Miriam Berretta
Collins Zamawe
Paul J Ferraro
Neal Haddaway
Jan Minx
Birte Snilstveit
John Eyers

Mapping energy efficiency interventions

April 2021

Evidence Gap Map Report 17

Energy and extractives

International Initiative for Impact Evaluation

About 3ie

The International Initiative for Impact Evaluation (3ie) promotes evidence-informed equitable, inclusive and sustainable development. We support the generation and effective use of high-quality evidence to inform decision-making and improve the lives of people living in poverty in low- and middle-income countries. We provide guidance and support to produce, synthesise and quality assure evidence of what works, for whom, how, why and at what cost.

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The evidence gap map reports provide all supporting documentation for the maps, including thematic background information, the methods and results, protocols, and analysis of the results.

About this evidence gap map report

This report presents the findings of a systematic search to identify and map the evidence base of impact evaluations and systematic reviews of interventions that aim to promote energy efficiency and energy conservation. All content in this report is the sole responsibility of the authors and does not represent the opinions of 3ie, its donors or its Board of Commissioners. Any errors and omissions are also the sole responsibility of the authors. Please direct any comments or queries to the corresponding author, Miriam Berretta, at: mberretta@3ieimpact.org.

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Executive editors: Birte Snilstveit
Production manager: Anushruti Ganguly
Assistant production manager: Akarsh Gupta

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Miriam Berretta
International Initiative for Impact Evaluation (3ie)

Collins Zamawe
3ie

Paul J Ferraro
John Hopkins University

Neal Haddaway
Stockholm Environment Institute and the Mercator Research Institute on Global Commons and Climate Change (MCC)

Jan Minx
MCC and the Priestley International Centre for Climate, University of Leeds

Birte Snilstveit
3ie

John Eyers
3ie

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Summary

This report presents the findings from an evidence gap map (EGM) of interventions that promote energy efficiency (EE) and energy conservation. The EGM systematically searched and reviewed the existing empirical evidence base and identified 299 studies. It brought this evidence together on an interactive platform (link) that gives a visual overview of the evidence and provides access to the individual studies. The EGM can be used to inform the design and implementation of new interventions, as well as funding prioritisation, to cover the identified gaps in evidence and synthesis.

This EGM is part one of a collaboration between 3ie and the independent evaluation function of the European Investment Bank, which funded this research project. Part two is a systematic review of EE building upgrades, which will be published by the end of 2021.

Background and methods

EE has great potential to reduce energy demand and consumption, thereby contributing to the reduction of global CO2 emissions. It is, therefore, not surprising that over the last decade, there has been an increasing global interest in EE. In 2019 alone, USD250 billion were invested in EE, with numerous programmes, policies and projects implemented to foster the adoption of EE technologies and practices among different end users, such as households, firms and industries, and public institutions. Therefore, it is of primary importance to learn about the effectiveness of EE interventions implemented thus far to inform future policies and investments.

The EGM gives an overview of the impact evaluations and systematic reviews on EE and energy conservation interventions published between 2000 and 2019. Through a systematic search of literature using eight academic databases and 46 organisational websites, the research team identified 46,701 records. After screening them against a pre-agreed inclusion and exclusion criteria protocol (Section 3.2), 299 studies (283 impact evaluations and 16 systematic reviews) were included in the map and presented against a matrix of intervention and outcome categories. This report summarises the findings of the EGM.

Summary of findings

The evidence base for EE and energy conservation interventions has increased steadily over the past 20 years. However, this evidence is fragmented, and several evidence gaps remain.

The evidence base is unevenly distributed geographically. The majority of studies evaluate EE interventions in high-income countries (75%), with more limited evidence available from low- and middle-income countries. The greatest number of the former studies come from the United States (105), followed by Europe (20) and Japan (17). Most studies on low- and middle-income countries come from China (11), India (10) and Mexico (8). This geographic concentration of the studies might be explained from two perspectives. Firstly, high-income countries generally consume more energy per household due to more intensive use of appliances and greater access to energy. Secondly, efforts to increase EE are stronger in high-income countries, and more resources are invested to implement EE interventions.

Impact evaluations for EE focus on a limited number of intervention categories. The most commonly evaluated interventions were the introduction of systems to monitor energy consumption (66); the direct provision of EE technologies and services (53); and the implementation of education campaigns to raise awareness of EE (40). For other intervention categories, evidence gaps remain. Few or no impact evaluations were identified for the following intervention categories: home appliance credit (0); equipment leasing (2); bank lending (2); utility-based programmes (2); technical assistance (3); capacity building (7); energy audits (10); EE legal frameworks (10); and disclosure policies (10).

Outcomes are also not equally measured, and available impact evaluations focus on relatively few outcomes. Most of the studies measured net saving of energy consumption (204). Other common outcome measures included changes in adoption of EE behaviours (85) and changes in awareness and attitudes (67). However, only a small number of studies (50) reported socio-economic outcomes, such as well-being and health, and changes in job creation and income. Similarly, only a small number of studies evaluate energy and environmental outcomes beyond energy use, resulting in a lack of evidence for greenhouse gas emissions and air pollution.

Furthermore, there is an important evidence gap at the end-user level. Eighty-six per cent of studies identified in the EGM evaluated interventions implemented at the household level, only 9 per cent at the business or industry level, and the remaining 5 per cent at the level of public institutions. This could be because it is easier to conduct evaluations among households than businesses, industry or public institutions; however, 39 studies demonstrate that it is possible to conduct impact evaluations at these levels, thus highlighting an important evidence gap, especially considering the large share of energy these entities consume.

Including data on the cost of an intervention is essential to ensuring that the evidence base is useful for decision makers who need to consider costs and relative cost effectiveness when deciding on intervention strategies. Yet, the EGM found that only 23 per cent of the studies (66) reported cost data in some form, with just under half providing the cost data without any further analysis on cost benefit, cost effectiveness or return on investment.

While there is growing consensus that mixed methods allow evaluations to capture information beyond programme effectiveness and shed light on the reasons behind the intervention’s success or failure, only nine applied both quantitative and qualitative analysis to evaluate the intervention.

The EGM did not find any systematic review assessed as high confidence:[1] of the 16 included, 9 were rated medium confidence and 10 low confidence. Furthermore, the EGM identified several synthesis gaps, which were clusters of primary studies in areas where no high-confidence systematic reviews had been conducted.

[1] The assessment used the Support Unit for Research Evidence (SURE) systematic review checklist (Annex C1).

Summary of implications

The map gives an overview of the available effectiveness evidence for EE interventions. It can be used to inform the design and implementation of new interventions, as well as funding prioritisation for interventions to cover the evidence gaps. It is a useful tool to raise decision makers' awareness of available evidence they can consult when planning new EE interventions.

Anyone commissioning or designing a new EE intervention should consider an impact evaluation, taking into account the research implications drawn from this map. For instance, it would be useful to evaluate interventions using rigorous methods in geographic areas most lacking in evidence. In addition, conducting a cost analysis, such as cost effectiveness or cost benefit, would help to identify the most cost-effective interventions.

Further, it would be useful to make completed evaluations publicly available to benefit the relevant communities and allow them to learn from the intervention.

The lack of high-confidence systematic reviews clearly identifies important synthesis gaps in the field, which funders and researchers might consider filling by funding and conducting rigorous studies.

Finally, given the publication trend and increasing relevance of EE, the evidence base is expected to grow considerably over the few next years; therefore, a *living* version of this map, or a regular update, will soon be needed.

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List of figures and tables

Acronyms list

EE	Energy efficiency
EGM	Evidence gap map
GHG	Greenhouse gas
HICs	High-income countries
IE	Impact evaluation
L&MICs	Low- and middle-income countries
RCT	Randomised controlled trial
SDG	Sustainable Development Goal
SR	Systematic review

1. Background

1.1 Trends in global emissions and energy efficiency

To mitigate the worst impacts of climate change and meet the Paris Agreement's temperature targets, rapidly reducing carbon emissions is imperative. Since the beginning of the industrial era (between 1750 and 2018), the concentration of CO2 in the atmosphere increased by approximately 50 per cent (Friedlingstein et al. 2019).

Although fossil fuel emissions existed before, since 1950 they have become the primary source of anthropogenic emissions into the atmosphere (Friedlingstein et al. 2019). Global anthropogenic greenhouse gas (GHG) emissions continuously increased from 1970 to 2010 (IPCC 2014), leading to an accelerated growth in their atmospheric concentrations. Between 2015 and 2019, this concentration was 20 per cent higher than it had been in the previous five years (WMO 2019).

After a brief decline in emission increases in the early 2000s, CO2 emissions have increased since 2010 by approximately 0.9 per cent per year. These oscillations are due to an emission decline in Europe and the United States, and an emission increase in China and India (Peters et al. 2020).

Between 1990 and 2016, the energy sector was responsible for the world's largest share of CO2 emissions. Over the past decade (2009–2018), 45 per cent of CO2 emissions came from the energy sector (mostly electricity and heating); 23 per cent from the industrial sector; 22.5 per cent from transportation; and the remaining 10 per cent from buildings, agriculture, fishing and other sectors (Peters et al. 2020). The increase of emissions from the energy sector was driven largely by the growing use of electricity, which rose over 19 per cent since 2010 (GABC 2019).

Ensuring access to sustainable energy—part of the seventh sustainable development goal (SDG7)—is an additional challenge. Despite the rise in global energy consumption, around one billion people do not have access to electricity, which limits their access to health services, education and the labour market, as well as reduces their welfare standards (UN DESA 2018). One barrier to modern energy access, particularly in low- and middle-income countries (L&MICs), is the low connection rate in on-grid areas even years after infrastructure is completed, resulting in a weak impact of electricity expansion in the short- and mid-term (Bonan et al. 2017).

Given the current trends in energy consumption and their impact on emissions, improving energy efficiency (EE) is of primary importance. There are three popular ways to reduce energy consumption: (1) raising the price of GHG-emitting energy use (e.g. via a carbon tax); (2) directly encouraging improvements in EE; and (3) directly encouraging the development of low-carbon energy sources.

Dubbed as the 'first fuel' by the International Energy Agency, EE is broadly defined as 'the ratio of output of performance, service, goods or energy, to input of energy' (Erbach 2015). EE is considered a cost-effective option to solve the dual challenge of reducing global emissions and ensuring energy access for everyone (EIB 2016; Bonan et al. 2017; BP 2019).

In the context of climate change mitigation, EE is considered fundamental for three reasons. First, it is recognised that reducing the demand for energy through EE is crucial to transforming the energy supply to meet the sustainable development goals and the target of limiting temperature rise to 1.5 degrees Celsius (Grubler et al. 2018). Second, compared to supply-side mitigation options, EE improvements are considered less risky (Von Stechow et al. 2015). Finally, recent research suggests that EE is a more granular process, which can be adopted much faster—an important advantage given the urgency to keep warming below 2 degrees Celsius (Wilson et al. 2020).

This map focuses on EE and energy conservation interventions that have been reported to be underutilised despite their cost effectiveness and immediate availability (Allcott and Greenstone 2012). Despite the recognised advantages of EE improvements over other approaches, such as raising energy prices or using low-carbon energy, the impacts of EE are theoretically ambiguous. For example, the well-known 'rebound effect'—EE may lead consumption to decline very little or even increase—was first hypothesised a century and a half ago by Jevons (1865) in his book *The Coal Question* and discussed by many others. Thus, a map of the evidence base on the effects of EE interventions is warranted.

1.2 Why it is important to undertake this evidence gap map

We follow the 3ie standards and methods for evidence gap maps (EGMs) (Snilstveit et al. 2016; 2017). EGMs are tools to help decision makers, project implementers, funders and researchers working in a sector or thematic area to make evidence-informed decisions. They make evidence in a field more accessible and facilitate the prioritisation of future research by mapping studies onto a framework of interventions and outcomes.

We develop EGMs using systematic methods to identify and describe all completed and ongoing impact evaluations (IEs) and systematic reviews (SRs) relevant to research objectives. Studies (both IEs and SRs) are mapped onto a framework of interventions and outcomes, providing a visual display of the volume of evidence for combinations of interventions and outcomes, the type of evidence (completed or ongoing), an indication of research gaps and, for SRs, a confidence rating reflecting the study's validity.

1.2.1 Investments in EE measures

Numerous countries and organisations are investing large amounts of money into EE measures. Globally, in 2019, USD250 billion were invested in EE across the industry, building and transport sectors—a similar figure to the USD240 billion invested in 2018 (IEA 2019; 2020). By region, Europe invested the most at approximately USD63.8 billion; the United States invested around USD32billion; China around USD30 billion; and other regions around USD25 billion; these figures have grown slightly since 2015 (IEA 2020).

A report by the OECD showed that investments in EE would need to increase eightfold between 2011 and 2035 (rising from USD130 billion to USD1.1 trillion) to meet the climate change goals of the 2015 Paris Agreement on Climate Change, demonstrating the importance of investments in EE (OECD 2016).

Several international organisations have established dedicated budgets and funds to tackle climate change, such as EIB and the World Bank. EIB and the European Commission are already at the forefront of climate action, running various initiatives and programmes aimed at cutting emissions and increasing EE. One example is the European

Local Energy Assistance facility programme, which has provided more than EUR168 million in grants for technical assistance on EE and renewable energy in buildings, homes and urban transport; the projects supported by this programme are expected to lead to over EUR6 billion in investment in energy and transport efficiency (EIB 2019).

The World Bank Group, through the International Finance Corporation, promotes sustainable growth and development of the private sector by investing in resource efficiency projects (World Bank 2017). The World Bank has also described other development benefits of EE, including enhanced energy security, improved reliability in the power system, reduced pressure on national and household budgets, and improved performance in critical areas such as health and education. The International Finance Corporation has supported various programmes across the world, including in China and India, where it has provided more than USD925 million to improve EE, meet climate change SDGs, and address challenges in the energy sector (World Bank 2017).

1.2.2 Existing IEs and evidence syntheses

Given the amount of money currently invested in EE, and the expectation for this amount to increase in the future, investors need to understand which interventions work the most effectively (Gillingham et al. 2018; Ferraro 2009; Schiller 2007; Vine et al. 2006; Frondel and Schmidt 2005).

To identify the effectiveness of an intervention, IEs use counterfactual analysis to provide valid, unbiased estimates of impacts. Experimental and quasi-experimental IE methods allow the estimation of an intervention's impact, which can be attributed to the programme by controlling for unobservable characteristics (Gillingham et al. 2018; Ferraro 2009; Schiller 2007; Vine et al. 2006; Frondel and Schmidt 2005).

Initially, we conducted exploratory work during which we identified numerous studies that evaluate EE interventions. Programmes that have been studied include weatherisation programmes (Fowlie et al. 2018), building code policies (Kotchen 2017), smart meters and feedback information (Shimada et al. 2015), EE lightbulb market interventions (Allcott and Taubinsky 2015), energy audits in the industrial sector (Duflo et al. 2013), and the uptake of efficient cookstoves in developing countries (Bensch et al. 2015; Calzada and Sanz 2018). These early findings suggested a vast amount of high-quality evidence[2] in this field, and an emerging need to synthesise and draw lessons from it.

During the exploratory work, we also identified some SRs that focus on one or more specific EE intervention types. However, an EGM has the additional value of giving a broader picture of evidence in the sector and revealing evidence gaps, including areas where there are clusters of primary studies and lack of synthesis. Some examples of SRs include: Rasmussen (2017), Nehler (2018) and Solnørdaland and Foss (2018), who focused on industrial EE and non-energy benefits; Kamal and colleagues (2019), who studied the social costs of EE interventions; Gonzalez-Caceres and colleagues (2019); Kivimaa and Martiskainen (2018), who synthesised interventions in buildings; Andor and Fels (2018); Tsang and colleagues (2012), who focused on behavioural change interventions to increase energy conservation; and Russell-Bennett and colleagues (2019), who focused on other household EE interventions.

[2] High-quality evidence in this field refers to IEs that use one of the methods listed in section 3.2.4.

The aim of our map is to create a comprehensive review of experimental and quasi-experimental evidence from both high-income countries (HICs) and L&MICs on EE interventions.

1.3 Study objectives and research questions

The aim of this EGM is to identify and describe available evidence of the effects of EE interventions that target households, public institutions, businesses and industrial facilities across the world. Mapping the evidence that assesses the effectiveness of these interventions identifies gaps in literature[3] where the number of evaluations or syntheses is low. It also facilitates the use of such evidence to inform decisions by making it easily accessible. The specific objectives of this EGM are as follows:

1. Identify and describe evidence on the effects of interventions to promote EE technologies and practices across the world
2. Improve access to this evidence for decision makers, project implementers, funders and researchers
3. Identify absolute[4] and synthesis gaps in the existing evidence base.

To achieve these objectives, we address the following research questions:

1. What is the extent of experimental and quasi-experimental evidence on the effects of EE interventions, and what are the characteristics of the evidence base?
2. What are the major gaps in the primary evidence base?
3. What intervention and/or outcome areas should be prioritised for primary research and/or evidence synthesis?

2. Scope of the EGM

2.1 Conceptual framework and theory of change

A standard definition of EE is:

> The ratio of energy required to perform a specific service to the amount of primary energy used for the process. Improving energy efficiency increases the productivity of basic energy sources by providing given services with less energy resources. — Goswami and Kreith 2007

This EGM centres on interventions aimed at improving EE at the level of households, public institutions, business and industry; we specifically focus on measures aimed at improving the EE of residential, public and commercial buildings, as well as investments in production processes, such as more energy-efficient equipment and machinery in small and medium-sized enterprises and industrial facilities. We focus on the sectors above to ensure the scope of the EGM is manageable. However, we acknowledge that other sectors, such as transportation, agriculture and water service, can also contribute to EE improvements.

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[3] *Literature* comprises IEs and SRs of effectiveness.

[4] *Absolute* gaps indicate an absence or very limited number of studies found under a certain intervention or outcome category.

Even within our sectors of focus, EE covers a broad range of interventions that cut across different areas: homes, public and commercial buildings, small- and medium-sized enterprises and industrial facilities. To develop a framework of interventions and outcomes for this EGM, we used the innovation diffusion model developed by Vine and colleagues (2006) as a starting point for understanding potential blockages in the adoption process. This model highlights the linkages between the development of EE technologies or services and their adoption in society, including market, information and behavioural failures (which the EE interventions included in this EGM aim to overcome).

The theory of change diagram below (Figure 1) provides a visual overview of the model. Vine and colleagues' theory represent the innovation diffusion process in two main phases: (1) build infrastructure and (2) fund and promote adoption. The first phase includes the development of technical information to make EE more accessible and able to be implemented. It also includes the adoption of new frameworks by public entities to enable uptake of the innovation, as well as firms' creation and enhancement of EE products and the development of installation and support infrastructure.

The second phase is focused on how to deliver the energy-efficient technology or service to end users in a way that enables them to use it effectively. This phase includes economic support, provision of knowledge, technical assistance and information dissemination (Vine et al. 2006).

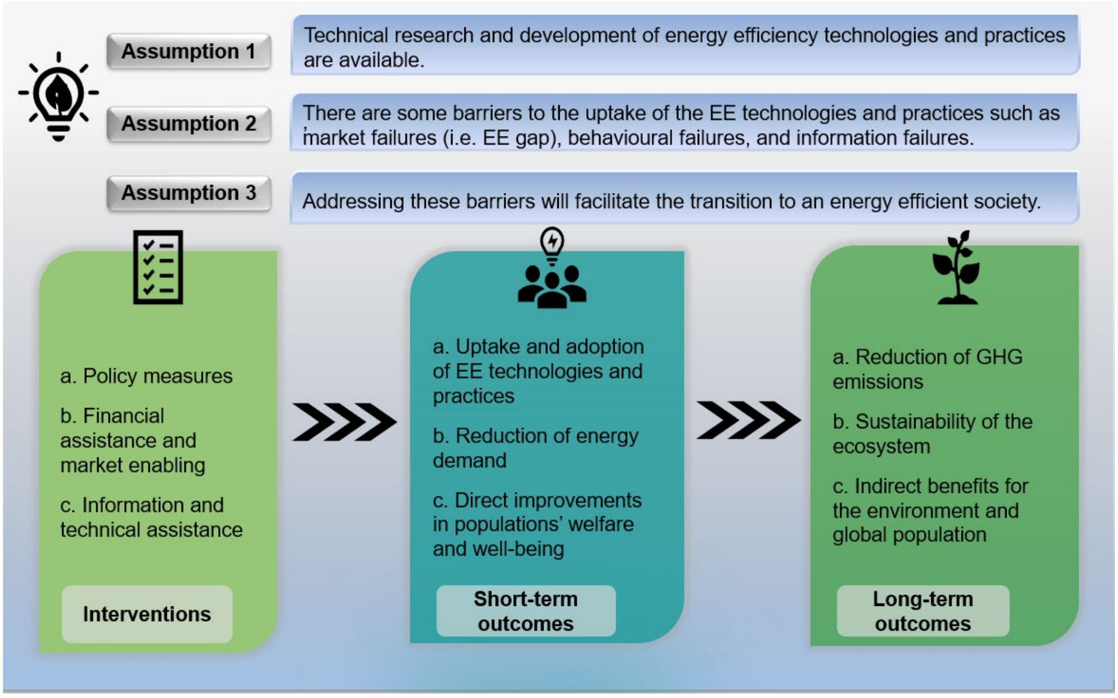
There are several barriers to the adoption of a new technology, including market failures, information failures and behavioural failures[5] (Allcott and Greenstone 2012; Ramos et al. 2015; Gillingham et al. 2018). To address these issues, various interventions can be implemented at the policy, economic and knowledge levels (Andor and Fels 2018; Quansah et al. 2017; Ramos et al. 2015; Schiller 2007; Tsang et al. 2012; World Bank 2015). This map is focused on understanding the effectiveness of these interventions.

We adapted a simple conceptual framework for EE interventions from the World Bank (2015), presented in Figure 2. The interventions are divided into three main types: (1) policies that encourage or force the adoption of EE technologies or practices; (2) interventions that provide economic assistance, such as subsidies, to facilitate the uptake of an EE technology or energy conservation; and (3) initiatives that increase the circulation of detailed information and technical assistance to support the adoption of EE technologies or practices.

The implementation of these interventions is likely to have both short- and long-term outcomes (Figure 1). In the short term, people will begin adopting EE technologies or practices, leading to less demand for energy with direct effects on welfare (e.g. cheaper utility bills) and health (e.g. lower rate of household pollution with the adoption of efficient cookstoves). In the long term, those improvements will reduce GHG emissions, contributing to a balanced ecosystem and long-term benefits both for the environment and the population (e.g. reductions in respiratory diseases and migration due to climate extremes).

[5] Behavioural failures: behaviours that deviate from rational choice theory.

Figure 1: Theory of change



Source: Authors

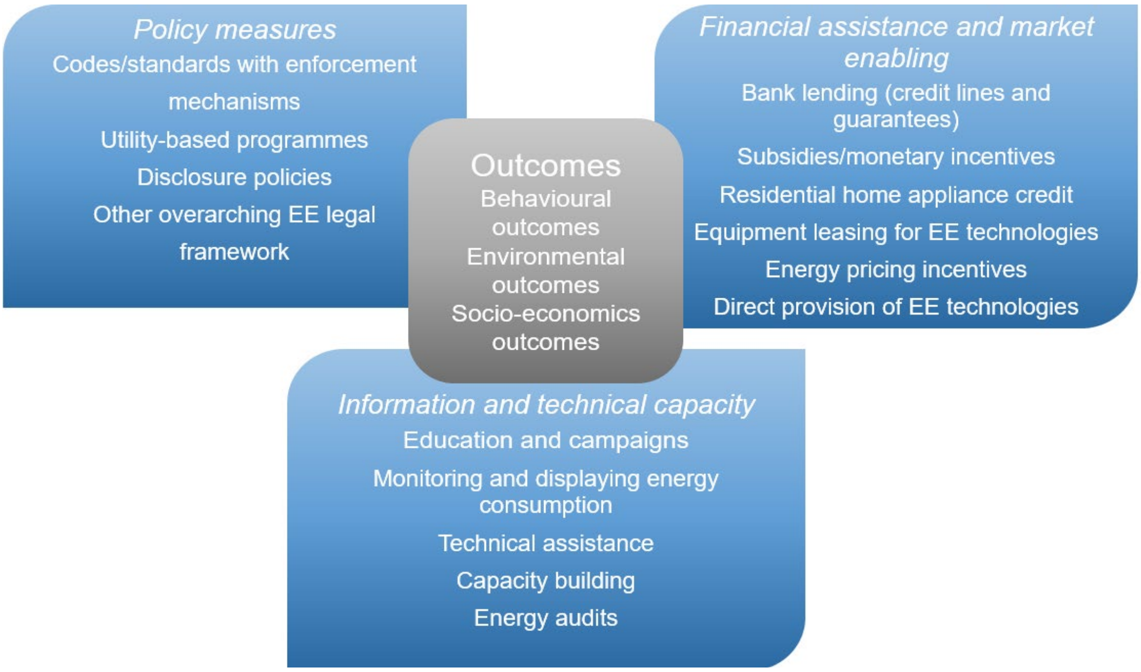
Figure 2 summarises the intervention types included in the framework, and provides an overview of the different EE policies, projects and programmes being implemented.

The first group of interventions includes policies and regulations that encourage or oblige individuals, businesses or other public institutions to become energy efficient, for example, by enforcing EE codes for buildings. The second group of interventions is made up of all the economic and financial instruments used to enable the adoption of EE technologies or services, such as bank lending, subsides, cash transfers or home appliance credits.

The third group of interventions entails those focused on providing information and technical capacity, with two broad objectives. First, it includes interventions that enable people, companies and government agencies to acquire necessary technical skills and knowledge to adopt energy-efficient technologies and behaviours. Second, it includes interventions that use information to nudge people, companies and government agencies to change their behaviours and use less energy, for example, by providing them with more information on the potential benefits of certain behaviours.

The outcomes captured in the EGM have been divided into three broad domains: behavioural, environmental and socio-economic outcomes. The first group includes any change in people's behaviour that leads to increased awareness of EE solutions; these outcomes can also be considered intermediate. The second group includes outcomes related to energy use, energy access, air pollution rates and GHG emissions. The third group includes a range of socio-economic outcomes, including savings, health status and employment rates.

Figure 2: Simple framework with domains of interventions and outcomes



Source: Authors, adopted from World Bank (2015)

3. Methods

3.1 Overall methodological approach

As mentioned in the previous section, we followed the standards and methods for EGMs developed by 3ie (Snilstveit et al. 2016; 2017). We systematically searched and screened all relevant completed and ongoing IEs and SRs. We mapped the studies that met the inclusion criteria onto the framework of interventions and outcomes, and then presented the results on an interactive platform, which provides a graphical display of the evidence in a grid-like framework.

The web-based visual display[6] of the map shows the volume of evidence for each intervention–outcome combination, the type of evidence (IEs or SRs, completed or ongoing), and a confidence rating for SRs. The map's online interactive platform provides additional filters so users can explore the evidence, for example, by focusing on certain regions, income levels or other groups. We summarise the methods used to conduct the EGM here, with additional information on the methodology appearing in Appendix E.

3.2 Criteria for including and excluding studies in the EGM

To be included in the EGM, studies had to meet the criteria defined in this section.

3.2.1 Population of interest

Studies needed to focus on three types of end users of EE technologies or practices: households, public institutions, and firms and industries across the world. We did not insert any geographic restriction.

[6] Link to the map online: https://gapmaps.3ieimpact.org/evidence-maps/energy-efficiency-egm

3.2.2 Interventions

We included studies of interventions that aimed to increase the adoption of EE technologies and practices, as specified in Section 2.1. Interventions fall into three main domains, as illustrated in Figure 1: policy measures, financial assistance measures and informational measures. Table 1 shows the specific intervention types included for each domain, drawing on a World Bank EE intervention framework (World Bank 2015).

Table 1: Interventions included in the framework

Intervention domain	Category	Description
Policy measures	Codes/standards with enforcement mechanisms	The introduction of EE standards (e.g. in the construction or renovation of buildings or houses to make them energy efficient, such as building energy codes as a subset of building codes, establishing baseline requirements and governing building construction to ensure EE).
	Utility-based programmes	Utility-based programmes are also called EE obligations, energy savings obligations and white certificates. These mechanisms place obligations on utilities to find energy savings equivalent to a certain percentage of their energy sales. Depending on the programme design, utilities can invest in end-use efficiency with their customers, or purchase energy savings from third parties. Some schemes also allow for trading of energy savings (Denysenko et al. 2018).
	Disclosure policies	Disclosure policies seek to reduce information asymmetries between building owners and prospective investors or renters so that this information can factor into decision-making processes (Kontokosta et al. 2020). For example, disclosure laws improve consumer awareness of the energy use of homes and buildings, which can have a significant impact on its economic value.
	Other EE legal frameworks	This includes any type of law or policy framework that encourages users to adopt EE technologies or services.
Financial assistance and market-enabling measures	Bank lending (e.g. credit lines and guarantees)	These programmes include credit lines or green mortgages from local banks to support EE investments. For example, they can support a portfolio of smaller EE investments, or support increasing the EE of production processes in factories, businesses, or small- and medium-sized enterprises. Examples of this type include: • Renovation of existing housing stock so it better maintains temperature in different types of weather, reduction in the amount of energy to heat or cool the building (e.g. weatherisation interventions, insulation, retrofit) • EE improvements in industrial facilities (e.g. interventions to increase the efficiency of factories' power plants by upgrading old ones or replacing them with more efficient models) • Upgrades of energy transmission systems to reduce the waste of energy.

Intervention domain	Category	Description
	Subsidies or monetary incentives	Subsidies or monetary incentives (e.g. cash transfers) to increase uptake of EE technologies or behaviours include renovations, weatherisation or the purchase of more EE technologies.
	Residential home appliance credits	Private or public credit lines for households to purchase more EE appliances.
	Energy pricing incentives	Interventions to change the price of energy, inducing a reduction in energy consumption. For example, time-of-use pricing is aimed at reducing energy consumption in peak hours. Another example are prepaid electricity meters.
	Provision of EE technologies or services	Direct provision by public or private organisations of more efficient technologies (or appliances) to heat, cook, cool or provide light (e.g. replacement of old refrigerators and air-conditioners with energy-efficient models).
	Equipment leasing for EE technologies	Leasing schemes to adopt more efficient technologies, especially in the industrial sector.
Information programmes and technical capacity development	Education campaigns	Processes such as education, communication campaigns or peer comparison to nudge people to change their behaviours and practices around energy consumption. Examples include flyers or face to face discussions to explain to consumers how to reduce their energy consumption by changing their behaviours or adopting a certain technology or service.
	Monitoring and displaying energy consumption	Interventions that provide households with their energy consumption records, thereby inducing them to use less energy. Some examples are home energy reports, feedback and smart meters delivered to households.
	Technical assistance	Interventions that provide access to specific technical assistance to implement and scale up EE technologies or practices. For example, the one-stop-shop option provides information on potential opportunities and funding access for EE investments.
	Capacity building	Interventions to build the capacity of individuals, communities or local authorities to understand, implement and use energy-efficient technologies, services, practices and behaviours (e.g. training or workshops).
	Energy audits	Energy audit requirements aim to improve building owners' awareness of cost-effective EE technologies opportunities.

3.2.3 Outcomes

Studies that covered at least one intervention of the framework and measured at least one of the outcomes in Figure 2 were included in the map. Table 2 lists the outcomes in more detail.

Table 2: Outcomes included in the framework

Outcome domain	Category	Description
Behavioural (intermediate) outcomes	Changes in awareness or attitudes	Knowledge and attitudes towards EE options and opportunities changed through exposure to the intervention.
	Adoption of energy-saving behaviours	Programme participants decide to adopt energy-saving practices, such us switching off the lights more often, using less water or following specific instructions.
	Uptake of the technology	Programme participants decide to act and adopt a certain technology.
	Upgrade to efficient technology	Programme participants decide to upgrade a certain technology.
	Use of the technology (once received)	Use of certain energy-efficient technologies changed through exposure to the intervention.
Energy and environmental outcomes	Net energy savings or consumption changes	Net energy or demand savings refer to the portion of gross savings attributable to the programme. This measurement involves separating out impacts that are the result of other influences, such as consumer self-motivation. Given the range of influences on consumers' energy consumption, attributing changes to one cause (i.e. a certain programme) can be quite complex.
	Energy security or access	Energy security is defined as the uninterrupted availability of energy sources at an affordable price. In this context, an EE intervention might have, for example, increased energy security by reducing energy costs due to more efficiency technologies.
	GHG emissions	Carbon-related emissions and non-carbon related emissions, such as methane, nitrous oxide and fluorinated gases.
	Water consumption	Net water consumption derived from the EE intervention.
	Air quality indexes and pollutions rates	Air pollution or GHGs that would have been emitted had more energy been consumed in the absence of the EE programme. These emissions can be the result of fuel combustion at an electrical power plant or the combustion of heating fuels, such as natural gas or fuel oil, at a project site.
Socio-economic outcomes	Income savings	Increased economic savings due to more efficient new or upgraded equipment or changed energy-saving behaviours.
	Health status, comfort and well-being	Better quality of life resulting from the adoption of EE technologies or practices that improve the living environment, such as by reducing the air pollution rate, decreasing rates of illness or increasing access to electricity.
	Job creation	New job creation due to the installation of new equipment or adoption of innovative practices that require expert personnel or additional workers.
	Building stock value	Increased property value due to the installation of new equipment or renovation of equipment.

3.2.4 Types of study

We include IEs that evaluate the effect of interventions using methods that allow for causal inference, or SRs of such IEs. We define the specific criteria required for inclusion below, drawing on commonly accepted standards for IEs (Gillingham et al. 2018; Ferraro and Hanauer 2014; Schiller 2007; Vine et al. 2006; Frondel and Schmidt 2005):

1. Randomised controlled trials (RCTs) with assignment at individual, household, community or other cluster level, and quasi-RCTs using prospective methods of assignment such as alternation.
2. Non-randomised studies with selection on unobservable:
3. Regression discontinuity designs, where assignment is done on a threshold measured at pre-test, and the study uses prospective or retrospective approaches of analysis to control for unobservable confounding
4. Studies using design or methods to control for unobservable confounding, such as natural experiments with clearly defined intervention and comparison groups, which exploit natural randomness in implementation assignment by decision makers (e.g. public lottery) or random errors in implementation, and instrumental variables estimation.
5. Non-randomised studies with pre- and post-intervention outcomes data in intervention and comparisons groups, where data are individual-level panels or pseudo-panels (repeated cross-sections), which use the following methods to control for confounding:
6. Studies controlling for time-invariant unobservable confounding, including difference-in-difference, or fixed- or random-effects models with an interaction term between time and intervention for pre-intervention and post-intervention observations
7. Studies assessing changes in trends in outcomes over a series of time points (interrupted time series), with or without contemporaneous comparison (controlled interrupted time series), with sufficient observations to establish a trend and control for effects on outcomes due to factors other than the intervention (e.g. seasonality).
8. Non-randomised studies with control for observable confounding, including non-parametric approaches (e.g. statistical matching, covariate matching, coarsened-exact matching, propensity score matching) and parametric approaches (e.g. propensity-weighted multiple regression analysis).
9. SRs were included if they describe the search, data collection and synthesis methods according to the 3ie database of SRs (Snilstveit et al. 2016).

We excluded all studies that do not fall under any of the criteria defined above. Examples of excluded study types are: simulation studies that aim to predict the effect of a certain technology, studies that assess the efficacy of a specific technology, observational studies with no control for selection bias, life-cycle analysis, feasibility studies, acceptability studies and non-systematic literature reviews.

The reasons for excluding these types of studies are that they either address different research questions or have a high risk of bias in the estimator of the intervention effects. For instance, efficacy trials are studies that examine a specific intervention, as implemented in a controlled setting, whereas we seek estimates under real-world conditions. Bivariate correlation studies provide analysis of the relationship between two variables, but the analysis does not establish causality because they do not control for confounding variables. Life-cycle assessments, on the other hand, do not intend to look at the effectiveness of an intervention as compared to an alternative course of action; instead, they focus on the environmental impact of a technology, process or service during the stages of its life cycle. Finally, feasibility studies look at the resources needed to implement a certain intervention and do not evaluate its effects.

3.3 Additional inclusion and exclusion criteria

We include both ongoing and completed IEs and SRs. EE is one of the fast-growing climate change sectors in the world, with several new technologies, programmes and policies developed each year and many others modified or phased out. Thus, to ensure that the EGM focuses on EE evidence relevant to the contemporary world, we excluded studies published before 2000. For example, evidence relating to the effects of EE interventions in 1970s would not be of much use and could distort the evidence base if such interventions are no longer in use.

Finally, we did not exclude studies on the basis of language, but initially, the search focused on English-language databases. Any non-English studies identified in the search results were screened and included if they met the inclusion criteria. See Annex E3 (c) for more information on non-English papers.

3.4 Search strategy

We searched a range of sources in academic and grey literature, including bibliographic databases (general social science and environment-focused databases), repositories of IEs and SRs, specialist organisational databases, and websites of bilateral and multilateral agencies. We worked with an information specialist to develop a detailed and sensitive search strategy,[7] primarily constructed by a combination of intervention and study design terms.

This strategy was then translated[8] according to the requirements and functionalities of different databases. We provide more information on the search strategy in Appendix A. The full list of sources covered in the search can be found in Appendix A.1, and an example of the search strategy developed for CAB Abstracts® is provided in Appendix A.2. In addition, we conducted backwards citation tracking of all the included studies, non-SRs and guidelines to identify additional studies. Once the draft EGM was completed, it was circulated to key experts and stakeholders to identify any studies not already identified.

[7] Sensitive search strategy: sensitive here is a synonym of comprehensiveness in relation to the types of studies that can be captured. Increased sensitivity of a search will reduce its precision and retrieve more non-relevant articles (Higgins and Green 2011).
[8] The search strategy employed in different databases makes use of strings of key words, often truncated and wildcard variations of the same terms, linked with Boolean operators (AND, OR, NOT or proximity operator [N3, N5, etc.]). These operators are different for each database, so they need to be 'translated'.

Once we obtained the search results, they were imported into the SR software EPPI-Reviewer®.[9] This platform is used to manage references, identify and remove duplicate studies, and screen records for inclusion using the procedures outlined below. At the title and abstract screening level, we used double screening combined with the EPPI-Reviewer® classifier machine-learning functionality to speed up the screening process. Initially, a randomly selected set of around 800 studies were screened to provide training to the team. During the training, the results given by the researchers were compared and any discrepancy in coding decisions discussed, including clarification of the inclusion criteria, as needed.

The classifier machine-learning algorithm in EPPI-Reviewer® was used to divide the studies under different codes based on their likelihood of inclusion, with a scale ranging from 0 to 99 per cent. After screening approximately 10,000 records, the results were used to run and 'train' the classifier on the type of included and excluded studies.

The classifier indicated that most of the remaining studies (28,385) had a low chance of being included (0–9%). Some remaining studies (3,838) had a higher likelihood of inclusion, but only a few were in the highest percentages (90–100%). All studies in the high likelihood bracket were screened. However, to ensure that the classifier identified the other studies correctly, we decided to manually double screen all remaining studies. Of those 28,385 in the 0–9 per cent range, only 26 were included after screening the title and abstract, but all were excluded after full-text screening.

We conducted full-text screening of each study that met all title and abstract screening inclusion criteria. Two reviewers from the core team independently examined the full text of each study in detail against the protocol and independently decided whether to include it; any disagreements between reviewers were then reconciled through supervision of a senior review team member. The output of this stage is a set of studies deemed suitable to be included in the EGM.

4. EGM findings

4.1 Search results

We conducted our search in May 2020. As the PRISMA[10] diagram (Moher et al. 2009) below shows, the search strategy returned 46,268 records (Figure 3). After removing duplicates, 42,223 records were left for screening at title and abstract. Screening these records, we identified 953 studies to review at full text. Among them, the majority (459) were excluded because the interventions were not relevant to the scope of the EGM.

A total of 150 studies were excluded due to their study design; another 116 were excluded due to their small sample size or because they did not have a valid control group; 65 were excluded because they did not address effectiveness; and a small number were excluded for other reasons. The final set comprised 299 studies, of which 283 are IEs and 16 are SRs.

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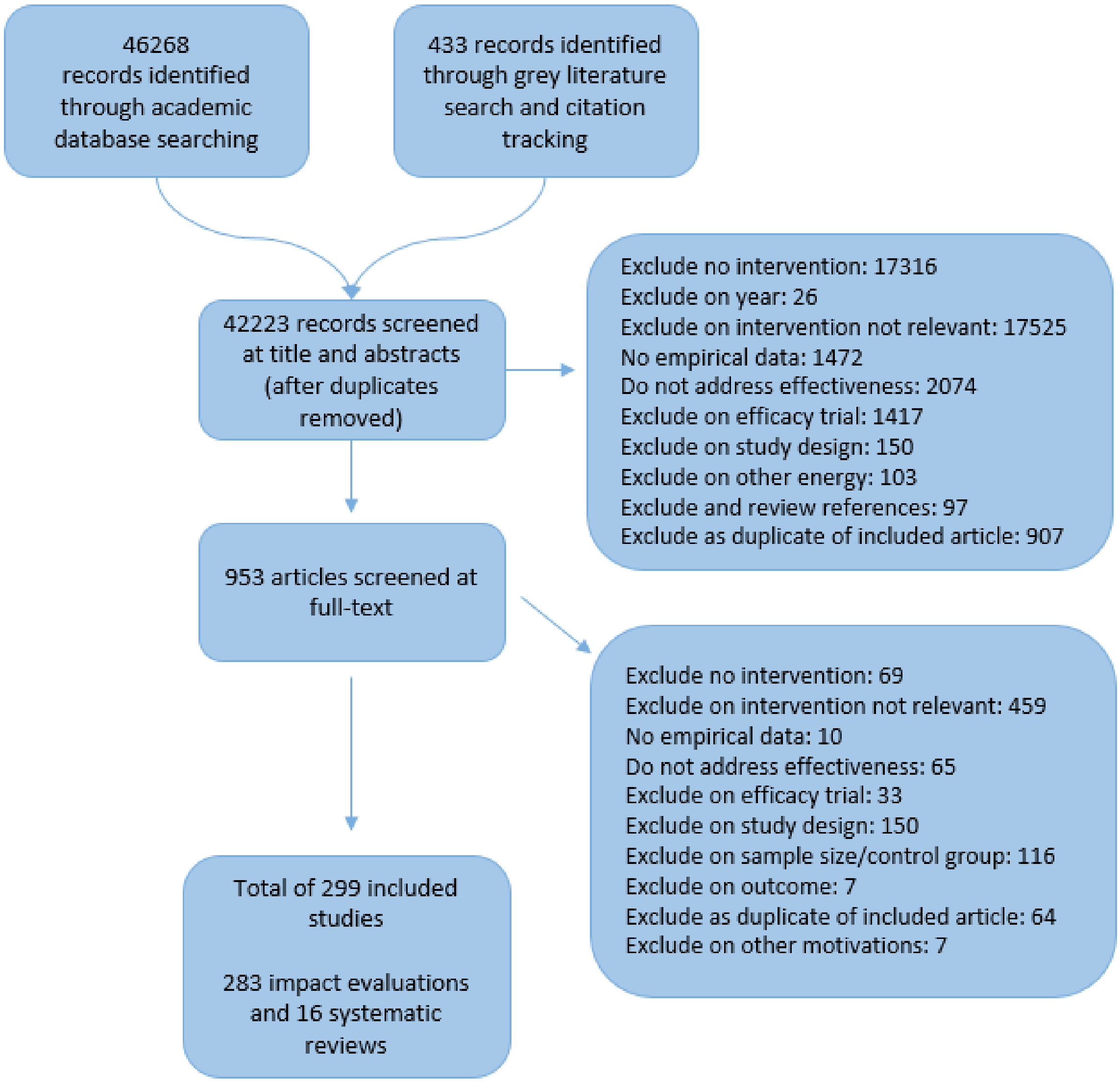
[9] EPPI-Reviewer 4® is software for all types of literature review, including SRs, meta-analyses, 'narrative' reviews and meta-ethnographies. For more information, visit: https://eppi.ioe.ac.uk/CMS/Default.aspx?alias=eppi.ioe.ac.uk/cms/er4&

[10] PRISMA stands for 'preferred reporting items for SRs and meta-analyses. For more information visit the PRISMA website: http://prisma-statement.org/PRISMAStatement/PRISMAStatement.aspx

Figure 3: PRISMA diagram

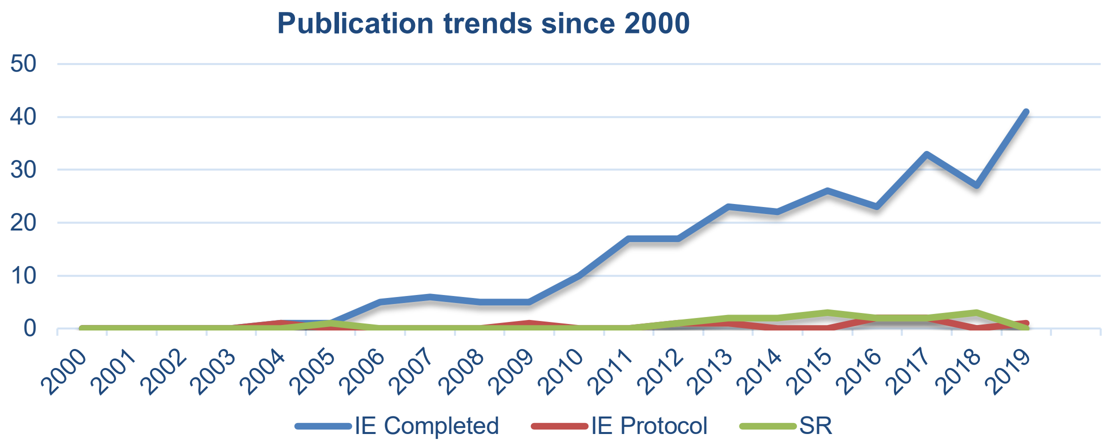


4.2 Characteristics of the evidence base

4.2.1 Publication trend over time

Figure 4 reports the publication trend of the IEs included in the EGM over time. The number of studies published increased substantially—from five per year in 2006 to 41 in 2019. Nine IE protocols (ongoing studies) were identified, with no clear increase over the last few years. Finally, we found a small number (16) of published SRs, with no substantial trend.

Figure 4: Publication trend by number of studies

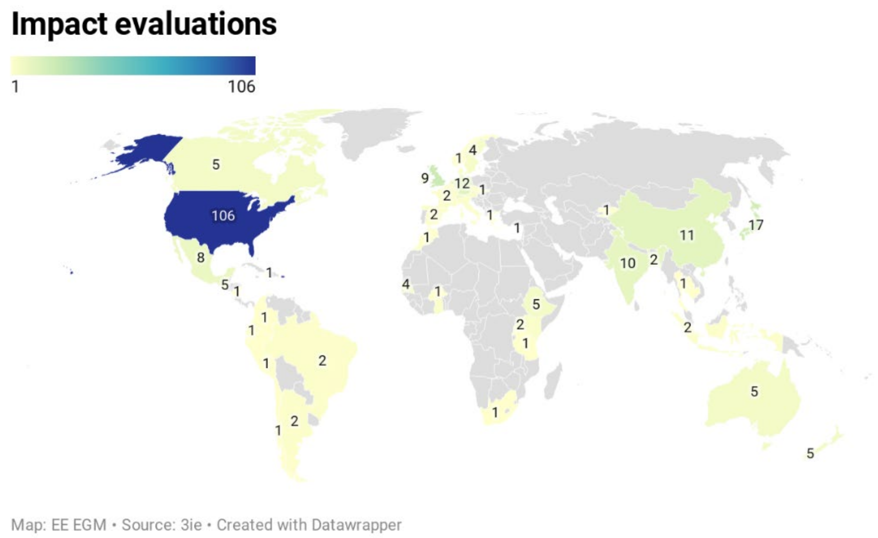


4.2.2 Geographic distribution

Figure 5 shows the uneven geographic distribution of IEs in the EGM: 75 per cent (213) were conducted in HICs, primarily in North America (110) and Europe and Central Asia (75). Only 20 per cent of the studies are from middle-income countries, including East Asia and the Pacific (44), Latin America and the Caribbean (23), South Asia (11), Sub-Saharan Africa (5) and the Middle East and North Africa (1). The remaining 14 studies all come from low-income countries in Sub-Saharan Africa, representing five per cent of the total number of included studies.

The SRs show a similar pattern, with four reviews focused on HICs and one on L&MICs; the remaining six SRs did not specify which countries the evidence came from.

Figure 5: Geographic spread of IEs



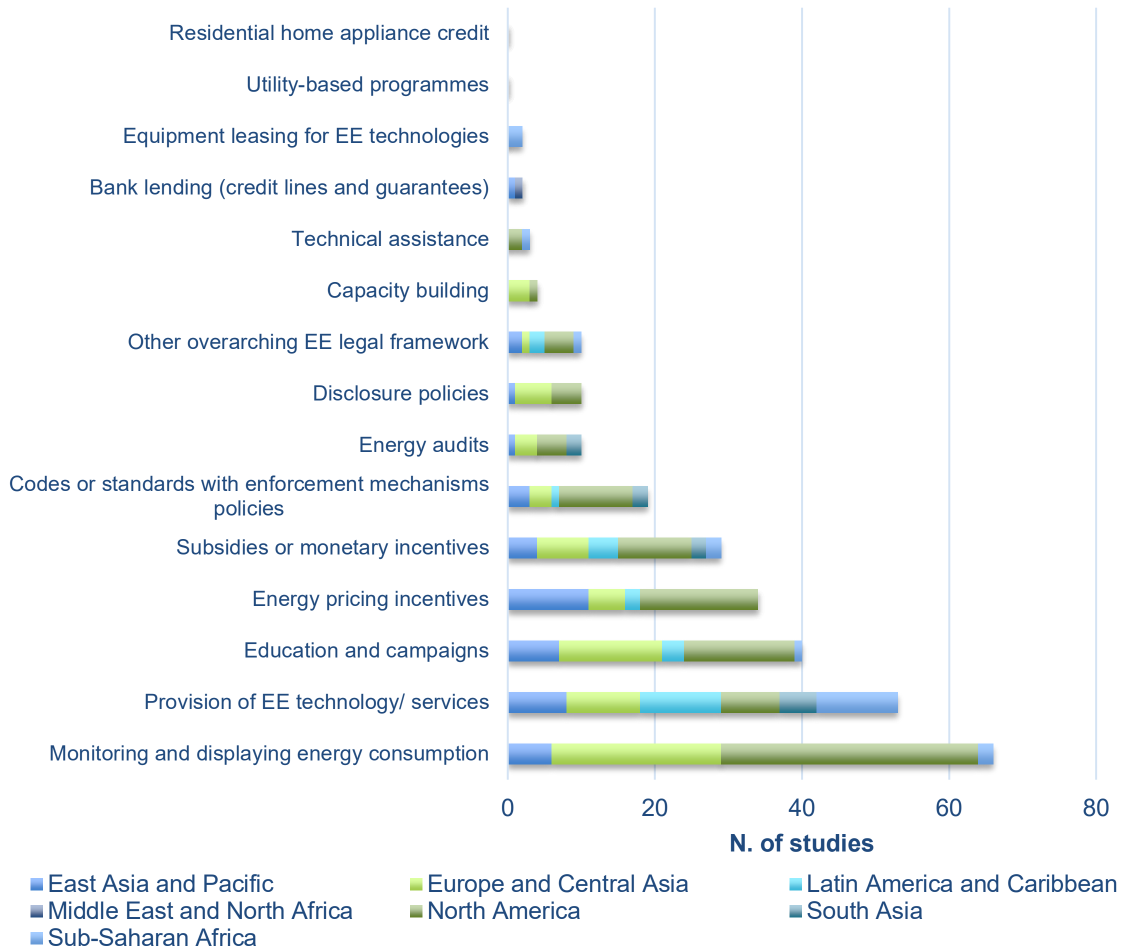
> **Box 1: Geographical distribution**
>
> 75 per cent of the studies are evaluations of projects implemented in HICs, especially North America (110 studies), with only 25 per cent of studies evaluating projects in L&MICs.

Figure 6 shows the distribution of interventions by region. It is worth noting that while the studies from HICs (including North America, Europe and Central Asia, and East Asia and the Pacific) cover almost all intervention types, studies conducted in L&MICs covered a limited number of interventions. For example, we see a very low number of studies in L&MICs evaluating the monitoring and displaying energy consumption interventions, with only two studies from Sub-Saharan Africa identified for this intervention type. This paucity of studies is likely due to this intervention being generally associated with smart meters—a technology widely used in HICs, but rare in L&MICs.

There is a high number of studies of interventions in L&MICs wherein technology was directly provided to participants, with a total of 27 studies across Latin America, Sub-Saharan Africa and South Asia. Most of these interventions are linked to the distribution of efficient cookstoves to reduce fuel consumption and indoor air pollution, and the provision of LED bulbs to households to reduce energy consumption.

In wealthier regions, the studies included under this category are mainly interventions that provide home energy improvements such as retrofits and insulation, in addition to distribution of smart meters to control energy consumption. Finally, some studies in L&MICs fall into the categories of subsidies or monetary incentives (8), education and campaign interventions (4) and energy pricing incentives (2).

Figure 6: Breakdown of IEs by intervention category and region

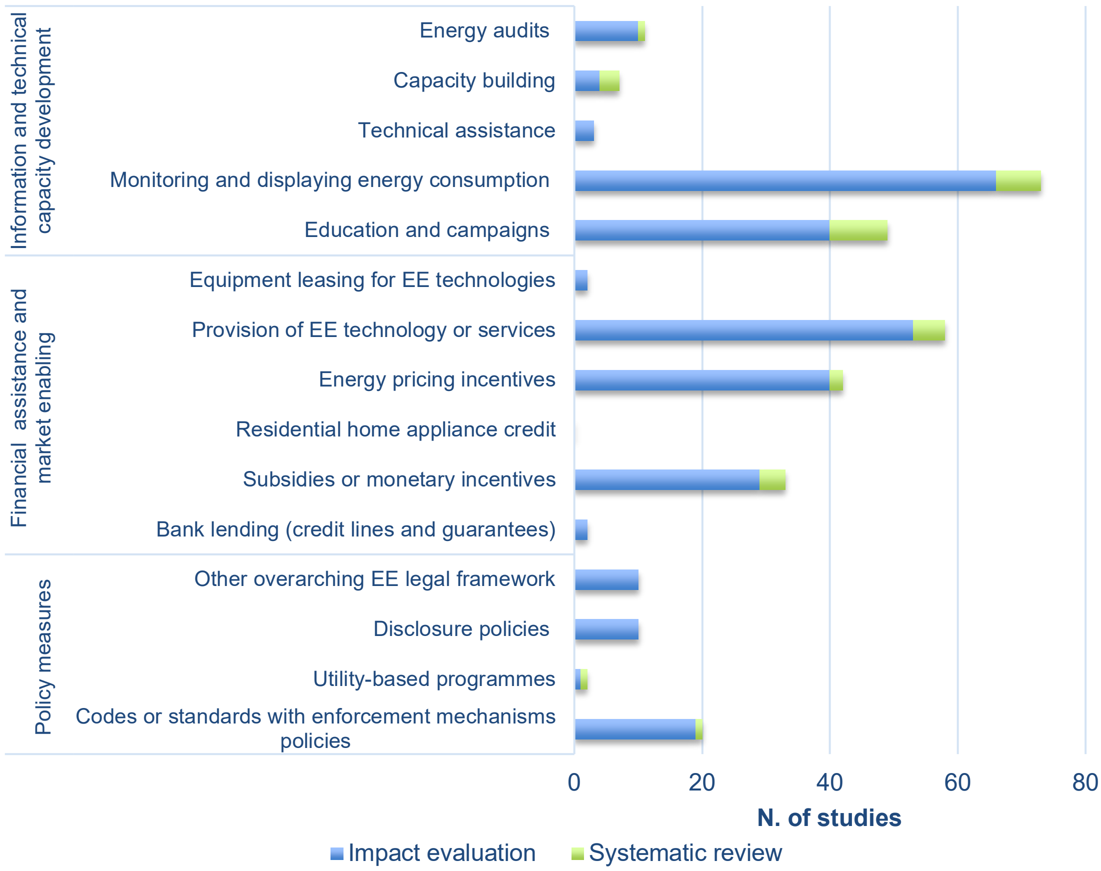


4.2.3 Interventions

Figure 7 shows the number of studies across the 15 EE intervention categories covered in this EGM. Most focus on monitoring and displaying energy consumption (66), education and campaigns (40), provision of EE technology or services (53), energy pricing incentives (40), subsidies or monetary incentives (29) and codes with enforcement mechanisms (19). There is limited evidence on the remaining intervention categories.

The intervention categories for which SRs were identified have a similar distribution as the IEs. More than half of the SRs focused on education and campaigns (9). Seven concentrated on interventions to monitor and display energy consumption, and five assessed interventions that provide EE technology or services. For six intervention categories, we did not identify any SRs (technical assistance, equipment leasing for EE technologies, residential home appliance credit, bank lending, disclosure policies and other overarching EE legal frameworks).

Figure 7: Frequency of intervention category by study type (IEs and SRs)



Of the 283 studies, we identified 81 where the intervention was combined with one or more additional components (Figure 8). These interventions are categorised according to the main intervention framework. The most common combinations are the following: energy pricing incentives with monitoring and displaying energy consumption (12) or with education and campaigns (8); and education and campaigns with monitoring and displaying energy consumption (7) or with subsidies (5).

Figure 8: Frequency of second intervention in multi-component intervention studies

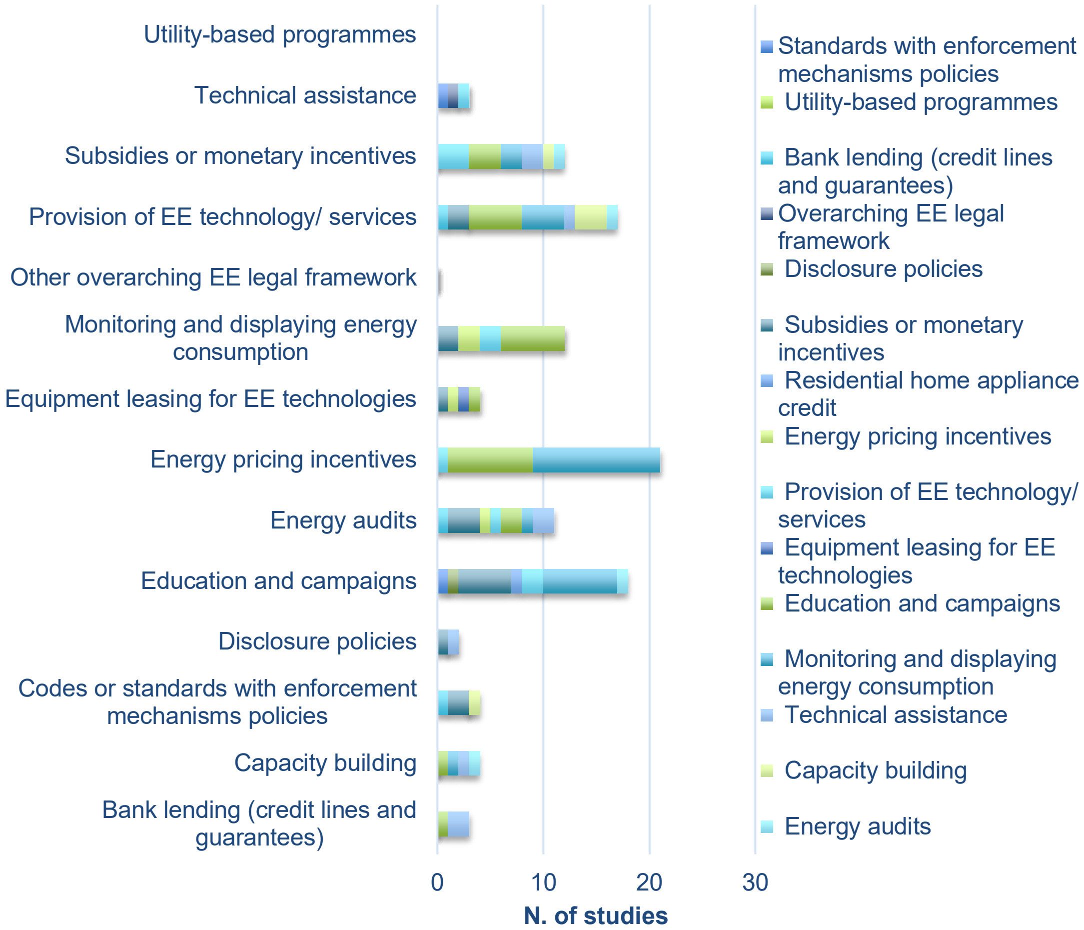
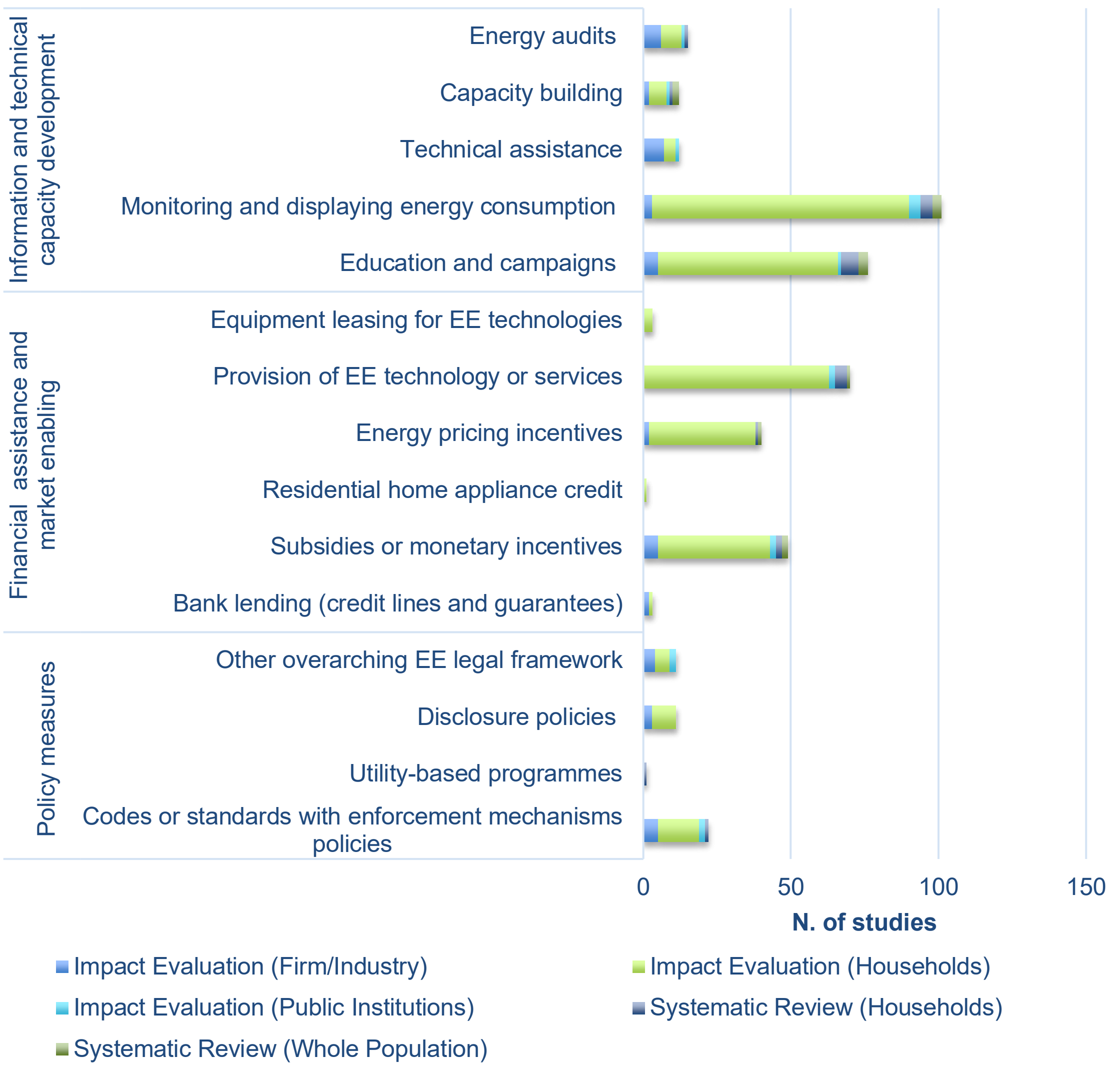


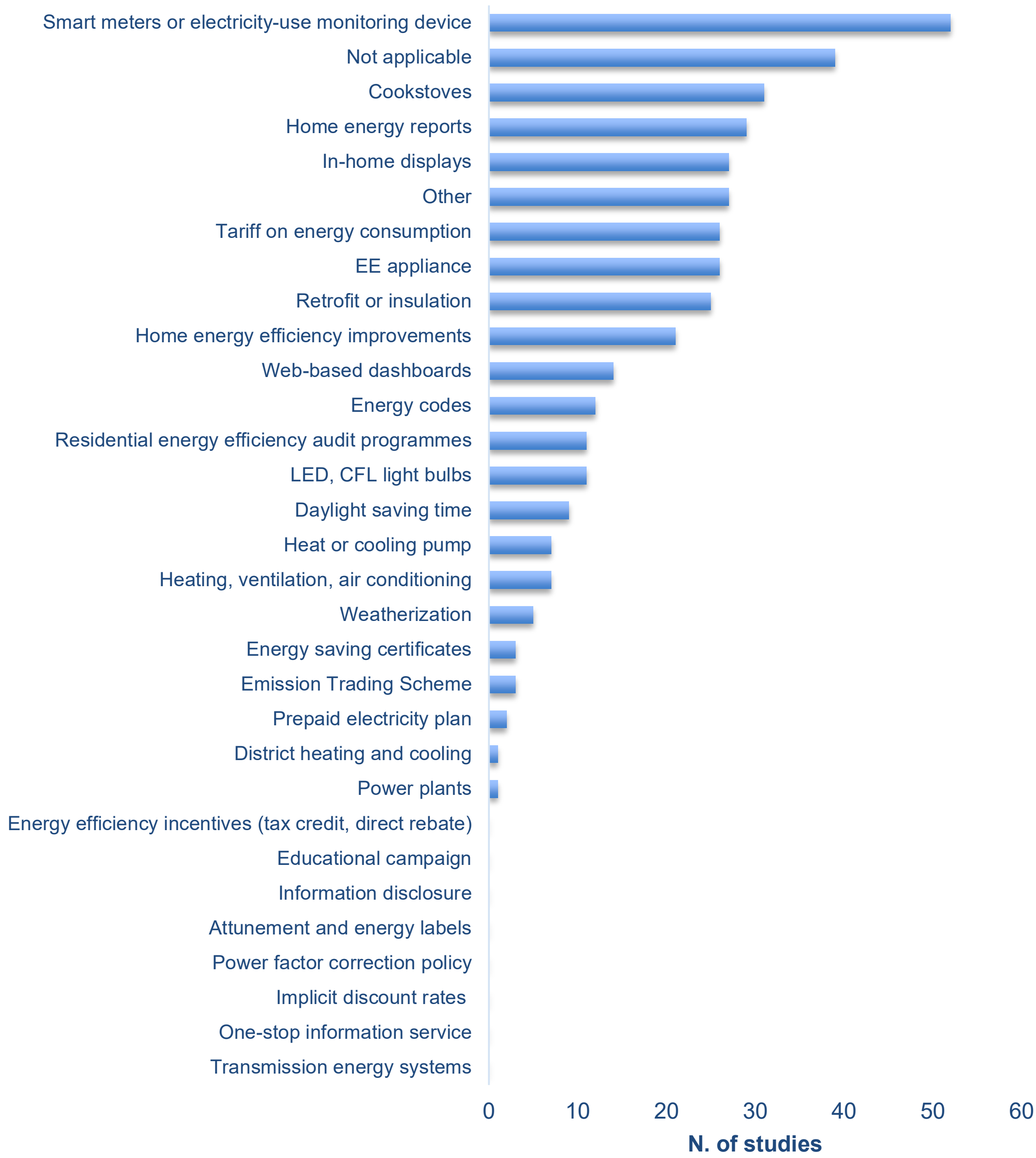
Figure 9 presents the number of studies broken down by intervention category and unit of intervention. Overall, 86 per cent of IEs (244) targeted households, whereas nine per cent (25) and five per cent (13) of the studies targeted firms and public institutions, respectively. Specifically, 87 of the overall 283 IEs studied interventions to monitor and display energy consumption in households, followed by the provision of EE technology or services (63) and education and campaigns (61). Among the 16 SRs, 12 focused on technologies or services at the household level, whereas 5 did not specify the unit of analysis.

Figure 9: Frequency of intervention by study type and unit of intervention



In addition to collecting data on intervention categories, where possible, we gathered more detailed data on the type of EE technologies in each intervention. As shown in Figure 10, the most studied technologies were smart meters or other electricity-use monitoring devices (52), energy-efficient cookstoves (31), home energy reports (29), in-home displays (27), energy consumption tariffs (26) and EE appliances (26). In 39 studies, no categorisation was applicable because they did not look at a specific EE technology.

Figure 10: Specific EE technologies evaluated in the interventions



4.2.4 Outcomes

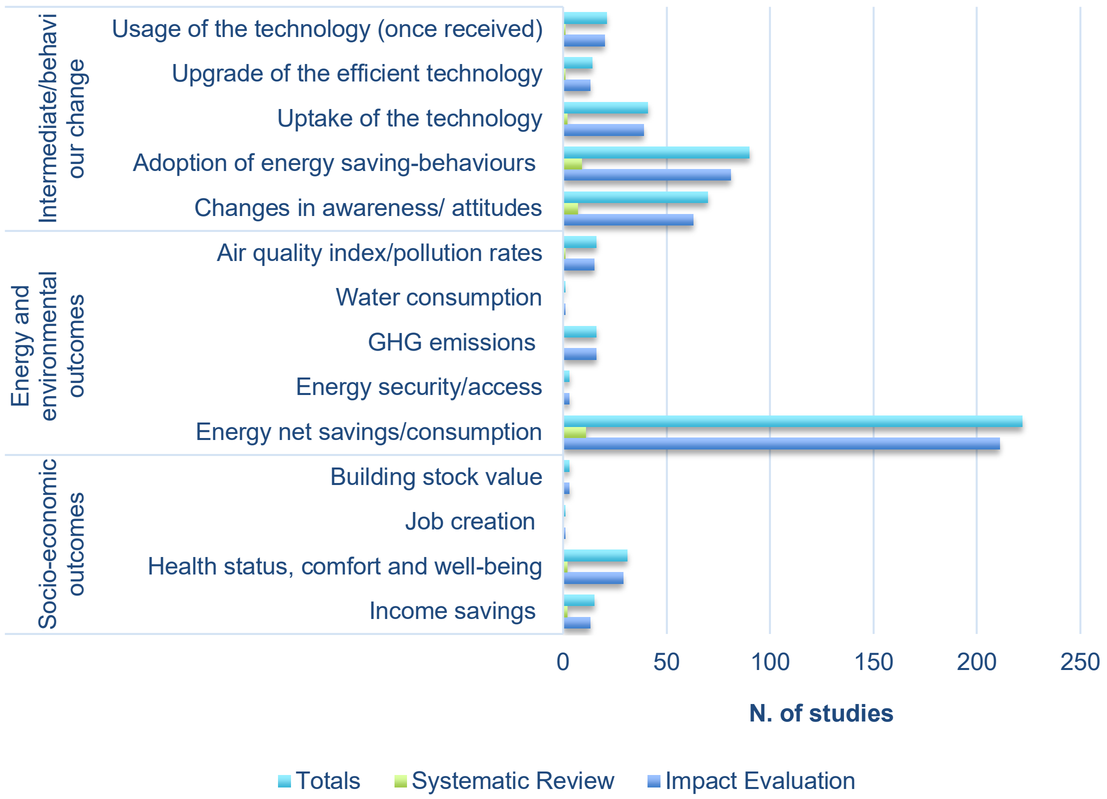
Figure 11 shows the number of studies that reported each outcome, broken down by study type. Many studies reported numerous outcomes across the three framework domains; therefore, the total number of studies in Figure 11 is higher than the number of included studies.

The most frequently reported outcome is energy consumption, documented by 211 of 283 IEs and 11 of 15 SRs. However, other outcomes under the energy and environmental outcomes domain have received less attention, with only one study addressing water consumption, 16 reporting on GHG emissions, and 15 on air quality and pollution. Three studies measured energy security—an outcome that might be out of scope for many EE projects that focus on efficiency instead of access.

Among behavioural (intermediate) outcomes, adoption of energy-saving behaviours and changes in awareness or attitude were widely covered (81 and 63 studies, respectively). For interventions that included the use of a technology, the reported outcomes also included uptake of the technology (39), use of the technology once received (20) and technology upgrade (13).

Social and economic outcomes were captured less frequently (50 studies). The most documented category was health status, comfort and well-being (29 IEs and 2 SRs), followed by income savings (13 IEs and 2 SRs). Only one study covered job creation, while three reported on building stock value.

Figure 11: Frequency of each outcome by study type



4.2.5 Equity dimensions and focus

We identified 88 studies that considered equity through various methodologies (Figure 12). Of these, the most common approach was the assessment of interventions targeting ‘vulnerable populations’ (36). This category typically corresponds to low-income households, both in HICs and L&MICs. In these settings, the aim of interventions was often to help participants improve their socio-economic and health outcomes. For example, adopting energy-efficient cookstoves could reduce energy expenditures and indoor air pollution.

The second most adopted approach to considering equity was subgroup analysis (26), including studies assessing effects of the intervention on people of different socio-economic status, mental health conditions and education levels, among others. Sixteen studies used heterogeneity analysis[11] to study the effects of the intervention on different groups, and another 12 studies included subgroup analysis by sex. Very few studies adopted more integrated approaches to incorporating equity considerations, such as an equity-sensitive research process[12] (4), an equity-sensitive analytical framework (3), direct measurement of inequality as an outcome (2) or an explicitly equity-sensitive methodology (2). Finally, only one study used an approach to ethics informed by gender and equity considerations.

Figure 12: IE equity focus

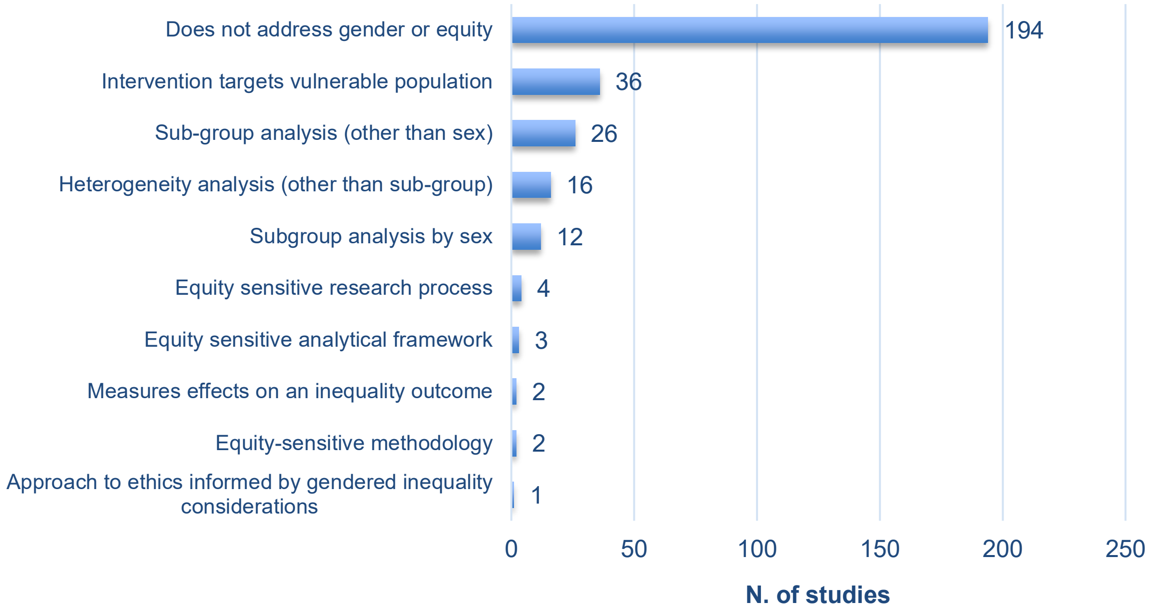


Figure 13 shows the breakdown of the dimensions of equity considered by the studies that addressed equity in some way. As the figure shows, most studies focused on socio-economic status (58), but some also considered participants' age (25), sex (18) and place of residence (urban/rural) (18). A few other studies took into account education level (8), other vulnerable populations (7), gender of head of household (7) and physical or mental disability (5). Only one SR (Maidment et al. 2014) addressed equity, by considering moderator variables[13] including income, age and socio-economic status.

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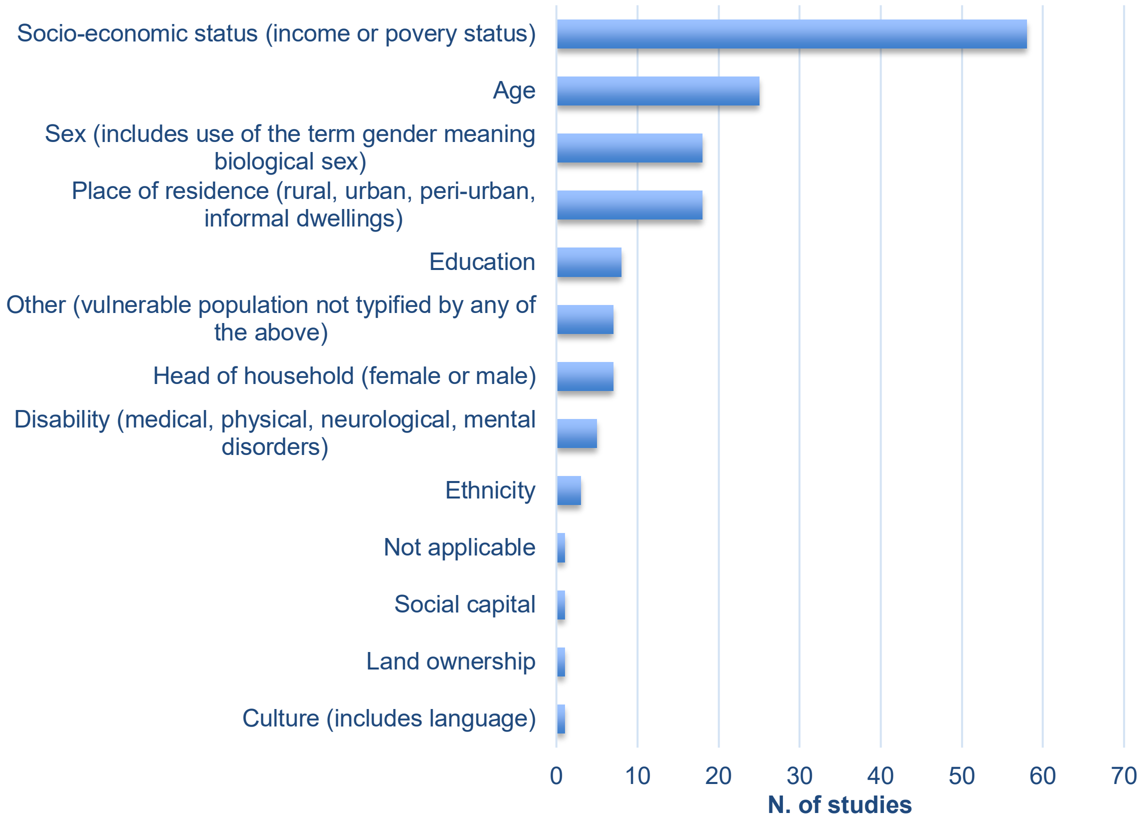
[11] Heterogeneity analysis (other than subgroup) definition: Does the IE go beyond calculating average treatment effects using a subgroup analysis? This can be done in a variety of ways, for example: combining the treatment with different characteristics or a quantile regression, which examines the effects across the range of the outcome variable. Source: 3ie Equity Coding Protocol Guidance (Annex B.2).

[12] For more information on these methods, see Annex B.2 (equity coding protocol guidance).

[13] Moderator variables are used to ‘moderate’ the interaction between two other variables. For example, they are used to determine how the socio-economic status (third variable) affects the strength and/or direction of the relationship between the intervention (first variable/dependent variable) and net energy consumption (second variable/independent variable).

Figure 13: IE equity dimension



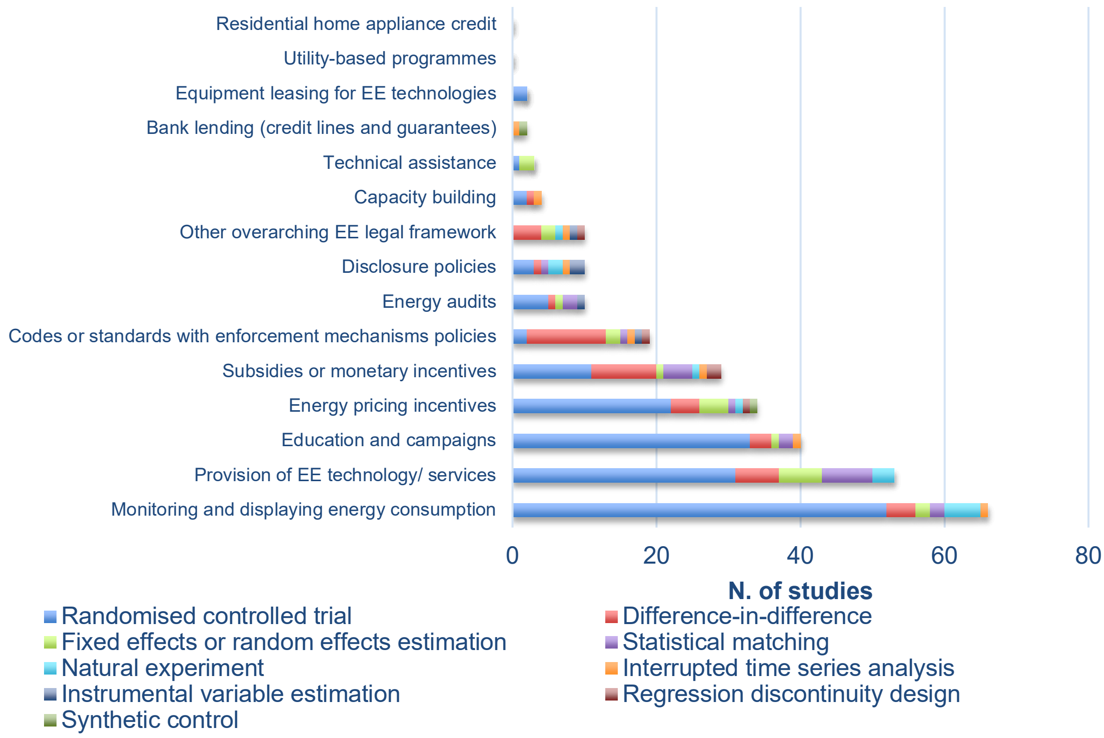
4.2.6 IE study design and cost data

Despite the known challenges associated with running experiments, almost 60 per cent of the included IEs used an experimental design, while the remaining 40 per cent applied different quasi-experimental designs (Figure 14). Specifically, 58 per cent of the IEs (164) were RCTs and 23 per cent (44) used a difference-in-difference study design.

The majority of RCTs evaluated the monitoring of energy consumption (52), education and campaigns (33), and interventions that provided EE technologies and services (32). RCTs were also widely used to evaluate energy pricing incentives (22), subsidies and monetary incentives (11) and energy audits (5). The second most common method was difference-in-difference (43), followed by panel data with fixed effects or random effects estimation (23), statistical matching (19) and natural experiment (13).[14]

[14] For more information on these methodologies see Annex E, Table 6.

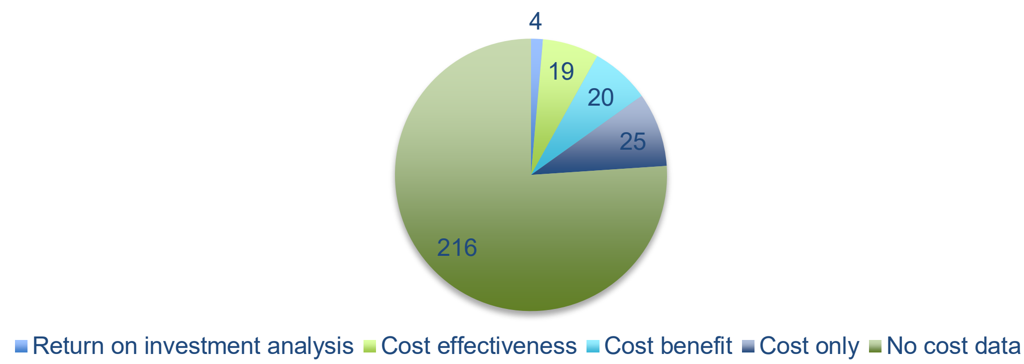
Figure 14: IEs by intervention category and study design



> **Box 2: Study design**
>
> Fifty-eight per cent of the studies (164) were RCTs and 23 per cent (44) used a difference-in-difference study design.

Of the 283 IEs, 23 per cent (66) reported cost data (Figure 15). Of these, 37 per cent reported cost data only, 29 per cent performed a cost-benefit analysis, another 28 per cent conducted a cost-effectiveness analysis, and the remaining 6 per cent reported a return on investment analysis.[15] Only one SRs (Lomas et al. 2018) included a cost-effectiveness analysis.

Figure 15: IE cost data



[15] One study reported both a cost-effectiveness and return on investment analysis, while another study included a cost-benefit and cost-effectiveness analysis.

4.2.7 SR synthesis methods and confidence levels

As noted above, we included 16 SRs. Ten studies used narrative or thematic synthesis, one used meta-analysis, and five used both synthesis methods.[16] We gave each SR a confidence rating of low, medium or high, based on a critical appraisal of the review methods. This rating should be interpreted as our guidance for how much confidence users may have in the findings of the respective SRs. More details of the methods used for this appraisal are provided in Annex C.

No SR was given a high-confidence rating. Six of the reviews were given a rating of medium confidence and 10 were rated as low confidence. The overall poor ratings are mainly due to a lack of risk of bias assessment.[17] Other issues include limitations in the comprehensiveness of the search strategy, or the procedures used to avoid bias in study selection and data extraction.

> **Box 3: SR confidence levels**
>
> We did not find any high-confidence SRs. Of the 16 SRs included, 9 have been rated as low confidence and 7 as medium confidence.

4.2.8 Findings from SRs rated as medium confidence

The findings presented in this section come from the six included SRs with a medium confidence rating. These reviews predominantly addressed questions relating to monitoring and displaying of energy consumption, provision of EE technology for households, and education and campaigns.

1. Monitoring and displaying energy consumption
   Three reviews (Karlin et al. 2015; Rand EU 2012; Andor et al. 2018) examined the effects of monitoring and displaying energy consumption by providing periodic reports or feedback on energy use or conservation. Karlin and colleagues (2015) assessed how and when feedback about energy use is the most effective and included 42 studies published between 1976 and 2010 worldwide. Rand EU (2012) analysed the effects of providing comparative energy consumption information and EE advice, using 48 studies published between 2000 and 2012. Andor and colleagues (2018) reviewed 38 international studies published up until the end of 2015 to assess the effects of social comparison interventions. The key findings and recommendations from these reviews were:
   a. Provision of home energy reports, which present both comparative consumption information and EE advice, led to 1 to 3 per cent reduction in energy use per household. Evidence from one review showed that social

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[16] A meta-analysis is a statistical (or quantitative) procedure for synthesising the results of different primary studies that examined similar research questions to identify common effects, whereas narrative or thematic synthesis is a qualitative approach that uses word and text to combine and explain findings of independent studies.

[17] In an SR, every included study should be quality-assessed using one of the risk of bias assessment tools developed. They usually take into consideration internal and external validity of the studies, how the study design has been applied and other aspects to assess the potential bias of the study results.

comparison interventions reduced household energy consumption by 1.2 to 30 per cent.

b. Providing feedback on household energy consumption appeared to promote energy conservation behaviours, because those who received the feedback used about three times less energy than those who did not. The approach was the most effective when: (1) it was combined with goal-setting or external incentive interventions; (2) it gave goal-based comparisons; (3) the feedback was provided via a computer; and (4) the feedback intervention was short (e.g. less than three months) or very long (e.g. longer than one year).

c. The largest proportion of energy saving associated with the provision of feedback or energy reports occurred among households that consume above-average levels of energy. Therefore, these interventions could be the most effective if they were to target such households.

d. The major issue with the interventions based on monitoring and display of energy consumption was that people who use relatively little energy might increase consumption upon learning that they are below-average consumers. Overall, this could cancel the gains made with the high-energy consumers.

e. There is evidence that providing periodic energy reports or feedback could sustain or even increase household energy reduction. The long-term effects and cost-benefit analysis should be embedded in IEs of interventions that monitor and display energy consumption.

2. Education and campaigns

   Education and campaigns were covered by two SRs in this EGM. The first review analysed the effects of applied games (gamification and serious games) on improved knowledge and learning related to energy consumption, using 26 primary studies from different countries (Johnson et al. 2017). The second review measured the effects of educational programmes on promoting energy-saving behaviours across 48 primary studies, as described in the preceding section (Rand EU 2012). The key findings and recommendations from these reviews were:

   a. Applied games improved general knowledge of energy consumption and conservation.

   b. Future research should explore whether the impact of applied games varies across different user groups and which game elements are the most effective. It is also important to investigate the effectiveness of applied games over a longer timeframe.

   c. Education programmes delivered at the same time as the adoption of new technology significantly improved household energy savings over and above that of the new technology by about 10 per cent.

   d. Team-based strategies that utilised peer support to promote energy-saving behaviour could reduce household energy consumption by 8 to 10 per cent. The success of this intervention, however, depended on a shared understanding between community group members and strong leadership.

3. Provision of EE technologies for households

   Two SRs assessed the effects of providing thermostats to private homes. Lomas and colleagues (2018) reviewed the energy savings, cost effectiveness and usability of heat control systems, and included 67 primary studies mainly from the United Kingdom and the United States. Munton and colleagues (2014) applied evidence from 20 primary studies to explore the extent to which the introduction of smart heating controls reduced energy usage. Key observations from these reviews were:

a. Smart thermostats in heat control systems did not appear to be more effective than the traditional non-smart thermostats in terms of energy saving. This was largely due to poor usability of the technology. For example, consumers who had problems operating the programmable timer tended to use the devices as simple on/off switches. Moreover, the following should be noted:
    - There were limited data on the effects of programmable thermostats and load compensations on energy savings.
    - There was a lack of robust data on the impact of heating control systems, which makes it difficult to produce reliable energy-saving estimates.
b. The effects of heating controls on energy demand did not only depend on the technical functions of the device, but also on how consumers used it in their households. Hence, quantification of energy saving from heat controls should consider both social (how the controls are used) and technical aspects the technology.
c. Future studies could improve the evidence base by measuring behavioural mechanisms that mediate the treatment effect of technology on energy use, such as monitoring house temperature and heating duration.

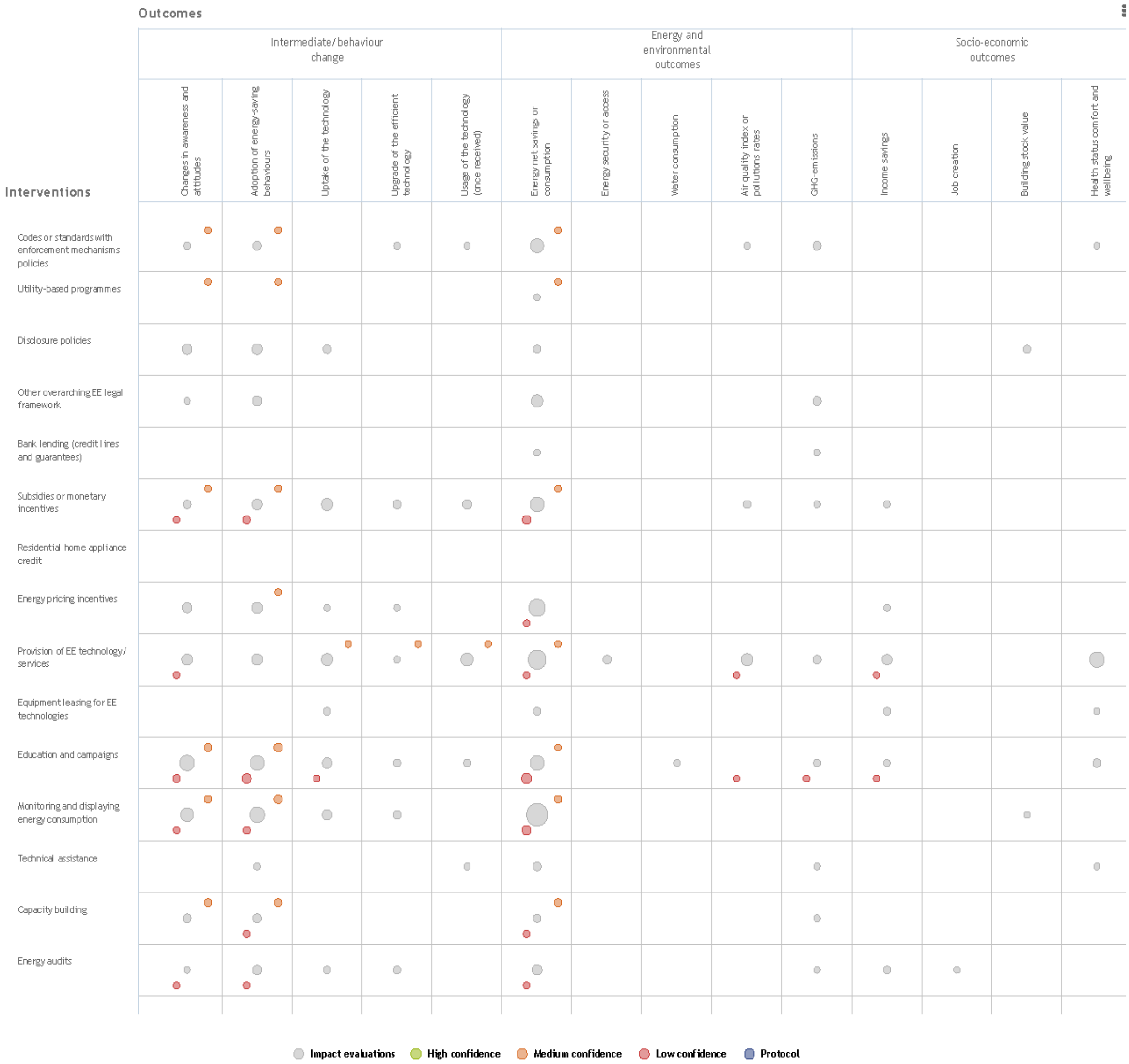
5. Gap analysis

Although the annual number of IEs for EE interventions has increased steadily, the EGM identified numerous evidence gaps (Figure16).[18] Two reasons can explain these gaps, as well as the relatively low number of studies included in the map. First, EE interventions have heterogeneous investment portfolios, which make evaluations complex and costly. Second, some experts from the advisory group suggested that in some cases, evaluations might not be publicly available, thereby hampering learning about the effectiveness of EE interventions.

We categorised the gaps into ‘absolute’ evidence gaps, where we identified few or no studies, and ‘synthesis’ gaps, where we identified a cluster of primary studies but no up to date or high-quality SRs (Snilstveit et al. 2017). Finally, we highlight some ‘methodological’ gaps that should be considered in future IEs.

[18] Online map: https://gapmaps.3ieimpact.org/evidence-maps/energy-efficiency-egm

Figure 16: Screenshot of the EGM



5.1 'Absolute' evidence gaps

The evidence base on the effects of EE interventions is fractured and unevenly distributed, with absolute gaps in the number of interventions. Studies are focused on a few intervention categories: monetary subsidies and incentives; energy pricing; provision of technology; monitoring and display of energy use; education and campaigns; and codes or standards with enforcement mechanisms. We observe 'absolute evidence gaps' characterised by few or no IEs in several categories: utility-based programmes; disclosure policies; EE legal frameworks; home appliance credit; equipment leasing; bank lending; energy audits; technical assistance; and capacity building.

Studies focus on a few outcome measures, creating absolute evidence gaps for key energy, environmental and socio-economic outcomes. While most of the studies report measures of net energy savings, only a few documented well-being and health outcomes, energy security, GHG emissions, air pollution, property value increase and job creation outcomes, which are important in assessing the overall impact of the intervention. There is also a lack of evidence measuring both energy and socio-economic outcomes: only 21 studies report at least one energy and socio-economic outcome.

Studies focus on interventions that target households, creating absolute evidence gaps for interventions that target industry, firms and public institutions. Energy-efficient upgrades should be of interest across households, industries and public institutions. However, out of 283 evaluations, 26 focus on the firm and industry level, 13 on the public institution level (such as universities and hospitals), and the remaining 244 focus on the household level. This bias is perhaps due to a greater simplicity in conducting evaluations among households than firms. However, we do identify some IEs at the firm level, demonstrating their feasibility and highlighting an important evidence gap at this level, especially considering the large share of energy firms and industries consume annually. Exploring and evaluating interventions to encourage industries and firms to be more energy efficient is an important means of decreasing their impact on the environment.

The evidence base is skewed towards HICs, with more limited evidence from L&MICs. We identify 70 out of 283 IEs from L&MICs, with 28 of these being from upper-middle-income countries. The evidence is also unevenly distributed within HIC and L&MICs. Among HICs, most studies come from the United States (105), with only 20 studies from Europe and another 17 from Japan; we found only a few studies across each of the remaining featured HICs. Numerous IEs come from the United States likely because, unlike other countries, utilities must prove to regulators that they have saved energy in order to obtain their incentive payments for meeting regulatory obligations. Among L&MICs, most studies come from China (11), India (10), Mexico (8), Guatemala (5), Ethiopia (5), Senegal (4) and Kenya (3), while we found no more than two studies for each country in the remaining L&MICs.

5.2 ‘Synthesis’ gaps

To provide clear conclusions and generalisable findings, an SR is usually based on one or more clusters of studies with comparable interventions and outcomes. We have identified several synthesis gaps—clusters of IEs with no high-quality effectiveness SRs available—for the following interventions:

Monitoring and displaying of energy (66). Most of these IEs come from North America (35) and Europe (23). Energy consumption is the most frequently measured outcome, and a few other studies reported intermediate behaviour-change outcomes.

Provision of EE technologies and services (53). These studies are widespread between different regions that include both HICs and L&MICs. They are unevenly distributed among outcomes. However, there is a cluster of 37 studies that measure changes in net energy consumption.

Energy pricing incentives (40). These studies mostly come from North America and Europe, and primarily measure energy consumption as an outcome.

Education and campaigns (40). Most of these studies come from North America and Europe, with a few from East Asia and the Pacific and Latin America. Their outcomes are equally distributed between energy consumption, change in awareness and attitudes, and adoption of EE behaviours.

5.3 Methodological gaps

There is a lack of systematic reporting of cost data, including cost-effectiveness and cost-benefit analysis. Sixty-six of the 283 included studies report cost data in some form, with just under half providing these data without any further cost-benefit, cost-effectiveness, or return on investment analysis. Including data on the cost of an intervention is essential to ensure that the evidence base is useful for decision makers who need to consider costs and relative cost effectiveness when deciding on intervention strategies. This gap in the characteristics of the existing evidence base should be addressed in any future studies.

Very few studies used mixed methods. We found only nine studies where both quantitative and qualitative methods were used to evaluate the programme. The use of mixed methods is important to capture additional information and better analyse the intervention. Future studies should make greater use of mixed methods.

6. Conclusions and implications

This EGM presents evidence on EE and energy conservation interventions based on a systematic mapping strategy. Decision makers can use the results of this map to identify the key characteristics of available evidence and take this evidence into consideration when designing and commissioning interventions. Researchers and funders can consider filling in the evidence gaps by funding and conducting research on those priority areas.

We found a total of 299 studies, of which 274 were completed IEs, 9 were ongoing IEs and 16 were completed SRs. Despite the increasing number of IEs published each year, there are some absolute evidence gaps among interventions and outcomes evaluated. They have also been skewed toward HICs. Additionally, we did not find any SRs we could rate at a high-confidence level. The most commonly evaluated interventions were: the introduction of systems to monitor energy consumption (66), the direct provision of EE technologies and services (53) and the implementation of education campaigns to raise awareness regarding EE (40). Most studies measured net savings of energy consumption (204). Other common outcome measures included changes in the adoption of EE behaviours (85) and changes in awareness and attitudes (67).

There are seven intervention categories with no or few studies, which represent ‘absolute’ gaps. There is similar unevenness in the reporting of outcomes, with only a few studies measuring socio-economic outcomes, such as health and well-being or changes in buildings’ values. There is also an important gap in studies at the end-user level: 86 per cent of studies evaluated interventions implemented at the household level, whereas only nine per cent were at the level of firms and industry, and 5 per cent were implemented among public institutions.

Most studies evaluated interventions in HICs (75%), particularly in the United States, which made up almost half of the studies (105). Only 25 per cent of studies included in the map evaluated interventions in L&MICs. This geographic concentration might be explained in two ways. First, households in HICs generally consume more energy per household due to more intensive use of appliances and greater access to energy. Per capita energy consumption varies more than tenfold across the world, with an average American consumer using four to five times more energy than an average Indian consumer.[19] Moreover, many people in L&MICs do not have access to electricity, especially in Sub-Saharan Africa and South Asia.[20]

Second, there are more efforts to increase EE in HICs, because more resources are available to implement EE interventions than in L&MICs. As reported by the World Bank in 2017, OECD HICs had the highest average EE score at 76 (on a scale between 0 and 100), followed by Europe and Central Asia at 54; Sub-Saharan Africa has the lowest score at 23.[21]

6.1 Implications for policy and programming

Decision makers and programme implementers can use this map when designing or implementing an intervention by taking into consideration the existing rigorous evidence, learning useful lessons from completed research and avoiding duplication of efforts. Hence, we suggest the following:

1. When commissioning a new EE intervention and the map shows no existing evidence for that intervention, or evidence is lacking in that geographic area, consider including an IE when implementing the intervention, following the research implications presented in the next section.
2. If there is evidence available for the intervention of interest, consider the results from medium-quality SRs (with some caution because they are not high-quality), and if useful, consult low-quality reviews to learn about the characteristics of the evidence base.
3. If no SRs are available, the findings from primary studies can be useful for programme design. However, because the results of one or several studies could not be generalised, they should be treated with caution. In using evidence from a single case evaluation, both IE experts and specialists in the sector should be consulted to assess the transferability of results to different contexts.
4. If there is a cluster of evidence on the intervention of interest shown in the EGM and no high-confidence SR exists, as in this map, consider commissioning an SR, ideally following guidelines that ensure high-confidence level of the results, as presented in the next section.

6.2 Implications for future research

Despite the challenges in conducting experiments to evaluate the interventions and contexts discussed herein, we found numerous RCTs and quasi-experimental studies. However, there are still many evidence gaps, as discussed in Section 5. When commissioning or designing a new evaluation, we suggest that researchers and funders consider the following:

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[19] Our World in Data, 2019. Graph: Energy use per person, 2019, world. Available at: https://ourworldindata.org/grapher/per-capita-energy-use?time=earliest..latest

[20] Our World in Data, Graph: Number of people without access to electricity. Available at: https://ourworldindata.org/grapher/number-without-electricity-by-region?time=earliest..latest

[21] RISE World Bank, 2018. Energy efficiency. Available at: https://rise.worldbank.org/data/files/energy_efficiency-two_pager.pdf.
RISE World Bank, 2019. Scores. Available at: https://rise.worldbank.org/scores

1. Conducting an IE for one of the following intervention categories: capacity building to develop EE skills, technical assistance to support those who want to switch to an EE technology, bank lending reserved for EE investments, and home appliance credit to support the purchase of more efficient appliances
2. Applying the most rigorous experimental and quasi-experimental methods (Section 3.2.4) that suit the available data, intervention type and context
3. Applying guidance from the Collaboration for Environmental Evidence, Campbell, and Cochrane, as well as reporting standards like PRISMA2020 or ROSES (or equivalent) to conduct high-confidence level SRs
4. Evaluating more EE interventions in L&MICs
5. Evaluating EE interventions that target firms, industry or public institutions
6. Measuring both energy-related and socio-economic outcomes
7. Including cost data, a cost-effectiveness analysis, a cost-benefit analysis or a return on investment analysis in the evaluation
8. Making use of mixed methods approaches to combine qualitative and quantitative evaluations for more holistic overviews of what affects intervention effectiveness
9. Reducing evaluations' costs, considering efforts made to standardise methods for evaluating EE projects and programmes, and ensuring consistency and common approaches (such as the international performance measurement and verification protocol)
10. Making new evaluations publicly available so that everyone can learn more about the effectiveness of these interventions
11. Recognising the necessity of a 'living map' or an update of this map in the near future, because the effectiveness evidence on EE is expected to grow rapidly.

Online appendixes

Online appendix A: Search strategy

https://3ieimpact.org/sites/default/files/2021-04/EGM17-EE-Report-Online-appendix-A-Search-strategy.pdf

Online appendix B: Data extraction tool

https://3ieimpact.org/sites/default/files/2021-04/EGM17-EE-Report-Online-appendix-B-Data-extraction-tool.pdf

Online appendix C: Critical appraisal tool for SRs

https://3ieimpact.org/sites/default/files/2021-04/EGM17-EE-Report-Online-appendix-C-Critical-appraisal-tool-for-SRs.pdf

Online appendix D: Details about the EGM advisory group

https://3ieimpact.org/sites/default/files/2021-04/EGM17-EE-Report-Online-appendix-D-Details-about-the-EGM-advisory-roup.pdf

Online appendix E: Methodology

https://3ieimpact.org/sites/default/files/2021-04/EGM17-EE-Report-Online-appendix-E-Methodology.pdf

Online appendix of included studies

https://3ieimpact.org/sites/default/files/2021-04/EGM17-EE-Report-Online-appendix-Ref-included-studies.pdf

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Over the past decade, 45 per cent of the carbon dioxide emissions came from the energy sector. Efficient use of energy has the potential to reduce energy demand and consumption, and impact emissions. As a result, there has been an increase in energy efficiency programmes and it is important to learn about their effectiveness to better inform future policies and investments. Authors of this report present the findings of an evidence gap map, which provides an overview of the impact evaluations and systematic reviews of interventions that promote energy efficiency and energy conservation.

Evidence Gap Map Report Series

International Initiative for Impact Evaluation
215-216, 2nd Floor, Rectangle One
D-4, Saket District Center
New Delhi – 110017
India

3ie@3ieimpact.org
Tel: +91 11 4989 4444

www.3ieimpact.org