Productivity impact from multiple impact perspective

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Abstract

Full economic assessment taking all the costs and benefits is required to enable the potential of any energy policy. However, today these assessments often exclude important factors such as co-benefits/multiple impacts of any energy policy. The inclusion of additional impact into decision-making analysis may influence any policy maker to design a policy portfolio. Most of the time, multiple impacts of energy efficiency policy are not incorporated into ex-ante policy analysis due to the absence of mature methodologies.

The purpose of this paper is to provide a comprehensive methodological framework which addresses the key challenges to incorporate multiple impacts especially productivity impact into a decision-making framework.

This study first talks about the importance of incorporating multiple impacts of energy efficiency measures into decision-making framework by taking productivity impact as an example and then it identifies the key methodological gap of multiple impacts especially productivity impact accounting. Lastly, it proposes a framework to quantify and monetize productivity impact in a systematic manner.

This paper contributes to the methodological toolbox by proposing the solutions to the key methodological challenges of aggregation of multiple impacts by taking productivity impact as an example. This study proposes a systematic and analytical framework which addresses key challenges such as double counting, additionality, baseline, context dependency and distributional effect to evaluate productivity impact.

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Introduction

Energy production and use emit two-thirds of the world's greenhouse-gas (GHG) emissions (IEA 2015). Energy-related carbon dioxide (CO_2) consumption increases along with global population (GEA 2012) (IPCC 2014), (IEA 2015). In the flip side, energy is one of the most important factors of human well-being. However, despite its importance, more and more energy extraction is exposing human-being to some key global challenges of the 21st century such as climate change, economic and social development, human well-being, sustainable development, and global security (GEA 2012) (IPCC 2014). In order to minimise these risks, energy efficiency can be a good option for short to mid time period (IPCC 2007) (IPCC 2014). In addition, energy efficiency policies not only reduce carbon dioxide (CO_2) emissions but recent studies such as (GEA 2012), (Ryan and Campbell 2012), (IPCC 2014), (Ürge-Vorsatz, Herrero, et al. 2014) (IEA 2015), have shown that energy efficiency policies can yield a wider set of additional benefits for the economy and society such as job creation, GDP growth, enhanced productivity, increase of energy security, positive impacts on health, as well as improvement of ecosystems. Some studies (see (Worrell, et al. 2003), (Ürge-Vorsatz, Novikova and Sharmina 2009) (Ryan and Campbell 2012)) even suggest that these non-climate benefits may have a higher value than the direct energy saving benefit. Thus, to develop more cost-effective sustainable energy policies keeping long-term economic goals in mind, multiple non-climatic benefits have to be accounted more comprehensively in the future policy assessment (Ürge-Vorsatz, Herrero, et al. 2014).

The improvement of energy efficiency in Europe aims at radically reducing overall energy consumption which results in less natural resource extraction. The European Commission aims to reduce greenhouse gas emission by 40 % in 2030 (compared to 1990) by increasing 25 % energy saving and shifting to renewable energy sources by 27 % (European commission 2014). Traditionally, energy savings and avoided cost due to energy saving used to be the key drivers of any energy efficiency policy ignoring the additional benefits. However, after quantification of these additional impacts, multiple impacts can also be considered as a driver of implementing energy efficiency policy.

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Limited use of multiple impacts in the assessment of sustainable energy policies

Non-energy or non-climate benefits such as in productivity, employment, GDP, energy security etc. are not always included during the assessment of a sustainable energy policy. As a result of which, cost-effective energy efficiency policy tend to be underestimated (Sauter and Volkery 2013). It is difficult to understand the net effect of an energy efficiency policy because these non-energy and non-climate impacts are often not quantified. Many of these benefits are non-marketable, indirect and which makes quantification process more difficult. However, this lack of methodology to quantify these additional impacts does not make them any less significant but the failure to accurately estimate the impacts, especially the benefits, result in less investment in energy efficiency. As per IEA 2012 report "these foregone benefits represent the opportunity cost of failing to adequately evaluate and prioritize energy efficiency investments and this opportunity cost may be very large, and in particular in a context of increasing global demand, stress on resources, and climate concerns, they may represent a cost that we cannot afford to bear" (Ryan and Campbell 2012).

Several terms (such as non-energy, non-climate, ancillary benefit, co-benefit and co-impact) are used to address additional impacts of energy efficiency. However, in this study to capture additional effects of energy efficiency, we will use the term multiple impacts. Here the term impact is used concisely instead of benefit because sometimes, additional impacts from energy efficiency measure may not be positive. For example, people may lose their jobs in the energy supplying sector due to increasing demand for energy efficiency.

Productivity is one of the key multiple impacts from energy efficiency measures but so far productivity is not clearly defined as a multiple impacts in energy circle. There are few studies (such (Fisk and Rosenfeld 1997), (W. J. Fisk 2000), (W. J. Fisk 2002), (Worrell, Laitner, et al. 2003), (Chapman, et al. 2009) etc.) which measure productivity for specific sector and they have measured only a few handful of aspects such as absence from work or health expenditure etc. Thus, quantitative value of productivity impact is scattered and mostly have important gaps in the context of geographical or technical coverage. These gaps and disperse findings are making productivity impact difficult to accurately evaluate and thus to incorporate in the policy evaluation (Ürge-Vorsatz, Kelemen, et al. 2015). Therefore, in order to estimate the value of productivity impact, there is a need of systematic quantitative framework.

Goal and structure of the paper

The goal of this paper is to contribute to the development of a "methodological toolbox" for evaluating multiple impacts especially productivity impact in a methodologically and theoretically consistent manner. Furthermore, this paper addresses to the key challenges faced during comprehensive accounting of multiple impacts and also proposes solutions to evaluate the impacts and integrate them into decision-making analysis (such as cost-benefit analysis).

This paper discusses the importance of multiple impacts from energy efficiency by using productivity impact as an example. By discussing the methodology of productivity impact (of improved energy efficiency measures in building sector), the paper also addresses the key challenges such as double counting, additionality, context dependency, perspective, scale and distributional effect, of evaluating multiple impacts.

The importance of productivity impact from a multiple impact perspective:

Productivity impact is one of the crucial multiple impacts from enhanced energy efficiency. In fact, many studies (see (Porter and Van der Linde 1995), (Boyd and Joseph X. 2000)) argue that productivity impact equal or greater than energy savings. Broadly productivity can be defined as relation between volume of input and output. However, the definition of productivity can be varied as per the perspectives (such as measurement, labour relations, training and development, management, budget, and finance) and sectors (such as building, industry, transport etc.) (Quinn 1978). Thus, it is crucial to define productivity before measuring it.

Productivity is one of the most important indicators of economic growth and development but despite its importance, many studies have argued that "productivity has been relegated to the second rank and it is ignored" (Singh, Motwani and Kumar 2000). However, with increasing global economic competence, it will be difficult to ignore productivity in the long-run. Thus, to regain the importance of productivity and also to estimate the potential of productivity impact from energy efficiency measure, quantification of productivity is mandatory.

There are few studies which tried to estimate the productivity of energy efficiency for a specific sector in order to establish the importance of productivity impact. Fisk's study shows that "the estimated potential annual savings and productivity gains are \$6 to \$14 billion from reduced respiratory disease, \$1 to \$4 billion from reduced allergies and asthma, \$10 to \$30 billion from reduced sick building syndrome symptoms, and \$20 to \$160 billion from direct improvements in worker performance that are unrelated to health." (W. J. Fisk 2000). On the other hand, Wornell et al show that without including productivity benefits, the potential for energy savings drops to half from 3.8 GJ/t of steel to 1.9 GJ. These single case studies on productivity show its importance as multiple impacts.

Definition of productivity

There are many measures of productivity such as multi-factor productivity, capital productivity, and labour productivity. Among these measures of productivity, labour productivity is a well-established indicator for several economic aspects such as economic growth, competitiveness, and living standards in an economy (OECD 2008). Labour productivity can be measured as the ratio between outputs produced within an economy in a year and total numbers of hours worked by the employees (OECD 2008). In this study, labour productivity is defined by defining different aspects of labour input efficiency. There are three key aspects of labour productivity identified in this study such as active days loss, workforce performance and earning ability which are building sector-specific productivity impact. However, as mentioned above the definition of productivity varies as per the perspectives and sectors and thus, it is crucial to define productivity before proceeding to measure. Most of the studies related to building energy efficiency measures define productivity by saving absenteeism days (being absent from work due to illness), health care cost and overall work performance (W. J. Fisk 2000), (W. J. Fisk 2002) (Mudarri and Fisk 2007), (Singh, et al. 2010), (Kadir, et al. 2015).

This study defines productivity by defining the different aspect of labour productivity related to building-related energy efficiency measures.

Active days loss: Active days stand for active work days. Therefore, active day's loss represents work days lost. Active days loss is a linear combination of absenteeism (absent from work due to illness) and presenteeism (Caverley, Cunningham and MacGregor 2007) where presenteeism can be referred as working with illness or working despite being ill (Mattke, et al. 2007). For example, a person might work slowly than usual with respiratory diseases or make mistakes in work during his illness. Here, presenteeism refers to productivity loss resulting from health problems such as asthma, cardiovascular diseases, and mental well-being. These diseases affect both quantity and quality of work (Paul 2004).

Active days can be wasted due to poor building conditions. Many studies (W. J. Fisk 2000), (W. J. Fisk 2002) (Mudarri and Fisk 2007) (Kadir, et al. 2015) shows how exposure to indoor air pollutants can cause several diseases such as asthma, cold, flu, allergy and even cardiovascular and cancer disease. These diseases are mainly caused due to inadequate air exchange rate and lack of filtration in buildings (Hänninen and Asikainen 2013). Through ventilation and filtration, one can control the quality of indoor air which includes humidity, structural moisture and mould growth (Hänninen and Asikainen 2013). Thus, installing improved Heating, ventilation and air conditioning (HVAC) system with proper filtration can improve productivity by saving active work days.

Workforce Performance: Workforce performance can be defined as overall performance of a workforce (workforce defines as an accumulation of all the employees at the workplace). Workforce performance basically measures the quantity of labour input per hour due to energy efficiency. Several case studies (such as (see (Seppänen, W., and Mendell. 1999), (Wargocki, et al. 2000), (Singh 2005)) show how indoor air quality and thermal comfort can affect a person's productivity which benefits the employer as well. Furthermore, a person's productivity can improve while working in a deep retrofitted building or passive building by avoiding mental stress or by improving mental well-being (Singh 2005). Thus, workforce productivity can be measured by measuring labour input per hour per person. Workforce productivity will be crucial for the tertiary building sector.

Earning ability: Earning ability here refer to as future earning ability loss of a child and parent's present earning opportunity loss. This part of productivity mainly concerns with two aspects 1) future impact on earning ability due to loss of school days 2) Parents absenteeism due to take care of his sick child. If a child misses his school days due to asthma and other sick building related symptoms then it would impact on the earning ability of the parents since they have to take care of the child being absent from his work and also the future earning ability of the child. In fact, excessive absent from school may disrupt a child's learning process and could be one of the causes for dropping out from school. It is seen that children who have asthma, are more absent from school compared to their healthy (with no asthma) classmates without asthma (Moonie, et al. 2006).

The role of ventilation and filtration on productivity-importance of energy efficiency measure in buildings:

Most of the studies mainly focus on the thermal comfort level to show the quality of indoor air. Though studies have shown that thermal comfort improves the performance of an individual but it has little to do to eradicate diseases related to indoor air quality (Wargocki, Sundell, et al. 2002) (Asikainen, et al. 2016). Air pollutant concentration can be reduced by installing a proper HVAC system with filtration in buildings (Asikainen, et al. 2016). Because ventilation stimulates the indoor air exchange rate (polluted) with outdoor air (presumably fresh and clean air, but contains some outdoor pollutants) which provide a healthy indoor environment (Wargocki, Sundell, et al. 2002). Furthermore, HVAC system removes moisture and dilute indoor pollutant exposure which ultimately improves human health (Wargocki, Sundell, et al. 2002).

In this study, ventilation rate refers to the rate of ventilation i.e. amount of airflow from outdoor to indoor. Several studies argue on the appropriate amount of ventilation rate "but the common conclusion was increasing the ventilation rate from 10 l/s per person up to 20 l/s per person may further reduce sick building symptoms" (Wargocki, Sundell, et al. 2002). In the commercial buildings, higher ventilation rate up to about 25 l/s per person is associated with reduced prevalence of indoor air quality related diseases (Asikainen, et al. 2016). Any rate below 10 l/s per person ventilation rate, would lead to high indoor humidity and moisture on building structure (see (Wargocki, Sundell, et al. 2002) (Fernandes, et al. 2009)) and high indoor humidity and moisture results in high dust mites presence and higher microbial growth which could be a source of building related disease (Fisk and Rosenfeld 1997) (Jones 1999) (Fernandes, et al. 2009).

Ventilation process involves airflow between the rooms by either natural forces such as thermal buoyancy and the wind or by mechanical processes such as air-conditioning. This air circulation inside the building not only reduces moisture but it also improves thermal comfort level which ultimately impact on work performance (Wargocki, Sundell, et al. 2002) (Li 2007).

HVAC system plays a dual role by removing indoor air pollutant concentration and on the other hand by stopping infiltration of outdoor pollutants such as particulate matter, particulates of biological origin (microorganisms, pollen, etc.), NO_x, Ozone (O_3). However, if HVAC system is not properly maintained then it can be a source of pollutants such as volatile organic compound itself (Wargocki, Sundell, et al. 2002). Thus, it is crucial to maintain HVAC system i.e. to clean the component and surface of HVAC system, change the cooler coil, humidifier etc. (Fernandes, et al. 2009).

Methods

This paper uses an inductive approach i.e. it starts with observation and based on these pre-researched observations, this paper proposes a methodological framework to quantify productivity impact (Thomas 2006) Ideally, a decision on energy-related investment or policy, should be taken based on potential full cost and benefits associated with the policy or investment but, this practically never takes place due to the absence of mature methodology (Ürge-Vorsatz, Herrero , et al. 2014) and also some of the multiple impacts overlap with each other which may cause double counting error. Therefore, this paper systematically accounts for all the challenges of quantifying productivity impact and proposes a solution to these challenges.

This paper's methodological framework is based on the concept of impact pathways. Impact pathway approach follows a bottom-up approach which starts from implementing energy efficiency measure and ends at the welfare end-point. The concept of impact pathway map was first initiated in ExternE project (ExternE 1995). Here, end-point can be defined as the last impact which is not transferring to another impact and also it is a policy maker's target. In this study, productivity is the potential endpoint due to its significance in the present decade.

Impact pathway

Impact pathway map is basically a causality map which starts from implementing building-related energy efficiency measures related to building sector such as improvements of building envelopes in building sector (both residential and commercial), improvements of Heating, ventilating, and air-Conditioning (HVAC) in building sector and improvements of lighting systems in building sector. These energy efficiency measures are the most common and most effective available measures for building sector and in this study, these energy efficiency measures are taken as an example to demonstrate impact pathway methodology. The aim of this impact map is to accurately identify and characterise how productivity impact unfolds and which factors enable or hamper its occurrence. This complex mapping approach of impact map enables productivity impact as multiple impacts in a more consistent way. Furthermore, pathway map minimises the chance of making double counting error of a single impact by clearly identifying the cause and effect chain.

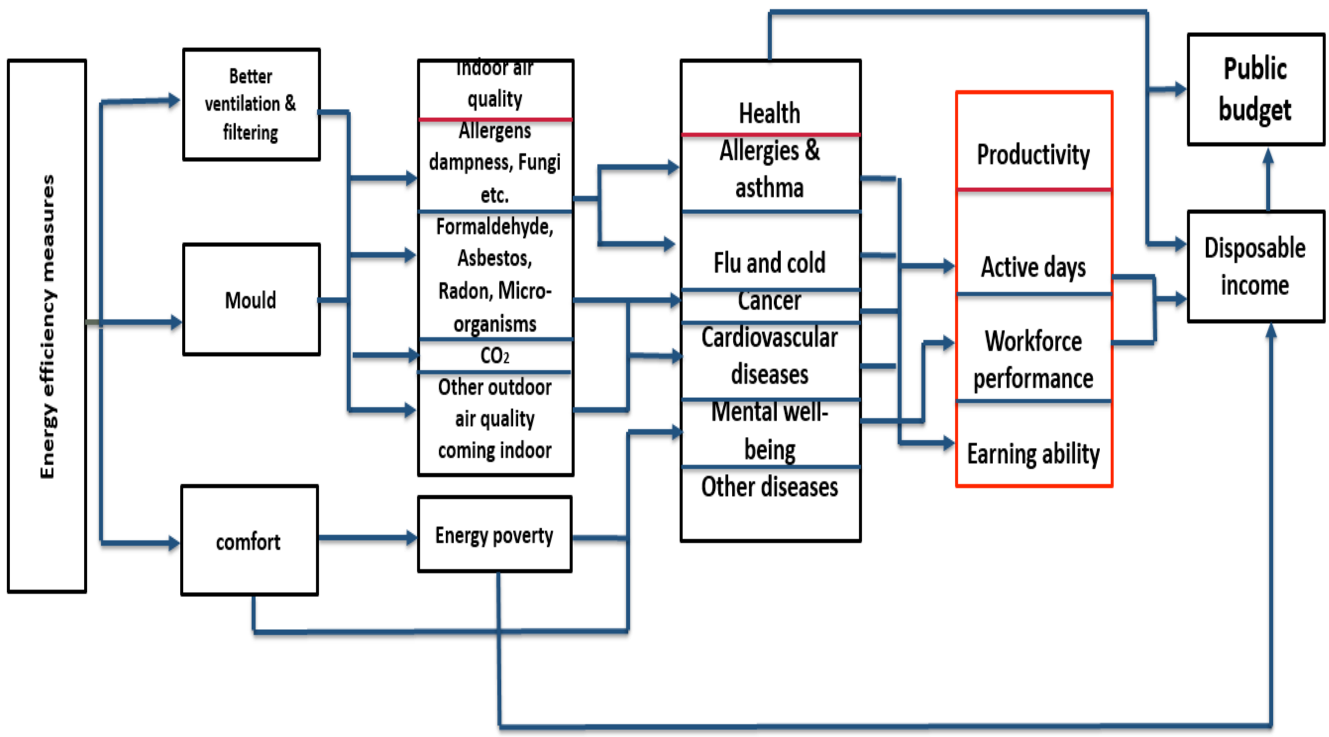

Figure 1. Illustration of the impact pathway map approach by taking productivity impact in building sector as an example. Source: Own elaboration.

Figure 1 shows the pathways leading towards productivity, starting from implementing building-related energy efficiency measures. This impact map enables the conceptual framework for mapping different impacts and impact end points.

Analysis of impact map 1: Figure 1 enables the relevant impacts and its pathways which are ultimately leading towards productivity. This identification of impacts reduces the risk of double counting. As it is discussed above, impact map shows the causal chain. In figure 1, after implementing the building-related energy efficiency measures, the first-degree effects are better ventilation and filtration, mould reduction and improvement in comfort level. These three initial effects lead to further impacts on air quality (by reducing indoor air pollutant exposure), energy poverty, and health. Health has the biggest impact on productivity. Both chronic and acute diseases such as asthma, allergy, cardiovascular, cancer etc. are caused by indoor and outdoor pollutant exposure. Each arrow shows a distinct effect and hence a distinct calculation is needed in order to quantify and monetised the impact. For instance, the arrow between mental well-being to productivity refers to the fact that improvement in mental well-being can result in performance enhancement. In order to capture this improvement in performance, labour input per hour can be measured before and after implementing energy efficiency measures.

Challenges to the methodology

1. **Additionality and baseline:** The size of impact would depend on factors such as additionality and baseline. The most popular definition of baseline is; the energy use or emissions that would occur without policy intervention (COAG 2012). However, sometimes the definition of what can be regarded as the baseline is not always clear. Furthermore, a baseline can be two types i.e. static or dynamic baseline and the degree to which a baseline is static or dynamic will have important implications in terms of which impacts can be considered additional. A fully dynamic baseline reflects all the changes in context-relevant factors which are expected to take place in future. On the flip side, the static baseline assumes some factors to be fixed over time. The degree to which a baseline is static or dynamic would have implications in terms of which impacts can be considered additional in order to avoid over-estimation. It is important to establish what portion of the impact which is being assessed is additional compared with the baseline. It needs to be noted that the size of impact depends strongly on baseline and additionality and from a policy maker's perspective, it is crucial to only take the additional impacts into account to avoid overestimation of the policy (Davis, Krupnick and G 2000). With appropriate baseline selection, additionality remains an issue in order to avoid overestimation. For instance, there could be few sick days which are not cured due to the installation of energy efficiency measure e.g. if a person workout daily then chances of having cardiovascular diseases would be lower. Here, energy efficiency measures have nothing to do with gaining active days. Therefore, we need to consider only those sick days which are affected due to poor indoor air quality and then when it get cured after installing energy efficiency measures, it will be an additional productivity impact which can be considered into the assessment.
2. **Double counting:** To tackle double counting, impact pathway methodology is proposed in this paper. As it is discussed throughout the paper that multiple impacts are not distinct and independent in nature but they exist in a web of causality, reinforcements and they may also overlap (Urge-Vorsatz and Chatterjee 2016). Thus, a careful assessment is required to evaluate impacts.
3. **Perspective**: While doing a cost-benefit analysis, a 'standing' is very important. The impact value may differ depending on the perspective. In this study, productivity impacts should be measured from three perspectives i.e. society, individual and investor.
4. **Context dependency:** Context dependency needs to be accounted during the time of integration. By context, we refer to few variables which provide the background for a particular policy (Urge-Vorsatz et al 2016). For instance, future earning ability of children also depends on parent's education level. For example, if a parent can teach his child then the missed school days would not have much impact on child's future earning ability.
5. **Distributional impact:** Cost-benefit analysis does not consider the difference between marginal utility of incomes across different income groups which are not practical. Lower income group would benefit more by enhancing working hours and in addition, social welfare gain would be much higher. For example, in Hungary, social welfare gain related to productivity accounts for 16–19 percent of net social benefits (Tirado-Herrero, Ürge-Vorsatz and Petrichenko 2013).
6. **Rebound effect:** Rebound effect basically talks about the phenomena that expected energy saving is not taking place due to increase in energy consumption due to economic feedback (Maxwell and McAndrew 2011) (D. Ürge-Vorsatz, et al. 2016). However, the rebound effect is not always can be seen from a negative perspective. For example, higher energy consumption after energy efficiency measure implementation can also be seen as higher energy consumption in an affordable price and higher comfort which has a positive influence on workforce performance (Wargocki, et al. 2000) (Almeida, et al. 2013) (D. Ürge-Vorsatz, et al. 2016).
7. **Physical metrics vs monetization:** Many of the aspects of productivity could have a controversial methodology for monetization. For example, monetarization of health has always been controversial. Thus, to avoid these controversies, a physical metric can be used to quantify productivity impacts. The physical indicator can justify the intensity of these impacts where monetization method is absent or controversial i.e. in other words, it can be used as a proxy for monetized value where monetized value is absent or monetization methodology is controversial (Stiglitz, Sen and Fitoussi 2009). Therefore, in this study, first, a physical metric will be proposed to quantify the impacts and then according to the physical metric, impact equation and monetization equation can be derived. For example, active days loss can first be estimated in a number of days and then it is monetised by using daily wage.

Table 1. Key challenges and proposed solutions for productivity impact assessment.

Methodological challenges	Way-outs
Baseline, additionality and context dependency	Incorporate as much variables as possible to accurately quantify the true additional productivity impact. Consider these variables while preparing the multiple impact pathways. Also, consider impact pathways in the baseline as well as in the energy efficient scenario in order to find out the additionality of the productivity.
Distributional impact	It is important to define how productivity impact will change the pre-existing inequality and whether any welfare weight factor will be applied to adjust these factors during the cost-benefit assessment.
Perspectives	Social perspective will be prioritized for productivity impact but all three perspectives are relevant for productivity.
Double counting	Prepare impact pathway map as extensive as possible in order to understand the various interactions and overlaps among impacts. This identification will minimise the chances of double counting.
Rebound effect	Direct and indirect rebound effect needs to be considered. However, for productivity impact, no significant rebound effect is identified.

Source: Urge-Vorsatz et al 2016 and own elaboration.

Table 1 summarises all the challenges related to methodology and its proposed solution discuss in this paper.

Conclusion

The importance of assessing multiple impacts due to energy efficiency measures have become a key area in climate change and energy studies. Ideally, a decision on climate or energy-related investment or policy should be taken with consideration of its full range of costs and benefits but, this almost never happens due to the absence of proper quantification and integration methodology. This paper recognizes the key methodological challenges including the possibility of double counting, of economic evaluation of multiple impacts and proposes a methodological framework to deal with these challenges.

This paper first identifies the key impacts due to building related improved energy efficiency measures and also proposes the methodology to quantify and monetize the productivity impacts. To avoid double counting, this paper creates impact pathway map which also help to quantify the significant outcomes and then impacts can be quantified accordingly. Lastly, the quantified impacts can be monetised where possible and then integration into a cost-effectiveness decision-making framework such as cost-benefit analysis will be easy.

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