Estimating the macroeconomic benefits of energy efficiency policy and measures

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Abstract

Economic performance and energy use have historically been intrinsically linked in many economies around the world. Increasingly, research is showing that energy savings from energy efficiency improvements can deliver wider benefits across the whole economy such as increases in employment, GDP, trade balances, energy security etc. Given the complexity of the interactions throughout the economy, and the high level of interest by governments in understanding and predicting them, it is important to have a robust methodological framework for carrying out energy efficiency policy assessments. There is also the question of how the macroeconomic benefits impact energy consumption and whether these indirect rebound effects offset much of the initial energy savings from the energy efficiency measures. This paper investigates these interactions and provides guidance to policy makers on how to measure the macroeconomic impacts of energy efficiency measures.

The objective of this paper is to provide some clarity on the methodologies and results from assessments of the macroeconomic impacts of energy efficiency policies and measures. It comprises a desktop study of published and unpublished literature in this area and the outputs include a summary of the values found in the literature for the main macroeconomic indicators and a set of guidelines for robust assessment for policy makers. This paper endeavours to break down the barriers for policy makers who would like to measure the macroeconomic impacts of energy efficiency measures by describing the different estimation approaches and the situations where their applications are most suitable.

1 Introduction: Increasing evidence of macroeconomic benefits

Economic performance and energy use have historically been intrinsically linked in many economies around the world. However, a number of countries have made progress in decoupling GDP growth from the growth of energy consumption as a result of both structural change in industrial economies and continued energy efficiency improvements. Increasingly, research is showing that energy savings from energy efficiency improvements can deliver wider benefits across the whole economy. How energy efficiency policies and outcomes impact macroeconomic performance needs to be better understood by policy makers.

Macroeconomic assessment is a mainstream branch of economic analysis that has built up a huge bank of knowledge and evidence over many years. This paper does not try to develop new methods of macroeconomic analysis but rather shows how existing techniques can be applied to assess the macroeconomic impacts of energy efficiency measures and improvements.

Major macroeconomic issues related to energy efficiency measures are first of all a link between energy bills and the trade balance of energy consuming countries, with the competitiveness of the economy. They may even drive a shift from demand-driven economies to a new supply-driven model where efficiency rather than consumption is the driver of growth. There is strong interest from politicians and the general public in economic development and growth issues, especially in the current economic climate of recession and relatively high energy prices in many countries. Policy makers are under pressure to estimate the potential impact of energy efficiency improvements on the wider economy by carrying out ex-ante assessment or appraisal of competing energy efficiency policies. In order to be able to present credible and transparent results, it is important that any macroeconomic assessment is carried out as rigorously and transparently as possible, and supported by sound analysis of the microeconomic public and private costs and benefits.

The objective of this paper is to provide policy makers with a guide to alternative assessment methods to estimate the macroeconomic impacts of energy efficiency policies. It is a complex subject and caution is needed when estimating the impacts of energy efficiency to avoid pitfalls such as crowding out other investment, rebound effects or energy price impacts in the calculation. There are also different levels of effects that can be difficult to distinguish from each other and/or double-counted. Various approaches can be taken which can appear confusing and off-putting to the uninitiated and risk neglecting a possible paradigm shift in the economic model due to wide-ranging and deep energy efficiency improvements. This paper avoids complex theoretical arguments and endeavours to provide a practical guide for interested policy makers on the different estimation approaches and the situations where their applications are most suitable.

2. Framing the macroeconomic impacts

The term macroeconomic in this paper is used to cover economy-wide effects that occur at national, regional and international level. It is concerned with the aggregate effects of energy efficiency measures which may be considered as comprising (i) the sum of the individual microeconomic effects, and (ii) the impacts of the whole economy resulting from non-linear complex interactions throughout the economy.

One way to look at the macroeconomic impacts is to separate them into:

- The costs and effects derived from investing in energy efficiency goods and services,
- The effects derived from the energy savings (or reduced costs) from actually realising an improvement in energy efficiency.

In many cases the first action taken as part of an energy efficiency measure is to invest in energy-efficient goods and/or services.[1] Once the energy-efficient technology or service is implemented, the second step is to actually realise energy savings from the new technology or service. These two steps separately bring about an array of direct, indirect and induced impacts that collectively cause macroeconomic effects.

It is useful to classify the effects in this manner because the direct, indirect and induced effects are included in both categories and it is easier to visualise the flow-through effect of the impacts in the wider economy than if the direct/indirect/induced effects were examined individually. A short explanation of these categories in the context of macroeconomic impacts is provided in the next subsections to assist in developing better methods to measure

[1] Energy efficiency improvements can also be undertaken without involving investment in energy efficiency-enhancing technologies or services, through behavioural change for example, in which case only the energy cost reduction effects apply in this discussion. However, in the large scale improvement in energy efficiency needed to optimize energy efficiency potential globally, both behavioural change and investment will be needed and therefore the investment effect will apply for most governments seeking to estimate the macroeconomic effects of energy efficiency measures.

them. Figure 1 below illustrates the different macroeconomic effects of energy efficiency measures.

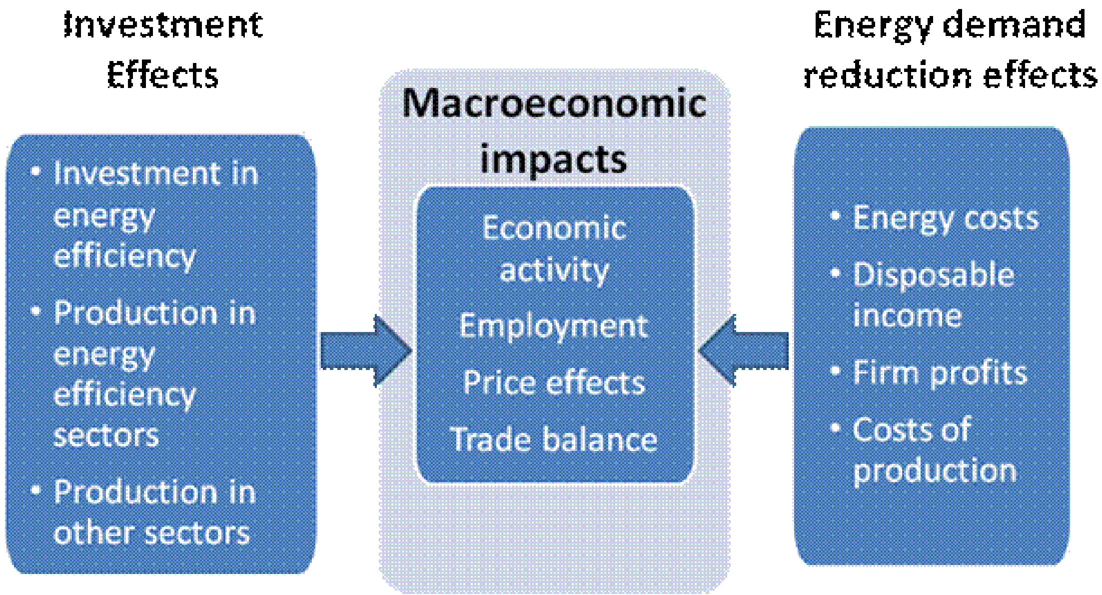

Figure 1: Framing the macroeconomic impacts of energy efficiency measures

It should be noted that the economic effects of energy efficiency measures are different for final consumers (ie households) and energy-using producers (ie businesses). Increased energy efficiency can lead to more competitive production for ‘business consumers’ of energy, while for final consumers increased efficiency mainly leads to a demand shift, from energy consumption to other goods. (Turner, 2013). For the consuming sectors, it is relatively straightforward to observe how investment in energy efficiency and energy savings can lead to increased spending and economic activity with second round effects such as employment, government revenue, and price effects (if other investment and spending is not crowded out). There are likely to be positive income effects, unless household wage demands increase as the labour supply becomes more competitive. The producing sectors are more complicated to categorise in terms of energy efficiency impacts as they can act both as consumers and producers and can be affected by a range of effects: their own investment in energy efficiency, a rise in demand for energy efficiency goods or services, increased productivity as a result of reduced energy costs or through second round effects in the wider economy due to increased employment in sectors delivering energy efficiency-related goods and services, reduced employment in energy intensive industries and multiplier effects.

Energy efficiency investment effects

Macroeconomic effects from energy efficiency investment are effects that mainly arise due to the new or reallocation of spending to sectors producing energy efficiency goods and services. The direct effect of this is higher production levels and employment in sectors delivering energy efficiency-enhancing services and products. There may be also second and third round re-spending effects that lead to an increase in overall economic activity where supply chains increase production and employment rises in energy efficiency-related and other sectors as demand –based growth occurs from new employees spending their wages across the economy.

Over time the trade balance may also be affected directly by the investment effect if the increase in demand for energy efficiency goods and services leads to increased economies of scale and specialization in energy-efficient goods and services, and a substitution of energy demand for improved energy efficiency and services. In turn this can lead to an improvement in competitiveness and technology innovation in the sectors involved. Energy efficiency measures could also cause negative trade effects if energy efficiency measures require positive net costs and decrease firm competitiveness.

On the other hand, investment in energy efficiency measures is likely to be offset, to some extent, by less investment in other sectors, with associated production, employment and second and third round effects. The timescale of the investment effects should also be considered, as it may be critical in demonstrating the full macroeconomic benefits of energy efficiency measures. For the consumer, household or business investing in energy efficiency, there is an initial upfront outlay (unless policy measures such as grants or pay as you save schemes are in place) that will affect their ability to make other investments and/or undertake consumption in the short-run and may lead to stranded assets. These short-term effects must be offset against the energy savings impacts described below. However, if the investment is cost-effective it should not reduce the competitiveness of a business. In the longer term, the effect of energy efficiency measures should become positive as the energy savings accumulate over time.

Box 1: Investment in energy efficiency

The recently published IEA Energy Efficiency Market Report estimates that total global investment in energy efficiency measures in 2011 reached USD 300 billion (IEA, 2013). This is based on a country-by-country analysis of reported public spending, combined with information about multilateral institutional investment and private spending where available. While this estimate is higher than other recent estimates (IEA, 2012a; Hayes et al., 2012), it is considered conservative because of the way energy efficiency investment is defined and the underestimation of private investment included in the total (Ryan *et al*., 2012).

Estimating global energy efficiency investment is difficult. There is no standard definition of what constitutes an energy efficiency investment. While in theory energy efficiency values should only include the incremental amount spent on energy efficiency, in reality the investments documented often include the total amount invested in an asset even though energy performance is only one part of the investment. In addition, data are patchy and not available in a consistent format; data on private sector investments are particularly difficult to access. Investments in energy efficiency are not systematically tracked, making a comprehensive estimate of the current global investment level difficult. Calculating a single leveraging ratio for public funds is not possible, requiring a wide range in the overall investment estimate. The IEA estimate includes surveys and interviews with public and private financial institutions to carry out a country-by-country analysis, using the following approaches:

- Country sources and estimates were used wherever available. This proved possible for larger countries, particularly in the OECD.

- If not, data from multilateral development banks and other relevant sources of public funding were used, to which a multiplier, based on the economic circumstances and practices of the individual country, was applied to scale up multilateral development banks and other public funding of energy efficiency across the economy.

In both cases, the particular manner in which a given country or multilateral development bank classified investments as being energy efficiency related were generally accepted as reported. Where possible, only the energy efficiency component of investments, rather than the entire project cost, was included. The methodology used leverage ratios applied to public funds where data for private investment was not available (see Ryan *et al*., 2012 for more details on leverage ratios). Public finance typically catalyses (i.e. leverages) private funds, and the leverage ratio provides an estimate of how much private finance is generated by public funds. Public funds attract private capital by mitigating risk and building awareness and capacity. Public financial institutions leverage public funds through private sector co-financing.

Source: IEA (2013b).

Energy cost reduction effects

If energy efficiency improvements reduce energy demand and costs there can be ramifications for the whole economy due to the macroeconomic effect of increased disposable income or profits realised by the individual, household or business.[2] These savings are then available to be spent by consumers on other goods (the spending effect), or in the case of the producing sectors they can be reinvested in the business or passed through as lower output prices to consumers. Energy efficiency measures in the producing sectors lead to energy cost savings and reduced costs of production, which could produce output price falls and give a forward ripple effect of falling costs throughout the economy creating productivity-led growth. This drives new production and purchase of inputs, some of which will come from local regions.

Estimations of the spending effect show it is substantially larger than the investment effect. Howland *et al.* (2009) estimated that the share of macroeconomic effect (in terms of gross state product) over the lifetime of the energy efficiency measures due to the spending effect was between 88 and 91% depending on the fuel. A second macroeconomic modeling study of the Eastern Canadian provinces (ENE, 2012), corroborates these finding in another geographic area. There it was found that the impact of the savings generated 70-90% of the overall GDP and employment impact in this region of Canada.

Another effect of reduced energy consumption may be reduced energy prices if the energy efficiency activities are sufficiently widespread and at scale. Some energy sources such as oil are global commodities and therefore demand in one region may not have a significant impact on energy prices. However there may be local supply constraints that translate to changes in energy prices locally if energy efficiency measures free the supply of the energy sources. Electricity prices can be reduced as each saved kilowatt-hour of electricity can reduce fuel, CO2 emissions and investment costs for fossil and renewable power plants and power grid expansion. A reduction in electricity consumption in Germany of 10 to 35 percent by 2035 compared to business as usual has been found to lower electricity generation costs by EUR 10 to 20 billion (Wuensch *et al.*, 2014). Countries can maintain positive economic growth while decoupling energy use, as energy efficiency can help mitigate higher energy prices.

If energy prices do fall, there will be positive impacts on competitiveness for the economy and consumers' disposable income.[3] In time global energy markets may be more closely linked and therefore if energy efficiency measures reduce energy commodity prices, all countries will gain.

Trade balances may be affected through several effects. Firstly, many OECD countries are energy importers and therefore reduced demand can reduce import bills and energy costs. For energy exporters, reduced energy demand frees up more supply for export if foreign demand for oil exceeds supply.[4] Another trade effect may appear if an economy becomes more competitive due to reduced energy costs, reducing export prices and increasing demand for that country's goods. However trade effects may also be negative if businesses become less competitive or if energy efficiency goods are imported.

[2] Assuming that energy prices do not increase.

[3] Final energy demand reductions may not always lead to price reductions. In a closed electricity market facing exogenously determined input fuel costs, electricity prices may even rise a little, owing to the need to spread the fixed costs of the electricity system over fewer units sold. Whether this effect is actually positive on retail prices will depend on the extent to which marginal plant are more costly, and the time of day of demand reductions (i.e. peak vs off-peak).

[4] And in the case of countries where there are energy subsidies, often in energy exporting countries, the public sector bill funding the subsidies is reduced. This issue is dealt with in the chapter on public budget effects.

3 Key macroeconomic impacts and sample results

The previous section outlined the categories of effects that can occur as a result of energy efficiency measures. This section describes the most common variables estimated as indicators for the macroeconomic impacts of energy efficiency measures. The main macroeconomic impacts estimated are:

- Economic output measured by Gross Domestic Product (GDP)
- Employment
- Trade balance
- Energy price changes

All of the above are dependent on the structure and nature of the economy, the scale and substance of realised energy efficiency outcomes, and the distribution of outcomes across consumers and producers.

Table 1 provides an overview of the indicators and their measurement in energy efficiency policy assessment. The variables are elaborated further in the text with some examples and a summary of estimates in the literature is provided.

Table 1. Overview of macroeconomic indicators for energy efficiency impact assessment

Impacted Area	**Indicator**	**Description**	**Illustrative Metrics**	**Comments**
Economic output (increase)	Gross Domestic Product (GDP)	The total market value of all final goods and services produced in a country in a given year.	Consumer spending (C) Investment (I) Exports - imports (E) Government spending (G)	The impact on GDP is usually modelled at the national (or regional) level, allowing the interactions of energy production, labour markets, economic structure and historical EE policies to be characterised. Since GDP comprises an aggregate of a large number of variables across the economy, the impact on GDP of EE activities is only likely to be measurable if the investment or EE improvement is large and has significant multiplier effects.
Economic output (change)	Trade balance	The changes in energy imports and exports as a result of changes in national energy consumption and prices as a result of either energy efficiency investment or energy savings effects. The economic structure of a country will determine the trade flow as a result of EE.	Imports Exports	The impact of energy efficiency programmes on energy imports are more important for energy-importing countries. Energy security is a key concern for energy-importing countries.
Energy price (decrease)	Energy unit price	The consequences are energy cost reductionerm for net importing countries and consumers and businesses.	Cost per unit energy Substitutability for energy Market trading conditions	If demand for energy falls, energy prices should decrease. The level of the fall is determined by factors such as the quantities of domestic energy supply, the substitutability and market trading conditions. If energy prices reduce there could be rebound effects.
Employment (increase)	Number of net new jobs	The number of net jobs that are created or lost, directly or	Net new jobs Sectoral employment	One of the key impacts for policymakers and politicians. Estimation of employment

		indirectly, through energy efficiency measures. Also the structural shifts in employment that may occur because of energy efficiency measures.	shifts Wage rates Labour intensity Local content	effects should be as transparent and robust as possible. Net employment should be estimated, taking both employment gains and losses into account. Good sectoral analysis is needed to properly understand current spare labour capacity, skills available, and changes in labour rates for relevant sectors.

All of the above are dependent on the structure and nature of the economy, the scale and substance of realised energy efficiency outcomes, and the distribution of outcomes across consumers and producers.

We describe each of these macroeconomic indicators and try to portray the scale of its importance. A summary of estimates in the literature is provided. However, readers should be aware that there are difficulties when comparing different studies. Studies may differ in, for example, (a) the methods used, (b) what is meant by (and included in) the efficiency improvement, (c) whether the spending on the efficiency-enhancing measures has been included in the estimation of the impacts, (d) what sector(s) efficiency improvements occur in and the importance of these in the context of the wider economy. This means that the results from different studies should not be directly compared with each other but rather serve as an indication of estimates that have been found.

Gross domestic product (GDP)

Most macroeconomic modellers include GDP as an output variable when looking at the economic impacts of EE measures on the economy and a sample of these results are presented here.[5] These results should be interpreted with caution because it is difficult to compare the results of different models due to differing metrics and scale of investments modelled. It is more difficult to see an effect on GDP when the EE policy or programme affects only part of the economy, *e.g.*, is sector-specific or small relative to the scale of the economy.

An impact assessment of the (at the time) proposed Energy Efficiency Directive was carried out by Cambridge Econometrics for the European Union. The E3ME macroeconometric model was used to examine the economic impacts of the directive. It found that reducing primary energy demand by 15.4% (or 283 Mtoe) by 2020 (compared with reference projections) would require additional investments of 0.84% (or EUR 26.6 billion[6]) leading to **a modest GDP increase of 0.25%** (European Commission, 2011).

Copenhagen Economics modelled the macroeconomic impacts of energy efficiency renovation of buildings in Europe. Energy efficiency measures delivering reductions of 65 to 96 Mtoe (756 to 1116MWh or 5.4 to 8.2%) in final energy demand in 2020 were estimated to require additional investment of EUR 41 to 78 billion, resulting in a **rise in GDP of EUR 153 to 291 billion per year.** These values are mainly calculated through estimating the number of jobs created as a result of the investment in energy efficiency and using multipliers to estimate the aggregated gross value added per job in different sectors (Copenhagen Economics, 2012). The study concluded that this was helpful given the weak position of many EU countries at the time. They found that this result could be achieved with regulatory reforms removing structural barriers to energy efficiency with and deliver savings for consumers and with no need for new public subsidies.

At national level the UK government commissioned two studies estimating the macroeconomic rebound effects associated with energy efficiency measures leading to a reduction of final energy demand of 8% and 5% in 2010. The researchers used econometric

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[5] It is recognized that GDP may not be the best indicator of economic wellbeing. The World Bank and UNDP, for example, suggest using the Human Development Index and other indices to reflect more broader measures of economic wellbeing. See: http://hdr.undp.org/en/content/measuring-human-progress-21st-century. The OECD has developed the Better Life index which recognises that economic activity may not be the most relevant parameter to citizens and suggests other criteria: e.g. http://www.oecdbetterlifeindex.org.

[6] In 2000 currencies.

and Computable General Equilibrium (CGE) models and found that **GDP rises by 1.26%** and **0.1- 0.2%**, respectively, as a result of the improvement in energy efficiency (Barker and Foxon, 2008; Allan et al., 2006)).

In Germany researchers have investigated the macroeconomic effects of the German energy efficiency plan and found that a final energy demand reduction of 6% by 2020 required annual investment of EUR 12 billion annually and delivered **an increase in GDP of 0.7%.** This estimation was also carried out using an econometric model (Lehr *et al.*, 2012).

Globally, the ENV Linkages model, a CGE model, has been used by the OECD to estimate the global economic impacts of achieving the Efficient World Scenario (EWS) in the World Energy Outlook 2012. There it is estimated that a 6% in 2020 and 14% in 2035 reduction in primary energy demand would require an additional investment on average of USD 472 billion annually through to 2035. This would lead to an increase in **GDP of 1.1% by 2035** with a third of that occurring by 2020. This additional demand for jobs and investment may be positive in a situation where many OECD countries face a slack in their economies and unemployment levels above their structural level (Chateau *et al*., 2014).

Few models include crowding out effects where increased demand for energy savings investment would make less room for other activities, including by driving up inflation and demand for labour. In the modelling of the German case, some crowding out is implicitly modelled, for example inflation and labour demand increase, however other channels of crowding out such as an increase in interest rates, investment competition in a company, if the investment budget is fixed, are not considered. If increased investment is financed through increased taxes, then crowding out may not be an issue, as there are increased savings.[7] However if investment is financed from other sources and access to capital is tight, then this could be an issue. Good practice should be to carry out sensitivity analyses with different investment scenarios.

Employment impacts

Supporting job creation is one of the most enduring issues of concern for policymakers and therefore estimated employment effects resulting from energy efficiency programme is likely to be a request of policy makers. Since this is such a popular issue, it is important that any estimation of employment effects is as transparent and robust as possible. Equally net employment should be estimated, taking both employment gains and losses into account.

The effectiveness of an energy efficiency programme in creating jobs will depend on the size and structure of investment and the type of energy saving interventions being supported. Jobs in energy efficiency services appear to have high labour intensity (assessed on the basis of the ratio between jobs required to produce a dollar of industrial output) than, for example, jobs in the capital intensive energy production sector (Energy Savings Trust, 2000; Pollin *et al.,* 2009). Jobs in maintenance and repair of equipment and buildings can also be a significant source of employment and should be included. Energy efficiency jobs are also often geographically dispersed and tend to range from low wage jobs to highly skilled technical work. Good sectoral analysis is needed to properly understand current spare labour capacity, skills available, and changes in labour rates for that sector.

It is important to be clear on the definitions of employment that are used in the analysis. Direct jobs are those that are created in either the manufacturing or installation of energy-efficient equipment. There may also be indirect jobs resulting from supply chain effects. Combined, these provide the total gross employment impact. The net impact is determined by

[7] This keeps the I-S amount in the GDP equation constant, see the estimation in the next subsection.

subtracting the jobs that may be lost elsewhere in the economy, for example in the energy production sectors, or as a result of limited labour market capacity leading to higher wage rates. An overview of the literature and a detailed description of estimating the jobs created through energy efficiency measures is estimated using an I/O model for Hungary (Urge-Vorsatz *et al.*, 2010).

As many of the jobs (but by no means all) associated with energy efficiency are temporary in nature, job-years is a preferable unit of measurement for estimating employment impacts. It is also important to provide an indication of the skill level or income associated with these jobs so that policy makers can understand what kind of jobs are generated. An alternative is to provide an estimate of the job impact in one particular year. Policy makers can then use the term "jobs" (appropriately caveated), as opposed to "job years", which is more difficult to communicate.

Sector-specific approaches are essential in detailing the jobs created in individual sectors and then aggregated to represent the whole economy. However, macroeconomic economy-wide approaches are especially useful in the context of labour market impacts, because jobs created in one sector may be partially offset by job losses in another sector. A single-sector approach might over- or under-estimate the net jobs created.

While not specialised labour models, macroeconometric, input-output and some CGE models can mimic a realistic representation of the labour market. They will estimate the number of jobs required and any labour market crowding out effects and whether there is capacity in the labour market. These models will not, however, be able to check that the available workforce has the necessary skills to fill the vacancies that are created by energy efficiency programmes. For this a more specific assessment of the key sectors (mainly construction-related) is required. If this supplementary analysis finds that there are likely skills shortages then this could have macroeconomic implications and the modelling scenarios should be revised to take this into account. An example of this approach is provided in Cambridge Econometrics *et al* (2011). Comparison with individual department or ministry labour forecasts is useful, to check the reality of the results.[8] Most of the studies outlined above for GDP estimation have also estimated the potential for jobs created as a result of energy efficiency measures. Different metrics can be used in reporting job creation but the most common is the net number of job-years created per unit invested in energy efficiency. **Values range from 7 to 22 job years per million euros invested**. Other authors report increases in employment per unit energy saved. The exception is the ENVLinkages CGE model which assumes a perfectly flexible labour market and therefore calculates no net employment gains but instead estimates **shifts of workers between sectors**.

Trade balance

Trade balances, i.e. the exports net of imports, are included in the GDP calculation above but are described separately here to better understand the phenomenon as it relates to energy efficiency measures.

Studies examining the macroeconomic benefits of energy efficiency measures are divided on whether trade balances are positively or negatively affected by the energy efficiency measures modeled. This is mainly related to what is actually being modeled in trade balances. Of the macroeconomic studies mentioned to estimate GDP, the global model, ENV-Linkage,

[8] More information on approaches to estimating green jobs in general is available in OECD's *Greener Skills and Jobs* report (2014). http://www.oecd-ilibrary.org/docserver/download/8514041e.pdf?expires=1400600232&id=id&accname=ocid43019508&checksum=9352C84895921810CB73BC5D7BA6CCD3

finds that world **trade is marginally increased at 0.2%** through strong stimulation of less energy-intensive goods and services in OECD countries in particular, whereas energy transformation industries experience a slowdown in activity and trade. The impact of the European Energy Efficiency Directive is also estimated to be **marginally positive for trade, at 0.5% increase**.

Studies carried out at national level for the UK and Germany show **both increases in imports and exports.** In Germany, the increased demand for energy efficiency goods and services and rise in private consumption as a result of the consumer surplus, lead to increased imports initially. However, researchers estimate that overall the impacts are positive for trade as energy imports are reduced and Germany exports goods and services related to energy efficiency if early initiative is taken (Lehr et al. 2012).

Box 2. Energy security

Increased energy security is a commonly cited economy-wide benefit of energy efficiency and conservation, although it is not generally included as an quantitative output of most macroeconomic models and hence is included as an aside here. Energy security is defined by the IEA as "the uninterrupted physical availability of energy at a price which is affordable, while respecting environmental concerns. The IEA's model of short-term security (IEA, 2011) and others (Cherp and Jewell, 2011; Scheepers *et al*., 2007) consider three aspects of energy security: robustness (adequacy and reliability of resources and infrastructure), sovereignty (exposure to threats from foreign actors) and resilience (ability to respond to diverse disruptions). Energy efficiency models tend to calculate energy imports as an output of the model and therefore focus on sovereignty and resilience.

In Germany, for example, over 70% of primary energy demand is met with energy imports and these make up 11% of German imports overall, with energy imports reaching EUR 102 billion in 2012 (Statistisches Bundesamt, 2013). Lehr *et al.* (2012) study estimates that **an ambitious energy efficiency strategy to reduce primary energy demand by 6% in 2020 would reduce energy imports by EUR 4.3 billion.** The authors stress that not only would energy efficiency measures improve the trade balance but would also provide a security against disruptions, as many of the countries supplying fossil fuels have a tendency to conflict such as the disruptions that occurred between Russia and the Ukraine. They reiterate that energy efficiency is the surest source of energy supply that exists (Lehr *et al.,* 2012).

Many studies modelling energy efficiency measures include energy security as one of the key rationales for countries to invest in energy efficiency. However, there are few examples where more analysis is carried out. It is simply assumed that any reduction in energy demand will improve a country's energy security. While this is true generally, analysis needs to be undertaken in each case to understand which energy fuels are likely to be saved through energy efficiency measures, as energy security is likely to mainly be improved when non-domestic energy sources are affected.

It can be expected that energy exporting countries will suffer a loss in exports if energy efficiency measures are implemented on a big enough scale. Export volumes could be expected to decline in countries producing at the margin, while export earnings are likely to decline in all energy exporting countries if the reduction in demand is large enough to bring about a reduction in energy prices. While the global ENV Linkages study shows more exports trade globally, it also shows that there are likely to be winners and losers in the global trade of energy. Energy imports, on the other hand, in energy-importing countries could be reduced through energy efficiency measures; for example it has been estimated that in Germany the gas import bill from Russia could be halved in ten years through energy efficiency measures in the industrial and buildings sectors (Ecofys, 2014).

Energy prices

There is a two-way relationship between energy demand and energy prices. On the one hand, total primary energy demand is an important predictor of energy prices as well as the energy mix. On the other, the level of energy price is a strong determinant of energy demand.

Improvements in energy efficiency may change consumption of energy in one fuel more than another (either because of the sector affected or because of energy price differences across fuels) with resulting implications for fuel prices and overall energy prices. Energy fuels are globally traded commodities and therefore unless energy efficiency measures are implemented at a large enough scale reducing energy demand significantly, it is unlikely that global energy prices will be impacted. However, should the trend to improve energy efficiency continue at a global scale, energy demand growth should be at least tempered and should mean that energy prices will be lower than they otherwise would have been.

The macroeconomic implications of larger changes in energy prices can be huge. The oil price spike of the early 1970's was a key factor in the economic crisis at the time.[9] On the other hand, the financial recession of 2008 caused demand for energy to contract, and oil prices fell from a high of USD 147/bbl in July 2008 to a low of USD 32 in December 2008, although by 2012 the average annual price for oil had risen again to USD108 a record price in real terms. The European Climate Foundation roadmap analysis found that a doubling in oil prices for 3 years could cost the EU economy €300 billion over the same time period (E3G, 2012; ECF, 2012).

Different approaches are taken with regard to energy prices in energy efficiency models. Energy prices can be calculated exogenously and then be part of the inputs; they can also form one of the outputs that occur as a result of the energy efficiency measures.

The IEA World Energy Outlook (WEO) uses a different approach with regard to energy prices in modelling the high energy efficiency scenario (EWS) in the WEO 2012, compared with other WEO scenarios. Where most WEO scenarios set energy prices as part of the scenario inputs, the WEO EWS sets policy measures and allows energy prices to change to reflect the change in equilibrium between energy demand and supply. The WEO 2012 EWS estimates that a reduction of primary energy demand globally of 6% in 2020 and 14% in 2035 through energy efficiency measures would lead to a reduction of USD 16 per barrel of crude oil in 2035 compared with the New Policies Scenario (IEA 2012).

4. Methodological approaches

Policy appraisal should include an assessment of the range of public and private costs and likely impacts of a policy. If possible, these impacts are quantified and monetised as part of a benefit-cost analysis. This allows policy makers and the public, once the results are published, to understand the rationale and consequences for implementing the policy. However, many of the non-energy benefits of energy efficiency policy are not routinely estimated in energy efficiency policy impact assessment.

This section discusses the options for policymakers who would like to estimate the macroeconomic impact of energy efficiency measures, for example as part of a policy appraisal process.[10]

[9] Not all the implications are negative - high energy prices can also stimulate innovation and reduce demand for energy.

[10] It could also be part of an ex-post policy evaluation using historical data.

Methodological options and indicators

Quantitative estimation of economy-wide economic impacts of energy efficiency is desirable so that the effects can be not only understood but compared to other measures in terms of costs, benefits and scale. Due to the nature of the complex interactions that can arise across the economy with a change in energy efficiency policy and related investment at a large scale, computer models that simulate different energy efficiency or economic scenarios are usually needed for this estimation. A range of economic models that utilise different methodologies are available to the policy maker to carry out this task. An overview of the methodologies used to assess ex-post the effects, socio-economic costs and efficiency of climate change mitigation policies and measures are summarised by Oeko-Institute et al., 2011; this section describes how these methodologies can be applied to estimate the macroeconomic impacts of energy efficiency measures.

Basic analysis of the macroeconomic impacts of energy efficiency can be carried out using a spreadsheet and the scope can be set as wide or as narrow as desired. Initially, a few key estimates are needed such as the scale of the costs of the programme, the likely investments that will be needed, the value of the energy savings, and the sectors in which increased spending is likely to occur. Then a calculation can be carried out to estimate key macroeconomic variables with and without (the baseline calculation) the energy efficiency programme.

More advanced modelling can include a number of different modelling approaches. Computable General Equilibrium (CGE) and macroeconometric models are the main modelling approaches used to model the macroeconomic impacts of energy efficiency measures. However these approaches are often combined with others. For example, both approaches often include I/O tables. Macroeconomic models also generally represent sector details, but generally not technology details.

It is desirable to incorporate both bottom-up and top-down approaches when modelling the macroeconomic impacts of energy efficiency measures. This allows engineering knowledge in the relevant sectors to be combined with economists' expertise on the wider economy. A bottom-up model provides a useful tool to develop a strong understanding of the microeconomic underpinnings of a sector, which can be combined with a top-down model to achieve economy-wide coverage. However this may be difficult due to data, time, and financial resource constraints (Hourcade *et al.,* 2006; Ghersi *et al.,* 2006).

While all the CGE and econometric models should be capable of producing the same type of results (GDP, employment, trade, CPI, value added, public budget), In the Annex, Table A provides a list of and the main characteristics of some of the models presented at the *IEA Roundtable on macroeconomic modelling of energy efficiency measures* January 25-26th 2013.

In general, models should be kept simple and focus on individual effects. It is unlikely that one single model will be able to model everything well and therefore policy makers can expect that several purpose-built models will be used linked together.

Modelling macroeconomic impacts of energy efficiency policies

The macro-economy, by definition, covers a broad range of sectors and there are a variety of impacts and estimation methods across the economy as a result of energy efficiency policies. Assessment of a wide range and number of impacts might become overly complex, so it is important at the outset to establish some priority macroeconomic indicators for examination. Indicators could be ranked in order of priority to allow for initial examination of a few first priority indicators, adding more if more detailed analysis is desired.

Different macroeconomic indicators are likely to differ in their importance to different stakeholders. For example, policy makers in finance ministries generally consider changes to GDP, trade balance, levels of employment, and public budgets most important. The general public is likely to favour changes to rates of employment, energy prices, disposable income, consumer price index (CPI) and any distributional effects. Energy ministries might be also concerned with energy security, while industry is likely to be interested in the levels of investment and any impacts on profits that might arise as a result of fiscal policies or increased demand for goods and services they can provide.

The process for policy makers modelling the macroeconomic effects depends upon the situation in terms of data, expertise and other resources, and the impacts to be estimated. Broadly, the estimation process begins by carrying out an initial assessment of the macroeconomic impacts and whether they are significant enough to warrant further assessment and then, if the answer is positive, a detailed analysis is pursued.

Box 3. Overview of steps to carry out impact assessment of macroeconomic impacts of energy efficiency measures

Plan: Decide which macroeconomic indicators should be estimated in addition to energy savings of the policy

Estimate:

- Estimate the energy savings as a result of the policy (this should be routinely carried out as part of an impact assessment of energy efficiency policy measure but is repeated here for emphasis)
- Carry out a basic assessment of the macroeconomic impacts
- Decide whether economy-wide impacts are significant enough to merit detailed estimation
- Decide the approach for detailed assessment
- Estimate of the macroeconomic impacts of energy efficiency policy scenarios, including baseline

Verify:

- Consider whether all issues are included
- Carry out sensitivity analysis

A critical first calculation for the estimation of macroeconomic or any other effects from the energy efficiency measures is the amount of energy saved by each policy option compared with the baseline option. This is because the key drivers of macroeconomic impacts (referred to above) are dependent on a reduction in energy costs as a result of the energy efficiency measures. In other words many of the non-energy benefits or impacts of the measures are linked to the energy savings actually achieved.

A basic assessment of the macroeconomic impacts of energy efficiency measures usually starts with a simple spreadsheet exercise to get a first impression of the level of impacts that can be expected. This should act as a first screening of the potential impact of the policies, to indicate whether there is likely to be impact from the measures significant enough to warrant more detailed modelling assessment. Although some data is required, this basic assessment should not involve sophisticated analysis or much time. This early stage assessment does give the opportunity to examine what data is available for more detailed assessment of the multiple benefits of energy efficiency measures.

Once a basic assessment of the macroeconomic impacts has been done, some analysis of the results is needed to decide whether more detailed estimation of the macroeconomic effects is worthwhile. Macroeconomists and ministry of finance officials should be consulted on their views on the level at which they would consider a macroeconomic indicator significant and worthy of further investigation.

A threshold indicator for changes to GDP or employment, for example, can be chosen, above which more detailed modelling could be carried out. The modelling results presented at the IEA Roundtable on the Macroeconomic Impacts of Energy Efficiency Improvements 2013 would suggest that when the impacts show more than 0.5% change then it becomes more worthwhile to carry out detailed analysis of the macroeconomic impacts of the energy efficiency measures. However, this should not prevent detailed modelling analysis where it is merited for other reasons.

A decision tree is proposed in Box 4 to help choose the most appropriate modelling approach to estimate a set of macroeconomic impacts of energy efficiency measures. Calculating the macroeconomic impacts is more likely to require cross-sectoral approaches such as computable general equilibrium or macroeconometric models given that an economy-wide estimation is needed.

Box 4. Decision-tree of assessment approaches

One way to approach the selection of a technique to estimate the multiple benefits is to use a decision tree. The figure illustrates series of questions whereby each answer should bring the policy maker closer to the modelling approach needed:

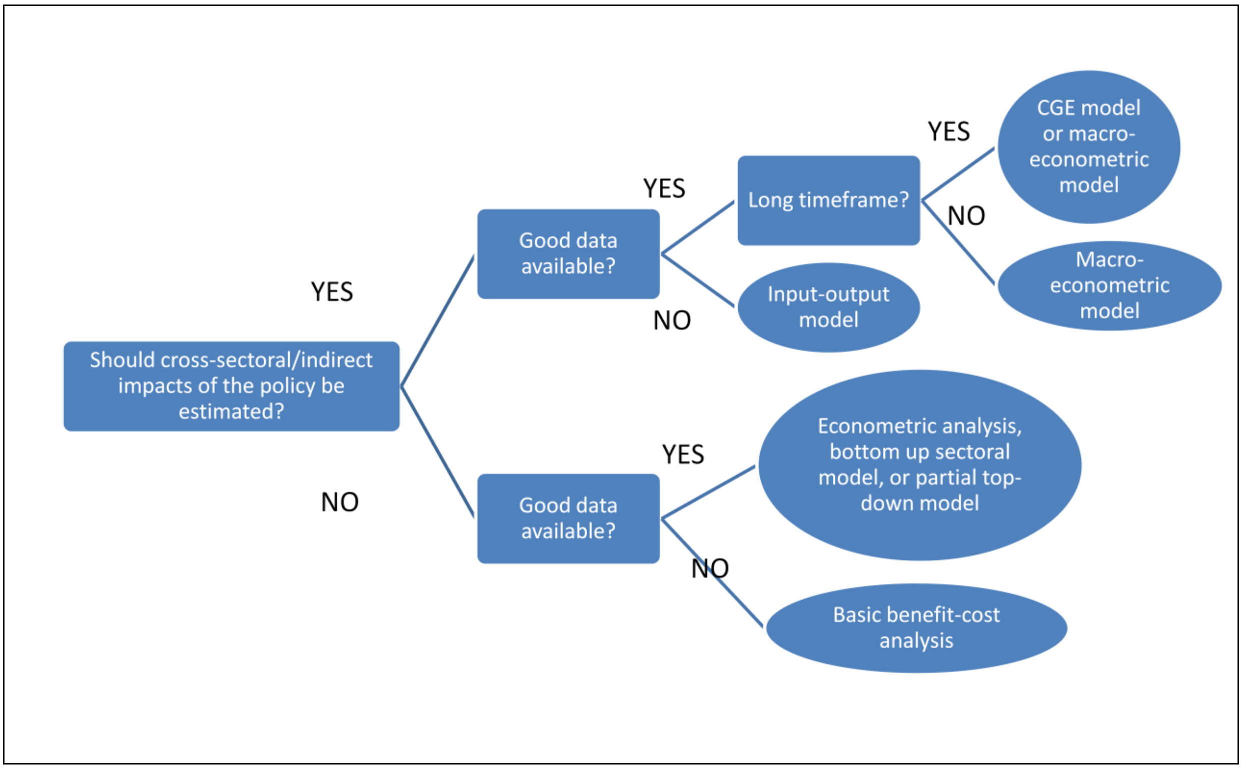
- Are indirect impacts from the energy efficiency measures expected, *i.e*. is more than one economic sector affected? If so, a general economic model will be required.

- Data availability: what data can be obtained in a short time frame and what quality is it? General equilibrium, macroeconometric and bottom-up models are data intensive. If disaggregated data is not available then input/output or more basic assessment models should be chosen.

- What resources are available for modelling in terms of staff capacity and expertise, and financial resources? And how much time is available for the appraisal process? CGE and macroeconometric models require significant resources and expertise, input/output models require less.

- What is the timeframe that should be modelled, i.e. how far into the future should be modelled? For very long-term forecasts, CGE models tend to be used. Macroeconometric models tend to be better for medium-term rather than long or short-term effects.

- How many different policy scenarios should be compared in the appraisal? More scenarios to be modelled may require longer modelling time and increase the complexity of the models so a simpler model such as a benefit-cost analysis may be best.



Once the modelling approach has been selected, the estimation process should get underway. Data should be collected to provide input parameters for all the variables required in the model. The data availability should have been a key factor in selecting the modelling approach and the sources of data should have already been identified.

In all cases it is critical to establish a baseline or business-as-usual situation against which the different policy scenarios can be compared. Sensitivity analysis should be carried out to test the robustness of the baseline. Then the policy scenarios should be parameterised and also modelled using the same underlying economic projections to allow comparison of the impact of the energy efficiency policy on macroeconomic indicators.

Consider whether the issues outlined in section 4 of this paper have been included in the modelling approach. For example, how are direct, indirect and induced rebound effects treated in the modelling estimations? The modeller and policy makers should be aware of the assumptions in the model with regard to crowding out. Distributional effects are often a key concern of politicians and the model should provide some detail on the societal distribution of the macroeconomic impacts and identify winners and losers as a result of the policy measures.

Once the results are obtained from the modelling analysis, it is important to test for robustness by carrying out a sensitivity analysis. This involves changing some of the input variables, such as energy prices or the underlying economic variables, and rerunning the model to see the effect this has on the modelling results. If the results appear to be overly changed by a small change in some of the parameters, then closer examination may be needed of the input variables and the relationships underpinning the model. A sensitivity analysis should also be extended to the baseline and test whether estimations based on different baseline yield consistent results.

5 Issues to consider in estimating macroeconomic impacts

Certain issues must be addressed when assessing the macroeconomic impacts of energy efficiency measures. Some of these issues are general considerations associated with assessing macroeconomic effects and others more related specifically to energy efficiency impacts and they also depend on the macroeconomic modelling method chosen, if any.

Crowding out

Spending on energy efficiency can "crowd out" other investments. The greater the scale and impact of energy efficiency policy, the more relevant the crowding out phenomena becomes. Since policy makers seek to encourage more, not less, private investment, it would be very helpful if macroeconomic models could examine this effect in some detail. However, the degree of crowding out that might occur is not something that existing models currently address adequately (Pollitt, 2014).

CGE models assume that all capital is allocated optimally, so an increase in investment in energy efficiency will mean that resources must be diverted from elsewhere (i.e. crowding out). Not all econometric models build in crowding out features as standard, while CGE models generally do.[11]

In reality, the speed with which crowding out or crowding in occurs depends on the structural and economic nature of a country, for example, the position in the business cycle or how well developed the financial system is and the scale of the investment in energy efficiency. It is important to compare the impact of energy efficiency investments with other investment choices. A counter-factual scenario is needed to determine whether there is additionality associated with energy efficiency policy measures, *i.e.* whether the energy efficiency measures would have happened without the policies. There may be a problem of double counting and/or free-riding and many models include some assumptions on free-ridership, however it is difficult to verify their accuracy.

Modelling macroeconomic rebound effects

Some of the macroeconomic impacts from energy efficiency measures outlined in this paper can potentially lead to a rise in energy consumption relative to the expected energy savings estimated based on the technical potential of the energy efficiency measure. This effect is called the macroeconomic rebound effect. The term has generally been viewed negatively, however this paper recognises that the rebound effect is not an inherently negative outcome, and may have positive societal welfare effects which are likely to be as, or even more, important for policy makers than the reduction in energy savings. Rebound effects should of course be included in calculations of cost-benefits of energy efficiency measures and so it is very important that the welfare effects are also included to avoid bias.

The rebound effect must be understood against the backdrop of the particular energy efficiency policy and the economic conditions, *e.g.* the rebound effect is time-, space-, policy-, economy-, and sector-specific. Time is very important as the rebound effect may have long run effects that only become visible over time. The rebound effect is different for the producing and consuming sectors where an increase in energy consumption arises through different processes (Turner, 2013). It is also important to understand rebound effect in an action context, *i.e.*, not just that it exists, but what policy design measures or packages could be used to off-set the effect (Van den Bergh, 2011).

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[11] In CGE models, new investment means potential for total capital stock to increase, rather than just being reallocated among sectors (leading to crowding out). In CGE models, there may be short run constraints on total capital, but once investment kicks in (through different dynamic processes, rather than traditional static CGE) this no longer needs to be the outcome.

Macroeconomic or top-down models are a powerful tool in conceptualising and estimating the rebound effects of specific energy efficiency policy measures. The direct rebound effect is likely best estimated in a sectoral, bottom-up model from which the results can then be fed into a macro model. The indirect rebound effect has been less estimated, which has implications for the macroeconomic effects of energy efficiency measures since the two are inextricably linked. However, recent research has suggestedthat the indirect rebound effects can be negative in some cases (Turner et al., 2013).

The total rebound effect is estimated to be in the range 10-30% in the UK and this is perhaps representative of other developed countries (Sorrell, 2007). The rebound effect can be expected to be higher in developing countries where growth rates are high and there tend to be more energy intensive activities. Overall Barker et al. (2009) have estimated that, for energy efficiency measures undertaken globally in the period 2013-2020, the total global average economy-wide rebound could amount to 31% of the projected energy savings potential by 2020, and rise to 52% by 2030. As this is a global average, it means that potentially the rebound effect is likely to be higher than 50% in some countries, however this result is disputed by some.

6. Conclusions

Macroeconomic impacts should form an important element of impact assessment of energy efficiency policies and measures. These impacts may even be of more interest to budget –wielding ministries such as Ministries of Finance than environmental or energy impacts.

Robust assessment of the macroeconomic effects is essential to provide credible information to policy makers, who may not be familiar with energy efficiency measures and targets. The approach taken to assess the macroeconomic impacts should be tailored to the resources of the public institution. Macroeconomic assessment can be data-intensive, require significant expertise and software and therefore time and resources should be allocated accordingly. This paper provides some indication of the results that can be expected for energy efficiency measures.

The **macroeconomic indicators** most likely to be affected by energy efficiency programmes are GDP, outputs (value-added + intermediate consumptions), household consumption, job creation, and trade. It is likely that only large-scale energy efficiency programmes will generate enough investment and expenditure to have a large enough impact on the normal economic flows of an economy to affect GDP. However, in all cases multiplier effects based on the energy cost reductions and while the initial investment in energy efficiency may not on its own be enough to meaningfully change (national) GDP, when all effects from implementing the policy are considered (i.e. savings component), the overall net impact can be significant.

The macroeconomic effects of energy efficiency programmes are generally **positive** in the sense that there is increased economic activity directly or indirectly as a result of the programme. However, caution is required as aggregate positive macroeconomic impacts may mask potentially contrasting distributional impacts.

Increased economic activity is likely to lead to fewer energy savings from the energy efficiency programme than the technical energy savings potential might have initially indicated, in other words a macroeconomic rebound effect may be observed. This paper shows that positive societal and welfare benefits may be at the root of the macroeconomic rebound effect and so the economic gain should be weighed up politically against some expected reduction in the energy or emissions saved. Something else to consider is that the economy in the future may be driven by cost-saving efficiency gains, rather than the current growth model of consumer spending to exploit cheap energy, as has been the case for the past two centuries. More analysis is needed of these effects.

Following the analysis, **realistic messages** should be provided to policy makers– energy efficiency measures cannot be expected to solve a nation's economic woes, nor provide the complete solution to social and environmental problems. The first and foremost goal of energy efficiency programmes should be to save energy at least cost, but the macroeconomic benefits should dispel any thinking that energy efficiency programmes are a burden to the economy.

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Annex

Table A. Models and main indicators used to model the macroeconomic impacts at IEA Roundtable on Macroeconomic Impacts of Energy Efficiency, January 2013

Model name	Model type	Scope	Impacts reported	Reference

World Energy Model	Partial equilibrium	Global	Energy prices and expenditures, investment	IEA (2012)
ENV-Linkages	CGE	Global	GDP, employment, trade and value-added by sector.	Chateau et al.,(2014)
E3ME	Econometric	EU Member States	GDP, employment, CPI, distribution, trade	Cambridge Econometrics (2014)
Copenhagen Economics model	PCGE/macro economic multipliers	Regional (EU)	GDP, trade, CPI, employment	Copenhagen Economics (2012)
PANTA RHEI	Input/Output	Germany	Employment, trade, value-added, production	Lehr et al. (2012a and b)
IKARIS	Bottom-up buildings systems model with I/O	Germany	Public budgets, employment	Kronenberg, et al. (2012)
ThreeME	CGE	France	GDP, employment, trade, distribution, public budget	Callonnec, et al (2013)/ADEME and OFCE
3CSEP model	Bottom-up buildings sector with I/O	Hungary	GDP, employment	3CSEP (2010)
GINFORS	Econometric	Global	GDP, employment, trade, CPI, distribution	Lehr *et al.* (2013)
SEAI modelling efforts	Cost Benefit Analysis with macromodel	Ireland	GDP, employment, public budget	SEAI (2012)
REMI	CGE and I/O	Canadian provinces	GDP, employment, public budget	Environment Northeast (2012)
HMRC CGE model	CGE and CBA	UK	GDP, employment, public budget	HM Treasury and UK DECC (2012)
UKENVI	CGE and I/O	UK	GDP, employment, trade, public budget, aggregate distribution effects, investment	

			behavior and sectoral activity levels.	