Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

# WP6 Macro economy

# Literature review on macroeconomic effects of energy efficiency improvement actions

## D6.1 report

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# 1 Background

## 1.1 Project outline

Within the call EE-12 of the Horizon 2020 programme, the EU funds several projects on "Energy Efficiency Research and Innovation". The COMBI project aims at quantifying the multiple non-energy benefits of energy efficiency together with the research partners University of Antwerp, University of Manchester, Copenhagen Economics and ABUD/Advanced Buildings and Urban Design, and is coordinated by the Wuppertal Institute for Climate, Environment and Energy. The multiple benefits of energy efficiency are gaining relevance in the research and the current policy discourse, but scientific evidence is yet scarce and scattered. Therefore, this project will gather existing approaches and evidence from the EU area, develop modelling approaches and come up with consolidated data on different benefits such as emissions (effects on health, ecosystems, crops, built environment), resources (biotic/abiotic, metals and non-metals), social welfare (disposable income, comfort, health), the macro economy (labour market, public finance, GDP), and the energy system (grid, supply-side, energy security). All project outcomes will be available at an open-source online database and be analysable via a graphic online-visualisation tool for personalising the findings as to their geographic location and selected benefits. To this end, the development of an aggregation methodology is of central importance to avoid double counting and presenting the various benefits on their various dimensions. Finally, insights for policy relevance will be derived and policy recommendations will be elaborated to facilitate the communication of the non-energy benefits in the relevant policy areas. In addition, the project is in touch with on-going processes of how to include multiple energy efficiency benefits into policy evaluation.

# 2 Macroeconomic benefits

## 2.1 Macroeconomic benefits of energy efficiency improvements

The macroeconomic effects of energy efficiency improvements (EEI) can be grouped into two categories: short-run (or business-cycle) effects on the one hand, and long-run (or structural) effects on the other. The distinction between the two is not primarily a matter of time scale, but rather the nature of the effect and how it influences the economy.

Short-run effects influence business-cycle fluctuations, normally the responsibility of fiscal and monetary policy. An example would be the impact on the business cycle of investment into improved energy efficiency in public buildings – if the economy is in a downturn, this additional investment will help boost economic activity, thereby reducing the severity of the recession, but the reverse holds true in an upswing. Macroeconomic variables affected include employment, output (GDP), public budgets, and inflation.

Long-run effects, on the other hand, affect the structure of the economy. An example would be improved labour productivity due to other multiple impacts, such as health or other productivity effects (e.g. due to better indoor climate) due to EEI. Such a labour-productivity increase will raise the long-run output level. In general, macroeconomic variables affected include relative prices (of energy-intensive goods relative to other goods; of exports relative to imports; etc.), trade flows, and the overall productivity in the economy, which in turn leads to changes in GDP and employment.

IEA (2014; Chapter 2) classify macroeconomic benefits into "investment effects" and "energy demand reduction effects". This classification relies on the source of the benefit, rather than its short- or long-run nature. However, the two categorizations overlap substantially, as short-run effects of EEI are mainly associated with the related costs (investment, public spending), while the long-run effects generally stem from energy savings themselves, as well as from other multiple impacts (productivity improvements, etc.) that derive from energy savings.

### 2.2 Macroeconomic evaluation perspectives

Policy evaluation asks the questions whether a certain policy is good. In this context, one might ask: good for whom? In COMBI, three perspectives are defined for policy evaluation: the end-user perspective, the societal perspective, and the public budget perspective.

In macroeconomics, the natural evaluation perspective is the societal one. Macroeconomic models deal with the economy as a whole, and when used for policy evaluation the standard approach is to compare societal welfare with and without the policy.

To the extent that a public budget perspective is considered, this is clearly a macroeconomic consideration. However, the public budget position can be valued and incorporated into a societal evaluation perspective. A maximisation of societal welfare can include any number of inputs, one of which may be the welfare costs of raising enough public funds to cover required public spending. In other words, instead of assessing budget effects using a separate budget perspective, one may simply incorporate the value to society of any such effects into the calculation of societal welfare. In this context, the concept of the Marginal Cost of Public Funds (MCPF; see e.g. Browning, 1976) may be useful – the cost to society of raising one euro of tax revenue is generally greater than one euro. This issue is discussed in detail in a forthcoming report for the Nordic Council of Ministers (Copenhagen Economics 2015).

## 3 Quantification approaches and macroeconomic models

Macroeconomic models describe how an economy's factors of production, such as workers, natural resources and physical capital, combine to produce goods and services. They treat the economy in its entirety, and describe how different parts of this system interact and influence each other.

### 3.1 Macroeconomic modelling as a tool for policy evaluation

There are two approaches to assessing policies that have macroeconomic effects: Cost-Benefit Analysis (CBA) and macroeconomic modelling. Policy evaluations are often carried out using CBA. When considering whether to undertake a project, a CBA involves adding up all the benefits of the project, and weighing them against the sum of the associated costs. Here, the terms 'costs' and 'benefits' should be understood in the broadest sense. A CBA is therefore essentially a synthesis of the economist's approach to decision making: if the (multiple) benefits to society of a certain project exceed its (multiple) costs, then it should be undertaken. If, on the other hand, the costs outweigh the benefits, it is better to hold off on the project – unless there are other reasons to go ahead with it that cannot be included in the CBA.

This approach is appropriate in many types of analysis, and most projects could in principle be evaluated using this kind of methodology. However, some policies have a wide range of effects, which interact in ways a traditional CBA cannot capture. A macroeconomic model may be needed to correctly quantify all the costs and benefits and their interactions.[1] A number of features of macroeconomic models that make them particularly useful in policy evaluations are their explicit treatment of interactions and feedbacks, their ability to deal with large effects, and the set of variables normally included in such models.

### Interactions and feedbacks

Macroeconomic models treat the economy like a system, with various interactions and feedbacks between its different parts. This makes them particularly well suited for analysing policies that have widespread effects on the larger economic system, or to analyse the effect of a combination of several policies, the effects of which may not simply add up in a straightforward manner. In the context of energy efficiency improvements, consider the implementation of a range of different improvement measures. The full effect on energy savings will likely not simply be the sum of all the individual effects, as there are interactions between them. For example, two energy efficiency actions considered within COMBI are improved energy efficiency of cars, and modal shift in passenger transport. In this setting, the resulting reduction in energy use will be due in part to better energy efficiency, and in part to the modal shift. In this situation, the total effect due to better energy efficiency will be smaller than what it would have been in the absence of a modal shift. Such interactions are kept track of in a macroeconomic model – the effect of a combination of policies is not just the sum of its parts.

The notion that all markets are interconnected, and that in an economic system everything can affect everything else, through changing relative prices, is captured in the concept of general equilibrium (GE).[2] As a concrete example, the system properties of macroeconomic models mean that any rebound effects associated with energy efficiency improvements can be endogenously included in the model structure, through changes in relative prices.

### Non-marginal effects

A policy may have large, or – in economist's jargon – non-marginal effects. In a traditional CBA, available estimates for various effects are likely to be marginal: how would outcome variables of interest change if a small policy change was introduced. This should not be surprising, since economics is all about how to value things on the margin. In practice, however, policy projects can be large, and just scaling up the marginal effect by multiplying it with the size of the policy change may not give the correct figure. Within a macroeconomic model, this can be taken into account.

[1] The use of a macroeconomic model is not restricted to ex-ante policy evaluations. A model could equally be used after a policy has been introduced, and data relating to policy measures and outcome variables can be used to calibrate the model. This will result in a model based ex-post policy evaluation.

[2] A GE occurs when there is a set of prices that make supply and demand equalize in all markets simultaneously, taking into account the interactions between markets. Changes in demand or supply in one market will in principle change the equilibrium prices in all other markets too.

### Macroeconomic variables

Certain variables are necessarily macroeconomic in their nature, and as such they cannot properly be assessed outside of a macroeconomic framework. Examples of such variables are relative prices, GDP, employment, public budgets and welfare. A more detailed discussion of each of these variables follows.

### Relative prices

Macro models include various prices, such as the prices of factors of production (e.g., wages and energy prices), relative prices across different sectors in the economy (prices of manufactured goods and of services), and average price levels across countries (real exchange rates). The general equilibrium structure of macro models means that these prices are not taken as given, but are determined inside the model, as the outcome of processes whereby supply and demand are allowed to equilibrate. Changing relative prices are important to keep track of, for two reasons. Firstly, changing relative prices will likely have distributional effects, for example if the economy shifts away from manufacturing and towards production of services. Secondly, they are an effect of the feedbacks and interactions mentioned above. Indeed, these general equilibrium interactions, which include changing relative prices, are the reason that policy effects on GDP, welfare, employment and public budgets are best assessed with a macro model.

### GDP and Employment

Gross Domestic Product (GDP) is a measure of the total monetary value of all goods and services produced in an economy over a year. Direct effects of economic policies on GDP can be assessed in a traditional CBA, but to the extent that relative prices change, a macroeconomic model is needed to capture the full effect of interactions and feedbacks.

Effects of economic policy on employment are particularly difficult to assess properly without a macroeconomic model. This is because the "creation" of a job somewhere in the economy is likely to go hand in hand with the loss of a different job somewhere else in the same economy. If the economy is in a recession, this means that there is cyclical unemployment, and there is scope for economic policy to reduce unemployment in the short run. However, as the business cycle evolves over time, and the economy comes out of recession and into a boom, cyclical unemployment will disappear. In this situation, any jobs created by policy will not be "additional". In the long run, increased employment can be achieved only through expanding the labour supply (bringing more individuals into the work force), or by reducing frictional or structural unemployment. Policies to achieve such goals are very different from policies to reduce cyclical unemployment.

The proportion of an economy's working-age population that is in paid employment (including self-employment) is referred to as the employment rate. The employment rate can change over time, due to three principal effects.

- Movements in and out of the labour force. Individuals are classified as not in the labour force when they are neither working nor looking to find work. This category consists of individuals who are long-term sick or disabled, who have taken early retirement, who are homemakers, etc.
- Changes in cyclical unemployment: this is unemployment that rises in a recession and falls in a boom.

Changes in frictional unemployment:[3] this is unemployment that arises when individuals are between jobs. Old jobs disappear and new ones are created all the time, and the length of time it will take an average laid-off worker to find a new job is determined not only by whether the economy is in a recession or in a boom. It also depends on structural (long-term) determinants such how well workers' skills match what employers look for, employment protection legislation, unemployment benefits, etc. Several EU Member States appear to be in a situation of long-term unemployment due to a permanent lack of demand for labour in relation to the productive potential of the workforce, even during phases of economic upswing. To the extent that energy efficiency investment requires more labour and brings more net benefits to the economy than other investment alternatives, energy efficiency may reduce this type of structural unemployment.

#### Public budget

The public budget is the balance of income and expenditure of an economy's public sector. The public budget may be in deficit in a given year, which will add to any debt that has already been accumulated, or in surplus, which will reduce the outstanding debt.

Economic policies will often change consumption patterns, which has effects on the public budget, both directly and through feedbacks. A subsidy on healthy foods, for example, will likely increase consumption of the products covered by the subsidy. This raises additional tax revenue, e.g. in the form of VAT. However, when consumers spend more on healthy foods, they must spend less on other things – less healthy foods perhaps, or indeed something else entirely. This reduced consumption will bring about a reduction in VAT revenue. An analysis focusing only on the market for healthy foods will miss these feedback effects, and lead to the wrong conclusion.

#### Welfare

Welfare is a measure of how well off a society is, including the enjoyment all households in the economy derive from the goods and services they consume, but also any other factors that affect their quality of life, such as inequality or environmental issues. While GDP and welfare tend to be closely related in macroeconomic models, welfare can go up while GDP falls. An example of this is a policy that causes a fall in industrial production in order to reduce environmental pollution. Such a policy would be desirable precisely when the loss in GDP would be more than offset by the value to society of reduced pollution – in other words, when welfare increases due to the policy.

When using a macroeconomic model for policy evaluation, the total welfare change is the sum of all effects, positive and negative, due to the policy. As such, the total welfare change is the macro-model counterpart to the bottom line in a CBA, but including all feedbacks that arise through changing relative prices.

## 3.2 Types of macro models

A simplistic categorization of macroeconomic models is to divide them into two broad categories: short-run and long-run models. Developed economies have long exhibited long-run trends of

[3] The term "structural unemployment" is also used. The two concepts differ slightly, in that "structural" unemployment usually refers to long periods of mismatch between unemployed workers' skills and the skills sought after by employers. "Frictional" unemployment is rather the "usual" spells of unemployment between jobs. In practice, it is hard to make a clear distinction between the two.

increasing economic activity, and short-run fluctuations around this trend. The two broad types of macroeconomic models have been developed to reflect these two properties of aggregate economies.

### Short-run macroeconomic models

Since Keynes's General Theory (1935) it has been widely agreed that short-run variations in economic activity are fluctuations around a long-run equilibrium level, and that economic policy should, if possible, seek to minimize these fluctuations.[4] This is due to so-called "nominal rigidities" – prices and wages are slow to adjust to the levels required for markets, especially labour markets, to clear in the short run. In the longer run, prices are free to adjust, and the economy should return to its long-run state – unless another shock hits the system that throws it off equilibrium. This process of shocks and slow adjustments to long-run equilibrium is referred to as the business cycle. Short-run macroeconomic models are designed for analysing the properties of the business cycle, and for evaluating counter-cyclical policies. These models are typically used in e.g. ministries of finance to assess the short-run impact of fiscal policy such as increased stimulus on economic activity, employment and public budgets. They are not used to assess overall welfare gains in the economy. Short-run models can be classified into two broad categories: macroeconometric models and Dynamic Stochastic General Equilibrium (DSGE) models. The main difference between these categories is that DSGE models are "microfounded" (see below), whereas macroeconometric models are not.

### Long-run macroeconomic models

These models ignore the short-term business-cycle fluctuations, and focus on the long-run equilibrium, or trend. Long-run models can also be grouped into two categories: Computable General Equilibrium (CGE) models, and growth models. Growth models characterize how an economy's GDP grows over time. These models are dynamic, in the sense that they describe not only different long-run equilibria, but the transition process between them as well. Another type of long-run models are so-called CGE models. These models tend to be static rather than dynamic, i.e., they are used to describe different long-run equilibria, but don't say much about the transition between these equilibria. In contrast, CGE models are often fairly detailed in their treatment of sectors of the economy (industrial production, manufacturing, services, etc.), which is typically not the case with growth models.

### Microfoundations of macroeconomic models

An important property of macroeconomic models is whether they are "microfounded" or not. This goes back to the so-called "Lucas critique" (Lucas 1976), which demonstrated that empirically observed relationships between variables are not always appropriate to use for policy evaluations. An important insight behind this critique was the role of expectations in creating economic outcomes: what households and firms believe about the future strongly influences what will actually happen. In the context of energy efficiency improvements, expectations about future prices of alternative technologies, as well as about relevant policies, are crucial. When households decide whether to switch from a traditional car to an electric one, for example, the expected costs

[4] Proponents of the so-called Real Business Cycle school of macroeconomics may disagree. In their view, it is the equilibrium that fluctuates continuously, and no economic policy could improve overall welfare. In other words, the economy is always at an optimum, and governments should therefore leave it to the market to operate on its own.

associated with the two alternatives will likely play an important role. Such a calculation relies on expectations about future fuel prices, about taxes and subsidies, including $CO_2$ prices, and about how quickly new infrastructure for electric vehicles will be built. For firms deciding how much resources to spend on developing better electric vehicles, such considerations are equally important.

More generally, Lucas (1976) argued that policy evaluations should be carried out using "microfounded" models, the aggregate properties of which are derived from microeconomic behaviour of individual agents. This includes an explicit consideration of discount rates, i.e., how economic agents value the future relative to the present, as well as of how households and firms make decisions when faced with various kinds of risk. Today, long-run macro models tend to have such microeconomic foundations, while this is not always the case with short-run models. Traditional short-run macro models use econometrically estimated equations for some macroeconomic regularities. In contrast to such macroeconometric models are the so-called DSGE models, which have strong microeconomic foundations. Some properties of different kinds of macroeconomic models are summarized in Table 1 below.

**Table 1: Macroeconomic models**

| | Time | Sectors | Key variables | Microfounda-tions | Examples |
|---|---|---|---|---|---|
| **Short-run** | | | | | |
| Macroeconometric | Dynamic | A large number | Unemployment, inflation, output gap | No | Models used in finance ministries and central banks |
| DSGE | Dynamic | A small number | Unemployment, inflation, output gap | Yes | |
| **Long-run** | | | | | |
| Growth | Dynamic | One or a few | Output, investment, welfare | Yes | DICE, RICE |
| CGE | Usually static | Relatively few to large numbers | Output (by sector), trade flows | Yes | EPPA, other GTAP-based models |

## Model applications

Short-run macroeconomic models are used for assessing macroeconomic stabilization policy, i.e., fiscal and monetary policy. The purpose of such policy is to reduce business-cycle fluctuations by stimulating the economy in downturns, and cooling it down in a boom. This means reducing cyclical unemployment, pushing the inflation rate up or down (as the case may be), and reducing the size of the output gap (the difference between the economy's potential output and its actual output). This requires a short-run macro model, with explicit representations of cyclical unemployment, inflation and the output gap. Both macroeconometric and DSGE models are used for this purpose. The advantage of macroeconometric models is that they are technically simple and easy to solve, which allows for a highly detailed sectoral structure. They lack proper microfoundations, however, which means using them for evaluating structural policy changes may lead to incorrect conclusions. DSGE models do not suffer from this problem, but are instead technically more complex, which means the sectoral detail must be less detailed. In practice, both types of models are used by ministries of finance and by central banks to forecast short-term economic trends and to assess policy, with unemployment and inflation rates as important output variables. Examples of DSGE models used in European central banks are the ECB's "New Area-Wide Model" (Christoffel et al, 2008) and the Swedish Riksbank's Ramses model (Adolfson et al, 2013).

Long-run macroeonomic models, on the other hand, are used for evaluating policies that affect the long-term equilibrium in the economy. Examples include trade policy (reducing import tariffs and quotas), innovation policy (subsidies to research and development activities), and education policies (improving skill levels in the labour force).[5]

One application of *CGE models* is in trade policy, often based on the data and modelling framework in GTAP (e.g., Narayanan et al, 2015). Such models describe trade flows of various types of goods between countries, and how they are affected by tariffs and other trade barriers, as well as changing relative prices in general – both within and across countries. Recent examples include Copenhagen Economics (2012a), which assesses the economic impacts for the EU of entering into an agreement on Foreign Direct Investment with China, and Francois et al (2013), which evaluates trade and welfare effects of the proposed Transatlantic Trade and Investment Partnership (TTIP).

CGE models often make use of *input-output (I-O) tables*. An input-output table keeps track of how intermediate inputs are used in the production of final inputs. For example, in order to produce steel, both energy and steel are needed as inputs. As to energy production, that will likely require both energy and steel as inputs as well. A similar situation occurs when goods produced in one country are used as inputs in the production of goods in a different country. These interdependencies between markets can be kept track of using I-O tables, which collect data on flows of intermediate inputs between sectors or countries.

Several studies have also used modelling based on I-O tables alone to calculate employment changes in different sectors following energy efficiency investments. However, such an approach falls short of modelling all macroeconomic impacts that could change the employment effects through further interactions between variables.

*Growth models* focus on the trade-off between the present and the future. Key variables in a growth model are savings and investment, which are the channels through which households decide how much of their current income to consume today, and how much to set aside for future consumption. This gives rise to a certain accumulation of physical capital, and one outcome of the model is the equilibrium interest rate. The structure of a growth model makes it well suited for analysing how changes in overall productivity will affect capital accumulation, GDP growth, wages and interest rates, and ultimately social welfare. Growth models have been used to study how innovation leads to higher productivity, which drives growth (e.g., Romer 1990), and how to optimally tax factors of production in order to raise funds for public spending (e.g., Chamley 1986; Judd 1985). More recently, growth models have also been used to answer the question how to best tax emissions of greenhouse gases, see e.g. Nordhaus (2008); more on this below.

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[5] The effects of such policies may of course manifest themselves already in the short run; the main distinction between short and long run effects is that the long-run effects are in principle permanent, whereas the short-run effects interact with the business cycle, and will essentially be washed away over time, as the economy moves through booms and recessions.

Some variables have a very different interpretation in short-run and long-run models, respectively. Examples of such variables are employment and unemployment. In a short-run model, unemployment fluctuates with the business cycle around a long-run equilibrium level. Whenever employment falls short of this long-run or trend level, fiscal or monetary policy that can push the employment level up is desirable. Such "job creation" efforts are not beneficial to the economy when times are good, however. When the employment level exceeds the equilibrium level, using policy to "create jobs" will not improve welfare in the economy. When there are few idle resources in the economy, creating new jobs will come at a cost of destroying other jobs, and to the extent that these newly created jobs are actually "additional", they will inevitably contribute to overheating the economy. It is important to note, therefore, that policy to create jobs through public spending is only beneficial to the economy at times when output is below potential.[6]

This is not true for long-run unemployment. In a long-run setting, employment is at its long-run level on average – there is no cyclical unemployment. To the extent that there is long-run unemployment, this stems from a mismatch between the skills that workers have, and the skills that employers require, or from a slow matching process, whereby successful employer-employee matches take a long time to materialise. Such unemployment cannot be addressed through stimulating the economy with public spending, as one would with cyclical unemployment. Rather, to reduce this kind of unemployment would require policies to improve the process of matching between employers and prospective employees, such as education and training, or reforming labour market policies. In addition to reducing long-term unemployment, long-term employment can be increased by expanding the labour supply, through policies that induce more people to join the labour force. Candidates for such policy measures are again labour market policies, or improvements in the efficiency of taxation.

## 3.3 Energy in macroeconomic models

Following the distinction between the short and long run laid out above, the macroeconomic effects of energy efficiency improvements (EEI) can be grouped into the same categories: short-run, or business-cycle, effects on the one hand, and long-run, or structural, effects on the other. The distinction between the two is not a matter of time scale as such, but rather the nature of the effect. Short-run effects are those that influence the business cycle in relation to the long-run trend, while long-run effects influence the long-run trend itself.

Some macroeconomic models explicitly incorporate energy production and consumption. As an example, William Nordhaus's DICE model (Nordhaus, 2008) is a calibrated[7] model of the world economy, where society as a whole decides how to best divide today's world GDP between consumption and saving, but also how much energy to use in production of goods and services. The model includes a measure of energy efficiency on a global macroeconomic scale, which determines how much "energy services" the world can extract from a given amount of energy. Energy use requires burning of fossil fuels, which causes emissions of greenhouse gases (GHGs),

[6] In practice, to know whether the economy is operating above or below its long-run potential at a given point in time, one will need an idea of what this long-run potential output is. While potential output is not directly measurable, short-run macro models use time-series data to estimate how the potential output level changes over time.

[7] Here, "calibrated" should be taken to mean a model that is not just a collection of assumptions and formulae, but where values have been assigned to relevant parameters and starting values, and where the model output are actual numbers for relevant variables.

which in turn gives rise to climate change, which destroys some of global GDP in future time periods. All of this is captured in the model, which is used to calculate the optimal consumption of fossil-fuel based energy. The model output also includes an optimal tax on emissions of GHGs, i.e., the tax that would maximize global welfare. This model structure, with an explicit measure of energy efficiency in the context of global welfare maximisation, permits an analysis of the welfare effects of energy efficiency improvements, and their implications for the optimal tax on GHG emissions.

While traditional growth models use one level of productivity for all economic activity, recent growth models have considered "energy saving technology" as a particular type of productivity that saves on energy, rather than all input factors taken together (e.g., Hassler et al, 2010). This approach treats energy efficiency improvements as determined within the model, rather than an exogenously assumed process.

Recent developments in applied macro-energy modelling include various calibrated hybrid and coupled models, which combine several modelling frameworks into a larger model. One example is the E3ME model (see e.g., Cambridge Econometrics, 2014), a model of the world economy that contains both a macroeconometric short-run component, as well as a CGE long-run component, coupled with a detailed energy system component. Another example is the LIFT model, developed at the University of Maryland. LIFT is a hybrid model of the US economy, again with both a macroeconometric component and a CGE component. LIFT has been coupled with MARKAL, an energy system model, for example in Steckley et al (2011), to analyse how energy efficiency policy influences energy demand. A different kind of hybrid is EPPA (Paltsev et al, 2005), a model of the global economy with both CGE and growth-model features, as well as a detailed energy system component. EPPA has been used mainly to analyse how policy affects emissions of GHGs and other pollutants. Barker et al (2007a) use MDM-E3, a macroeconometric model for the UK economy, coupled with bottom-up estimates of effects of UK energy efficiency and climate policies.

### 3.4 How should this be related to energy efficiency

Macroeconomic models are often used to assess reductions in energy use due to EEI policies, including rebound effects.[8] Barker et al (2009) assess the rebound effect for the world economy, following energy efficiency policies for 2013-2030 discussed in IEA (2006), and find a long-run global rebound effect of around 50% of the savings, if not counterbalanced by additional policies.

In terms of employment and GDP, studies to date have focused mainly on the short-run employment effects, and the associated effects on GDP. Whether such effects are large or small, or even welfare improving, depends substantially on whether the policy is introduced at the right point in the business cycle, as stressed in Copenhagen Economics (2012b).

EEI policies can have important effects on global energy prices, as well as both relative energy prices between countries and relative prices of different energy sources. Price and trade effects are not always incorporated in an endogenous fashion in macro-energy modelling efforts. For example, the IEA's World Energy Outlook publications have traditionally treated energy prices as

[8] Examples include Allan (2006) and Barker et al (2007b), and the collection of articles in Huntington and Smith (eds., 2011).

exogenous scenario assumptions in their forecasts. IEA (2012) introduced a different approach with endogenous energy prices. This made it possible to estimate that a 14% reduction in global primary energy demand (in 2035) would be associated with an oil price reduction of 16 USD per barrel, relative to a baseline scenario. EE improvements that take place regionally rather than globally will affect relative energy prices between countries, which will have knock-on effects on trade, in energy as well as in goods and services whose production requires energy. Therefore, to properly assess price and trade effects, a modelling approach that explicitly deals with trade will be useful. This is especially relevant for large policy changes, with large demand effects. In an EU context, the implications of energy demand reductions also depend on whether they happen inside or outside the ETS sector, which can also be captured in a macro model.

Table 2 below illustrates our planned approach to analysing the macroeconomic effects of energy efficiency improvements, based on this literature review. The table lists a few examples of EE measures, which are representative of the range of measures on the COMBI shortlist. The analytical approach to evaluating these measures depends on whether you are interested in business-cycle effects or long-run/structural effects. Examples of important short-run considerations are the amount of initial investment required, and the speed of implementation of the policy. Potential short-run employment effects are determined by these factors, but also depend on whether the investment is likely to involve spending on local labour costs. Important structural effects include the direct effects on energy demand (including rebound effects), productivity effects stemming from other multiple impacts, and various relative price effects.

**Table 2: Macro-effects of exemplary specific EE improvements**

| | **Short-run effects** | | | **Structural effects** | | |
|---|---|---|---|---|---|---|
| **Measure** | **Investment required** | **Employment effects** | **Speed of implemen-tation** | **Direct effects on energy demand** | **Productivity effects** | **Relative price effects** |
| Building envelope improvements in existing buildings | Substantial investments, public or private | Large potential | Relatively quick | Direct effect of less energy use + rebound effect | Health and comfort effects, leading to labour productivity improvements | Lower energy demand may affect energy prices |
| Improved energy efficiency of road vehicles, through efficiency mandates | None initially (mandates). Later (private) investment in new vehicles, and in R&D | Little potential | Full effect likely to take a long time to manifest itself | Direct effect of less fuel use + rebound effect | In longer run, additional effects from R&D and innovation | Road transport may become relatively cheaper, leading to a shift from rail to road transport. Possibly also a demand shift from traditional fuels towards biofuels/electricity. |
| Process heating in steel production | Improvements to furnaces; new (better) furnaces. | Some potential | Depends on lifetime of installed machines | Direct effect of less energy use in production | | Steel intensive products cheaper compared to other products. Also, domestic steel more competitive in trade. |

These three measures differ in terms of investments required, and hence in their short-run employment effects. To improve existing building envelopes will require a substantial amount of investment upfront. In addition, a large part of the costs involved will be labour costs, which suggests a large short-run employment potential. Investing in improved or better furnaces for steel production will also involve substantial investments, but the employment effects may not be as large. This is because new furnaces are a capital expense, and to the extent that such machinery is imported, the main employment effect may happen outside of the domestic economy. With stricter standards for the energy efficiency of road vehicles, there may be no initial employment effect at all, if the policy measure is a mandate for new cars. Over time this may lead to investment into R&D activities, but again this effect may happen largely outside the domestic economy. In assessing short-run effects of a measure, it is important to take into account its speed of implementation – if the intended effects of a policy measure only materialise slowly over time, it may turn out to be very difficult to effectively use the measure for short-run macroeconomic stabilisation.

In terms of structural effects, all measures are associated with reductions in energy demand, with potential rebound effects that need to be accounted for. Additional benefits come in the form of productivity effects. For example, better insulation in buildings may lead to higher labour productivity, both through better health of workers, and also directly through better comfort in the working environment.[9]

All measures are also likely to have relative price effects. For example, more efficient furnaces in steel production lowers the cost of producing steel, which has two effects. On the one hand, it makes steel-based products cheaper relative to other products, which have not experienced a similar reduction in production costs. On the other hand, it lowers the cost of producing steel domestically, relative to steel production elsewhere in the world, where similar energy efficiency improvements have not been introduced. This makes domestically produced steel more competitive on world markets, which will affect trade patterns.

As to more efficient road transport, this makes road transport relatively cheaper, compared to, say, rail transport. This may lead to greater demand for road transport. This is part of the rebound effect. Over time, the policy may lead not just to more energy efficient cars, but also to vehicles running on different fuels. Consumers may substitute fossil-fuel based transport for electricity or biofuel based transport, to a greater extent than would have happened in the absence of this policy measure. This will lead to changing relative prices for different energy sources, which may in turn lead to more investment into R&D in renewable technologies for transport, further boosting productivity in the long run.

# 4 Methodological challenges

## 4.1 Additionality and baseline issues

In a policy evaluation, it is important to know what the default or baseline outcome is. Fortunately, this is easy to deal with in the context of a macroeconomic model. A model can be set up and

[9] Here is a link between COMBI WPs 3 and 5, which will study these issues, and WP6 on macro effects.

calibrated to historical data, and then run in a “baseline setting”, without accounting for the policy in question. The outcomes of this run is the baseline used for comparisons. The model can then be run in a “policy setting”, and the policy evaluation consists in comparing the outcome of such a run with the established baseline.

### 4.2 Distributional aspects

The distributional aspects of macroeconomic effects can be inter-temporal or intra-temporal. Inter-temporal aspects concern how the costs and benefits of a policy are distributed over time – the costs of the policy may show up at implementation, whereas the benefits may only materialise in the future. Such a policy shifts welfare from the present to the future. Many macroeconomic models are dynamic, and as such they can easily address inter-temporal distributional concerns. To the extent that the same individual is alive both at implementation and at later stages, the overall effect on this individual can be worked out using a net present value, of income or utility, over their lifetime. To the extent that different generations are involved, the welfare effect to society can be calculated using a similar approach – the overall welfare effect is the net present value of, for example, yearly welfare effects, which in turn are aggregations of individual yearly utilities.

Intra-temporal distributional aspects deal with how benefits and costs of a policy are distributed across different individuals or households at one point in time. To address such issues, some heterogeneity between households (e.g., differences in income or wealth levels, or in productivity) is needed. This is typically not included as a first step in macro models, but can be added on if deemed relevant.

### 4.3 Interrelationships between multiple benefits

There are potential interactions between the various multiple benefits of EEI, and the macroeconomic benefits are themselves often a consequence of other multiple benefits, such as productivity improvements from better health and comfort due to better indoor climates (WP5), as well as from reduced pollution (WP3). There are also links to energy security (WP7), through changes in the structure of demand and supply of energy at the macro level. Macroeconomic modelling is actually a way to address this. Different benefits can be combined in a consistent way in the same macro model run, and the net welfare effect will be found. One can then carry out separate model runs, including only certain benefits, to get at the partial effects of individual benefits.

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