Energy efficiency for more goods and services in developing countries

Research report
November 2020

UKaid
from the British people

Energy for Economic Growth
Research Programme

ESMAP
Energy Sector Management Assistance Program

Acknowledgements

This research report was developed as part of the research activity "*Energy efficiency in developing countries: Towards a paradigm shift in assessing its contributions to development*" conducted under the ***Energy for Economic Growth (EEG) Research Program***. The research was conducted by, and the report authored by, Benoit, Philippe (Adjunct Senior Research Scholar, Columbia University's Center on Global Energy Policy); de Wit, Joeri; Lukas, Aditya; and Zinetti, Silvia. The research team would like to acknowledge the contributions of Meier, Peter; Sarkar, Ashok; and Singh, Jas.

The support by the ***Energy Sector Management Assistance Program (ESMAP)*** is gratefully acknowledged. ESMAP is a partnership between the World Bank and 18 partners to help low and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets.

Contents

Abstract 4
1 Introduction 5
2 Review of literature and recent practice 6
2.1 Energy efficiency as a tool for generating energy savings 6
2.2 Energy efficiency for more goods and services 7
2.3 Review of a sample of economic analyses from World Bank projects 10
2.4 Shortcomings of the "traditional" economic analysis 12
3 Suggested framework for economic analysis of energy efficiency projects 13
3.1 Overview 13
3.2 Project categories 14
3.2.1 Brownfield energy efficiency project: Reduce energy consumption (Category 1) 14
3.2.2 Brownfield energy efficiency project: Increase goods or services (Category 2) 15
3.2.3 Greenfield energy efficiency project (Category 3) 15
3.2.4 Supply side energy efficiency project (Category 4) 15
3.3 Approaches for economic analyses of energy efficiency investments 16
3.3.1 Status quo counterfactual 16
3.3.2 Alternative scenario counterfactual 17
3.3.3 Greenhouse gas accounting 18
3.3.4 Addressing the rebound effect 19
4 Application of the framework for economic analysis on a case study 19
4.1 Context of the case study 20
4.2 Economic analysis 20
4.2.1 Costs and benefits 21
4.2.2 Results 22
5 Conclusion 25
6 References 28
Annex A: List of reviewed literature 32

Abstract

Energy efficiency is often seen as a tool for reducing energy consumption and generating cost savings rather than for producing additional goods or improving the level of services, such as increasing a company's manufacturing output or increasing quantity, quality, and continuity of water supply. This research report discusses the importance of recognizing such benefits from energy efficiency in low and middle-income countries, which are characterized by unmet demand for essential goods or services and higher economic growth rates. It further discusses how the additional utility resulting from the so-called "rebound effect" can be valued as economic benefit. Based on a review of literature and of guidance material for economic analysis in multilateral development banks and a review of a sample of economic analyses of World Bank energy efficiency projects, the authors suggest an extension of current World Bank guidelines for economic analysis to better describe how an improvement in the level of goods or service provision resulting from energy efficiency measures can be quantified. The research report presents an example of an economic analysis for a brownfield project, in which existing air-conditioning units are replaced by more efficient ones, and for a greenfield project, in which new air-conditioning units are installed in yet unconditioned space.

1 Introduction

Many economic actors, particularly in developing countries, under-invest in demand-side energy efficiency (EE) despite its primary role in low-carbon transition scenarios (IEA, 2018, pp. 25-26), the multiple benefits of EE (IEA, 2019), and the typically high economic rates of return (see Section 2.3). According to the Regulatory Indicators for Sustainable Energy (RISE), a set of indicators to help compare national policy and regulatory frameworks for sustainable energy, low-income countries are particularly lagging behind in terms of EE regulations (World Bank, 2020).

Besides a range of well-known barriers to implementing EE (see Table 1), a key part of the lack of appeal in developing countries is that EE is often seen as a tool for reducing energy consumption and generating cost savings rather than for producing additional goods or improving the level of services that developing countries need to raise the standards of living of their populations. For example, EE measures can help expand a city's water supply system with improved quality, quantity, and reliability of supply; more efficient space-conditioning can improve attendance and learning in schools; energy-efficient manufacturing equipment and processes can increase a company's manufacturing output while keeping energy costs down. Although valuation of these benefits may present challenges, a framework for economic analysis should recognize them to strengthen the rationale and narrative for EE investments that increase supply of goods and services.

Table 1. Barriers to implementing EE

Barrier	Description
Policy and regulatory issues	Low energy pricing, lack of codes or standards, failure to enforce codes and standards where they do exist, import duties on efficient equipment, and weaknesses within relevant institutions.
High project development and transaction costs	High transaction cost involved in conducting energy audits and measurement and verification, comparing alternative technologies, and making what are often small and dispersed project investments.
Lack of awareness and information	Lack of credible energy consumption data, information on EE potential and opportunities, and evaluations of EE programs and their costs/impacts.
Poor incentives	For example, the entities making capital investment decisions are not the same as those that pay the energy bills and would benefit from EE, or they have competing priorities, or expect to see assured returns in a relatively short time frame.
Behavioral inertia	Reluctance to do things differently, try new approaches, or take action in the face of perceived risk. This may be strengthened where consumers are not charged cost-reflective energy tariffs.
High upfront cost	High upfront cost of EE measures and lack of access to financing.

Source: World Bank (2016; 2018)

The purpose of this research report is to answer the question: "How should we frame the economic analysis for EE projects in developing countries, where an increase in goods or service delivery is a principal contributor to development?" Building on a review of literature and current approaches used by multilateral development banks (MDBs), the research report extends the guidance for economic analysis of EE projects at the World Bank to describe how such analysis can be carried out for EE projects that aim to improve the level of goods or services provided. Thus, the target group of the report is MDBs and government staff that work on EE in developing countries and economic analysis of EE projects.

2 Review of literature and recent practice

The research effort included a review of literature and guidance material for economic analysis in MDBs (Annex A includes a list of literature reviewed), a consultation process with international EE experts (including MDBs, academia, think tanks, and nongovernmental organizations), and a review of a sample of economic analyses of World Bank EE projects. The main objective of the review and consultation process was to determine the extent to which literature identifies a different role for EE in developing countries than in developed ones, how economic analyses for EE investments in developing countries are currently being carried out, and how other benefits that go beyond energy savings are reflected in the economic analysis. The main findings of this effort are discussed in the following sections.

2.1 Energy efficiency as a tool for generating energy savings

Much of the discourse on EE has primarily centered around generating energy savings and the associated greenhouse gas (GHG) emission reductions as key drivers for EE policies and national goals (European Commission, 2019; Belzer, Bender, & Cort, 2017; Wei & Liao, 2016; IEA, 2019). These benefits have resonated well with many developed countries where living standards are high and the demand for essential services such as electricity for appliances and lighting, water supply and sanitation, space heating or cooling, etc., is met for most of the population. The focus on energy savings is reflected in the approaches used by MDBs and other international organizations to evaluate EE projects. According to guidance/technical notes and publications on evaluating EE projects[1], the main economic benefits of EE projects are related to the economic cost of the energy saved and associated GHG emission reductions. Although there is recognition that other economic benefits can be substantial in some cases, the guidance documents usually note that these are difficult to quantify.

Given this focus on energy savings, the rebound effect (or take-back effect), which is the reduction in expected energy savings from EE measures because of behavioral responses (Sorrell, 2007; Borenstein, 2014; Figus, Turner, McGregor, & Katris, 2017; Gillingham, Rapson, & Wagner, 2015; Barker & Foxon, 2008; Zhou, Liu, Feng, Liu, & Lu, 2018), has a negative connotation and is often believed to reduce the economic benefits of an EE measure. For example, improved fuel efficiency in cars can lead to an increase in road travel as the cost of each kilometer drops, or improved lighting efficiency in households can reduce the incentive to switch off lights in empty rooms. The total rebound effect has two components: (i) the direct rebound effect—the increase in consumption of a good or service caused by the lower cost of that good or service; and (ii) the indirect rebound effect—the increase in consumption of goods or services, other than the one for which costs have decreased, with the money saved. In the case of replacing residential lights with more energy-efficient ones, the direct effect would be the increase in the hours that lights are kept on due to the lower cost of their operation[2] and the indirect effect could be an increase in the operating hours of residential fans due to savings from operating lights.

---

[1] For e.g., the World Bank (World Bank, 2017, p. 37-39), Inter-American Development Bank (Inter-American Development Bank, 2017), European Investment Bank (European Investment Bank, 2013), European Commission (European Commission, 2014), U.S. National Renewable Energy Laboratory (Li, Haeri, & Reynolds, 2018), and the UK Government (UK Government, 2018, p. 69).

[2] Note that systems for energy management in nonresidential sectors would limit rebound effects of this nature. For example, lighting in public buildings would be limited to working hours or may even be scheduled to turn off automatically.

The reduction in expected energy savings due to the rebound effect is often seen to lower the associated GHG emission reductions, diminishing climate change benefits. This concern is particularly relevant for EE projects funded by climate funds. However, the increase in consumption due to the rebound effect can provide economic benefits as it creates additional utility to the user and, more broadly, to the economy (IEA, 2014, p. 23; Ryan & Campbell, 2014, p. 18; de la Rue du Can, McNeil, & Leventis, 2015; van den Bergh, 2011). A literature review carried out by Economic Consulting Associates (2014), which reviewed 163 academic papers and other published studies containing 241 different reported estimates of the magnitude of rebound effects, summarized ranges of rebound effects for different sectors and country groups (Table 2). The rebound effect tends to be larger in low- or middle-income countries than in high-income countries, particularly in the residential sector, mostly because of the unmet demand for energy-consuming services and higher economic growth rates in low- and middle-income countries. The existence of the direct rebound effect is largely accepted in literature; however, there is much greater controversy over the indirect rebound effect and its magnitude. In some cases, the rebound effect could even exceed 100 percent, wiping out any energy savings (but generating other benefits).

Table 2. Ranges of the rebound effect

Country group			Residential - Heating	Residential - Other	Industrial and Commercial
Country group	*High Income*	Direct effect	20-40%	0-20%	0-20%
		Total / economy-wide effect	40-60%	10-30%	20-40%
	Middle + Low Income	Direct effect	--	10-30%	0-20%
		Total / economy-wide effect	--	30-50%	20-40%

Source: Economic Consulting Associates (2014)

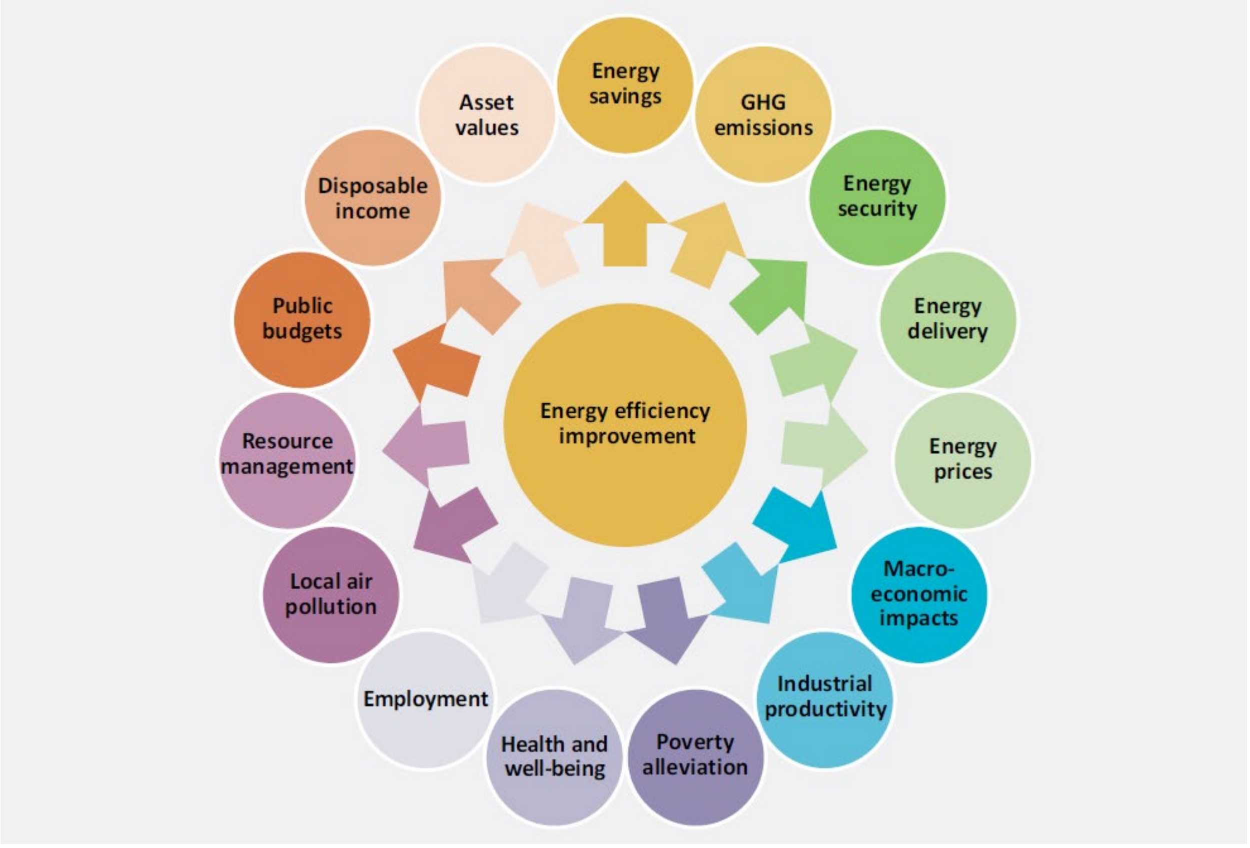
While there is some recognition that the rebound effect results in additional utility, reviewed guidance notes on evaluating EE projects often simply state that the additional utility is difficult to quantify (World Bank, 2017, p. 146; European Investment Bank, 2013, p. 125). A few guidance notes, e.g., UK Government (2019), note that the direct rebound effect should be valued since there is a directly related welfare benefit. According to this guideline, the direct rebound effect should be valued at the retail price of the energy as this captures the gain in welfare (the retail price acts as a proxy for the consumer's willingness-to-pay, [WTP]). It is not essential to value the indirect rebound effects as this requires an analysis of changes in disposable income and expenditure that is disproportionate in most appraisals.

2.2 Energy efficiency for more goods and services

While the discussion in developed countries focuses on energy savings and the rebound effect, many low- and middle-income countries are looking to increase their energy supply to meet their increasing energy demand, even as the energy intensity of their economies declines. Across the developing world, energy consumption has nearly doubled since 2000 and is projected to increase by another 40 percent through 2030 (Benoit, 2019). Implementing EE measures would limit the increase in energy consumption as these economies grow and make progress toward the SDGs. However, while EE is being supported in developing countries, they still under-invest in demand-side EE, lag behind in terms of EE regulations (World Bank, 2020), and do not implement many economically viable EE investments (IEA, 2019).

Although the majority of available literature on EE focuses on energy savings, there have been efforts in recent years to better recognize the multiple benefits of EE, including benefits outside of the energy sector (IEA, 2014; World Bank, 2017). These include, but are not limited to health benefits, improved comfort levels, increased property values, increased competitiveness of businesses and industry, job creation, and GDP growth (see Figure 1 and Table 3), which contribute to progress toward various SDGs.

Figure 1. The multiple benefits of EE



Source: IEA (2014)

Table 3. Most commonly cited multiple benefits of EE

Benefits	Indicators	Methods
Energy savings	Unit of energy saved in kWh or monetary value	Measurement
O&M cost reductions	Replacement and inspection rate of equipment and monetary value	Measurement
Health impacts	Hospitalization and mortality rates, medical costs	Measurement
Labor productivity	Days off work, days off school	Measurement
Comfort	Indoor temperature, humidity level, and monetary value	Survey of willingness to pay or comparison
Energy access	Energy services provided (lumen-hours in the case of lighting, useful energy in the case of heating or cooling)	Measurement
Water savings	Quantity of water saved (liters) and monetary value	Measurement
Property values	Monetary value	Measurement
Safety	Number of accidents prevented	Measurement
Competitiveness	Market share, cost per unit of output, energy intensity	Measurement
Avoided capacity	Avoided capacity (kW) and saved monetary value	Power sector modeling
Avoided transmission & distribution	Avoided kWh losses and saved monetary value	Power sector modeling
Avoided peak load	Avoided peak capacity (kW) and saved monetary value	Power sector modeling
Reduced credit and collection costs	Saved monetary value	Measurement
Increased reliability	Value added ($) produced, number of avoided power outages	Modeling and measurement
Energy security	Avoided energy imports (terajoules, etc.) and saved monetary value	Modeling
Public budget savings	Saved monetary value	Measurement
Avoided energy subsidy	Saved monetary value	Modeling
Indirect public budget	Saved monetary value	Modeling
GHG emissions	Ton of CO_2 equivalent and saved monetary value of avoided damages	Measurement and emissions factors
Pollutant emissions	Ton of pollutants reduced and saved monetary value of avoided damages	Measurement and concentration modeling
Ozone depleting substance	Ton of ozone depleting potential and saved monetary value of avoided damages	Measurement and emissions factors
GDP growth	Monetary value	Macroeconomic modeling
Job creation	Net number of jobs created	Macroeconomic modeling
Energy price	$/kWh reduction	Macroeconomic modeling
Energy poverty	Number of households	Survey

Source: World Bank (2017)

While it is relatively straightforward to estimate the economic benefit of energy savings (typically valued at the avoided cost of energy generated and distributed to the consumer), it is often a challenge to measure the economic benefits of these multiple benefits. A study, carried out as part of a Horizon 2020 research project "Calculating and Operationalizing the Multiple Benefits for Energy Efficiency in Europe", concluded that including multiple impacts in evaluating low-carbon energy options and policies significantly increases the economic benefits, but is a complex task that lacks appropriately elaborated methodologies. A review of selected social cost-benefit analysis case studies attempting a full coverage of co-benefits in the buildings and industry sectors found that co-benefits and nonclimate benefits were between 53 percent and 350 percent of direct benefits in Net Present Value (NPV) calculations (Ürge-Vorsatz, et al., 2016). Many of the multiple benefits of EE contribute to economic growth in both developed countries (World Bank, 2017; ECONorthwest, 2016; ECONothwest, 2016; CADMUS, 2015; Belzer, Bender, & Cort, 2017; Malone, et al., 2014; Ryan & Campbell, 2014; Vivid Economics, 2013) and developing countries (TERI, 2018; United Nations Environment Programme, 2017; Cantore, Calì, & Velde, 2016; Cantore, 2011; Farrell & Remes, 2009). In addition, EE also provides poverty alleviation benefits at the household level, even in advanced economies. For example, EE programs for lower-income households in the United States were found to promote economic growth for these households through creating jobs, lowering energy bills, keeping money in the local economy, and providing other social benefits (Oppenheim, 2015).

The recognition of the multiple benefits of EE is a step toward more comprehensively capturing the economic benefits of EE measures. However, the point being made in this paper is that the economic benefits of additional outputs–goods and services–that an energy intensive process can produce through EE investments are not fully recognized. As described earlier, in high-income countries, where livings standards are high, demand for essential energy-consuming services is met for most of the population, and economic growth rates are moderate, energy savings represent a significant share of the economic benefit from EE measures. In low- and middle-income countries, which are characterized by unmet demand for essential goods or services and higher economic growth rates, the relative importance of benefits from EE measures shifts from energy savings toward provision of more goods and better services to the population.

2.3 Review of a sample of economic analyses from World Bank projects

A sample of economic analyses from 26 World Bank projects that included EE components (approved between 2016 and 2019) was reviewed. The objective of the review was to identify what economic benefits, besides energy savings, were quantified in EE projects. Fifteen projects were led by the Energy Practice; five by the Social, Urban, Rural, & Resilience Practice; two by the Water Practice; and one each by the Agriculture, Education, Environment & Natural Resources, and Transport Practices. The projects led by the Energy Agriculture, and Environment & Natural Resources Practices had project objectives that focused on increasing EE, reducing energy consumption, and/or reducing GHG emissions. Most (9 out of 11) projects led by Practices other than Energy had project objectives related to the Practice's sector (but included EE components).

The economic analysis of all 15 projects led by the Energy Practice and the two projects led by the Agriculture and Environment & Natural Resources Practices respectively, quantified the benefits from energy savings and/or associated GHG emission reductions. One project also quantified benefits outside the energy sector (local health benefit approximated by the avoided damages of fossil fuel generation on human health). The nine projects that had objectives unrelated to the energy sector quantified benefits such as improved road safety, avoided public and private costs of flood damage, or reduced pollution from sewage discharge. In most of these projects (6 out of 9), the economic analysis also quantified the benefits from energy savings; the economic analysis in the remaining three projects did not mention benefits from EE.

In projects that included EE retrofits of public buildings, the improvement in comfort levels in the buildings (improved indoor temperatures, improved lighting conditions) was typically captured through quantifying energy savings compared to an adjusted baseline energy consumption, as described in the "Guidance Note on Measurement and Verification for World Bank Energy Efficiency Projects" (World Bank, 2020). This concept should be applied in the case of suppressed demand—a situation where the energy services provided are insufficient due to poverty or lack of access to modern energy infrastructure. For example, buildings may have substantially lower than normal energy use baselines due to inadequate energy services such as underheating in schools, missing or broken equipment, lack of cooling, or a lack of affordability to fully operate existing equipment at their capacities. If building EE retrofit projects result in higher quality of services and improved comfort levels, the energy savings are determined by comparing the post-project energy consumption with an adjusted baseline energy consumption, which is the amount of energy that would have been consumed in the absence of the intervention to produce the same level of service. It is important to note that this approach requires the presumption of adequate service levels which, in the case of building retrofits, can be determined using standards for thermal comfort and indoor lighting.

In addition to the quantified economic benefits, the description of the project rationale and economic analysis of the 15 projects led by the Energy Practice described other economic benefits that were not quantified, e.g., increased energy security, increased competitiveness, economic growth, improved health and air quality, enhanced disaster resilience, improved municipal services, improved safety, job creation, and improved building conditions and real estate value. One of the reasons these additional benefits were not quantified was that the economic returns of the projects, based on quantifying energy savings, were sufficiently high to justify the investments.

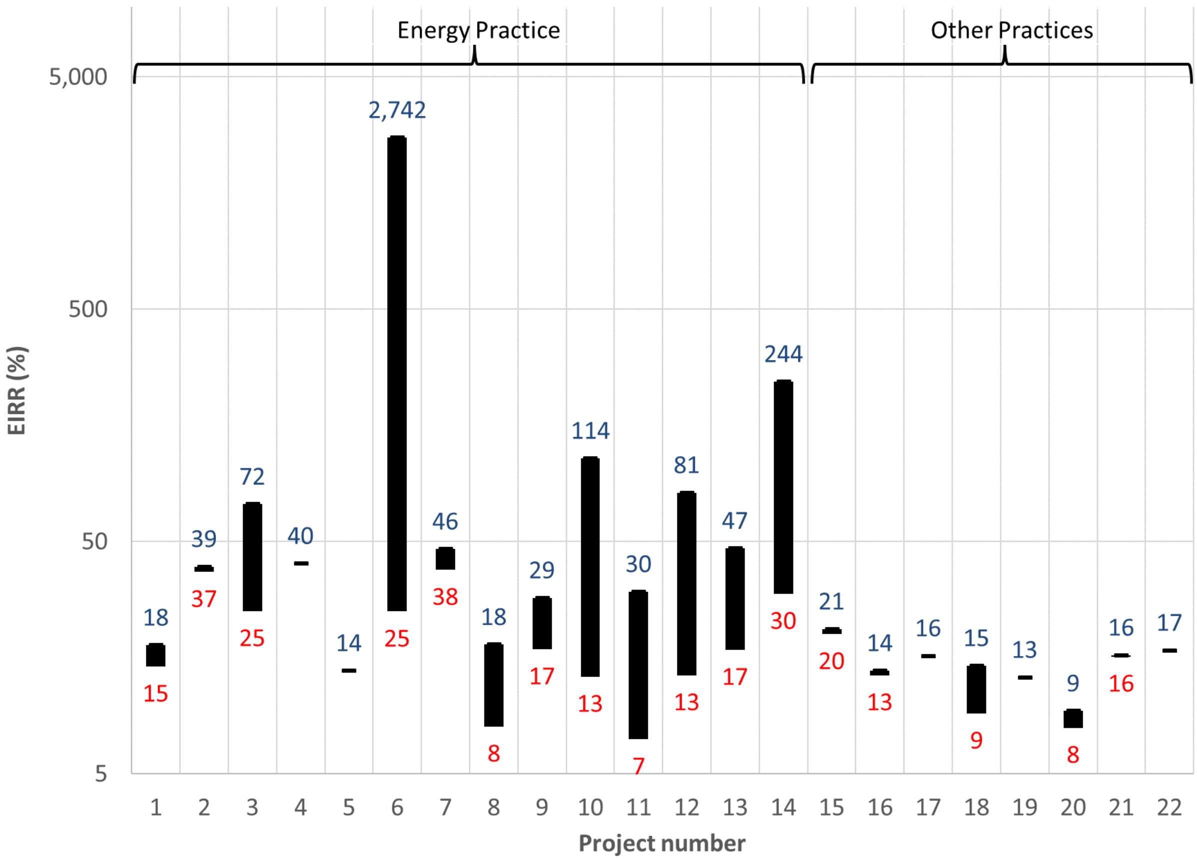
A key indicator used for the economic cost-benefit evaluation of World Bank investments is the Economic Internal Rate of Return (EIRR). Investments are considered economically viable if the EIRR is higher than the social discount rate[3]. The ranges for EIRRs of 22 projects in the sample[4] are presented in Figure 2. All presented EIRRs have been calculated using the shadow price of carbon as described in the "Guidance Note on Shadow Price of Carbon in Economic Analysis" (World Bank, 2017). In many cases, the economic analysis for a single project results in multiple EIRRs calculated for different project components or for a sample of representative investments. Therefore, ranges of EIRRs are presented for most projects from (i) the lowest EIRR within a project to (ii) the highest EIRR within a project. Most of the projects' EIRRs are relatively high, with a simple average of 18 percent for the lowest EIRRs within

[3] The social discount rate for World Bank projects is based on the Ramsey formula: $r=\beta+\varepsilon*\sigma$ where the pure rate of time preference $\beta=0$, the elasticity of marginal utility of consumption $\varepsilon=2$, and the expected growth rate of per capita consumption σ is based on the per capita GDP growth.

[4] For 22 out of the 26 projects, the economic analyses provided EIRRs. For the remaining 4 projects, other measures of the cost-benefit were used.

projects. For projects in the Energy Practice, the EIRRs in the sample were higher, with a simple average of 20 percent for the lowest EIRRs within projects. These EIRRs usually exceed the social discount rates for developing countries.

Figure 2. Ranges of EIRRs of 22 World Bank lending operations that include EE components



Source: World Bank data

2.4 Shortcomings of the "traditional" economic analysis

Although most existing guidance and frameworks for economic analysis of EE projects focus on the economic benefits from energy savings and associated GHG emission reductions, they can, to some extent, capture the economic benefits from an improvement in service levels or increase in production through an EE measure if the concept of adjusting the baseline energy consumption is applied (as described in Section 2.3). For example, if a building is significantly underheated prior to an EE retrofit, and after the EE retrofit the indoor temperature norms are met, it is possible that the energy consumption does not decrease due to the retrofit. In this case, a key benefit of the EE retrofit would be an increase in the indoor temperature rather than absolute energy savings. The existing guidance for economic analysis approximates the benefit of increased indoor temperature by quantifying energy savings compared to the adjusted baseline energy consumption (i.e., the amount of energy that would have been consumed in the absence of the EE retrofit to deliver indoor temperatures according to the norm). Similarly, in a Small and Medium Enterprise (SME) EE project, in which existing SME equipment is replaced by more energy-efficient equipment with higher production capacity, the energy consumption may not decrease after the equipment replacement due to the increase in production. In this case, a key benefit of the EE project would be an increase in production rather than absolute energy savings. As in the building retrofit example, the benefit of increased production could be captured through quantifying energy savings compared to the adjusted baseline energy consumption (i.e., the amount of energy that would have been consumed in the absence of the EE project to meet the post-project production). In both examples, the energy consumption in absolute terms may increase after the EE investment, but the specific energy consumption (i.e., the energy consumption to provide a specific indoor temperature or to manufacture a product unit) would decrease.

If the benefits of an EE project shift from generating absolute energy savings toward improving the level of goods or services provided, one may argue that the focus of the project objective and the economic analysis should also shift in a similar manner. In the case of the SME EE project, for example, presenting energy savings (calculated compared to the adjusted baseline energy consumption) can create confusion if, in fact, the absolute energy consumption increases as a result of the EE project, and may not be aligned with the project beneficiary's objective of increasing production output while limiting an increase in energy consumption. Instead of focusing on the energy savings, the project development objective could include growth of SMEs. Benefits such as an increase in SME revenue or net fulltime equivalent jobs created could be quantified in the economic analysis. This issue becomes more obvious in greenfield EE projects (i.e., projects that provide additional goods or services through the addition of new rather than replacement of existing energy end-use infrastructure or equipment), Greenfield EE projects aim to provide these additional goods or services in a more energy-efficient manner rather than in a Business-as-usual (BAU) scenario, but certainly increase the energy consumption compared to the status quo. A consultation process with various stakeholders[5], including institutions from developing countries, international organizations, and academia, revealed interest for a stronger narrative on the role of EE in providing additional goods or services supported by expanded project economic analysis guidance.

3 Suggested framework for economic analysis of energy efficiency projects

3.1 Overview

For the purpose of this framework, EE projects are broadly defined as projects that decrease the "specific" energy consumption (energy input/unit of output) for the provision of goods or services compared to BAU. In certain cases, EE projects aim at improving the level of goods or services provided, i.e., the output for which energy is being consumed as an input. Absolute energy consumption may or may not decrease, but specific energy consumption will decrease. This framework describes how the economic analysis can be carried out for these types of projects. It also addresses greenfield EE projects

[5] Stakeholder consultations were carried out with the United Nations Environment Program (UNEP); Energy Research Institute (TERI); former Chilean Energy Ministry Official, past president and current member of the International Association of Energy Economists (IAEE); Inter-American Development Bank (IDB); Asian Infrastructure Investment Bank (AIIB); US State Department, Regulatory Assistance Project (RAP); Agence Française de Développement (AFD); Alliance to Save Energy (ASE); Economic and Human Dimensions Research Associates, and Energy Efficiency for Industrial Processes (EEIP).

and discusses implications of the rebound effect. This framework does not propose a new methodology, but rather illustrates how economic benefits and costs shift for different types of EE project categories.

3.2 Project categories

This framework covers four categories of projects. Three project categories involve measures to improve demand-side EE (ratio between output of goods or services and energy consumed), while the supply-side project involves measures to improve efficiency in the production and delivery of energy to consumers. Table 4 and the following section describe the changes resulting from these project categories compared to status quo in terms of (a) level of goods or services provided, (b) absolute final energy consumption, and (c) specific energy consumption for goods or services provided.

Table 4. Project categories

Project category		Changes compared to status quo		
		(a) Level of goods or services provided (unit of output)	(b) Absolute final energy consumption (energy input)	(c) Specific energy consumption for goods or services provided (energy input/unit of output)
Demand side EE	**1) Brownfield EE project: Reduce energy consumption**	→	↓	↓
	2) Brownfield EE project: Increase goods or services	↑	↓ → ↑	↓
	3) Greenfield EE project	↑	↑	Not defined
	4) Supply side EE project	↑	↑	Not defined

→ No change ↑ Increase ↓ Decrease

Source: Authors

3.2.1 Brownfield energy efficiency project: Reduce energy consumption (Category 1)

These projects aim to reduce energy consumption; they do not aim to change the level of goods or services provided. Both absolute energy consumption and specific energy consumption are expected to be reduced. An example of a project in this category is an investment to replace inefficient light bulbs in residential homes with more efficient light bulbs to provide the same level of service (the light output of the existing, inefficient light bulbs is equal to that of the new, efficient bulbs and the hours of operation of the lights are assumed to remain the same) with lower energy consumption (the new, efficient bulbs consume less energy). However, in some cases, the achieved reduction in absolute energy consumption could be lower than predicted due to the rebound effect (see Section 3.3.4). Guidance for the economic analysis of such projects can be found in Annex 2 of the "Power Sector Investment Projects: Guidelines for Economic Analysis" (World Bank, 2017).

3.2.2 Brownfield energy efficiency project: Increase goods or services (Category 2)

These projects aim to reduce the specific energy consumption while improving the level of goods or services provided. For example, in an industrial EE project, the beneficiaries' objectives could include increasing industrial production or improving the quality of produced goods through replacement of existing equipment by new and more energy-efficient equipment. (Note that there could be other benefits not directly linked to increasing the level of goods or services provided such as reduced maintenance cost or increased operating life of equipment.) Another example is a project in which buildings are retrofitted to improve their EE (e.g., upgrade of heating, cooling and ventilation systems; lighting; insulation; windows) and comfort levels (e.g., improve indoor temperature if there is underheating or undercooling). In both project examples, the increase in industrial production or the improvement of comfort levels reduces the absolute energy savings (i.e., energy savings versus the actual pre-project energy consumption baseline) but provides important economic benefits. Since the increase in energy consumption for the provision of more goods or services could reduce the energy savings brought about by the increased EE, absolute energy consumption may (i) decrease, (ii) remain the same, or (iii) increase compared to status quo. In any case, the level of specific energy consumption would be reduced.

3.2.3 Greenfield energy efficiency project (Category 3)

These projects aim to provide additional goods or services through the addition of new rather than replacement of existing energy end-use infrastructure or equipment. This includes, for example, installing streetlighting where there is none, installing air conditioners (ACs) in uncooled public buildings, expanding water supply services, or constructing new buildings with heating, cooling, lighting, etc. The level of goods or services provided and the absolute energy consumption will certainly increase as a result of the project. Since greenfield projects add new infrastructure or equipment, a specific energy consumption in the status quo cannot be defined. However, the objective of a greenfield EE project is to provide additional goods or services in a more energy-efficient manner than in a BAU scenario (see Section 3.3.2).

3.2.4 Supply-side energy efficiency project (Category 4)

Supply-side EE projects involve measures to improve the efficiency in the production and delivery of energy to consumers, e.g., improving efficiency of electricity generation by upgrading gas turbines to combined cycle, or reducing technical losses in electricity transmission or distribution. These projects typically result in more energy delivered to consumers and, therefore, the level of services or goods provided and the absolute final energy consumption are expected to increase. In contrast to demand-side EE projects, a supply-side EE project is usually not directly linked to a specific provision of goods or services (such as the provision of water supply or street lighting). Therefore, a definition for specific energy consumption cannot be provided. Guidance for the economic analysis of such projects can be found in Annex 3 of the "Power Sector Investment Projects: Guidelines for Economic Analysis" (World Bank, 2017).

3.3 Approaches for economic analyses of energy efficiency investments

As with all project economic analysis, the project counterfactual needs to be clearly established. Typical counterfactuals for EE projects are:

(i) *Status quo* counterfactual, in which there is no change in level of goods or services provided. Note that maintaining the status quo might entail capital expenditures (e.g., to replace infrastructure or equipment at the end of its useful life).

(ii) *Alterative scenario* counterfactual, in which the same level of goods or services is provided as under the project.

A brownfield EE project that aims to reduce energy consumption (Category 1) would typically be evaluated against a status quo counterfactual. A brownfield EE project that improves the level of goods or services (Category 2) or a greenfield EE project can be evaluated against either a status quo or an alternative scenario counterfactual. The following sections illustrate the approach for an economic analysis using both counterfactuals with examples for different project categories.

3.3.1 Status quo counterfactual

For Category 2 (Brownfield EE project: Increase goods or services) and Category 3 (Greenfield EE project) projects, compared to status quo, there will be an increase in the level of goods or services provided by the project for which the value needs to be estimated. The economic analysis that follows is no different than that for other investment projects that lead to more goods and services versus the status quo, whether in the energy sector or other sectors (see Table 5).

Table 5. Approach for economic analysis using the status quo counterfactual

Project category	Category 2. Brownfield EE project: Increase goods or services	Category 3. Greenfield EE project
Project example	Water supply project that improves service levels (e.g., increase the number of water supply service connections, increase hours of supply, improve water quality) and EE of water supply. Measures could include upgrade or extension of transmission mains, treatment plants, pumping stations, reservoirs, distribution network, etc.	New installation of efficient streetlights in an unserved area.
a) Estimate the value of the incremental goods or services provided by the project	Avoided direct coping costs (lower coping costs for households caused by intermittent water supply, e.g., construction of household water tanks, purchase of water from vendors), avoided indirect coping costs (e.g., reduced sickness caused by poor water quality, reduced time and wage loss because households receive a private connection instead of relying on public taps), value of incremental water accessed due to increased hours of supply, etc.	Improved safety, reduced traffic accidents, benefits from stimulating local commerce, etc.
b) Estimate the value of the change in energy consumption and associated GHG emissions	This involves a comparison between the energy consumption before (status quo) and after the project. The EE of water supply would be improved by, e.g., greater efficiency in pumping and a reduction of water losses, leading to a lower specific energy consumption (units of energy consumed per unit of water supplied). However, the improvement of service levels could require more energy. The net effect could be a reduction or an increase in absolute energy consumption. The change in GHG emissions would follow directly from the change in absolute energy consumption.	Increased energy consumption and associated GHG emissions from new street lighting installations.
c) Estimate other project economic costs and benefits	Capital expenditures for water supply infrastructure and equipment, changes in O&M for the water supply system, other externalities, etc.	Capital expenditures for installation of new streetlights, poles, controls and distribution lines; O&M cost for the new street lighting infrastructure; etc.

Source: Authors

3.3.2 Alternative scenario counterfactual

The first step is to establish an alternative scenario that provides the same level of goods or services as the project. For a brownfield EE project, the alternative scenario could involve increasing the level of goods or services using the existing infrastructure or equipment, if its capacity can accommodate the increase. If the existing capacity is insufficient, or for greenfield EE projects, the alternative scenario involves constructing or installing new infrastructure or equipment assuming BAU EE. Feasible assumptions should be made for BAU EE (also refer to World Bank, 2020, for guidance regarding establishing the BAU scenario), for example, assuming the existing infrastructure or equipment is used for its remaining useful life (if the existing equipment capacity can accommodate the increase) or equipment that is assumed to have been installed in the absence of the project (for an increase beyond the existing equipment capacity or for the time after its remaining useful life). Consequently, the key economic benefit is derived from energy savings and associated GHG emission reductions of the project compared to the alternative scenario (see Table 6).

Table 6. Approach for economic analysis using the alternative scenario counterfactual

Project category	Category 2. Brownfield EE project: Increase goods or services	Category 3. Greenfield EE project
Project example	Buildings retrofit project that improves the EE and comfort levels (increase of indoor temperature to norm temperature, typically 20 to 22°C) of buildings. Measures could include upgrade of heating and ventilation systems, lighting, insulation, windows, etc.	Installation of efficient ACs in public buildings which have no cooling.
a) Establish an alternative scenario that provides the same level of goods or services as the project	The indoor temperature in the buildings before the project was below the required norm temperature. In the alternative scenario, the buildings are not retrofitted and the indoor temperature is increased to norm temperature without any retrofit, resulting in an increase of heating fuel consumption.	Under a BAU scenario, conventional ACs would be installed to provide the same level of cooling as the project.
b) Estimate the value of the reduction in energy consumption and associated GHG emissions of the project versus the alternative scenario	The project investments deliver the norm temperature levels with less heating fuel than the alternative scenario, resulting in energy savings and GHG emission reductions compared to the alternative scenario.	The project investments deliver the desired cooling levels more efficiently than the alternative scenario, resulting in energy savings and GHG emission reductions compared to the alternative scenario.
c) Estimate other economic benefits and costs versus the alternative scenario	Capital expenditures for the building retrofits, increased O&M costs due to additional equipment, etc. Benefits may include a decrease in O&M cost due to lower maintenance need of new equipment compared to old equipment, etc.	Incremental capital expenditures for more efficient ACs (compared to conventional ACs).

Source: Authors

3.3.3 Greenhouse gas accounting

During the stakeholder consultations, concerns were raised about possible conflicts with climate-change objectives, because an increase in production of goods or provision of services was perceived to be accompanied by an increase in overall energy consumption and corresponding GHG emissions. The "IFI Approach to GHG Accounting for Energy Efficiency Projects" (International Financial Institutions Technical Working Group on Greenhouse Gas Accounting, 2019), deals with this issue by setting out a common approach of accounting for net GHG emissions of EE projects. It allows for baseline emissions to be calculated based on a scenario that provides a similar level of service or output provided by the project. This concept is similar to the one of adjusting the baseline energy consumption as described in Section 2.3. It is recommended that GHG accounting for IFI corporate purposes follow this methodology whereas GHG emissions calculations for of the project economic analysis flow directly from the energy balances relative to the identified counterfactual.

3.3.4 Addressing the rebound effect

As described earlier, the rebound effect is usually defined as the reduction in expected energy savings from EE investments because of behavioral responses. Taken broadly, this definition would classify the reduced energy savings from any increase in goods or services as rebound. Clearly, a large increase in goods or services following an EE investment in developing countries reflects a situation of unmet demand for those goods or services, for which the value can be estimated using the methods illustrated above. It is often misunderstood that the rebound effect necessarily reduces the economic net benefit of an investment. Rather, the reduction of economic benefits of the rebound effect is confined to those associated with reduced energy savings. These energy savings are generally not lost but put to other beneficial uses creating other types of economic benefits. In the case of replacing residential lights with more efficient ones, the direct rebound effect would be the increase in the hours that lights are kept on due to the lower cost of their operation and the indirect rebound effect could be an increase in the operating hours of residential fans due to cost savings from operating lights. The economic benefit could be convenience from leaving the lights and fans on for longer periods.

Oftentimes, one can make assumptions about the minimum value associated with the direct rebound effect that allow it to be calculated directly from the applied methodology. If rebound does not lead to the provision of additional project-valued goods or services, then it might still have value equal to that of the foregone energy savings. For example, if the beneficiary of the residential lighting project (Category 1) pays the electricity bill (no-principal-agent problem) and decides to keep lights on in an unoccupied room, one could argue (assuming rational behavior) that the reduced energy savings are valued by at least as much as the cost of energy to the beneficiary. If the rebound does lead to the provision of more project-valued goods or services then its value would be captured using the methods for Categories 2 and 3 projects described above: With the status quo counterfactual, the economic value of the rebound would be captured in the incremental goods or services provided by the project (Table 5, Step b); with the alternative scenario counterfactual, the economic value of the rebound would be captured in the reduction in energy consumption of the project versus the alternative scenario (Table 6, Step b).

4 Application of the framework for economic analysis on a case study

This section presents an example of an economic analysis to illustrate some of the previously discussed concepts. An economic analysis is carried out for a brownfield project, in which existing ACs are replaced by more efficient ones, and for a greenfield project, in which new ACs are installed in yet unconditioned space. The two project options are then compared in terms of economic returns. The example builds on an ESMAP-supported study to identify EE investment opportunities in public buildings in Ghana.

4.1 Context of the case study

Globally, buildings are responsible for a large and increasing share of total energy consumption. There is a large potential for cost-effective efficiency improvements in many buildings. A focus on public buildings can provide a strong demonstration effect ("leading by example"), help build the market for EE services and equipment, and reduce energy bills to ease the financial burden on public sector budgets. The case study focuses on enabling investments to improve EE in existing public buildings in Ghana. In 2015, the Ghana Energy Commission conducted audits in ministry buildings, finding that between ACs, lighting and refrigerators (the top three items in terms of energy-consuming types of equipment), 88 percent of energy consumption was accounted for by air-conditioning. An audit of three ministry buildings with broader coverage of equipment found that specific energy consumption in the facilities was around 134 kWh/m^2/year, around 70 percent of which was accounted for by air-conditioning.

The EE of an AC is described in terms of the coefficient of performance (COP), which is the ratio between the amount of thermal energy that the AC transfers (i.e., the amount of cooling it provides) and the amount of electricity it consumes. For example, a unit with a COP of 3.5 would provide 3.5 kWh of cooling for every 1 kWh of electricity consumed. Current minimum energy performance standards (MEPS) in Ghana make it illegal to import or sell ACs with a COP below 2.8, while to qualify for a five-star rating, the COP must exceed 4.0. Several energy audits that have been conducted found different ranges of COPs for existing ACs. An energy audit conducted by the Accra Metropolitan Assembly (AMA) of its headquarters found the average COP for the ACs in use was about 2.53, which is lower than even the worst performing units permitted on the Ghanaian market. Walk-through audits of commercial and public buildings conducted by a consulting firm (Econoler GFA) found higher COP values for ACs, ranging from 2.6 for retail and commercial non-office buildings to 3.24 for office buildings. In the ministry buildings audited by the Ghana Energy Commission, the COP of existing ACs was not estimated, although it was observed that 58 percent were unlabeled and therefore presumably had a COP of lower than 2.8.

4.2 Economic analysis

While the underlying investment study for this case study evaluated comprehensive EE renovation of public buildings (building envelope measures, upgrade of lighting and air-conditioning systems), for presentational purposes, the economic analysis presented here considers only the installation of efficient air-conditioning units with a COP of 3.8. The economic analysis was conducted by calculating the discounted benefits and costs of a brownfield (retrofit) project, as envisioned by the investment study, as well as a greenfield project. The counterfactual for the brownfield project is a BAU scenario, in which the existing ACs with a COP of 2.5 continue to be in use until they are replaced by ACs meeting the MEPS with a COP of 2.8. The counterfactual for the greenfield investment is no investment such that the targeted buildings have no cooling. The project is considered economically viable if the EIRR exceeds the social discount rate. In accordance with World Bank guidance, a social discount rate twice the expected real per capita growth rate is used. In Ghana, real per capita growth rates are assumed to be at 3.1 percent over the next five years[6], yielding a social discount rate of 6.2 percent.

A comparison between brownfield and greenfield investments is made on the basis of a number of simplifying assumptions. First, space that is cooled in both cases is the same. Since costs and benefits are all defined per square meter of floor area, space is a numeraire in the model and scaling it up or down has no impact on the EIRR, it only increases the NPV in direct proportion to the surface area considered. For this reason, the analysis is illustrated for a space of one square meter. Second, the thermal properties of the brownfield and greenfield buildings are the same, such that an equal amount of energy is required to achieve the same degree of cooling by the same AC. Third, the operation of the AC units is the same in both buildings, such that they are run for an equal amount of time at the same electricity costs. These assumptions could easily be relaxed to conform to realistic investment choices being considered but would not change the fundamentals of the concepts that are illustrated here.

Based on the audits, a cooling requirement of 246 kWh/m^2/year (837,339 BTU/m^2/year) is needed to meet the desired ambient temperature. The AC units are mini-split systems with a cooling capacity of 5.3 kW (18,000 BTU/hour or 1.5 tons). Existing ACs in the brownfield case have a COP of 2.5 and therefore use 97 kWh/m^2/year of electricity to achieve the required cooling output[7]. Should existing ACs need to be replaced in the BAU counterfactual scenario, the BAU replacement AC has a COP of 2.8 requiring 87.6 kWh/m^2/year of electricity. The efficient AC used to replace old ones has a COP of 3.8 and therefore only uses 64.7 kWh/m^2/year. ACs are expected to last 15 years and the ACs that are replaced are at the end of their useful life and have no residual value.

4.2.1 Costs and benefits

The following costs and benefits are quantified, with all monetary values in real US$ 2020 terms: (i) Capital investment costs of the ACs at US$37/m^2 for efficient ACs and US$27/m^2 for BAU ACs. (ii) Fuel costs of the marginal generator, which needs to ramp up or down depending on the change in demand for electricity. In Ghana, the marginal generator is assumed to be a gas plant. Gas is valued at the price of 6.44 US$/MMBtu in 2020 increasing to US$10.8/MMBtu in 2030. Gas price forecasts through 2039 are based on the April 2020 World Bank commodity price forecasts. A heat rate of 8,500 BTU/kWh is assumed yielding marginal fuel cost for generation of US$ 0.055/kWh in 2020. (iii) GHG emissions costs: CO_2 emissions of gas-based generation are estimated using emission factors of 0.51 kgCO_2/kWh. Consistent with World Bank guidance on the social cost of carbon (SCC), a high and low cost of carbon trajectory are used, with values at US$85/t$CO_2$ and US$42/t$CO_2$ respectively in 2020, which increase thereafter at 2.25 percent annually in nominal terms. (iv) Benefits from cooling such as comfort and productivity that bring economic value: Although these benefits are not quantified *a priori*, the analysis determines the willingness to pay based on a current use of ACs in office buildings and based a switching value analysis that equalizes the NPV of the alternative investment decisions..

[6] Due to global macro-economic uncertainty related to the COVID-19 pandemic, forecasts are highly uncertain. The World Economic Outlook (April 2020) edition, forecast real per capita GDP growth rates of -0.53 percent in 2020 and 4.2 percent in 2021. It has been assumed that after 2021, a 4 percent real per capita GDP growth rate will be maintained so that the 5-year average is around 3.1 percent.

[7] Alternative audits for public buildings in Ghana put the electricity requirement at 65 kWh/m^2/year (Econoler, 2016).

Nonquantified costs and benefits could include: (i) macroeconomic and employment benefits from potential local manufacturing of ACs; (ii) local externalities associated with natural gas consumption including the impacts associated with gas resource extraction, damage costs of air pollutants during consumption, heavy metal emissions, groundwater contamination, thermal pollution from cooling water disposal and other; and (iii) other environmental externalities related to disposal of older ACs.

4.2.2 Results

Table 7 presents the summary of the economic analysis. The brownfield investment EIRR was calculated and the WTP for cooling was set such that it yielded the same NPV for the greenfield investment excluding the impact of GHGs emissions.

Table 7: Summary of economic analysis with WTP for cooling set to equalize net benefits excluding GHGs

Summary of economic analysis	**Units**		
	Units	Brownfield	Greenfield
Social discount rate	[ ]	6%	6%
Project lifetime	[ ]	15	15
Economic rate of return			
EIRR excluding GHGs	[ ]	26%	13%
EIRR including GHGs	[ ]	37%	1%
NPV			
Costs			
Incremental CAPEX new AC	[US$]	34.8	34.8
Incremental fuel costs	[US$]	-	61.5
Incremental GHG costs	[US$]	-	19.7
Benefits			
Avoided CAPEX BAU AC	[US$]	25.7	-
Avoided fuel costs	[US$]	22.0	-
Incremental cooling benefits	[US$]	-	109.1
Avoided GHG costs	[US$]	7.1	-
Net economic flows			
Net benefits excluding GHGs	[US$]	**12.8**	**12.8**
Net benefits including GHGs	[US$]	19.8	(7.0)
Lifetime GHG emissions	[Tons CO2]	(0.2)	0.6

Source: Original calculations for this report

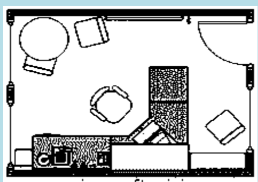
The summary table illustrates the elements discussed in Section 3 for a brownfield project with BAU counterfactuals. Both brownfield and greenfield investments incur the same expenses for new ACs. Relative to the counterfactual, fuel costs and GHG emissions are avoided in the brownfield investment but are incremental in the greenfield investment. All benefits for the greenfield investment arise from additional cooling, making the WTP for cooling an important parameter. To achieve the same NPV as the brownfield investment excluding GHGs, the greenfield investment would need a value for cooling of USc 4.6 per kWh of cooling output. When considering the brownfield and greenfield investments as project options, this would be the switching value for the WTP for cooling that would make the investments equally attractive based on the NPV (note that NPV is not the only criteria of a cost-benefit analysis, and in this scenario, the EIRR of the greenfield investment is half that of the brownfield investment). Figure 3 illustrates what a switching value of USc 4.6 per kWh of cooling output means in more practical terms. It implies a WTP of US$228 per year to cool a 20 m^2 office to the recommended temperature as defined by the audit, with electricity costs of US$282 per year.

Figure 3. What does a switching value of 4.6 USc/kWh of cooling mean?

COOLING STANDARD

Cooling requirement
245 kWh/m^2/year

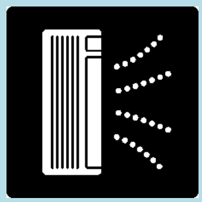
Office area
20m^2



BENEFIT

Cooling output
4,908 kWh/year

Economic benefit
US$228/year
Based on WTP of 4.6 USc/kWh



COST

Electricity consumption
1291 kWh/year for US$282/year
Based on a COP of 3.8 and electricity tariff of 22 USc/kWh

Capital investment for efficient ACs
US$740

$

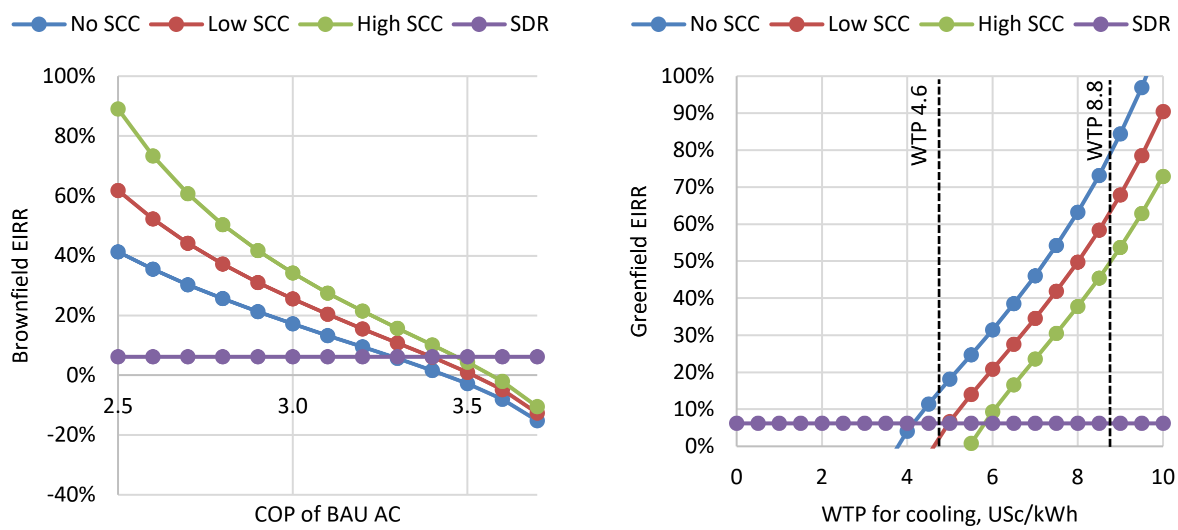
Source: Original calculations for this report

Including the costs of GHG, the switching value of WTP for cooling increases to 5.8 USc/kWh. However, both switching values are lower than the WTP that follows from the running of existing ACs at the going electric tariff of 22 USc/kWh. Namely, with a COP of 2.5, running the existing AC in the brownfield office building implies a WTP for cooling output of 8.8 USc/kWh. If this is interpreted as the minimum WTP for cooling, then the greenfield investment yields greater net economic benefits with or without GHG accounting.

When brownfield and greenfield investments are considered simultaneously, the economic analysis must pay attention to parameters of uncertain value that affect the economic viability of one investment relative to the other. Key uncertain parameters in this case study are (i) the WTP for cooling, which has an impact on the NPV of the greenfield investment, (ii) the efficiency of the BAU ACs, which only has an impact on the brownfield investment, and (iii) the SCC, which has an impact on both investments in opposite directions (a higher value increases economic benefits of avoided CO2 emissions for the brownfield investment, but increases economic costs of increased CO2 emissions for the greenfield investment). The sensitivity of the EIRR to these parameters is illustrated in Figure 4.

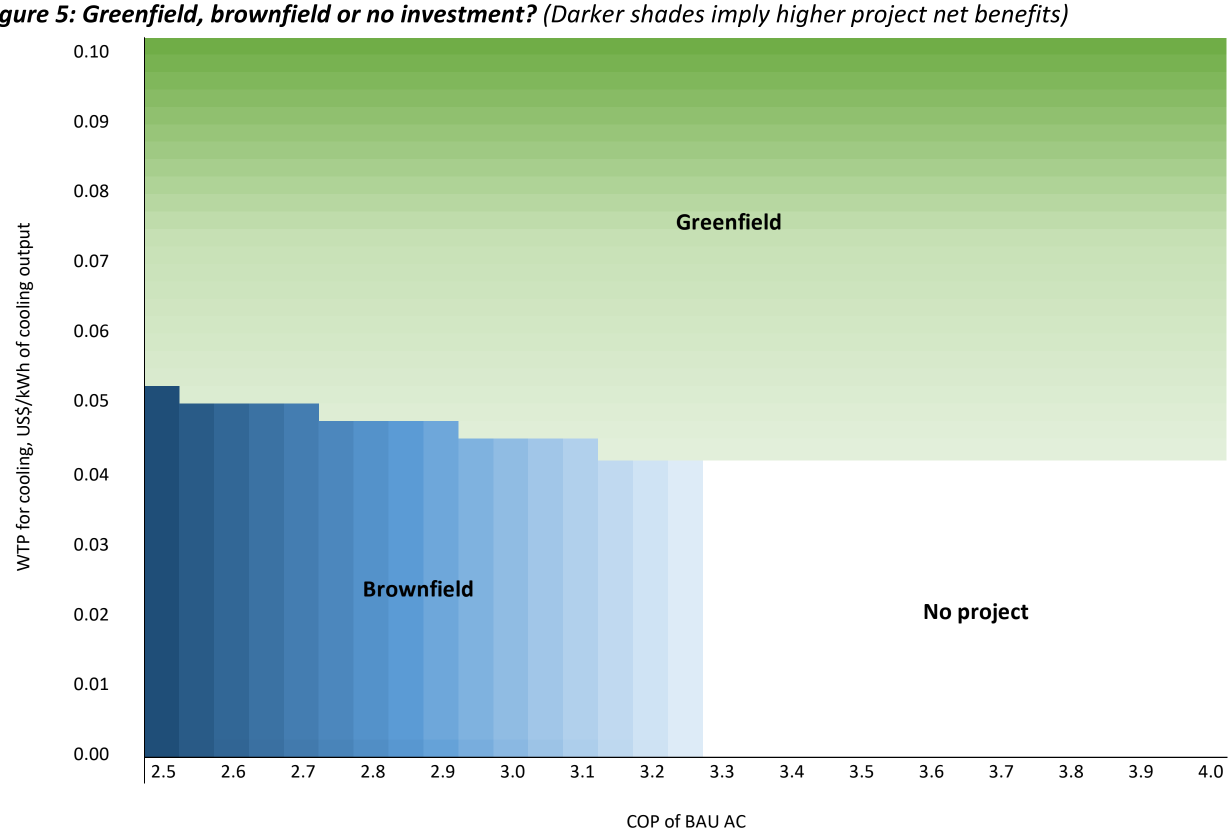
In spite of uncertainty about parameters such as the COP of the counterfactual AC and the WTP for cooling, efforts to bring to light the sensitivity of the EIRR to these parameters and determine switching values to prefer one investment over another would, over time, build a repository of information to benchmark and compare future investments to. For this case study, Figure 5 brings together both parameters to illustrate what the best investment decision would be based on the highest NPV criterion excluding GHG emissions costs.

Figure 4. Brownfield EIRR vs efficiency of BAU AC, and greenfield EIRR vs WTP for cooling



Source: Original calculations for this report

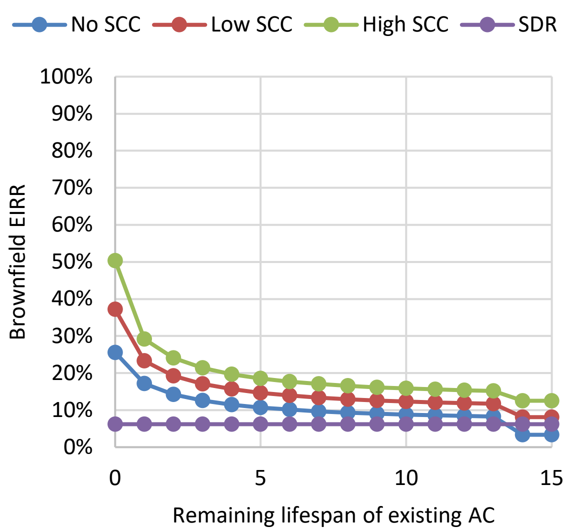
Figure 5: Greenfield, brownfield or no investment? *(Darker shades imply higher project net benefits)*



Source: Original calculations for this report

This case study illustrates an interesting point related to the importance of establishing a clear counterfactual. In the brownfield investment, the remaining lifespan of the existing ACs have a dramatic impact on the EIRR because they determine when capital expenditures are incurred in the counterfactual BAU. Figure 6 describes the impact of the remaining lifespan of the existing ACs on the EIRR. In this case study, the EIRR of a brownfield investment drops by more than half when the old ACs that are to be replaced could on average keep running for an additional two more years. A reassessment of the investment decision would shift significantly in favor of a greenfield investment. It is important to note that the impact of delaying required capital expenditures varies in proportion to the discount rate, which is generally higher in developing countries where real per capita incomes are rising more rapidly.

Figure 6: Rebound effect and timing of investments on brownfield EIRR



Source: Original calculations for this report

5 Conclusion

A review of literature, guidance documents for the economic analysis of EE investments at MDBs and other international organizations, and o a sample of recent World Bank projects with EE components (26 World Bank lending operations approved between 2016 and 2019) concluded that economic benefits quantified in projects whose objectives focus on EE are almost exclusively the economic cost of energy saved and the associated GHG emission reductions. While both the literature and the descriptions of the reviewed EE projects recognize that there are additional economic benefits, it is typically noted that these are difficult to quantify. Since the EIRRs of the reviewed World Bank EE projects were relatively high and exceeded social discount rates, with a simple average of 18 percent for the lowest EIRRs within projects, the projects were economically justified without quantifying additional benefits.

However, the recognition of the economic benefit from the increase in the level of goods and services provided is particularly important for low- and middle-income countries, where the benefits from EE measures shifts from energy savings toward other benefits such as an increase in production or improvement of essential services. While the existing guidance and frameworks for economic analysis usually do not suggest approaches to capture these benefits, the review of a sample of World Bank economic analyses has shown that these benefits are often captured to some extent by determining energy savings compared to an adjusted baseline energy consumption. However, this may not be an adequate approach in all situations. For example, for greenfield EE projects or brownfield EE projects, in which a project beneficiary's primary objective is to increase production relative to a counterfactual (while limiting an increase in energy consumption) through EE measures, it would be preferable to value the economic benefit from the increase in the level of goods or services provided by the project as these goods and services typically have higher economic value than energy savings. The research therefore extended World Bank guidelines for economic analysis of EE projects to better describe how an improvement in the level of goods or services provided can be quantified. The framework covers three demand-side EE project categories: (i) Brownfield EE projects that aim at reducing energy consumption; (ii) brownfield EE projects that aim at reducing the specific energy consumption while improving the level of goods or services provided; and (iii) greenfield EE projects that aim at providing additional goods or services through the addition of new rather than replacement of existing energy end-use infrastructure or equipment. The framework describes the main steps of the economic analysis with two possible counterfactuals: (a) a status quo counterfactual, in which there is no change in level of goods or services provided and (b) an alternative scenario counterfactual, in which the same level of goods or services is provided as under the project. In fact, in several EE projects in the reviewed sample of economic analyses, an alternative scenario counterfactual has been implicitly used by determining energy savings compared to an adjusted baseline energy consumption. The framework also clarifies that the rebound effect does not necessarily reduce the economic benefit of an EE project and provides guidance how the additional utility resulting from the rebound effect can be valued. As long as prices reflect economic cost and those costs are borne by those that make the decision to consume more goods or services, continued consumption at the expense of energy savings increases net welfare.

The suggested framework for economic analysis was applied to a case study on investing in energy-efficient ACs, comparing a brownfield EE versus a greenfield EE investment decision. The case study illustrates that (i) a focus on EE savings and avoided GHG emissions could eliminate viable investment alternatives with non-quantified benefits from consideration; (ii) even if the true value of these benefits are uncertain, efforts to calculate switching values could provide useful information, and if done consistently over time may allow for a better ranking of investment alternatives; and (iii) assumptions about the counterfactual to an EE investment are critical and need to be clearly established prior to the economic analysis.

The application of the framework, or of economic analyses that value the increase in production or service levels from EE projects in general, could favor a shift from brownfield EE projects that save energy in absolute terms toward brownfield EE projects that increase goods and services and toward greenfield EE projects. The suggested framework also helps address concerns about the rebound effect, which is often raised when discussing EE measures. Since demand-side EE usually requires measures and actions outside the energy sector (e.g., EE in buildings, transport, industry, agriculture, municipal services such as water supply or street lighting), quantifying an increase in production or service levels will require collaboration with experts in these sectors. In fact, many opportunities for EE that involve an increase in production and service levels (brownfield and greenfield EE) are likely to be led by stakeholders in these sectors; therefore, collaboration between the energy sector and other sectors is essential.

6 References

Barker, T., & Foxon, T. (2008). *The Macroeconomic Rebound Effect and the UK Economy. Research Report.* UK Energy Research Centre. REF UKERC/WP/ESM/2008/001. https://ukerc.rl.ac.uk/UCAT/PUBLICATIONS/The_Macroeconomic_Rebound_Effect_and_the_UK_Economy.pdf.

Belzer, D., Bender, S., & Cort, K. (2017). *A Comprehensive System of Energy Intensity Indicators for the US: Methods, Data and Key Trends.* United States. DOI: 10.2172/1373003.

Benoit, P. (2019). *Energy and Development in a Changing World: A Framework for the 21st Century.* https://energypolicy.columbia.edu/research/energy-and-development-changing-world-framework-21st-century.

Borenstein, S. (2014). A microeconomic framework for evaluating energy efficiency rebound and some implications. *The Energy Journal, vol 36(1) DOI: 10.5547/01956574.36.1.1*.

CADMUS. (2015). *Focus on Energy Economic Impact 2011-2014.* Retrieved from https://www.focusonenergy.com/sites/default/files/WI%20FOE%202011%20to%202014%20Econ%20Impact%20Report.pdf

Cantore, N. (2011). *Energy efficiency in developing countries for the manufacturing sector.* Retrieved from https://open.unido.org/api/documents/4817789/download/Energy%20efficiency%20in%20developing%20countries%20for%20the%20manufacturing%20sector

Cantore, N., Calì, M., & Velde, D. (2016). Does energy efficiency improve technological change and economic growth in developing countries? *Energy Policy, 92. doi.org/10.1016/j.enpol.2016.01.040*, 279-285.

de la Rue du Can, S., McNeil, M., & Leventis, G. (2015). *Rebound Effects in the Context of Developing Country Efficiency Programs. Final Report.* Super-Efficient Equipment and Appliance Deployment Initiative (SEAD). https://eta.lbl.gov/sites/all/files/publications/lbnl1004377.pdf.

Economic Consulting Associates. (2014). *"The Rebound Effect for Developing Countries", Phase 1 Final Report, Evidence on Demand with the assistance of the UK Department for International Development (DFID).*

ECONorthwest. (2016). *The Economic Impacts and Macroeconomic Benefits of Energy Efficiency Programs in Oregon.* Retrieved from https://www.neec.net/wp-content/uploads/2017/10/neec-econ-oregon-update-aug2016.pdf

ECONothwest. (2016). *The Economic Impacts and Macroeconomic Benefits of Energy Efficiency Programs in Washington.* Retrieved from https://www.neec.net/sites/default/files/page_attach/neec-econ-washington-update-aug2016.pdf

European Commission. (2013). *Green Paper. A 2030 framework for climate and energy policies.* Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0169

European Commission. (2014). *Guide to Cost Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020.* Luxembourg: Publications Office of the European Union, 2015. doi:10.2776/97516.

European Commission. (2019). *Clean energy for all Europeans.* Luxembourg: Publications Office of the European Union, 2019. doi:10.2833/9937. Retrieved from https://op.europa.eu/en/publication-detail/-/publication/b4e46873-7528-11e9-9f05-01aa75ed71a1

European Investment Bank. (2013). *The Economic Appraisal of investment Projects at the EIB.* https://www.eib.org/en/publications/economic-appraisal-of-investment-projects.

Farrell, D., & Remes, J. (2009). *Promoting energy efficiency in the developing world. McKinsey & Company.* Retrieved from https://www.mckinsey.com/business-functions/sustainability/our-insights/promoting-energy-efficiency-in-the-developing-world#

Figus, G., Turner, K., McGregor, P., & Katris, A. (2017). Making the case for supporting broad energy efficiency programmes: Impacts on household incomes and other economic benefits. *Energy Policy, vol 111. https://doi.org/10.1016/j.enpol.2017.09.028*, 157-165.

Gillingham, K., Rapson, D., & Wagner, G. (2015). The Rebound Effect and Energy Efficiency Policy. *Review of Environmental Economics and Policy, Volume 10, Issue 1*, 68-88.

IEA. (2014). *Capturing the Multiple Benefits of Energy Efficiency.* Paris: IEA.

IEA. (2018). *Energy efficiency. Analylsis and outlooks to 2040.*

IEA. (2019). *Multiple Benefits of Energy Efficiency.* Retrieved from https://www.iea.org/reports/multiple-benefits-of-energy-efficiency

IEA. (2019). *World Energy Outlook.* IEA.

Inter-American Development Bank. (2017). *Energy Efficiency in Public Lighting. Technical Note (commissioned by the Inter-American Development Bank (IDB) to Econoler).* Inter-American Development Bank.

International Financial Institutions Technical Working Group on Greenhouse Gas Accounting. (2019). *IFI Approach to GHG Accounting for Energy Efficiency Projects.* Retrieved from https://unfccc.int/sites/default/files/resource/Energy%20Efficiency_GHG%20accounting%20approach.pdf

Japan's Minstry of Economy, Trade, and Industry. (2020, May 28). *Energy efficiency and conversation*. Retrieved from https://www.meti.go.jp/english/policy/energy_environment/energy_efficiency/index.html

Li, M., Haeri, H., & Reynolds, A. (2018). *The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures.* Golden, CO: National Renewable Energy Laboratory. NREL/SR-7A40-70472. http://www.nrel.gov/docs/fy18osti/70472.pdf.

Malone, L., Howland, J., Poirier, M., Langille, B., Gobeil, B., Dunsky, P., & Petraglia, L. (2014). *Energy Efficiency: Engine of Economic Growth in Canada. A Macroeconomic Modeling & Tax Revenue*

Impact Assessment. Retrieved from https://acadiacenter.org/wp-content/uploads/2014/11/ENEAcadiaCenter_EnergyEfficiencyEngineofEconomicGrowthinCanada_EN_FINAL_2014_1114.pdf

Oppenheim, J. (2015). *Energy Efficiency and Economic Development in the North Country, New York.* https://www.stlawu.edu/sites/default/files/resource/Economic%20Impact%20of%20Energy%20Efficiency%20Investment%20in%20the%20NC%202%20083115%20FNL%20clean.pdf.

Roy, J. (2000). *The rebound effect: some empirical evidence from India.* Energy Policy, 28 (6-7). doi.org/10.1016/S0301-4215(00)00027-6.

Ryan, L., & Campbell, N. (2014). *Estimating the macroeconomic benefits of energy efficiency policy and measures.* Berlin: International Energy Policy & Programme Evaluation Conference. https://www.iepec.org/conf-docs/papers/2014/Nina%20Campbell.pdf.

Singh, J. (2019). *Presentation of World Bank Portfolio Review for Energy Efficiency.*

Sorrell, S. (2007). *The Rebound Effect: An Assessment of the Evidence for economy-wide energy savings from Improved energy efficiency.* UK Energy Research Centre. Retrieved from http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/the-rebound effect-report.html.

TERI. (2018). *Energy Efficiency Potential in India.* Retrieved from https://www.energyforum.in/fileadmin/user_upload/india/media_elements/publications/09_Energy_Efficiency_Potential_in_India.pdf

UK Government. (2018). *The Green Book. Central Government Guidance on Appraisal and Evaluation.* HM Treasury, UK Government. www.gov.uk/government/publications.

UK Government. (2019). *Valuation of Energy Use and Greenhouse Gas. Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government.* HM Treasury. UK Government https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794737/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal-2018.pdf.

United Nations Environment Programme. (2017). *Renewable Energy and Energy Efficiency in Developing Countries: Contributions to Reducing Global Emissions.* Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/22149/1_Gigaton_Third%20Report_EN.pdf?sequence=1&isAllowed=y

Ürge-Vorsatz, D., Kelemen, A., Tirado-Herrero, S., Thomas, S., Thema, J., Mzavanadze, N., . . . Chatterjee, S. (2016). *Measuring multiple impacts of low-carbon energy options in a green economy context.* Applied Energy. 179, doi.org/10.1016/j.apenergy.2016.07.027.

van den Bergh, J. (2011). Energy Conservation More Effective with Rebound Policy. *Environmental and Resource Economics, 48 (1). DOI 10.1007/s10640-010-9396-z*, 43–58.

Vivid Economics. (2013). *Energy efficiency and economic growth. Report prepared for The Climate Institute.* Retrieved from https://www.vivideconomics.com/wp-content/uploads/2019/05/1-Vivid_Economics_-_Energy_efficiency_and_economic_growth.pdf

Wei, Y.-M., & Liao, H. (2016). Relationship Between Energy Efficiency and the Economic System_Measuring Energy Efficiency. *Energy Economics: Energy Efficiency in China. https://doi.org/10.1007/978-3-319-44631-8_2*, 53-80.

World Bank. (2016). *Why Energy Efficiency Matters and How to Scale It Up.* Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/23636/Why0energy0eff0d0how0to0scale0it0up.pdf?sequence=5

World Bank. (2017). *Assessing and Measuring the Performance of Energy Efficiency Projects. ESMAP Technical Report 011/17.* Washington D.C.: World Bank Group.

World Bank. (2017). *Does Energy Efficiency Promote Economic Growth? Evidence from a Multi-Country and Multi-Sector Panel Data Set. Policy Research Working Paper; No. 8077.* Retrieved from https://openknowledge.worldbank.org/handle/10986/26949

World Bank. (2017). *Guidance note on shadow price of carbon in economic analysis.* Retrieved from http://pubdocs.worldbank.org/en/911381516303509498/2017-Shadow-Price-of-Carbon-Guidance-Note-FINAL-CLEARED.pdf

World Bank. (2017). *Power Sector Investment Projects: Guidelines for Economic Analysis. Technical Notes.* Washington, DC: World Bank Group.

World Bank. (2017). *Power Sector Investment Projects: Guidelines for Economic Analysis. Update: 20 February 2017.* Washington, DC: World Bank Group.

World Bank. (2018). *Financing Energy Efficiency, Part 1: Revolving Funds.* Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/30388/129733-BRI-PUBLIC-VC-LW88-OKR.pdf?sequence=1&isAllowed=y

World Bank. (2020). *Guidance Note on Measurement and Verification for World Bank Energy Efficiency Projects.*

World Bank. (2020). *Regulatory Indicators for Sustainable Energy - RISE.* Retrieved from https://rise.worldbank.org/

Zhou, M., Liu, Y., Feng, S., Liu, Y., & Lu, Y. (2018). Decomposition of rebound effect: An energy-specific, general equilibrium analysis in the context of China. *Applied Energy Vol 221. https://doi.org/10.1016/j.apenergy.2018.03.074*, 280-298.

Annex A: List of reviewed literature

The various reports reviewed are organized into the following six categories: (a) guidelines for economic analysis of projects; (b) EE and economic development; (c) the multiple benefits of EE; (d) EE in developing countries; (e) the rebound effect; (f) the rebound effect in developing countries; and (g) other.

A. Guidelines for economic analysis of projects

Asian Development Bank. (2017). Guidelines for the economic analysis of projects. Mandaluyong City, Philippines: Asian Development Bank, 2017. http://dx.doi.org/10.22617/TIM178607-2. Available under a CC BY 3.0 IGO license.

Dixon, J. A. (2012). Economic Cost-Benefit-Analysis (CBA) of Project Environmental Impacts and Mitigation Measures: Implementation Guideline. Inter-American Development. p. cm. (IDB Technical Note ; 428). Available at https://publications.iadb.org/publications/english/document/Economic-Cost-Benefit-Analysis-(CBA)-of-Project-Environmental-Impacts-and-Mitigation-Measures-Implementation-Guideline.pdf.

European Commission. (2014). Guide to Cost Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020. Luxembourg: Publications Office of the European Union, 2015. doi:10.2776/97516

European Investment Bank. (2013). The Economic Appraisal of investment Projects at the EIB. Available at https://www.eib.org/en/publications/economic-appraisal-of-investment-projects.

UK Government. (2018). The Green Book. Central Government Guidance on Appraisal and Evaluation. Available at www.gov.uk/government/publications.

UK Government. (2019). Valuation of Energy Use and Greenhouse Gas. Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government. HM Treasury. UK Government https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/794737/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal-2018.pdf.

Li, M., Haeri, H., & Reynolds, A. (2018). The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures. Golden, CO: National Renewable Energy Laboratory. NREL/SR-7A40-70472. http://www.nrel.gov/docs/fy18osti/70472.pdf.

World Bank. (2017). Power Sector Investment Projects: Guidelines for Economic Analysis. Technical Notes. Update: 8 May 2017. Washington, DC: World Bank Group.

World Bank. (2017). Power Sector Investment Projects: Guidelines for Economic Analysis. Update: 20 February 2017. Washington, DC: World Bank Group.

World Bank. (2017). Guidance note on shadow price of carbon in economic analysis. Retrieved from http://pubdocs.worldbank.org/en/911381516303509498/2017-Shadow-Price-of-Carbon-Guidance-Note-FINAL-CLEARED.pdf

World Bank. (2020). Guidance Note on Measurement and Verification for World Bank Energy Efficiency Projects.

B. Energy efficiency and economic development

Ashis, R., & Zhang, F. (2017). Does Energy Efficiency Promote Economic Growth? Evidence from a Multi-Country and Multi-Sector Panel Data Set. Policy Research Working Paper; No. 8077. Washington, Dc: World Bank. https://openknowledge.worldbank.org/handle/10986/26949 License: CC BY 3.0 IGO."

Belzer, D., Bender, S., & Cort, K. (2017). A Comprehensive System of Energy Intensity Indicators for the US: Methods, Data and Key Trends. United States. DOI: 10.2172/1373003.

CADMUS. (2015). Focus on Energy Economic Impact 2011-2014. The Cadmus Group, Inc. Retrieved from https://www.focusonenergy.com/sites/default/files/WI%20FOE%202011%20to%202014%20Econ%20Impact%20Report.pdf.

Department of Renewable Energy, Ministry of Economic Affairs, Royal Government of Bhutan. (2016). Report on Macroeconomic Impacts of Sectoral Energy Efficiency Initiatives in Bhutan. This report is a part of the studies conducted for the formulation of the draft Energy Efficiency and Conservation Policy of the Royal Government of Bhutan. Retrieved from https://www.moea.gov.bt/wp-content/uploads/2018/07/Macro-economic-Impact-of-EEC-Policy-in-Bhutan.pdf.

ECONorthwest. (n.d.). The Economic Impacts and Macroeconomic Benefits of Energy Efficiency Programs in Oregon. Portland, OR: Retrieved from https://neec.net/sites/default/files/news_img/WA-EnergyEfficiency_Report.pdf.

ECONorthwest. (2016). The Economic Impacts and Macroeconomic Benefits of Energy Efficiency Programs in Washington. Executive Summary. Retrieved from https://www.neec.net/sites/default/files/page_attach/washington-energy-efficiency-executive-summary.pdf.

Holmes, I., & Mohany, R. (2012). The Macroeconomic Benefits of Energy Efficiency: The case for public action. London, UK: Third Generation Environmentalism Ltd (E3G). Retrieved from https://www.e3g.org/docs/E3G_The_macroeconomic_case_for_energy_efficiency-Apr_2012.pdf.

Howland, J., Murrow, D., Petraglia, L., & Comings, T. (2009). Energy Efficiency: Engine of Economic Growth. A Macroeconomic Modeling Assessment. Rockport, ME: Environment Northeast, Inc. Retrieved from http://acadiacenter.org/wp-content/uploads/2014/10/ENE_ExecSum_EnergyEfficiencyEngineofEconomicGrowth_FINAL.pdf.

Laitner, J. S., Eldridge, M., & Elliott, R. N. (2007). The Economic Benefits of an Energy Efficiency and Onsite Renewable Energy Strategy to Meet Growing Electricity Needs in Texas. American Council for an Energy-Efficient Economy. ACEEE Report Number E076. Retrieved from https://aceee.org/research-report/e076.

Malone, L., Howland, J., Poirier, M., Langille, B., Gobeil, B., Dunsky, P., et al. (2014). Energy Efficiency: Engine of Economic Growth in Canada. A Macroeconomic Modeling & Tax Revenue Impact Assessment. Environment Northeast, Inc. (now Arcadia Center) Retrieved from https://acadiacenter.org/wp-content/uploads/2014/11/ENEAcadiaCenter_EnergyEfficiencyEngineofEconomicGrowthinCanada_EN_FINAL_2014_1114.pdf.

National Grid Customer Department. (2014). Macroeconomic Impacts of Rhode Island Energy Efficiency Investments. REMI Analysis of National Grid's Energy Efficiency Programs. Retrieved from http://rieermc.ri.gov/wp-content/uploads/2018/03/macroeconomic-impacts-of-rhode-island-energy-efficency-investments.pdf.

Oppenheim, J. (2015). Energy Efficiency and Economic Development in the North Country, New York. Retrieved from https://www.stlawu.edu/sites/default/files/resource/Economic%20Impact%20of%20Energy%20Efficiency%20Investment%20in%20the%20NC%202%20083115%20FNL%20clean.pdf.

Oppenheim, J., & MacGregor, T. (2008). Energy Efficiency Equals Economic Development. The Economics of Public Utility System Benefit Funds. Retrieved from https://www.entergy.com/userfiles/csr/docs/Poverty_book.pdf.

Oppenheim, J., & Macgregor, T. (2002). The Economics of Low-Income Electricity Efficiency Investment in Arkansas. Prepared for the Entergy Corp. Retrieved from http://www.apscservices.info/EEInfo/Econ_of_Low_Inc_Eff.pdf.

Oppenheim, J., & MacGregor, T. (2006). The Economics of Poverty: How Investments to Eliminate Poverty Benefit All Americans. Developed for Entergy. Retrieved from http://democracyandregulation.com/detail.cfm?artid=99&row=1.

Ryan, L., & Campbell, N. (2014). Estimating the macroeconomic benefits of energy efficiency policy and measures. International Energy Policy & Programme Evaluation Conference, Berlin (p. 26). Retrieved from https://www.iepec.org/conf-docs/papers/2014/Nina%20Campbell.pdf.

Sharma, N., Smeets, B., & Tryggestad, C. (2019). The decoupling of GDP and energy growth: A CEO guide. McKinsey & Company. Retrieved from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-decoupling-of-gdp-and-energy-growth-a-ceo-guide.

Vivid Economics. (2013). Energy efficiency and economic growth. Report prepared for The Climate Institute. Retrieved from https://www.vivideconomics.com/wp-content/uploads/2019/05/1-Vivid_Economics_-_Energy_efficiency_and_economic_growth.pdf.

Wei, Y.-M., & Liao, H. (2016). Relationship Between Energy Efficiency and the Economic System_Measuring Energy Efficiency. Energy Economics: Energy Efficiency in China. *Springer International Publishing Switzerland 2016. DOI 10.1007/978-3-319-44631-8_2*.

C. Multiple benefits of energy efficiency

Cagno, E., & Moschetta, D. T. (2018). Only non-energy benefits from the adoption of energy efficiency measures? A novel framework. Journal of Cleaner Production, 1319-1333. doi.org/10.1016/j.jclepro.2018.12.049

Dean, B. (2015). Multiple benefits of energy efficiency in buildings and the urban environment. (Presentation). IEA, Paris. Retrieved from https://unfccc.int/files/bodies/awg/application/pdf/03_iea_brian_dean.pdf.

EPA. (2018). Quantifying multiple-benefits of Energy Efficiency and Renewable Energy. A Guide for State and Local Governments. Retrieved from https://www.epa.gov/statelocalenergy/quantifying-multiple-benefits-energy-efficiency-and-renewable-energy-guide-state.

European Commission. (2016). The Macroeconomic and Other Benefits of Energy Efficiency. Final report. European Commission, Directorate-General for Energy, Contract no. ENER/C3/2013-484/03/FV2015-523 under the Multiple Framework Service Contract ENER/C3/2013-484. https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf

Fawcett, T., & Killip, G. (2019). Re-thinking energy efficiency in European policy: Practitioners' use of 'multiple benefits' arguments. Journal of Cleaner Production, 210, 1171-1179 doi.org/10.1016/j.jclepro.2018.11.026

IEA. (2014). Capturing the Multiple Benefits of Energy Efficiency. IEA, Paris. Available at https://webstore.iea.org/capturing-the-multiple-benefits-of-energy-efficiency.

Kerr, N., Gouldson, A., & Barrett, J. (2017). The rationale for energy efficiency policy: Assessing the recognition of the multiple benefits of energy efficiency retrofit policy. Energy Policy, 712-221. doi.org/10.1016/j.enpol.2017.03.053

Malone, E. (2014). Driving Efficiency with Non-Energy Benefits. ACEEE National Symposium on Market Transformation. Retrieved from https://www.synapse-energy.com/sites/default/files/SynapsePresentation.2014-04.0.Driving-Efficiency.S0093.pdf.

NEEP. (2017). Non-Energy Impacts Approaches and Values: An Examination of the Northeast, Mid-Atlantic, and Beyond. Retrieved from https://neep.org/sites/default/files/resources/NEI%20Final%20Report%20for%20NH%206.2.17.pdf.

Nehler, T. (2018). A Systematic Literature Review of Methods for Improved Utilisation of the Non-Energy Benefits of Industrial Energy Efficiency. Division of Energy Systems, Linköping University. Retrieved from http://www.diva-portal.org/smash/get/diva2:1283639/FULLTEXT01.pdf.

Nehler, T. (2018). Linking energy efficiency measures in industrial compressed air systems with non-energy benefits – A review. Renewable and Sustainable Energy Reviews, 89, 72-87. doi.org/10.1016/j.rser.2018.02.018

Nehler, T., & Rasmussen, J. (2016). How do firms consider non-energy benefits? Empirical findings on energy-efficiency investments in Swedish industry. Journal of Cleaner Production, 113, 472-482. doi.org/10.1016/j.jclepro.2015.11.070

Oppenheim, J., & MacGregor, T. (2014). Accounting for Health Benefits. International Energy Policy and Programmes Evaluation Conference, Berlin Retrieved from http://www.democracyandregulation.com/attachments/146/Accounting_for_Health_Benefits..pdf.

Puig, D., & Farrell, T. (2015). The multiple benefits of measures to improve energy efficiency. Copenhagen, Denmark: UNEP DTU Partnership. Available at https://storage.googleapis.com/sead-siteassets/Multiple-benefits-of-measures-to-improve-EE.pdf.

Rosenow, J., & Bayer, E. (2017). Costs and benefits of Energy Efficiency Obligations: A review of European programmes. Energy Policy, 107, 53-62. doi.org/10.1016/j.enpol.2017.04.014

Russell, C., Baatz, B., Cluett, R., & Amann, J. (2015). Recognizing the Value of Energy Efficiency's Multiple Benefits. Research Report IE1502. American Council for an Energy-Efficient Economy. https://aceee.org/research-report/ie1502.

Ryan, L., & Campbell, N. (2012). Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements. OECD/IEA, 2012. doi.org/10.1787/20792581

Schweitzer, M., & Tonn, B. (2003). Non-energy benefits of the US Weatherization Assistance Program: a summary of their scope and magnitude. Applied Energy, 76, 321–335. doi.org/10.1016/S0306-2619(03)00003-5

Sing, J. (2016). Why Energy Efficiency Matters and How to Scale It Up. Live Wire;2016/53. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/23636 License: CC BY 3.0 IGO.

Skumatz, L. A. (2015). Efficiency Programs' Non-Energy Benefits: How States Are Finally Making Progress in Reducing Bias in Cost-Effectiveness Tests. The Electricity Journal, 28, 96-109. doi.org/10.1016/j.tej.2015.09.008

Thema, J., Thomas, S., Teubler, J., Chatterjee, S., Bouzarovski, S., Mzavanadze, N., et al. (2017). More than energy savings: quantifying the multiple impacts of energy efficiency in Europe. ECEEE 2017 Summer Study – Consumption, Efficiency & Limits. https://epub.wupperinst.org/frontdoor/deliver/index/docId/6709/file/6709_Thema.pdf.

United Nations Economic Commission for Europe. (2011). Increasing Energy Efficiency to Secure Energy Supplies in the CIS region. United Nations Economic Commission for Europe. http://www.unece.org/fileadmin/DAM/energy/se/pdfs/eneff/publ/Incr_EE_SecureEnergySupplies_Report_e.pdf.

World Bank. (2017). Assessing and Measuring the Performance of Energy Efficiency Projects. ESMAP Technical Report 011/17. Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/531691498680679016/Assessing-and-measuring-the-performance-of-energy-efficiency-projects.

Ürge-Vorsatz, D., Kelemen, A., Tirado-Herrero, S., Thomas, S., Thema, J., Mzavanadze, N., et al. (2016). Measuring multiple impacts of low-carbon energy options in a green economy context. Applied Energy. 179, 1409-1426. doi.org/10.1016/j.apenergy.2016.07.027

D. Energy efficiency in developing countries

Barnes, D. F., & Samad, H. (2018). Measuring the Benefits of Energy Access. A Handbook for Development Practitioners. Inter-American Development Bank. p. cm. — (IDB Monograph; 653). http://dx.doi.org/10.18235/0001459.

Cantore, N. (2011). Energy efficiency in developing countries for the manufacturing sector. Working Paper 15/2011. United Nations Industrial Development Organization.

Cantore, N., & Calì, M. V. (2016). Does energy efficiency improve technological change and economic growth in developing countries?. Energy Policy, 92, 279-285. doi.org/10.1016/j.enpol.2016.01.040

Farrell, D., & Remes, J. (2009). Promoting energy efficiency in the developing world. McKinsey & Company. Retrieved from https://www.mckinsey.com/business-functions/sustainability/our-insights/promoting-energy-efficiency-in-the-developing-world.

Farrell, D., Remes, J., & Charles, D. (2008). Fueling sustainable development: The energy productivity solution. McKinsey & Company 2008. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Fueling%20sustainable%20development/MGI_Fueling_sustainable_energy_productivity_solution_perspective.ashx.

Fowlie, M., & Phadke, A. (2016). Energy Efficiency in the Developing World. EEG State-of-Knowledge Paper Series, Oxford Policy Management, Center for Effective Global Action, Energy Institute @ Haas. https://www.gov.uk/dfid-research-outputs/energy-efficiency-in-the-developing-world. 28p.

Roland-Holst, Kahrl, F., & Triolo, R. (2005). Economic Benefits of Energy Efficiency in Developing Countries. Department of Agricultural and Resource Economics, UC Berkeley. Retrieved from https://www.ocf.berkeley.edu/~tbrooks/portfolio-item/wb-ee/.

The Energy and Resources Institute (TERI). (2018). Energy Efficiency Potential in India. Commissioned on behalf of Bureau of Energy Efficiency Ministry of Power, Govt. of India, and Indo-German Energy Forum Support Office c/o Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Available at https://www.energyforum.in/fileadmin/user_upload/india/media_elements/publications/09_Energy_Efficiency_Potential_in_India.pdf.

United Nations Environment Programme. (2017). Renewable Energy and Energy Efficiency in Developing Countries: Contributions to Reducing Global Emissions. United Nations Environment Programme, 2017. Job. No: DTI/2132/PA. https://wedocs.unep.org/bitstream/handle/20.500.11822/22149/1_Gigaton_Third%20Report_EN.pdf?sequence=1&isAllowed=y.

E. Rebound effect

Athavale, S., & Knaus, K. (2017). Energy Efficiency Policies and the Rebound Effect. Review of International Instruments and Recommendations for Austria. Österreichische Energieagentur – Austrian Energy Agency. Retrieved from https://en.energyagency.at/fileadmin/dam/pdf/projekte/klimapolitik/CATCH_Review_Paper_final.pdf.

Barker, T., & Foxon, T. (2008). The Macroeconomic Rebound Effect and the UK Economy. Research Report. UK Energy Research Centre. REF UKERC/WP/ESM/2008/001. Retrieved from https://ukerc.rl.ac.uk/UCAT/PUBLICATIONS/The_Macroeconomic_Rebound_Effect_and_the_UK_Economy.pdf.

Borenstein, S. (2013). A microeconomic framework for evaluating energy efficiency rebound and some implications. Severin Borenstein. NBER Working Paper No. 19044. Retrieved from https://www.nber.org/papers/w19044.

Farese, P., Gelman, R., & Hendron, R. (2012). A Tool to Prioritize Energy Efficiency Investments. Technical Report. NREL/TP-6A20-54799. National Renewable Energy Laboratory (NREL). Retrieved from https://www.nrel.gov/docs/fy12osti/54799.pdf.

Figus, G., Turner, K., McGregor, P., & Katris, A. (2017). Making the case for supporting broad energy efficiency programmes: Impacts on household incomes and other economic benefits. Energy Policy, 111, 157-165. doi.org/10.1016/j.enpol.2017.09.028

Gillingham, K., Rapson, D., & Wagner, G. (2015). The Rebound Effect and Energy Efficiency Policy. Review of Environmental Economics and Policy, 10 (1), 68–88. doi.org/10.1093/reep/rev017

Greening, L. A., Greene, D. L., & Difiglio, C. (2000). Energy efficiency and consumption- the rebound effect - a survey. Energy Policy, 28, 389-401. doi.org/10.1016/S0301-4215(00)00021-5

Jin, T., & Kim, J. (2019). A new approach for assessing the macroeconomic growth energy rebound effect. Applied Energy, 239, 192-200. doi.org/10.1016/j.apenergy.2019.01.220

Koesler, S., Swales, K., & Turner, K. (2016). International spillover and rebound effects from increased energy efficiency in Germany. Energy Economics, 54, 444–452. doi.org/10.1016/j.eneco.2015.12.011

Ryan, L., & Campbell, N. (2014). Estimating the macroeconomic benefits of energy efficiency policy and measures. International Energy Policy & Programme Evaluation Conference, Berlin. https://www.iepec.org/conf-docs/papers/2014/Nina%20Campbell.pdf.

Ryan, L., Turner, K., Figus, G., Campbell, N., Lecca, P., McGregor, P., et al. (2016). Can we retain the economy wide benefits of energy efficiency while reducing the energy rebound? Department of Economics, University of Strathclyde. Available at https://strathprints.strath.ac.uk/56448/.

Sorrell, S. (2009). Jevons Paradox revisited. The evidence for backfire from improved energy efficiency. Energy Policy, 37 (4), 1456–1469. doi.org/10.1016/j.enpol.2008.12.003

Sorrell, S., Gatersleben, B., & Druckman, A. (2018). Energy sufficiency and rebound effect. Concept paper. eceee and the authors 2018. Retrieved from https://www.energysufficiency.org/libraryresources/library/items/energy-sufficiency-and-rebound effects-concept-paper/.

Steve, S. (2007). The Rebound Effect: An Assessment of the Evidence for economy-wide energy savings from Improved energy efficiency. UK Energy Research Centre. Retrieved from http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/the-rebound effect-report.html.

Turner, K. (2012). Rebound effects from increased energy efficiency: a time to pause and reflect. Stirling Economics Discussion Paper 2012-15. Division of Economics, Stirling Management School, Cottrell Building, University of Stirling. Available at http://www.management.stir.ac.uk/research/economics/working-papers

Turner, K., & Katris, A. (2017). A 'Carbon Saving Multiplier' as an alternative to rebound in considering reduced energy supply chain requirements from energy efficiency? Energy Policy, 103, 249-257. doi.org/10.1016/j.enpol.2016.12.057

Van den Bergh, J. C. (2011). Energy Conservation More Effective with Rebound Policy. Environmental and Resource Economics, 48 (1), 43–58. DOI 10.1007/s10640-010-9396-z

Vivanco, D. F., Kemp, R., & van der Voet, E. (2016). How to deal with the rebound effect? A policy-oriented approach. Energy Policy, 114–125. doi.org/10.1016/j.enpol.2016.03.054

Zhou, M., Liu, Y., Feng, S., Liu, Y., & Lu, Y. (2018). Decomposition of rebound effect: An energy-specific, general equilibrium analysis in the context of China. Applied Energy, 280–298. doi.org/10.1016/j.apenergy.2018.03.074

F. Rebound effect in developing countries

Davis, L. W., Martinez, S., & Taboada, B. (2018). How Effective is Energy efficient Housing Evidence? From a Field Experiment in Mexico. Inter-American Development Bank. IDB Working Paper Series; 843. Retrieved from https://www.nber.org/papers/w24581.

Davis, S. (2010). Measuring the rebound effect of EE initiatives for the future. A South African case study. Project Number: EU0607-122. Energy Research Centre, University of Cape Town. Retrieved from http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2010/10-Davis_Rebound_effect.pdf.

Davis, S. (2011). Measuring the rebound effect of energy efficiency initiatives for the future A South African case study. Addendum to final report: Water heating in middle to high income households. Energy Research Centre, University of Cape Town. Retrieved from https://www.africaportal.org/publications/measuring-the-rebound effect-of-energy-efficiency-initiatives-for-the-future-a-south-african-case-study/.

de la Rue du Can, S. M., & Leventis, G. (2015). Rebound Effects in the Context of Developing Country Efficiency Programs. Final Report. Super-Efficient Equipment and Appliance Deployment Initiative (SEAD). Retrieved from https://storage.googleapis.com/sead-siteassets/Rebound effects-and-Developing-Countries_DRAFT-FINAL.pdf.

Economic Consulting Associates. (2014). The Rebound Effect for Developing Countries. Phase 1 Final Report, Evidence on Demand with the assistance of the UK Department for International Development (DFID). Evidence on Demand. DOI: http://dx.doi.org/10.12774/eod_cr.march2014.eca.

Roy, J. (2000). The rebound effect: some empirical evidence from India. Energy Policy, 28 (6-7), 433-438.doi.org/10.1016/S0301-4215(00)00027-6

G. Other

Dienst, C., Ortiz, W., Pfaff, J., & Seifried, D. (2013). Energy efficient lighting for sustainable development. Wuppertal Institute for Climate, Environment and Energy. Retrieved at https://seors.unfccc.int/applications/seors/attachments/get_attachment?code=NG125PFE4WHMWSYAK8TCAKIHMWX0F4QD.

European Commission. (2013). Green Paper. A 2030 framework for climate and energy policies. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0169

IEA. (2019). *World Energy Outlook.* IEA.

Inter-American Development Bank. (2017). Energy Efficiency in Public Lighting. Inter-American Development Bank. Technical Note (commissioned by the Inter-American Development Bank (IDB) to Econoler).

Johnson, A., Phadke, A., & de la Rue du Can, S. (2014). Development of energy savings potential for street lighting in India. Ernest Orlando Lawrence, Berkeley National Laboratory. Retrieved from https://ies.lbl.gov/sites/all/files/lbnl6576e.pdf.

Sarkar, A., Singh, S. K., Jain, N., & Dwidedi, V. (2015). India - Energy-efficient street lighting: implementation and financing solutions (English). Washington, D.C.: World Bank Group. Available at http://documents.worldbank.org/curated/en/444081468282557427/India-Energy-efficient-street-lighting-implementation-and-financing-solutions.

Shahzad, K., Cucek, L., Sagir, M., Ali, N., Rashid, M. I., Nazir, R., et al. (2018). An ecological feasibility study for developing sustainable street lighting system. Journal of Cleaner Production, 175, 683-695. doi.org/10.1016/j.jclepro.2017.12.057

Shehadeh, N. H. (2015). Sustainable Streetlighting. A guide to efficient public streetlighting for Lebanon. UNDP-CEDRO Publication. Retrieved from http://www.cedro-undp.org/content/uploads/Publication/151201033346832~StreetLightingReport-FinalPages.pdf.

World Bank. (2018). Financing Energy Efficiency, Part 1: Revolving Funds. Retrieved from https://openknowledge.worldbank.org/bitstream/handle/10986/30388/129733-BRI-PUBLIC-VC-LW88-OKR.pdf?sequence=1&isAllowed=y

World Bank. (2020). Regulatory Indicators for Sustainable Energy - RISE. Retrieved from https://rise.worldbank.org/