post estimates to calculate the impact of policy on buildings and industry. Similarly, methodological papers are frequently ascribed as “method 10“ because they also present diverse methods to assess evaluation savings as in the case of Eichhammer et al., (2008) and Boonekamp (2005) where all sectors are considered within the evaluation.

[10] https://epatee.eu/sites/default/files/epatee_case_study_lithuania_renovation_programme_with_eu_funding.pdf

[11] http://saee.gov.ua/sites/default/files/3_JESSICA%20in%20LT%20%28EN%29%20%282015-11-10%29.pdf

Figure 5 displays the different calculation methods applied in the papers.

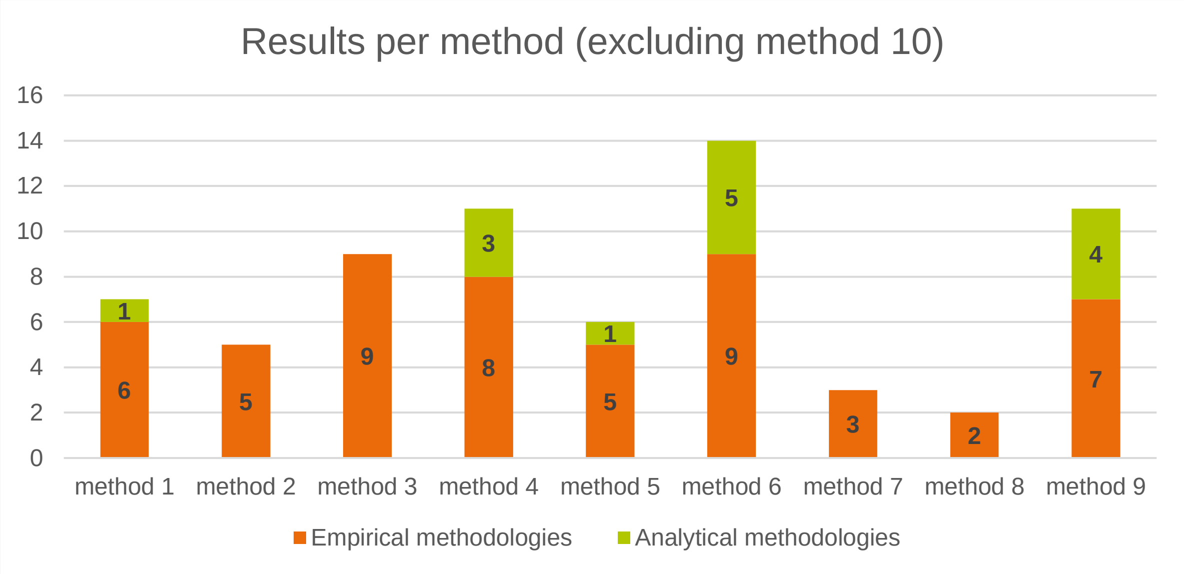


Figure 5: Calculation methods by type of paper

Source: own compilation based on Knowledge Base

Bottom-up methods

- **Method 1:** Direct measurement of unitary energy savings (unit usually participant)
- **Method 2:** Unitary energy savings are established on the basis of billing analysis (unit usually participant)
- **Method 3:** Deemed estimate of unitary energy savings (unit usually equipment; could be participant if end-use actions are uniform)
- **Method 4:** Mixed deemed and ex-post estimate; unitary energy savings based on equipment sales data, inspection of samples, monitoring of equipment (unit usually equipment; could be participant if end-use actions are uniform)
- **Method 5:** Detailed engineering estimates (e.g. calibrated simulation); implying more or less complex modelling of the individual unit (e.g. by calculating an energy balance of an individual building or company in the dataset - hence unit usually participant)

Mix bottom-up/top-down methods

- **Method 6:** Modelling (e.g. stock-modelling, simulation)
- **Method 7:** Based on share of specific equipment or practice in the market (diffusion indicators)

Top-down methods

- **Method 8:** Monitoring of energy consumption indicators (either energy consumption for whole sectors or sub-sectors, or specific energy consumption indicators for specific end use equipment).
- **Method 9:** Top-down modelling (e.g. econometric methods, simulation at aggregated level)

Others

- **Method 10:** Diverse methods (e.g. combinations of methods, guidelines or meta-evaluations that consider several types of methods)

There is a good level of precedent information regarding the various methodological types, which are applied with homogeneity in both analytical and empirical papers (see Figure 6). Simple analysis suggests that correction factors that have a precedent body of information within the theoretical/analytical papers (e.g. on spill-over, rebound or free-rider effects) have their methodologies applied within the practical/empirical evaluations (see Figure 7). One assumption could be that when there is a low level of precedent theoretical information (additionality, energy security) these evaluation criteria are less commonly included in evaluations, or apply less homogenised methodologies.

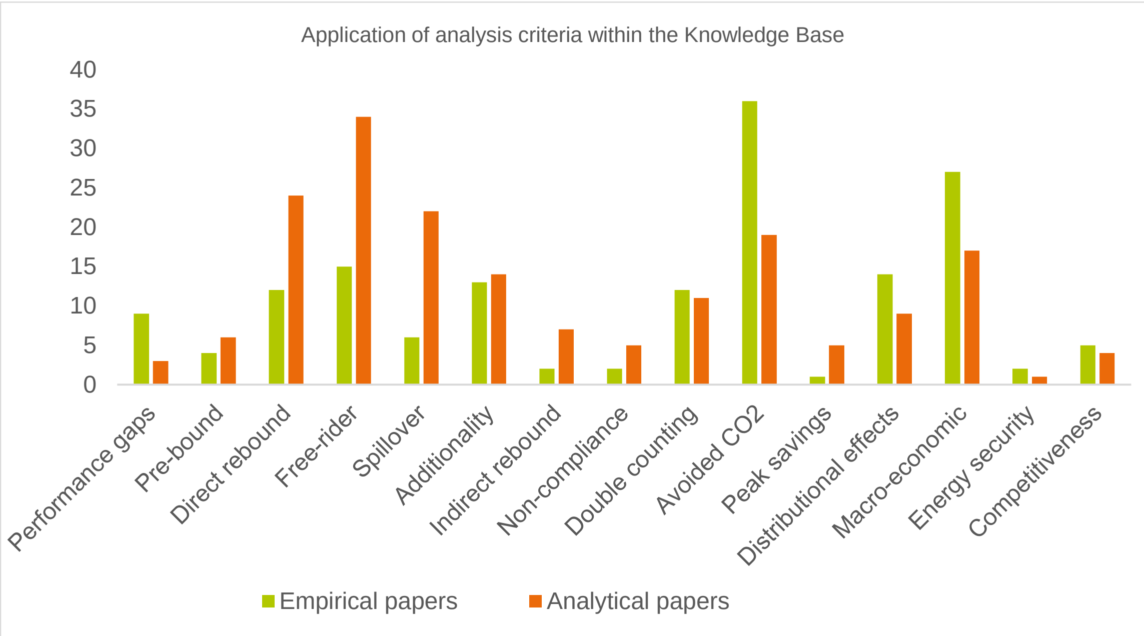
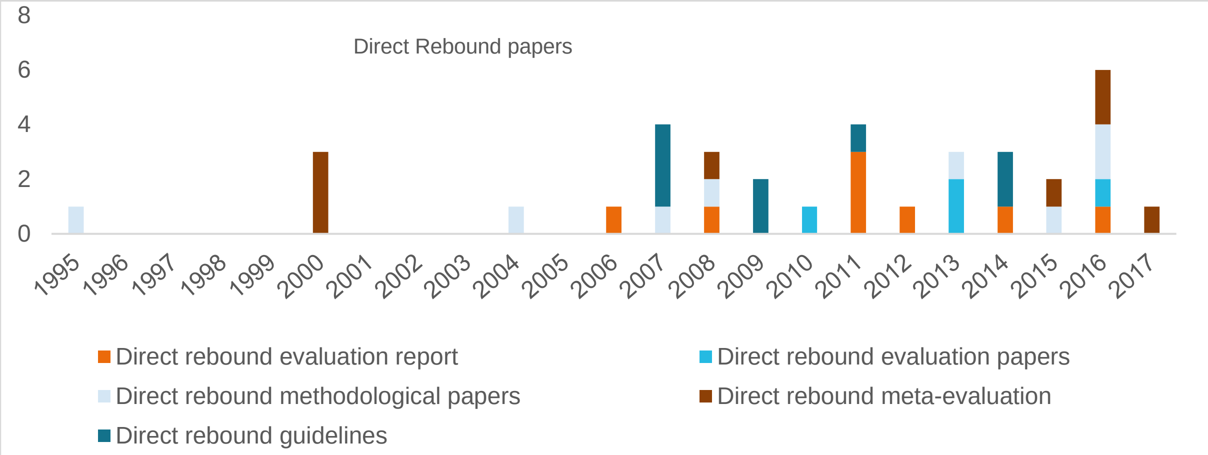


Figure 6: Distribution of empirical and analytical papers by different effects

Source: own compilation based on Knowledge Base. Note: Double counting of papers possible.



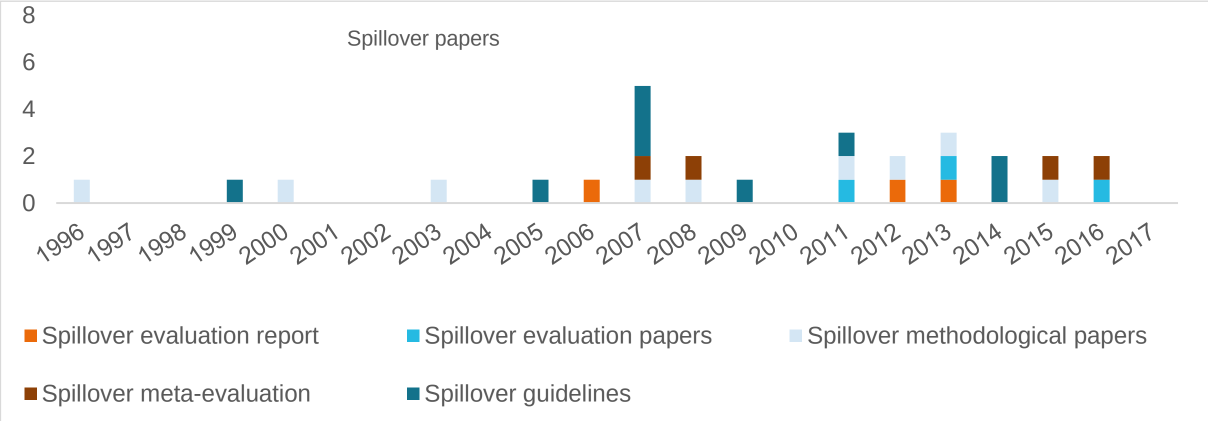


Figure 7: Distribution of papers discussing rebound effects and spill- over effects over time

Source: own compilation based on Knowledge Base

Overall, energy savings are covered across all evaluations in more or less depth, and methodologies are applied appropriately across all studies, but are somehow mechanism or sector dependent, i.e. evaluations of fiscal policies apply rather top-down methods while financial support employ rather bottom-up methods. However, the framing of the Knowledge Base in particular with respect to methodologies means that levels of information might be lost regarding the specific methodologies that are applied.

3 | Insights and shortcomings in evaluation papers

3.1 Selected issues and suggested approaches

In light of the EU Energy Union's goals of a secure, sustainable, affordable and competitive energy supply and its combat against climate change, Directives such as the EED, EPDB or RED are considered as relevant instruments of the EU's energy and climate strategy. For example, the EED calls for Member States to set up energy efficiency policies, i.e. energy efficiency obligations or alternative policy instruments (EED Article 7, European Union 2012) to stimulate investments into energy efficiency measures to achieve energy savings. Beyond the EU's sustainability goal, the economic principle of efficient allocation calls for efficient uses of scarce resources, i.e. energy savings should be achieved at least cost (which can be understood in different ways, depending on stakeholders' points of view, time perspective, etc.). In addition to efficient allocation of resources, additional costs, which are induced for example by energy efficiency investments, have to be accounted for. Subsequently, target achievement as well as evaluating the efficient allocation of resources and assessing the resulting impacts for the economy are decisive preconditions for the successful implementation of the energy strategy. In this context, evaluations of energy efficiency policies and programmes can be used to address these three core issues:

- achieved energy savings,
- efficiency of policies with respect to used resources and
- further (economic) impacts.

The selected evaluation studies in the Knowledge Base comprise studies looking at efficient use of resources, energy savings and further impacts of policies and programmes. Roughly 30% of those studies address the three aforementioned themes – net energy savings, costs and macroeconomic effects. Among them, only few analytical/theoretical papers are concerned with methodological aspects of how to assess and depict macroeconomic effects or cost efficient policies.

How energy savings are assessed, depends on the purpose of the assessment. In the following discussions, we consider three typical evaluation criteria: target achievement, effectiveness, cost-effectiveness or efficiency. The basis of these three purposes are energy savings and costs, i.e. their quantification. However, there is a small, but ongoing, partially controversial discussion on their calculation, and different terminologies or meanings in the energy efficiency literature, e.g. gross savings, net savings, additional saving, type of costs. For example:

- The SWD(2013)451final (European Commission 2013) clarifies the term "material to" as "the party in question must have contributed to the realisation of the specific individual action …" and the support should have a significant effect on the decisions to undertake an EEA. This is distinct to additional savings or additionality discussed in literature, which are not undoubtedly defined (Rosenow et al. 2016). Free-riding is an important aspect when deriving net energy savings. It is broadly discussed but slightly differently defined in a variety of papers (see for example Wade and Eyre (2015), Olsthoorn et al. (2017), Malm (1996), Rietbergen et al. (2002), Moser (2017)).
- There are some discussions and definitions regarding the terms effectiveness, cost-effectiveness and efficiency. For example cost effectiveness (Khan 2006) and efficiency (Schlomann et al. 2017) are used interchangeably.

- There are different perspectives of costs (Khan 2007), for example costs for society, government or private entities such as companies or households, or utilities as implementer of the EED (Suerkemper et al, 2012). There is no overall cost term that includes all costs that arise due to energy efficiency policies and compares it to overall benefits or energy savings.

Given the different purposes of assessing energy savings and conducting evaluations, and the variety of terminologies that might act as barriers to a common understanding, this section looks into three topics:

1. **Energy savings**: The first discussion topic is concerned with whether evaluation studies use the "right" energy savings. This means, whether it explicitly assesses energy savings to measure target achievement, or whether it assesses energy savings to improve programme or policy design, for which efficiency of used resources as well as the effectiveness - causal relationship between policy/programme and energy savings - is crucial. Depending on the purpose, different steps and methods of assessing energy savings are needed. As stated in some studies (Thomas et al. 2012) the way of assessing energy savings to monitor the national target achievement with respect to the goals set in the EED is not necessarily identical to the way of assessing energy savings of policy measures or programmes that aim at evaluating their effectiveness (Schiller 2007) and efficiency to improve their design.

2. **Cost effectiveness or efficiency of policies or programmes**: It is the core element of evaluations of energy efficiency programmes to help improving policy design and budget allocation (Yushchenko and Patel 2017) and hence contributing to cost efficiency of policies or programs. Besides the respective data on energy savings, a conceptual framework on the different types of costs is thought as supportive when assessing efficiency.

3. **Macroeconomic impacts**: There is a variety of different impacts, for different actors. If evaluations can give evidence that energy efficiency policies or programmes go hand in hand with positive impacts on the economy, society might be more supportive or at least less rejecting with respect to energy policies. Therefore, an economy-wide assessment of the impacts of policies or resources is important and comparable effects, i.e. based on a common concept are needed to be able to assess and compare the macroeconomic impact of an EE actions (EEA).

This report states that the purpose of the evaluation determines the type of energy saving and costs to be assessed. In addition, the purpose of the evaluation should be in line with the policy objectives. Energy savings can be assessed with different approaches – understood here as a mix of data, baseline and calculation methods applied. The approach has some influence on which effects e.g. rebound, free-rider, have to be taken into account. Further, for policy/programme evaluations it is argued that the net energy savings adjusted by all effects display the effectiveness of a programme or policy, and the efficiency of a policy when related to costs. Finally, it suggests some terminologies and definition of other economic impacts, which can be used as benchmarks (see Figure 8).

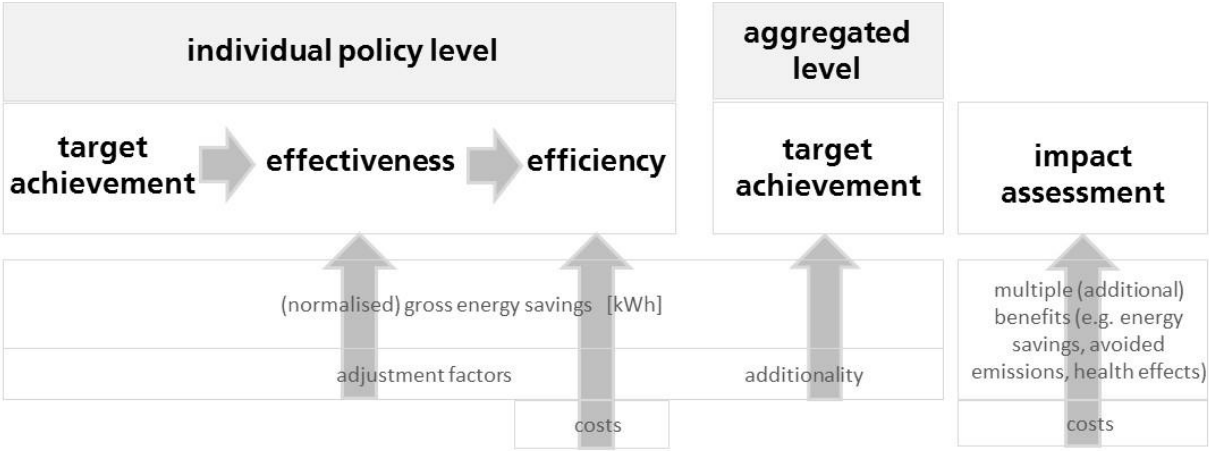


Figure 8: Objectives of evaluations and respective terminologies

3.2 The purpose of evaluation and energy savings

To compare impacts of energy efficiency programmes and energy savings across policies, sectors and countries, Andersson et al. (2017) conclude about the case of energy audit programmes that uniform performance standards are needed e.g. data categorization, calculation methods, disclosure of discount rates, lifetimes, as well as basic indicators such as programme cost effectiveness and total energy savings on the basis of standardized processes. In theory, standardisation facilitates assessments and comparisons. In reality, prevailing of missing data, vaguely defined objectives and unclear concepts of programmes and policies is hampering or questioning the use of standards. Moreover, comparing policies is rarely the primary evaluation objective of policy makers who usually commission evaluations to get information about the policies they are responsible of. Nevertheless, transparency and basic concepts are supportive in evaluating policies and programmes. This applies for the assessment of energy savings for national as well as programme targets. Particularly, transparency in the documentation of evaluation results is essential to enable discussions, as well as to trace how these results were obtained.

In this section we first give a brief review on literature regarding the different aspects that can be accounted for when assessing energy savings. Then we suggest a concept, i.e. which "type" of energy savings should be used for which purpose of evaluation and programme objective.

3.2.1 Literature review on additionality, free-riding and gross vs. net energy savings

In most studies, the first step of bottom-up calculations provides as result **gross energy savings** at the level of the EEA. They are commonly defined as the difference in (normalised) energy consumption when an EEA has been implemented compared to a situation before the implementation of the EEA, e.g. in Eichhammer (2008), Schiller (2007). Net energy savings are defined in varying clearness. For example, Khan (2007) defines **net savings** as the difference between a situation with EEA and one without EEA and the situation without EEA might include autonomous energy efficiency improvements. Whereas Violette and Rathbun (2017) consider **net energy savings** as the results to the question "What are the impacts of that policy?" They can be assessed against a baseline that is defined to represent what would have happened in the absence of the policy. This baseline is also called the counterfactual scenario (Violette and Rathbun, 2017). Depending on the "design" of the counterfactual, net energy savings can be derived directly, and could but may not necessarily account for spill-over effects or free-riding (as these effects might already be taken into account through the counterfactual, e.g., when using experimental or quasi-experimental approaches comparing participants and control groups). Or net energy savings can be derived from gross energy savings and taking into account further adjustments. For example, for Broc et al. (2009), energy savings according to the ESD (Energy Services Directive, 2006/32/EC) are derived by including multiplier effects, double counting and possibly free-rider effects. Many other authors (Fleitner et al. 2012; Schlomann et al. 2015; Paramonova and Thollander 2016; Vine and Sathaye 1999; Thomas et al. 2012; Moser et al. 2012) also call for an adjustment of gross savings by effects such as free-riding, double counting or spill-overs to derive net savings. As Khan (2007), many authors agree that free-riding and rebound effects give rise to an overestimate of the real savings achieved from an EEP and has to be taken into account when deriving net savings (Thomas et al. 2012; Fleitner et al. 2012; Nilsson et al. 2008). While the definition of spill-over and rebound effects is intensively but less controversially disputed (outlined in Section 2.3.8), the term free-riding and additionality is not clearly and uniformly defined. However, there is a broad agreement on the general understanding of net energy savings, and the actual use or case specific definition depend on the evaluation objective, data availability and stakeholders' views.

The EED obliges the EU countries to set up an energy efficiency obligation scheme or alternative measures to achieve new energy savings of at least 1.5% on an annual basis and the Member States have to report these obtained savings. Those new savings should be **material** (i.e. with a clear contribution from the programme or policy) [12] **and additional. Additional** is defined here as additional to the savings obtained by other existing EU policies or requirements (EED Annex V and European Commission 2013). In particular, this refers to the minimum standards set in the EPBD, EcoDesign Directive (2009/125/EC) or emission performance standards for vehicles (regulations 443/2009 and 510/2011) (Rosenow et al. 2016). The intention of referring to additionality in the EED is considered as avoiding double counting of energy savings from minimum standards prescribed by other EU legislations and energy savings from the respective EEP under investigation in the framework of the EED.

Alternatively, some Energy Efficiency Obligation schemes (EEOs) do not rely on regulations but have established other benchmarks as baseline, for example a market average in energy consumption (as done in the Italian white certificates scheme described in Di Santo et al. (2014) and Di Santo and Biele (2017)). Subsequently, energy savings have to be additional to this benchmark. In this case, the implicit assumption is that the replacement of the equipment would have been done anyway. And that in the absence of the scheme, the end-users would have bought an equipment equivalent to the market average. Additionality is thus defined in this case according to a deemed business-as-usual scenario.

Following Bundgaard et al (2013) "a saving is deemed additional if it would not have been implemented … without the obliged party's involvement." Moreover, "the net impact is the additional energy saving effect resulting from the obliged parties' efforts, savings that would be realised without the EEO do not contribute to the net impact." (Bundgaard et al 2013). Given this definition, and the expression of net impacts equalling reported savings adjusted for technical accuracy, additionality, rebound and spill-over, suggests that the additionality is the reciprocal/counterpart of free-riding. In the Danish case additionality is evaluated ex-post through surveys of end-users who received an EEA reported for the scheme. The results from the ex-post evaluation are used to define additionality factors (the reciprocal of free-rider factor) that are taken into account in the next period.

[12] "*The term 'material' means that the party in question must have contributed to the realisation of the specific individual action in question, and that the subsidy or involvement of the obligated, participating or entrusted party must not have had what is clearly only a minimal effect in the end user's decision to undertake the energy efficiency investment. The term 'demonstrably' means that the Member State must be able to show that this is so*." (European Commission, 2013)

With respect to energy efficiency obligations, Moser (2017) applies different terms to address net savings in the context with free-ridership (see Box 1). He defines additionality, i.e. additional EEA as those EEA that would not have been implemented without the respective energy efficiency policy in force. Further, Moser (2017) states the higher the share of additional measures, the more effective is the policy instrument. He applies different terms for energy savings: Envisaged savings are assumed savings under a given set of policies, accredited savings are derived on the basis of standardized savings metrics, while real savings differ by the additionality principle from accredited savings.

Moreover, Violette's and Rathbun's (2017) understanding of additionality refers to the level of an individual policy and links it to spill-over effects. They consider additional savings are achieved when a programme participant or nonparticipant installs an EEA outside the programme or implements an EEA as a result of the programme's influence, respectively, but is not accounted for in the programme savings.

Finally, Wade and Eyre (2015) argue that an ideal ex-post evaluation would compare energy use of participants with the energy use of a counterfactual scenario, i.e. the energy use of the same participants if they had not participated in the programme. For a reasonable estimate of the counterfactual energy use, several factors need to be accounted for, among them "the extent to which participating households would have taken programme-supported actions to save energy even without the programme (free-ridership, or lack of additionality)." In this sentence, the meaning of additionality could be understood as reciprocal/counterpart to free-riding.

These various definitions of additionality clearly show the different levels of perspective: (i) aggregated or supra/national level: additionality refers to benchmarks (e.g. standards, market averages) to avoid double counting or ensure energy savings above the techno-economic feasibility. (ii) disaggregated level or actor level - programme participants: additionality is linked to free-riding (participants would have taken programme-supported actions even without the programme). (iii) disaggregated/actor level – non-participants and non-programme EEA: additionality refers to non-programme supported actions of participants, and actions of non-participants, both induced by the programme (spill-overs).

Free-riding in literature:

Malm (1996) picked up early discussions on **free-rider** effects in the context of energy efficiency programmes. According to him, free-riders are actors that would have invested into energy efficiency measures (EEA) even in the absence of support programs. Other authors (Paramonova and Thollander 2016; Vine and Sathaye 1999; Wade,, Joanne and Eyre 2015) comply with this definition: free-riders are market actors who make use of facilities or support for energy efficiency actions, but would have taken energy saving actions anyway, even without respective incentives. When assessing energy savings, free-rider effects are relevant as soon as subsidies are involved (Nilsson et al. 2008; Nauleau 2014). Similar, Moser et al. (2012), who use dead weight as synonym to free-rider effects, define free-riding in the context of an EEA that would have been implemented without subsidisation (e.g. subsidy). Vine et al. (2001) subsume free-ridership also for labelling and standard programs.

Moreover, some authors distinguish between different types of free-riders: Total, full or pure free-riders would have installed the same EEA at the same time whether or not the program is offered, partial free-riders implement only a part of the EEA, deferred free-rider would have installed a less efficient or the same EEA but at a later time (Schiller 2007; Broc et al. 2009; Collins and Curtis 2016). Olsthoorn et al. (2017) distinguish between weak free riders and strong free riders. The first type decides to adopt an EEA when propositioned with an attractive EEA whereas the latter has already decided to adopt an EEA in the near future. The weak free-ridership depends on income, risk and time preferences and environmental identity. In contrast to this, free drivers are persons whose awareness has been raised by hearing about the program (Alberini and Bigano 2015; Vine and Sathaye 1999).

Box 1: Free-riding in evaluations of energy efficiency policies.

In this report, we chose to define “additional energy savings” and “net energy savings” to reflect the difference in two frequent evaluation purposes, assessing respectively target achievement and programme efficiency, as discussed in the next section.

3.2.2 Energy savings to monitor target achievement and assess programme efficiency

First, looking at the literature discussion in the preceding section, one can state that the term “additional energy savings” within the meaning of the EED aims at avoiding double counting with other EU policies and regulations. The line of arguments is that its reference to minimum standards that should be taken into account to get “additional” savings means not to include anyway achieved savings through these other policies or standards.

Second, this report starts from the definition used in in the literature for “net energy savings” as energy savings that would not have happened in the absence of the policy (see e.g., Bundgaard et al 2013 about additional savings,).

We apply two criteria to differentiate between additional and net energy savings: (i) the perspective – aggregated level of programmes/policies and individual policy or actor level, and adjustment effects – and (ii) adjustment factors – direct rebound effect, spill-over effect, free-rider effect and double counting.

Energy savings at the aggregated (superior) level are based on energy savings derived from a bundle of respective policies or programmes. In the frame of the EED, energy savings reported by Member States for the **achievement of the target** of EED article 7 should be **additional** in the sense of being beyond those savings from minimum standards set in other EU policies and regulations, or when including other benchmarks (e.g. market averages), should be additional in the sense of being beyond those savings that could be achieved with “business-as-usual” (average) efforts or actions. More generally, the definition of additional energy savings when assessing target achievement should be consistent with the way the target was defined (i.e. the baseline for evaluating energy savings achieved should be the same as the baseline used to set the target).

If however, the objective is not to monitor a target achievement, but the **effectiveness and efficiency** of individual programmes or other policies to improve policy designs and make programmes more efficient, the evaluation should consider all other factors that could influence energy savings, i.e. rebound, spill-over and free-rider effects when relevant. This quantity corresponds to **net energy savings**, as introduced in section 2.3.7 and defined respectively for this report in Table 7. The choice of the adjustment effects to take into account can depend on the type of policies and policy objectives, used data and baseline as they might already be accounted for in the counterfactual. For example, free-rider effects might not be relevant when evaluating a regulation or are already accounted for in a counterfactual based on control trials/groups. Rebound effects might be considered even as a positive impact when evaluating a policy tackling fuel poverty.

Table 7. Definitions used in this report for "additional" and "net" energy savings.

Perspective:	Aggregated level of policies – macro level	bundle of programmes – meso level	individual programme/actor - micro level	Level of an EEA - system level

Purpose of the evaluation:	Target achievement		Effectiveness, efficiency	
Adjustment factors:				
Rebound effect	X	X	X	
Spill-over effect	X	X	X	
Free-rider effect		X	X	
Double counting Business-as-usual*	X X	X X	 X	
Type of energy savings:	**Additional energy savings**		**Net energy savings**	**Gross energy savings**

Note: policy: based on governmental action leading to programmes and EEA. Note: *the efficiency target is quantified on a business-as-usual baseline,

Subsequently, the reasoning is when evaluating the achievement of national energy savings targets, the focus of the analysis is on actual consumed energy, or the national energy savings. Thus, consumers' behaviour (rebound) as well as spill-over effects influence the energy consumed, and double counting of programmes' energy savings is excluded. But how efficiently energy savings are achieved is irrelevant when analysing target achievement at the aggregated level, and thus, free-riding does not matter. In contrast, assessing free-rider effects (and possibly other adjustment effects) is essential when evaluating the effectiveness or efficiency of policies, as the level of analysis is the individual programme/policy level, and the objective is to compare the impacts of the policy or programme (i.e. results that can be attributed to the policy or programme) with its objective (effectiveness) or its means (efficiency).

Subsequently, the purpose of the evaluation determines which type of energy savings net or additional - is relevant to assess. To assess the respective "type of" energy savings, the following steps are suggested when using a bottom-up approach (see also e.g. Schlomann et al. 2015; Broc et al. 2009; Paramonova, Thollander 2016):

1. **Assessment of energy consumption**: → **final or primary energy consumption with EEA and normalisation (**Figure 9**)**:
   this includes a clear presentation of the type of energy and fuel (missing in many evaluations), i.e. primary or final energy consumption, and gas, electricity or else. Further, the type of data and sources e.g. primary data or secondary data, should be made transparent, because correction or normalization of data depends on the type of data. For example, energy consumption needs to be normalized, i.e. adjusted by erratic factors such as heating/cooling degree days, occupancy level, etc. and by macroeconomic factors such as business cycle or structural effects. Moreover, implementing an EEA entails changes in consumption behaviour, which is captured by direct metering but not when using sales or statistics.

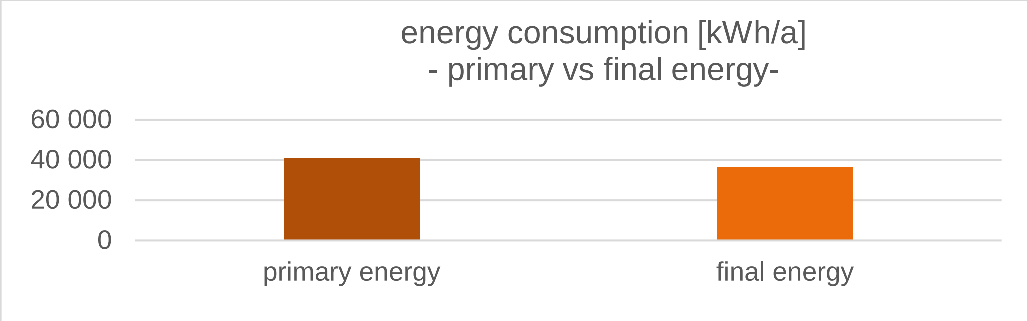


Figure 9: Energy consumption measured in terms of primary and final gas consumption of a retrofitted single house

Source: own illustration, energy consumption of a retrofitted single house (building stock) based on data of Erfahrungsbericht EEWärmeG, Germany, 2013; PEF gas: 1.1

2. **Assessment of gross energy savings**: → **energy consumption of baseline situation (before) minus energy consumption with EEA (after)**:
   there are several approaches to assess energy consumption and energy savings (see Schlomann et al. (2015) for an overview) ranging from direct energy savings based on direct measurements of energy use to modelling of energy consumption based on statistics and stocks. The situation with an EEA is compared to a hypothetical situation without the implementation of EEA. Ideally, the situations differ only by the EEA, all other factors are equal (ceteris paribus) or normalised when needed (see normalisation factors in Table 5). The hypothetical situation is often called baseline (Schlomann et al. 2015). When assessing gross energy savings, the baseline is defined as the situation before the EEA was implemented. When the evaluation is based on measured or metered data of energy consumption, it is often needed to normalise "before" and "after" energy consumption to account for possible changes in weather conditions, production, occupancy rates, etc. When the evaluation is based on estimated or modelled data of energy consumption, it can be needed to correct "before" energy consumption for prebound effect, and "after" energy consumption for performance gaps.

3. **Assessment of additional energy savings for national target achievement: → energy savings assessed by a comparison with the baseline used to set the target**:
   When assessing additional energy savings to report about target achievement, first a baseline is defined in line with the baseline used to define the target. For example, the article 7 of the EED is meant to deliver energy savings additional to the other EU energy efficiency policies and regulations. Therefore, energy savings are to be evaluated against a baseline that includes the effects of these other policies. Depending on the policy objectives and the way the target is set, the baseline might also include other factors influencing energy savings. In practice, this baseline is often applied by defining additionality criteria or eligibility conditions. For example, some types of EEA can be excluded from the eligible types of EEA because they are deemed to have low or no additionality (e.g., appliances are excluded from many EEO schemes in Europe, because of the EcoDesign requirements (regulations)). Thus, double counting of energy savings originating from regulations and EEO is avoided, thus savings from regulations are counted only once at the aggregated national or supra-national level.

4. **Assessment of net energy savings to show efficiency of policies → gross savings adjusted by free-rider and other effects** (Figure 10):
Net savings account for difficulties in delineating effects from various policies, e.g. double counting, or other factors (e.g., free-rider and spill-over effects). Depending on the type of calculation method and applied baseline, the assessment of energy savings might already accounts for these effects (e.g., when the baseline is defined as a counterfactual scenario based on a control group). If not, gross savings are corrected by factors (Schlomann et al. 2015), such as attribution issues. Net energy savings are needed to show how effective policies and efficient financial supports are. Therefore, only those savings of EEA will be taken into account that would not have happened anyway, i.e. that are implemented only because of the policy or programme. In this context, we cite Bundgaard et al (2013), who emphasis the significance of additionality for cost-effectiveness: “an additionality factor below 10%… thus strongly points to low cost-effectiveness.”

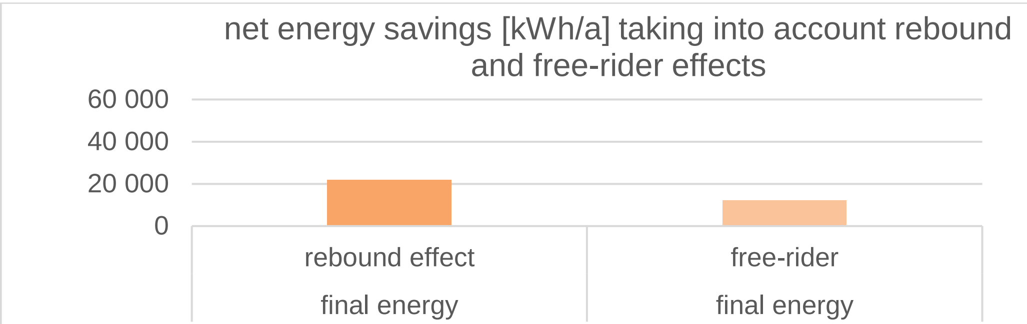


Figure 10: Energy savings (corrected for rebound effect) and net energy savings (taking into account free-rider effects)

Source: own illustration, energy savings from retrofitting of single houses (building stock) based on data of Erfahrungsbericht EEWärmeG, Germany, 2013: rebound effect: 26.7%, see Aydin et al. (2017), free-rider effect: 44%, see Nauleau (2014)

Overall, the suggestion is to differentiate between the types of energy savings in dependence of the perspective/level and purpose of the evaluation. This is summarized in Table 8.

Table 8: Energy savings by levels and purpose

Type of energy saving	Explanation	Evaluation purpose and related level
Gross energy savings	Difference between baseline (**situation before** implementing the EEA) and the situation with EEA (after implementation), taking into account relevant normalisation factors (Violette and Rathbun, 2017).	Achievement/Contribution of the EEA --> energy savings at the ; individual EEA level
Additional energy savings	Difference between the **baseline as used to set the target** (usually taking into account effects of other policies, i.e. **double counting** or **business-as-usual developments**) and the situation with EEA.	**Target achievement** at the aggregated level, e.g. national level, European level (EED) avoiding double counting; meso/individual level going beyond business-as-usual
Net energy savings	Gross energy savings adjusted by free-rider and possibly other effects (see **adjustment**	**Effectiveness and/or efficiency** of policy or programme - at the

	effects in Table 5), or net energy savings directly assessed by an **experimental or quasi-experimental approach**	level of an individual programme/policy (EEP))

3.3 Efficiency of policies

Khan (2006) defines target achievement as the extent to which targets that were set for the instruments have been achieved. Schlomann et al. (2017) provide a more general definition: ”... the degree of implementation of the objectives originally defined.” while they relate effectiveness with the causality of an EEP, i.e. to which extent the EEP has stimulated the energy savings. In case no quantified target was defined for the policy or programme, the target achievement and effectiveness cannot be determined. In any case, assessing energy savings as described in the section before is a prerequisite when evaluating effectiveness and/or efficiency, i.e. it is necessary but not sufficient, because of costs. Thus, the following paragraph looks at costs related with EEP.

3.3.1 Literature review

Cost effectiveness is defined as the cost per amount of energy saved. It is depicted as Euros per unit of energy saved (Khan 2006)), or as Euros per gross savings (Broc et al. 2017). Krey et al. (2014) discuss levelised cost of conserved energy, which is analogue to the concept of levelised cost of energy. There are further approaches such as the net present value of the estimated benefits from an EEA compared to the estimated total costs (Schiller 2007) or the net present value of total costs (Paramonova and Thollander 2016). Other authors, such as Harmelink et al. (2008), refer cost effectiveness to the amount of money i.e. total costs invested to achieve the savings compared to energy savings adjusted for free-rider effects.

Effectiveness of a measure is understood as a different term. Rietbergen et al. (2002) and Khan (2007) refer to the causality or the contribution of an EEP to energy savings target when speaking of effectiveness. Similarly, Europe Economics (2016) refers to effectiveness as impacts of policies on energy savings stemming from policies and Broc et al. (2017) define it as an “gross” achievement of the EEP related to its targets.

In contrast, Broc et al. consider **efficiency** of a policy as costs of the EEP in relation to its “net” results. Similarly, Moser (2017) defines efficiency as costs per unit saved energy and effectiveness as the achieved, real energy savings, and Schlomann et al. (2017) as “funding to be compared with the results obtained through the funding.”

There are different perspectives of **costs** (Khan 2007); costs for society, government or private entities such as companies or households. Calculating cost effectiveness entails assumptions about discount rates and depreciations periods of measures. Based on the cost-effectiveness tests used in the US, and more specifically in California (see Annex, Table 12), Yushchenko and Patel (2017) distinguish costs of the EEP into program costs, which include financial incentives, program administration costs of the public and private entities, and costs of program participants, which includes remaining investment costs of households. They also account for lost revenues of utilities from lower demand for energy due to energy savings. One key point of the cost-effectiveness figures is that the types of benefits and costs to take into account depend on the perspective. Harmelink et al. (2008) indeed highlight that costs differ by the perspective: end user, society and government.

Total costs of the EEP comprise total costs for installation, additional administrative costs of utility and agencies implementing the program. Incremental costs are total costs less the net present value of other changes in costs related to the EEA and the total installed costs of an alternative EEA, that would have been installed in the absence of the program (Eto et al. 1996). Rosenow and Bayer (2017) distinguish between programme, societal, administrative and start-up costs. According to them programme costs occur for the obliged parties and comprise financial support payments, internal administration and implementation costs of the EEO. Social costs includes costs of obliged parties and of participants.

Similar to Grösche et al. (2013) and Bundgaard et al (2013), this report considers free-ridership as an issue when evaluating efficiency of program interventions or policies and not when monitoring target achievement.

3.3.2 Perspectives and levels of policy efficiency

This report subsumes that policy **effectiveness** relates to the causality of the policy with respect to implementing an EEA and achieving energy savings, while **efficiency** in a narrow sense refers to ratio of costs spent for an EEP to achieved energy savings. In this report effectiveness and efficiency is defined according to Schlomann et al. (2017):

- **Effectiveness** is defined as the contribution of the EEA to targeted energy savings and is measured as additional savings when assessing target achievement, and as net savings when assessing effectiveness of an individual policy or programme, or gross savings when focussing only on the impact of the EEA solely.
- **Efficiency** refers to the costs spent or paid per unit of savings, i.e. whereas net energy savings are applied when looking at the efficiency of a policy or programme or EEA costs, additional savings are used when assessing efficiency of achieving a target. Some papers refer to this as cost-effectiveness (see 3.3.1).

That is, efficiency accounts for the financial aspect, i.e. the amount spent for the policy or programme or EEA to get additional or net savings, and is measured in Euros per kWh energy savings. In a first step, the scope of costs and benefits is limited to the costs incurred with the installation and implementation of the EEA, and benefits in terms of energy savings. In a broader sense, these costs include also program costs (administration) and transaction costs of the state, target groups and obliged/entrusted party to implement the policy. Total cost include both private costs of the EEA, i.e. investments into EEA, operation and maintenance costs plus programme, transaction costs, etc. When looking at efficiency, assessed energy savings and costs should be coherent, i.e. refer to the same basis (level, see next paragraph).

Regarding the cost issue, this report relies on the approach of Barker et al. (2007) and Vine and Sathaye (1999), where costs are distinguished by the perspectives, and by the analysis framework of Breitschopf et al. (2016), which distinguishes costs by the level – system, actor, economy - they accrue, and applies the additionality principle: since costs are compared to net energy savings, the costs should also be “net” in the sense of additional to the status quo. The status quo comprises costs of an old system with the same characteristics of the new system or situation. In the terminology of Breitschopf et al (2016) additional or net costs are the difference of the costs of a new system with better energy efficiency to the “status quo costs”. In other words, net costs are costs in addition to costs of a reference situation. In literature they are also sometimes called marginal costs.

System level: at the system level, costs accrue when efforts are made to reduce energy consumption. This is regardless of the type of actors such as obliged party, private investor or state. These costs include investment, operation and maintenance expenditures - if existing - for any EEA. Boonekamp (2006) suggests a categorisation of energy-using systems into a micro, meso and macro level, where the focus is on the energy service e.g. supply of light through bulbs (micro), supply of light in offices (meso) and transport services (macro). In this report, the boundaries are given by the system in which energy is consumed and the system is defined by the EEA with its immediate costs and energy savings. Therefore, energy savings outside the system e.g. spill-over effects are excluded, as rebound and free-rider effects are. The *investment efficiency* (see Table 9), which is defined as the costs at the system level per unit gross energy savings, shows how efficient an EEA is without taking into account any behavioural or distributional aspects.

Micro and meso level: the **micro and meso levels** take the perspective of different actors, which are the consumers, obliged parties such as energy suppliers, investors, financial actors, businesses and the legal authority. In our understanding, this level includes behavioural and distributional aspects. The European Commission (2016b) provides an overview of affected stakeholder groups in its impact assessment.

- They comprise for the state/regulator/authority all costs associated with implementing the programme, administration costs and transactions concerning programme elaboration and coordination, and in case of financial support payments, also these costs. Programme and transaction costs are close to Rosenow and Eyre (2016)'s definition of administrative costs.
- For the obliged party, costs comprise the financial support to consumers, as well as transactions such as designing and improving the programme and administrative costs for implementing the programme, i.e. programme costs according to Rosenow and Bayer (2017).
- Finally, the consumer bear the remaining additional investment (and operation & maintenance) costs plus individual transaction costs (e.g. time spent for information, coordination). Additional investments are costs that accrue in addition to the status quo situation[13].

Costs and benefits at the micro/meso level encompass all costs and benefits that arise from implementing EEA within an energy efficiency policy or programme and that are born by these actors. These costs or benefits (e.g. energy savings) are all in addition to otherwise implemented actions, i.e. they accrue only due to the EEA or policy, and would not have accrued without the EEA or policy. Comparing these additional costs to additional or net energy savings provides an efficiency metric. For each perspective (individual, obliged/entrusted party, state…) and purpose (effectiveness and achievement) a metric can be calculated. When looking at a single actor such as a consumer or obliged party, we speak about the **micro-level**. For example, from the perspective of an individual obliged entity the *programme efficiency* reports how efficiently the funds of the scheme are used to induce savings. It is measured as costs per net energy savings (see Table 9).

When evaluating programmes encompassing different groups of obliged parties and energy efficiency investments, we speak about the **meso level**. For example, the *policy efficiency* for the obliged/entrusted party displays how much financial resources are needed to obtain one unit of additional savings to achieve the target/obligation (see Table 9). For the state/nation the *aggregated efficiency* (costs per additional savings) is useful to evaluate policies, as it points out how much it costs to achieve one more unit of energy savings at an aggregated level. However, it requires a high degree of harmonisation when assessing energy savings and costs of all programmes and EEA[14].

[13] For example the heating system has to be replaced. The status quo should be defined according to the baseline used to calculate the energy savings. Depending on the cases, the status quo can thus be a system similar to the old one, a system meeting the current minimum energy performance requirements or a system representing the market average. The new system with higher efficiency might cost more than the "status quo system". The cost difference between the "status quo system" and the more efficient one are defined as additional costs.

[14] Another commonly used success criteria for the programme is the *leverage effect*, which signals how much private capital is mobilised by giving subsidies or rebates. A low contribution and high energy savings make the EEA not only attractive from an obliged/entrusted party's perspective but also from a final energy consumer's perspective.

Macro level: these are costs paid by and benefits accrued to the whole society (or economy) for EEA that are implemented in the framework of energy policies and programmes. Regarding direct costs, these are costs directly associated with the EEA, i.e. costs for the investments (sum of the customers' and obliged/entrusted parties' share, including cost recovery) and transactions of all actors. Moreover, indirect costs encompass negative and positive effects in the energy technology industry and its upstream industries, for example a decline or increase in value added due to reduced production of energy or increased production of EE technologies, and induced effects occurring in all sectors for example lower energy expenditures, or reduced production of energy intensive products or increased production of consumer goods, respectively. The additional direct costs are compared to additional energy savings and the ratio is here called *aggregated efficiency* (see Table 9) which is in some studies synonym to measure efficiency. However, when including indirect and induced effects (costs and non-energy benefits) and assessing the national impacts then the ratio of an aggregated indicator such as changes in GDP (due to the policy target) to net energy savings (national) shows how efficiently the target is achieved; this is often called *macroeconomic impacts* of EE. Normally, this is done by comparing the GDP or value added of a situation with EEP to one without EEP. What macroeconomic impacts are, is discussed in the next section.

Table 9 provides an overview on different efficiency indicators. The costs (where they accrue) determine the level. Gross savings are only relevant for the system level, as they show which EEA are most efficient (*investment efficiency*) without taking into account any effects such as rebound, spill-over or double counting. At the micro-level, net savings account for actor's behaviour and the metric is called *participant efficiency,* if it is relevant for individual consumers' decisions (e.g. consumption and investments), while *programme efficiency* with net savings (accounting for free-riding) provides a measure for diverse support efficiencies from the perspective of obliged parties or the state. Efficiency indices at the meso level (perspective of obliged parties and state), for example *policy efficiency,* are used when costs of several programmes are considered and compared to additional energy savings of those programmes, where double counting is accounted for.

Table 9: Efficiency – a matrix of energy savings and costs by levels and perspectives

Efficiency: costs [€] / energy savings [kWh]		**Energy savings from EEA or EEP [kWh]**			**Other benefits**
		gross savings	net savings	additional savings (target achievement)	Impacts (including non-energy benefits, see 3.4)
Costs by levels and perspectives [€]	System level: • Additional investment, operation and maintenance expenditures	investment efficiency			
	Micro level:				
	• Final energy consumer (remaining additional investment and transaction costs)		participant efficiency*		
	• Obliged/entrusted party (financial support, administration and transaction costs)		programme efficiency**		
	• State (financial support, administration and transaction costs)				
	Meso level:				
	• Obliged/entrusted party (financial support, administration and transaction costs)			policy efficiency***	
	• State (financial support, administration and transaction costs)				
	Macro level				
	• Additional investment, operation & maintenance expenditures, transaction, administration costs including cost recovery			aggregated (national/supranational)**** efficiency	macroeconomic impact

*Source: own depiction. Note: *includes behavioural aspects (e.g. rebound effect). ; ** energy efficiency programme (e.g. from utility or government). *** policy as a bundle of programmes .****aggregated referring to a national, supra-national or superior policy (e.g. energy savings target, EED);*

3.4 Expanding the scope of evaluation

As discussed in section 2.3.8, there are multiple benefits of EEA beyond energy savings. Applying the concept of additionality means that we only look at benefits that are additional, whereas additional is understood in the sense of benefits occurring only because of the EEA. As those multiple benefits comprise direct and indirect effects, and as there might be also negative effects of EEA, i.e. costs, we prefer the term “impacts”. Taking the multiple benefits outlined in International Energy Agency (IEA) (2014) and the overview in Table 6 as basis for the discussion on other impacts, and applying the classification as depicted in Table 9, the range of other impacts is outlined in the following.

3.4.1 Other impacts discussed in literature

Energy efficiency investments have a broad range of impacts on individuals, energy systems, industries, government and the whole society as well as on different areas such as environment, resources, climate, health, economy, welfare and well-being. Individuals are directly affected by health and well-being impacts, which in turn affects the macro economy by changes in health expenditures and work days. The industrial sector as an economic agent faces impacts on its competitiveness, for example through improved production, operation and maintenance, better working environment for its workers which all translates into value added, employment and growth effects at the macro-level. In the energy sector (system), energy savings or shifts in energy demand might reduce power demand during peak times, losses of transmission and distribution, and hence reduce energy prices, and subsequently costs. This in turn affects the economy through changes in consumption of final consumers. With respect to energy security, there is a broad range of definitions. In an narrow sense, energy security refers to reduced imports of fossil fuels (Diekmann et al. 2016), which is captured through the value added. Finally, any changes in investment or consumption expenditures and production affects the public budget through tax revenues, energy expenditures of the public sector and subsidies (see for an overview of these effects International Energy Agency (IEA) (2014) and Trianni et al. (2014)).

In summary, individual households as well as industries and the public sectors are affected through non-monetary impacts (well-being) and monetary impacts (prices, expenditures, revenues, costs). There are some studies trying to assess impacts on the market (Neij, 2001) or different economic impacts of indirect rebound effects, e.g. Raynaud et al. (2015), but to account for all different economic impacts, a comprehensive macroeconomic approach is needed, which quantifies effects in monetary units, if possible and useful. This is why in many evaluation studies impacts on GDP or employment are assessed (European Commission 2016a).

Macroeconomic impacts incorporate through different impact mechanisms all effects, be it competitiveness, distributional effects, peak-savings or energy security, expressed in different ways and varying level of detail (Schumacher 2012). And a literature review on macroeconomic impacts of EEP shows that there is a large variation in results in studies assessing employment effects (Mikulić et al. 2016). Thus, macroeconomic impacts of energy efficiency policies, or rather the estimation methods deserve special attention, especially because this is found to be the major concern of households according to Nauleau (2014).

Table 10: Other impacts by levels

level	Impacts on health and well-being	Impacts on the industrial sector	Impacts on the energy industry and services	Impacts on the public sector (budget)	Macro-economic impacts
System (EEA)	-	-	Mitigation of peak demand, reduced losses in transmission, and distribution, energy security (supply)	-	energy security (reduced imports)
Micro/meso: affecting actors: workforce, households, industries…	Individual health, health expenditures	Competitive-ness due to efficient production, working environment, etc.	Energy prices and expenditures Lower energy sales	Energy expenditures, recovery payments, tax revenues of public household	Distributional impacts (financial burden, changes in income, etc.), Structural changes in industries
Macro: value added, GDP, employment	Production (working days, well-being)	Value added in industries	Production and value added in energy sector, consumption of households	Consumption and investment of public sector	Value added in industries

Source: own depiction

Vine and Sathaye (1999) captured the significance of macroeconomic impacts in a nutshell when stating that "projects' survival is dependent on whether it is economically sound, i.e. the benefits outweigh the costs and are equitably distributed." They list potential macro-economic impacts of EEA, such as changes in gross domestic product (GDP), jobs created, foreign exchange and trade. Also Rosenow and Bayer (2017) find that energy efficiency programmes and obligations deliver further benefits than just energy savings, for example benefits for the energy system through flexible demand, which leads to reduced peaks and to benefits in the whole economy in form of growth and employment. A case study on different EEP conducted by Khan (2007) points out that macroeconomic impacts are indeed included as goal in some evaluations of EEP. Further, not taking into account the macroeconomic impacts can underestimate the economic contribution of energy efficiency programmes and policies. In contrast Schiller (2007), MEDDTL et al. (2011) and DECC (2014) report about evaluations assessing co-benefits such as net impacts on employment, labour income, industry output or value added. However, in all three studies hardly any information is provided on the method of the applied macroeconomic impact assessment (sometimes because these other impacts have been analysed in separate studies). In this respect, Diefenbach et al. (2016), Barker et al. (2007) and BMLFUW (2014) differ from these studies, as they assess employment impacts and describe their employed estimation method. IEA (2014) also explicitly highlights in its study on multiple benefits of EEP the fact that there is a lack of systematic evaluation of these non-energy benefits, including macroeconomic effects. Currently, the Knowledge Base encompasses around 40 studies mentioning the significance of macroeconomic impacts (e.g. Europe Economics (2016), Boonekamp (2006)), but not many of them discuss the methodological approach how to assess these macroeconomic benefits. Therefore, this report aims to contribute to the discourse of macroeconomic impacts with the following considerations.

3.4.2 Macroeconomic impacts

In the framework of the energy transition, macroeconomic impacts of renewable energy deployment and implemented energy efficiency measures has been estimated, e.g. in European Commission (2016b) European Commission (2016c). These studies quantify the change in value added or GDP, in employment, reduced fossil fuel imports, avoided GHG emissions and health effects. Especially the macroeconomic impacts have been intensely disputed, as different model types with differing input parameters report different impacts on employment and GDP. For example, in the study of European Commission (2016b) two macroeconomic models used for this assessment report changes in GDP between – 0.22% and 0.39% in case the energy efficiency target increases by three percentage points to 30%. Laurent et al. (2017) describes the UK method of assessing health effects. Regarding the macroeconomic impact of efficiency programmes and EEA, simple coefficient based assessments are applicable. However, for a better understanding of the different assessment approaches, the concept of Breitschopf et al. (2013b) is applied, that distinguishes between direct, indirect and induced effects of renewable energy use, and between net and gross employment or growth effects. A similar classification is applied by Mikulić et al. (2016).

Direct effects result from investments, which entail increasing demand for energy efficiency technologies or products, which in turn increase the demand in national production sectors of relevant goods and related operation and maintenance. Indirect effects emerge through the industries' increased production factor demands (investments and intermediate goods), which in turn lead to indirect effects, namely demand effects in upstream industries (see Table 11). In case of energy efficiency investments, these effects have stimulating impacts on the economy, as they generate additional demand and increase economic activity (Mikulić et al. 2016), if they do not crowd out investments in other industries or sectors. In addition, the investments induce secondary effects in other parts of the economy: they reduce energy consumption, and thus the available budget for other consumption goods becomes larger in households while the production in the energy sector declines, such that both effects change production levels and value added through the circular flow of the economy. The induced effects can be positive – increasing production and consumption – or negative – dampen production and consumption.

When taking into account direct or direct and indirect effects, then the resulting impact is called *gross impact*, e.g. gross employment. In case direct, indirect and induced effects are included the resulting impact is called *net impact* (see Table 11). This impact can be negative or positive, depending on the strength of the induced positive and negative effects. It is always a comparison between a situation with EE measures in place and one without any EE measure (reference scenario).

To assess net impacts, macroeconomic models are needed that fully depict the interdependencies. While for assessing gross effects, input-output tables (to capture direct and indirect effects) or labour coefficients per unit of investment or survey in the respective supply companies (direct effects) are sufficient (Breitschopf et al. 2013a). Quite a number of evaluations report on macroeconomic impacts. Among them only a few are transparent regarding the assessment approach. However transparency about the approach is very important, as it depends on the assessment approach, which effects are included or not. For example studies including direct and indirect effects report higher growth or employment impacts as if only direct effects are included, while assessing net impacts (e.g. GDP) the impacts might even become negative. Subsequently, depending on the methodology or type of effects included, the impacts on GDP or employment might significantly differ. Moreover, employment effects can be depicted as full time equivalents or as head count on an annual basis or cumulated over several years.

Like for energy savings, there is a variety of methods and indicators that can be used to evaluate and report about other impacts. Therefore, it is essential to ensure a minimum level of documentation of these results and how they were evaluated. This is important for transparency (enabling to discuss the results on a clear basis) and for further use (keeping the memory of the results, and providing clear information for correct interpretation).

Table 11: Direct, indirect and induced effects and macroeconomic net and gross impacts

Effects	Production affected in sectors that …	Model/approach			Impacts	
direct	… directly provide EE goods and services	Coefficients (labour, value added e.g. per specific investment); survey data (DECC 2014)	Input-output table, e.g. Diefenbach et al. (2016), BMLFUW (2014), Mikulić et al. (2016)	Macro-economic model e.g. European Commission (2016b), Barker et al. (2007)	Gross impact, e.g. gross employ-ment	Net impact, e.g. GDP
indirect	… are upstream industries of the EE industry					
induced	… provide energy supply and consumption goods					

Source: own depiction based on Breitschopf et al. (2013a)

4 | Conclusions

This report describes the main features and criteria of the Knowledge Base of the EPATEE project and identifies key issues and some disputable areas of the literature composed in the Knowledge Base. It supports the thesis that theoretical and methodological discussions of topics precede empirical and practical studies. Further it gives evidence of a large variety of studies and approaches, but on the other hand it highlights the need to elaborate and use common, transparent and replicable calculation methods for energy savings. Promoting a minimum level of documentation of evaluation methods and results would be a first step in this direction. In the meantime, there are several disputable areas such as additionality and free-riding in the context of net energy savings, costs in the context of efficiency indicators, and macroeconomic effects.

Regarding energy savings, it is argued that the additionality mentioned in the EED Article 7 and presented by Rosenow et al. (2016) aims at avoiding double counting of energy savings with other EU energy efficiency policies. Thus, this definition is not identical to additionality as discussed by e.g. Moser (2017) where it is defined as energy savings that would not have happened in the absence of the policy or programme and free-rider as energy savings that would have happened even in the absence of the policy or programme (see Table 5). The free-rider effect has to be taken into account in evaluations that aim at evaluating effectiveness or assessing efficiency i.e. accounted for to make policies more efficient, i.e. compare costs to net savings. Additional savings are applied when assessing target achievement. Thus, the purpose of the evaluation – target achievement or effectiveness – determines how energy savings are calculated or adjusted.

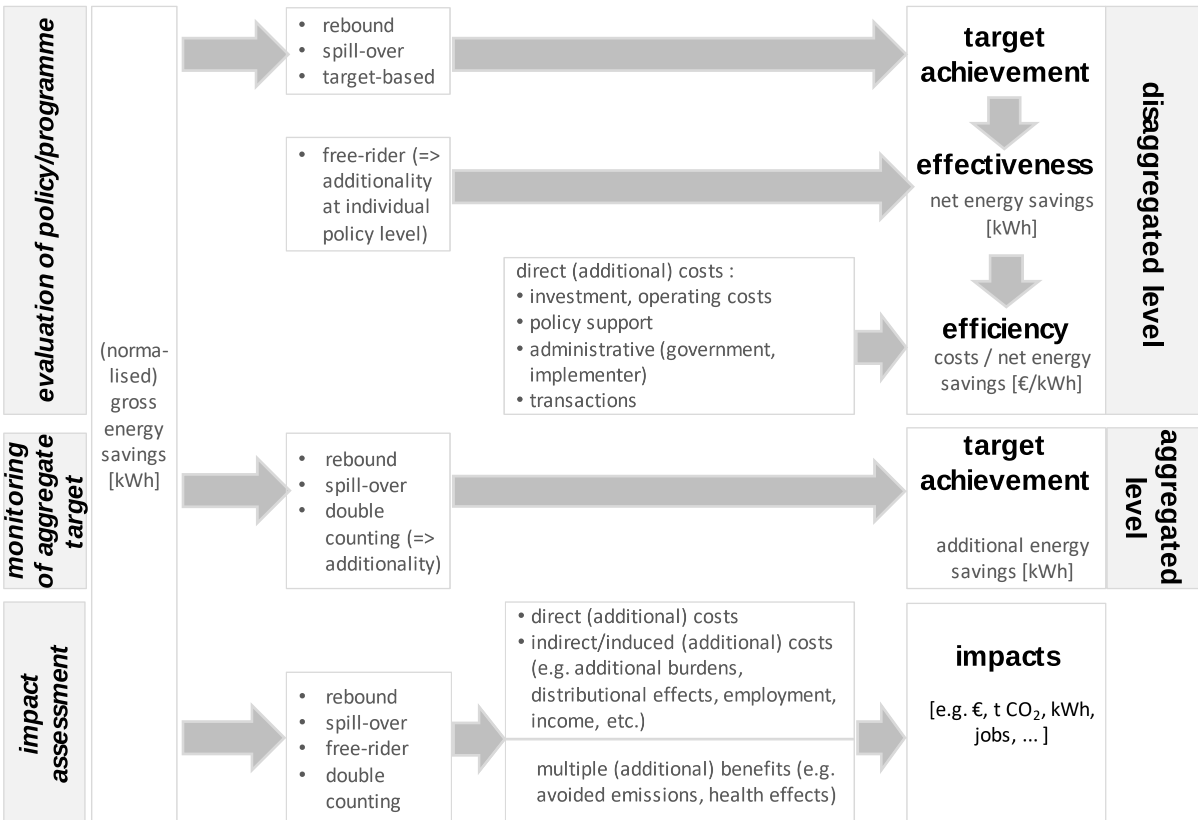


Figure 11: Overview of objectives of evaluations and the respective indicators

With respect to efficiency (costs per energy savings), costs are distinguished by their level and actor perspective. That is, the system level defined by the EEA, the micro and meso level defined by the actors that are affected by the EEA and policy, and the macro level, which represents the whole society and economy. The perspective corresponds to the different actors, final energy consumer, obliged/entrusted parties and the state/government or regulatory authority. At the micro level, the purpose of the evaluation pursues the efficiency of programmes (net energy savings), at the macro level the purpose is to assess how much one unit of energy savings target costs (additional savings). E.i. for policy makers focussing on the EED and climate targets, the policy efficiency (costs per additional savings) is crucial, whereas policymakers aiming at programme improvements, the programme efficiency (costs per net savings) is important. Moreover, as energy savings are (additional or) net savings, costs should also be net (additional). Thus, costs of a situation with an EEA and policy is always compared to costs of a situation without an EEA and policy, here called status quo situation. Figure 11 summarises these findings on energy savings and efficiency.

Finally, to measure efficiency on the level of the economy (economy-wide), macroeconomic impacts of EEA and programmes are key criteria. Macroeconomic impacts are commonly measured by employment, GDP or value added. They can be expressed as changes in growth and employment, which both present major economic objectives of an economy and are essential elements of welfare. Yet, mainly gross figures are used, as net effects require complex modelling efforts and, even then, they lack comparability due to very heterogeneous input parameters and model philosophies. In addition, net impacts always require a comparison between two situations, a situation with EEP and one without EEP. When including benefits beyond energy savings, they should be additional in the sense that they would have not occurred in this extent in a situation without EEP.

By contrast, gross impacts at the macro level often refer only to a situation with EEP and thus ignores potential effects of a situation without an EEP. Moreover, gross impacts might include differing direct and indirect effects, which also depends on the methodology applied, leading to variations in results. This is, why transparency (and thus documentation) of the applied methodology as well as common terminologies and methodological approaches are suggested.

5 | Annex

Table 12. Cost-effectiveness tests as defined by the California Public Utility Commission.

Test	Benefits	Costs	Description
PCT - participant cost test	Financial incentives Energy cost savings to participants Applicable tax credits (all)	Costs of energy efficiency measures (incremental)	Shows costs and benefits for energy consumers who take part in the energy efficiency program.
PACT - program administrator cost test	Avoided costs to utility	Financial incentives Program administration costs	Compares the costs of deploying the energy efficiency program with other supply-side options from the utility perspective.
RIM - ratepayer impact test	Avoided costs to utility	Financial incentives Program administration costs Lost utility revenue due to reduced energy bills	Evaluates potential impacts on energy tariffs from the nonparticipant perspective.
TRC - total resource cost test	Avoided costs to utility Environmental and non-energy benefits Applicable tax credits (received from outside utility service territory)	Total costs (see Fig. 2)	Estimates the change in energy costs for all energy consumers (i. e., participants and non-participants) within the utility service territory.
SCT – societal cost test	Avoided costs to utility Environmental and non-energy benefits	Total costs (see Fig. 2)	Accounts for costs and benefits of the energy efficiency program for society as a whole.

Source: table 1 of Yushchenko and Patel (2017) (table adapted from (EPA, 2008; Rufo, 2014))

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