BRISKEE

Behavioural Response to Investment Risks in Energy Efficiency

D4.3: WORKING PAPER ON MACROECONOMIC MODELLING

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Contents

1 Introduction

In this paper, the macroeconomic effects of energy efficiency measures in households in the EU-28 will be analysed. It is part of the project BRISKEE (Behavioural Response to Investment Risks in Energy Efficiency). The BRISKEE project has the objectives of providing evidence-based input to energy efficiency policy-making by investigating the role of household decision-making on three levels:

1. On the micro level, the project provides empirical evidence on the factors that influence investment decisions for energy efficiency technologies in households, in particular focusing on the role of household preferences for time discounting and risk, accounting for possible differences by technologies, household types, and countries.

2. On the meso level, the project explores the impact of time discounting and risk preferences, and of policies affecting those factors on technology diffusion and energy demand in the residential sector in Europe up to 2030. The project uses inputs from the micro-level analysis in order to improve the representation of investment decisions in energy demand modelling tools.

3. On the macro level, BRISKEE explores the long-term macroeconomic impacts of changes in micro-economic decision-making and of energy efficiency policy on employment and GDP in the EU up to 2030. The macroeconomic modelling uses input from the scenarios generated in the energy demand models.

Energy efficiency is one of the main pillars of European climate and energy policy (European Commission 2010, 2011c, 2011d, 2011b, 2011a). Improving energy efficiency can also deliver a range of economic benefits to the European society (OECD/IEA 2012). Next to individual-level and sectoral benefits, such as increases in household incomes and the competitiveness of companies, on the macroeconomic level energy efficiency may have desirable effects on GDP, employment, trade balances, and security of energy supply.

Energy efficiency has been widely studied on the micro level, whereas only a small number of studies have analysed the macroeconomic impacts of energy efficiency. The IEA (2014) provides a good overview of the multiple levels on which energy efficiency can have an impact. On the macro level, Integrated Assessment Models (IAMs) are often used to capture the multiple macroeconomic mechanisms unfolding in the wake of energy efficiency measures. Pollitt et al. (2016), using the macro-econometric E3ME model, expect overall positive impacts on GDP and employment in Europe, whereas a considerable negative impact is predicted upon extraction utilities and EU Member States where this sector has a high share. In a global study on measures to close the 2020 emissions gap, Barker et al. (2015) find positive impacts of energy efficiency on GDP with a global increase of 0.5 % by 2020 and a reduction of unemployment and the creation of 6 million net jobs by then. Turner (2009), using a Computable General Equilibrium (CGE) model, finds positive GDP and employment effects of energy efficiency in the UK. However, she analyses a case in which the energy efficiency improvement is exogenous and costless. Also concentrating on the UK economy and using the MDM-E3 model, Barker et al. (2007) find a positive development for GDP and employment until 2010 under energy efficiency policies.

Other reports do not base their studies on complex models but use other quantitative or qualitative methods for the evaluation of the macroeconomic impacts of energy efficiency. Mirasgedis et al. (2014) evaluate the impact of energy efficiency policies on the Greek building and construction sector and find evidence for significant employment benefits. However, they do not use a dynamic macroeconomic model, but a static Input-Output Model. Furthermore, even though they account for positive benefits of energy cost savings reallocated to other consumer goods after the initial investment phase, they do not tackle the impacts which might happen during the investment phase if energy cost reductions are not high enough to compensate for investment outlays. Saunders (2013) focuses on the fuel/GDP ratio by using a top-down theoretical macroeconomic model of a neoclassical growth variety to find the qualitative conclusion that the increase in GDP due to a reduction in fuel consumption is most likely small. Croucher (2012) studies the impact of energy efficiency standards for the Southwestern States of America by using a qualitative method and discussing how these may be incorrectly estimated or even completely ignored within the literature. He finds evidence that by trend the economic effect of energy efficiency is over-estimated: Energy efficiency standards tend to create jobs in relatively low-paid sectors (e.g. retail and service sector) which comes at the cost of a reduction of employment in higher paid job sectors (e.g. utility sector). A review by the OECD/IEA (2012) comes to the conclusion that regarding the creation of jobs with a short lead time, energy efficiency has significant potential. Net improvement in this case can be traced back to energy efficiency programs through direct job creation on the one hand and indirectly through consumer surplus spending. A reduced unemployment rate can additionally be beneficial for the national budget.

Previous meta-analysis of growth and employment effects of energy policies have shown that various factors are important to interpret results (see Walz and Schleich 2009). Among the most important ones are the level of no-regret-potentials, which drive down net costs for the economy, the assumptions about capital markets and macroeconomic situations, which influence the level of crowding out effects of investments, and the composition of the economy analysed, especially whether or not investment goods and energy is produced domestically or imported. Furthermore, policy instruments play an important role, especially if the energy policy is accompanied by a green tax reform, which lowers labour cost simultaneously to reduced energy consumption, and provides for a substitution towards higher labour input. Finally, modelling characteristics play a role, e.g. the difference in results of CGE models compared to Keynesian econometric models. All this leads to the conclusion that there is still uncertainty with regard to the outcome of energy efficiency improvement. Clearly, the results quoted above cannot be transferred directly to the changes in energy efficiency, which are analysed within the BRISKEE project.

The paper is structured as follows. Section 2 presents the methodological approach used for modelling the macroeconomic effects of energy efficiency improvements. Section 3 summarizes the macroeconomic impulses generated from the energy demand projections of the energy demand models Invert/EE-Lab and FORECAST. The results of the macroeconomic analysis are presented in chapter 4, which closes with a discussion and interpretation of the results.

2 Methodological approach

This section describes the methodological approach that is applied in the BRISKEE project for transferring the results from the energy demand modelling (WP 3) into the inputs for the macroeconomic model ASTRA (WP 4).

2.1 Characterization of macroeconomic effects of energy efficiency measures

Accelerating the adoption of energy efficiency technologies and services inevitably affects the whole economy through structural effects of the impulses resulting from the energy efficiency strategy, which induce further effects on the macroeconomic level (Walz and Schleich 2009; IEA 2014): An energy efficiency strategy induces positive and negative demand impulses. On the one hand, increased investments in energy efficiency technologies and services constitute a positive impulse on the economy. On the other hand, the reduction of energy demand leads to reduced demand for the output of the related sectors; they are negative impulses. The effect of differences in magnitude between positive and negative impulses are subject to theoretical discussions between neoclassical oriented economists and Keynesian economists:

- From a neoclassical perspective, additional demand effects are likely if the negative impulses surmount positive impulses, and vice versa. An example for the first case are energy efficiency investments, which exceed the reduction in energy demand. Then it can be assumed, that a real increase in domestic demand for some goods is only possible if other forms of demand are reduced. Thus, in the neoclassical tradition, the sum of positive and negative domestic impulses is assumed to be zero, and additional investments in energy efficiency crowd out other forms of demand (e.g. private consumption) to ensure this identity. In order to prevent misunderstandings, it has to be stressed that positive impulses of energy efficiency exceeding negative ones do not necessarily translate into these measures imposing additional costs for the investors: Energy efficiency investments reduce energy costs during the life-span of the technologies, that is also long after the initial investment taking place. The macroeconomic condition of positive impulses equalling the negative impulses, however, is set for each period of time, and relates for streams of investments. Thus, in the short and medium run (e.g. between 2020 and 2030), a strategy which increases investment in energy efficiency is likely to involve higher positive impulses than negative energy demand impulses. This has to be compensated for by lower consumption impulses in this time period. In the long run, however, that is beyond 2030, the effects of energy efficiency investments taken between 2020 and 2030 still continue to reduce energy demand. Thus, there is a different time dimension between positive and negative impulses: investments and associated negative compensation effects take place early, but savings accrue over lifespan of products, so negative impulse and associated positive compensation remains after investment period..
- In a more Keynesian flow of arguments, the economy might not be operating at its full production potential. There are various explanations for that, such as price and wage stickiness. Recently, various explanations have been brought forward why the economic crisis has led to extended periods of low interest rates with low inflationary pressure, and demand being lower than supply. Global savings gluts (Bernanke 2015) might be one explanation. Persistent liquidity traps (Eggertson and Krugman 2012), or - in the tradition of Alvin Hansen - secular stagnation (Krugman 2014; Eggertson et al. 2016; Summers 2015 and 2016) are two others, which are in particular consistent with positive effects of demand stimulation. Under these assumptions, additional demand can be met without crowding out other forms of demand. In this case, the differential between positive and negative impulses can be met

for example by deficit financed public subsidies or by private savings without crowding out effects.

The structural demand effects of positive and negative demand impulses induce further macroeconomic effects, and contribute to a change in the structural composition of the economy. Additionally, the reduction of energy demand lowers the dependence on imported fossil fuels, which has a positive impact on national trade balances. Changes in the structural composition of the economy also contribute to changing imports, and lead to effects on the average labour intensity of the economy. The effects are described in Table 1.

Table 1: Effects resulting from investments and energy cost reductions for consumers of energy efficiency technologies

Effects resulting from investments (positive impulses)	Energy efficiency investments increase demand in sectors providing energy efficiency technologies and services, leading to increased production and employment in these sectors and the upstream sectors related to them. Furthermore, they enhance the chances of domestic producers to increase their technology exports.
Effects resulting from energy cost reductions (negative impulses)	Energy savings reduce spending on energy, leading to reduced production and employment in these sectors, and the upstream sectors related to them.
Effects resulting from compensation of impulse differentials	The differences between investment increases (positive impulses) and energy cost reductions (negative impulses) may affect disposable income and thus consumption in economic sectors not related to energy efficiency. In a neoclassical tradition, it can be assumed that the sum of positive and negative impulses equals zero.
Macroeconomic income effects	Changes in production of investment and consumption goods lead to changes in income, which induce further multiplier effects. The impact of these macroeconomic effects on sectors differ, and add to changes in the structural composition of the economy induced by the positive and negative impulses.
Effects resulting from changes in the structural composition	The economic sectors differ with regard to import shares and labour intensity. Thus, macro-level changes in the sectorial composition of the economy lead to changes in overall import and labour intensity of an economy.

Estimating the macroeconomic effects of energy efficiency policy requires a detailed understanding of how the policy measures act on the micro level. For example, policy measures that address investments in thermal insulation have an effect (among others) on the construction sector, whereas product policy measures have an impact on the sectors that produce such products. It is therefore necessary to evaluate the projected energy savings at a technologically detailed level. The methodological approach applied in the BRISKEE project creates a coupling between the detailed bottom-up energy demand models Invert/EE-Lab (for buildings) and FORECAST (for appliances) with the macroeconomic system dynamics model ASTRA-EC. The coupling approach combines technology-based engineering knowledge in the relevant energy-using sectors with a macroeconomic perspective by taking advantage of the detailed data on technologies in the energy demand models, and of the dynamic input-output structure in the macroeconomic model. The approach therefore addresses one of the shortcomings of macroeconomic modelling, which generally represents sector details, but does not support technology details (IEA 2014).

2.2 Modelling approach

The macroeconomic effects of the energy efficiency policy scenarios generated in WP 3 of the BRISKEE project are analysed using a three-step methodology (see Figure 1). In the first step, the investments and energy cost reductions induced in the scenarios are calculated using a detailed bottom up modelling approach. In a second step, the investments and savings are allocated to the affected economic sectors. In a third step, the macroeconomic impacts are calculated using the dynamic input-output based macroeconomic model ASTRA-EC. The methodological approaches that are applied in each of the three steps are outlined in the following subsections.

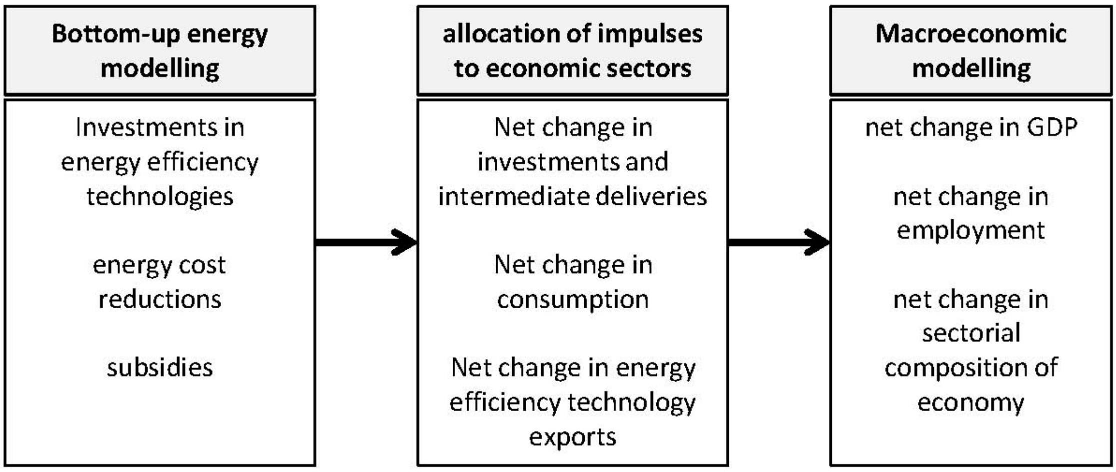

Figure 1: Modelling approach

2.2.1 Bottom-up energy demand projections (step 1)

The data on energy demand and investments are based on the scenarios presented in D 3.1 of the BRISKEE project, where energy demand projections are provided using bottom-up simulation models that capture the diffusion of energy efficiency technologies. The energy demand modelling platform FORECAST[1] is used for projecting the energy demand of residential appliances. The modelling platform Invert/EE-Lab [2] is used for projecting the energy demand for buildings.

The energy demand models include a detailed technology database and use a logit approach for modelling decision-making including observed barriers and heterogeneous expectations among decision makers (households or companies). The modelling approaches for the three policy scenarios include a mix of policy measures to support an accelerated diffusion of energy efficiency technologies, including minimum efficiency requirements and standardization, taxes, subsidies and a range of information-based measures (for details see BRISKEE D 3.4, forthcoming).

1 www.forecast-model.eu
2 www.invert.at

2.2.2 Allocation of investments and savings to economic sectors in input output tables (Step 2)

In order to transfer the outputs of the bottom-up modelling (WP 3) to the macroeconomic model ASTRA-EC (WP 4), the changes in investments, consumption, energy demand and subsidies are allocated to the economic sector classification of the Input-Output tables used in ASTRA-EC. In the bottom up models, investments and energy savings are calculated considering individual energy efficiency measures and are not necessarily in the same sectoral classification as the economic sectors in the Input-Output tables. For each energy efficiency measure, it is therefore necessary to allocate the results from step 1 to the economic sectors of the Input-Output-tables. Furthermore, it is necessary to determine the sectoral splits of the changes in the consumption bundle. The following sections outline how the results are transformed for residential appliances and residential buildings.

Residential appliances
For residential appliances, the macroeconomic effects are driven by the (individual) investments in energy efficient appliances undertaken by consumers (whose investments are treated as consumption in national accounting, except for investments in the building infrastructure – see following section) and the energy cost reduction for consumers. Both the investments and the energy cost reductions are included in the consumption vector, where the investments lead to increased consumption in sectors producing energy efficient residential appliances. The energy cost reduction leads to decreased consumption in the electricity-providing sector. The consumption changes are not simply additive; they are multiplied by sectoral elasticities and overall consumption shares are re-normalised, so that there is no aggregate consumption change. This distinction is important since it is not assumed that bottom-up policies change the marginal propensity to consume.

Residential Buildings
For buildings, deriving the inputs for the macroeconomic modelling is more complex due to the variety of efficiency technologies, investors, financing mechanisms and the landlord-tenant structure. The energy efficiency technologies can be split up into two broad categories: building envelope (i.e. thermal retrofits) and heating, ventilation and air conditioning (HVAC) technologies. The HVAC technologies are further split up into the following types:

1. Fossil
2. Biomass
3. Heat pumps
4. District Heating
5. Electric Heating
6. Solar Thermal

In addition to different technologies, different constellations of landlords and tenants (private households and companies) should be considered in macroeconomic analyses if the respective information is available.

The energy efficiency investments of **private home owners** enter the input-output module of the macroeconomic model through the investment vector, where the elements corresponding to the sectors producing the efficiency technologies and providing services related to the installation of these technologies increase. As stated in the previous section, private households' expenditures are entirely contained in the consumption vector with the exception of investments in the building infrastructure, which are portrayed by the investment vector. The resulting energy savings, on the other hand, are portrayed by a decrease in the element of the consumption vector corresponding to the energy sector. The investments in thermal retrofits and efficient HVAC technologies are typically financed through varying combinations of subsidies, credits, and private capital. In the case of subsidies received by private households, government expenditures are modelled to rise. Credit financing increases the consumption vector element corresponding to the financial sector. The reduced savings level and the increased value of the buildings are not considered in the model (see also Table 2).

Energy efficiency investments of **private landlords** are also represented by increasing the investment vector elements corresponding to the sectors producing the efficiency technologies and credit services. The energy cost reduction of the tenant is represented by decreasing the element of the consumption vector corresponding to the energy sector. The financing of private landlords' investments is portrayed in the same way as that of private home owners.[3] Similar to the case of residential appliances, the investments in HVAC technologies and corresponding energy savings do not lead to a change in aggregate final demand but merely a shift between consumption purposes (see also Table 2).

Commercial landlords for residential buildings: even though a fraction of the residential buildings are owned by companies, housing associations or housing cooperatives (in Germany, about 35 % of all rented properties), this distinction is not made in the BRISKEE project due to a lack of data. Energy efficiency investments of the housing industry and residential building cooperatives would also be represented by increasing the element of the investment vector that corresponds to the sectors producing efficiency technologies as well as related services. The energy savings of the tenant (private household) would be represented by decreasing the value of the consumption vector element corresponding to the energy sector, analogous to tenants of private landlords. Also analogous to private landlords, the energy efficiency investments are typically financed through varying combinations of subsidies, credits, and retained earnings. The difference between private and commercial landlords therefore only lies in a slightly differing portrayal of investments and subsidies, which is assumed not to have a large influence on the aggregated macroeconomic effects.

Table 2: Macroeconomic impulses from energy efficiency measures for buildings

	Drivers for macroeconomic effects	**Representation in macroeconomic model**	**Relevant sectors**	**Effects**
Private home owners and private landlords	Investments	Investment vector	Minerals, chemicals, metal products, industrial machines, electronics, plastics, construction, other market services	Increase
	Energy savings	Consumption vector	Energy	Decrease
	Financing	Consumption vector	Banking and insurance	Increase

2.2.3 Macroeconomic modelling (Step 3)

3 In Germany, it is possible to pass on the costs of the energy efficiency investments to the tenants through an 11% increase of the rent (§559 of the German civil code). However, not all EU countries have such schemes in place and little data is available on whether landlords actually make use of this clause.

The macroeconomic model ASTRA-EC is at the core of the BRISKEE macroeconomic analysis in WP 4. ASTRA-EC is based on the System Dynamics methodology and emphasizes dynamic interactions, the integration of differences in short- and long-run effects and an explicit modelling of supply-side restrictions. The model contains 25 economic sectors and uses the time span from 1995 to 2013 for calibration. The model equations are empirically evaluated and, as a result of econometrically estimated equations, the agents in the model are myopic and thus the model philosophy employs the concept of bounded rationality.

Figure 2 provides a schematic illustration of the modelling logic of ASTRA-EC and shows how the main policy impacts derived from the energy demand models (WP 3) flow into the macroeconomic modelling in WP 4. As outlined in the previous section, the energy efficiency measures covered in the energy demand models lead to changes in investments (e.g. investments in energy efficiency technologies) and consumption (e.g. reduced energy demand). As indicated in *Figure 2*, these bottom-up impulses are integrated in ASTRA-EC mainly by changing the investment demand and consumption vectors. Consumption (together with investment, government expenditures and exports) forms the second quadrant of input-output tables, which is equivalent to final demand when imports are subtracted. Final demand represents the demand side of the economy. It is complemented by the supply side, which is fed by capital, labour and technological progress, representing the production potential of the economy. Gross Domestic Product (GDP) is derived by balancing both the supply and the demand sides of the economy. GDP growth initiates further growth in consumption, triggering investments to meet this new consumption demand (white arrow in *Figure 2*). These feedback effects between GDP, income, consumption, investments and again GDP are a key feature of ASTRA-EC and allow for the modelling of induced effects of the implementation of energy efficiency measures. Taking into account these induced effects is particularly important when modelling the long-term macroeconomic effects of energy efficiency policy. A more detailed description of ASTRA-EC can be found in the Appendix.

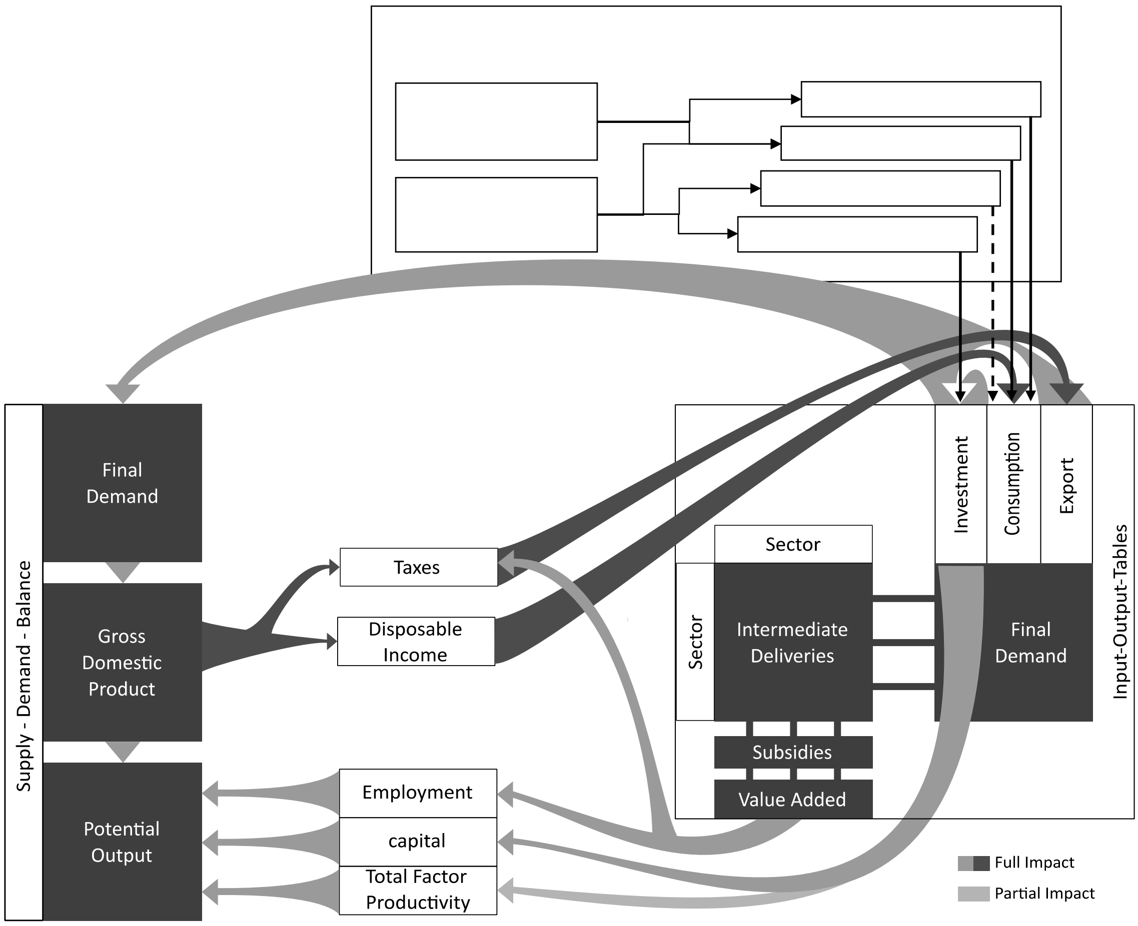

Figure 2: Macro-economic modelling logic in ASTRA-EC. Source: own illustration

The impulses derived from the bottom-up energy demand models are implemented in ASTRA-EC in the following manner (cf. *Figure 2*):

- Consumption changes due to investments in appliances are implemented as relative changes to the baseline scenario in the consumption vector without changing overall consumption. This affects the elements of the consumption vector corresponding to the sectors producing energy efficient appliances.
- Investment changes due to investments in efficient heating technologies for buildings are implemented as relative changes to the baseline scenario in the investment vector without changing the overall level of final demand. The changes in the investment vector apply to sectors that produce energy efficient building technologies.
- In private households, energy is regarded as a consumption good and a reduction of energy demand is applied as a reduction in the consumption vector. The only affected sector is the energy sector.
- Subsidies are applied to the government sector and thus change government consumption and the government budget. The positive consumption impulse counteracts the consumption normalisation outlined in section 2.2.2 by re-increasing overall consumption at the level of the subsidies. However, higher government expenditures may induce a crowding out effect due to government borrowing or increase in revenues.

- Additional exports of energy efficiency technologies increase final demand. As these exports are financed by non-EU countries, no crowding-out effect within the EU has to be taken into account.

These impulses not only directly affect the sectors producing appliances and efficiency technologies for buildings but also indirectly affect other sectors through the interconnectedness of the economy. The reduction in energy demand also indirectly leads to reductions in energy imports. In addition, the changes in consumption induce further macroeconomic effects, including a change in aggregate value added (GDP), leading to subsequent changes in the overall investment volume, employment and productivity. Therefore, the production potential of the economy may change as a result of the energy efficiency measures.

3 Macroeconomic impulses

This section summarizes the output from the energy demand models on the country level. The energy demand models deliver investment impulses for each country and technology. These investment impulses are then broken down into sectoral impulses per country based on detailed sector mappings for each technology covered (see Figure 3). The energy demand impulses are allocated to the energy sector and the subsidies to the government sector (see section 2.2.3). The country-level impulses for appliances and building technologies are summarized in sections 3.1and 3.2, respectively. In addition, the output from the export scenarios, which are based on improving the competitiveness of the European suppliers of energy efficiency investment goods, are presented.

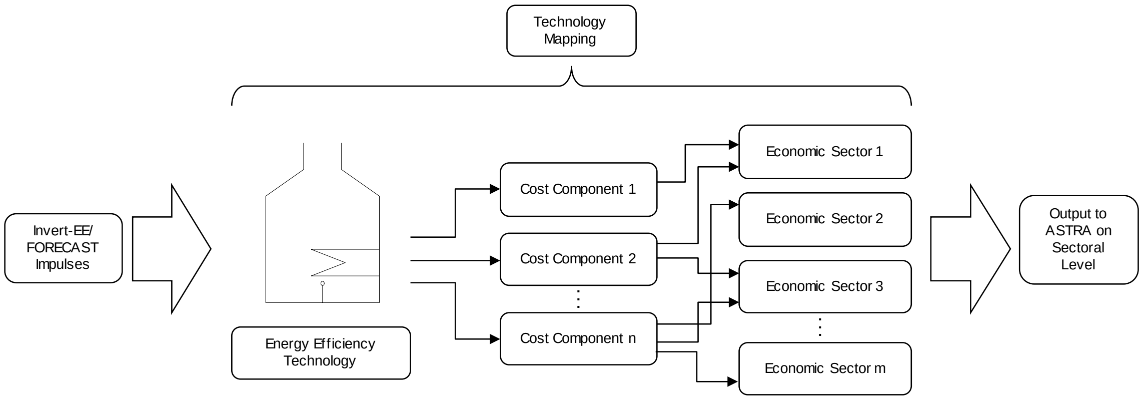

Figure 3: Illustration of the impulse conversion for the macroeconomic modelling, own illustration

3.1 Appliances

This section presents the outputs from the energy demand model FORECAST for appliance and lighting technologies, e.g. refrigerators, washing machines, lighting and televisions.

3.1.1 Investments

The following table shows the differences of investments to appliance and lighting technologies as the differences between the increased-policies scenario or the new actor-related policies scenario and the current-policy scenario.

Table 3: Overview of differences of investments in appliance and lighting technologies in Mio EUR, difference (D2) between increased-policies scenario and current-policy scenario, difference (D3) between new actor-related policies scenario and current-policy scenario

	2020		2025		2030	
Country/scenario	**D2**	**D3**	**D2**	**D3**	**D2**	**D3**
Austria	44.5	111.1	387.4	392.7	355.8	360.2
Belgium	94.0	215.9	718.3	743.6	645.8	670.7
Bulgaria	57.3	98.7	223.0	223.8	229.4	230.5
Croatia	72.0	143.5	328.2	336.7	310.0	318.2
Cyprus	13.0	20.3	46.6	48.3	41.8	43.3
Czech Republic	29.6	65.6	218.6	227.2	202.7	210.6
Denmark	33.7	95.5	460.3	470.9	385.6	394.4
Estonia	11.4	17.5	56.1	56.4	46.3	46.8
Finland	35.1	85.6	426.9	433.7	372.3	379.1
France	460.9	1114.9	3959.8	4086.4	3499.9	3623.3
Germany	255.3	956.0	3736.4	3885.3	3075.6	3235.0
Greece	151.1	227.1	462.2	482.0	413.7	431.8
Hungary	44.8	72.3	193.1	196.0	185.3	188.6
Ireland	75.5	123.3	290.6	298.5	287.6	295.2
Italy	999.9	1993.5	4558.2	4676.3	4305.5	4419.9
Latvia	8.2	14.1	31.4	31.0	30.1	29.7
Lithuania	13.8	21.8	46.2	45.8	42.3	41.9
Luxembourg	4.6	9.0	32.8	33.2	32.7	33.0
Malta	5.8	8.6	21.3	22.3	18.9	19.7
Netherlands	109.5	305.7	1159.8	1196.2	1062.6	1098.1
Poland	96.5	215.8	776.2	783.9	688.8	695.3
Portugal	90.6	173.5	445.1	463.9	375.0	391.0
Romania	155.2	258.4	737.0	740.9	619.3	622.0
Slovakia	11.8	25.0	81.9	83.2	73.9	75.7
Slovenia	15.8	47.3	137.0	141.2	118.3	122.8
Spain	690.7	1038.2	2003.8	2078.9	1888.1	1956.7
Sweden	64.4	165.1	827.7	841.6	734.8	747.5
United Kingdom	297.5	1031.8	4184.5	4280.1	3642.5	3738.7

3.1.2 Energy expenditures

The following table shows the differences of energy costs for appliance and lighting technologies as the differences between the increased-policies scenario or the new actor-related policies scenario and the current-policy scenario.

Table 4: Overview of differences of energy costs for appliance and lighting technologies in Mio EUR, difference (D2) between increased-policies scenario and current-policy scenario, difference (D3) between new actor-related policies scenario and current-policy scenario

	2020		2025		2030	
Country/scenario	**D2**	**D3**	**D2**	**D3**	**D2**	**D3**
Austria	-49.0	-57.8	-151.3	-180.2	-197.9	-241.5
Belgium	-66.0	-74.8	-189.5	-219.6	-249.7	-298.8
Bulgaria	-7.6	-10.0	-31.7	-40.7	-54.7	-69.9
Croatia	-11.1	-13.5	-47.6	-57.0	-75.5	-90.5
Cyprus	-5.5	-6.7	-15.0	-18.7	-18.5	-24.4
Czech Republic	-19.7	-22.1	-63.9	-73.2	-83.7	-96.4
Denmark	-61.6	-67.6	-171.8	-191.5	-177.0	-203.3
Estonia	-7.9	-8.1	-16.8	-17.6	-14.7	-15.8
Finland	-57.4	-58.9	-129.8	-134.0	-92.6	-99.2
France	-273.3	-343.2	-903.4	-1135.5	-1231.5	-1573.3
Germany	-615.8	-791.0	-2501.0	-3167.6	-3825.5	-4890.1
Greece	-61.8	-75.4	-168.3	-210.7	-220.6	-290.2
Hungary	-15.8	-17.3	-51.2	-56.2	-62.1	-69.2
Ireland	-59.1	-62.1	-131.0	-140.6	-113.4	-127.7
Italy	-153.5	-187.8	-661.0	-792.3	-1048.5	-1256.9
Latvia	-3.7	-4.1	-11.0	-12.4	-14.3	-16.4
Lithuania	-7.1	-8.4	-19.0	-22.3	-25.1	-30.6
Luxembourg	-1.4	-1.8	-7.0	-8.3	-12.3	-14.5
Malta	-0.9	-0.9	-2.3	-2.5	-2.7	-3.0
Netherlands	-106.8	-122.6	-310.1	-362.5	-401.2	-486.1
Poland	-28.2	-36.8	-147.5	-178.6	-259.2	-309.8
Portugal	-37.3	-41.3	-112.4	-126.4	-126.0	-144.5
Romania	-36.7	-43.7	-115.2	-136.5	-156.5	-188.7
Slovakia	-11.8	-14.4	-31.1	-38.4	-45.2	-57.0
Slovenia	-7.4	-8.8	-17.7	-21.8	-23.3	-29.8
Spain	-186.2	-245.9	-614.3	-804.5	-903.7	-1210.2
Sweden	-131.3	-149.7	-348.1	-401.0	-383.0	-459.7
United Kingdom	-577.0	-635.5	-1479.4	-1664.3	-1548.5	-1814.7

3.2 Buildings

This section presents the data input from the energy demand model Invert/EE-Lab to the macroeconomic model ASTRA-EC. The data exchange focuses on differences in costs and spending on energy carriers and investments into heating systems as well as thermal renovation measures. Please also see the summary report of WP3 for details on energy demand developments in the building sector for building technologies, e.g. heating systems and insulation.

3.2.1 Investments

The following table shows the differences of investments in building technologies as the differences between the increased-policies scenario or the new actor-related policies scenario and the current-policy scenario. The investments include investments into heating systems as well as investments in thermal retrofit measures (excluding maintenance measures without efficiency improvements).

Table 5: Overview of differences of investments in building technologies (heating systems and thermal retrofits) in Mio EUR, difference (D2) between increased-policies scenario and current-policy scenario, difference (D3) between new actor-related policies scenario and current-policy scenario

	2020		2025		2030	
Country/scenario	**D2**	**D3**	**D2**	**D3**	**D2**	**D3**
Austria	46.0	145.8	63.3	288.0	63.7	215.1
Belgium	349.6	605.0	465.0	574.3	254.5	410.7
Bulgaria	212.8	352.1	247.7	404.2	319.3	440.4
Croatia	11.6	185.0	38.7	235.4	50.2	281.1
Cyprus	18.9	30.1	25.5	44.0	25.8	48.0
Czech Republic	315.0	544.3	422.7	780.4	695.5	983.1
Denmark	-73.7	18.8	7.4	133.2	-17.8	163.0
Estonia	56.8	93.3	74.9	105.2	57.9	99.8
Finland	29.6	553.8	37.9	550.8	113.7	565.9
France	5196.8	7587.6	4791.8	7349.4	5140.7	9275.9
Germany	6493.3	7040.0	6272.5	5087.3	6732.4	8062.0
Greece	1030.3	1298.9	753.3	854.5	33.5	389.5
Hungary	0.0	28.7	85.3	202.2	-45.2	272.1
Ireland	261.8	343.8	341.8	489.1	448.4	567.5
Italy	541.5	4673.4	1633.3	4304.7	2445.9	4600.2
Latvia	-16.0	10.7	-18.9	24.1	-23.1	24.8
Lithuania	38.0	90.2	44.7	106.1	56.4	125.3
Luxembourg	-3.8	3.1	7.8	18.3	1.3	29.2
Malta	15.1	19.3	22.3	24.4	20.4	26.1
Netherlands	196.6	660.5	68.8	578.2	151.8	425.9
Poland	2431.3	2546.1	3013.5	2721.5	3279.8	3462.5
Portugal	331.1	314.0	144.3	160.9	132.9	222.4
Romania	56.9	418.1	7.1	357.7	-5.4	457.4
Slovakia	3.4	60.5	11.6	55.2	27.6	72.2
Slovenia	266.5	350.7	249.1	300.9	176.5	271.0
Spain	-146.9	-266.9	-156.6	77.1	229.3	656.2
Sweden	97.1	396.6	149.3	508.9	295.6	547.5
United Kingdom	3662.2	5260.2	5268.5	6711.1	7358.1	9044.9

3.2.2 Energy expenditures

The following table shows the differences of energy costs for building technologies as the differences between the increased-policies scenario or the new actor-related policies scenario and the current-policy scenario.

Table 6: Overview of differences of energy costs for building technologies in Mio EUR, difference (D2) between increased-policies scenario and current-policy scenario, difference (D3) between new actor-related policies scenario and current-policy scenario

	2020		2025		2030	
Country/scenario	**D2**	**D3**	**D2**	**D3**	**D2**	**D3**
Austria	134.4	109.3	-155.0	-205.8	-276.7	-348.6
Belgium	-98.2	-149.8	-217.1	-335.8	-244.1	-476.3
Bulgaria	-54.0	-116.7	-146.4	-255.0	-267.1	-418.0
Croatia	0.9	-64.8	-13.6	-139.1	-40.7	-216.8
Cyprus	-0.9	-3.8	-2.9	-6.8	-4.5	-10.7
Czech Republic	-137.0	-245.7	-462.3	-641.2	-825.9	-1098.3
Denmark	-335.0	-379.9	-288.4	-399.5	-332.1	-538.7
Estonia	-7.9	-14.0	-17.1	-27.0	-25.2	-38.7
Finland	-14.9	-42.7	-24.9	-112.9	-39.4	-184.6
France	-1950.8	-2888.6	-2582.3	-4516.7	-3218.2	-6452.0
Germany	-1252.2	-1453.0	-2302.4	-2548.0	-3304.9	-3602.5
Greece	-138.3	-266.0	-316.7	-512.5	-349.3	-651.2
Hungary	-3.4	-36.1	-54.5	-103.6	-125.9	-199.1
Ireland	-73.3	-136.8	-164.3	-265.0	-265.3	-425.8
Italy	-36.7	-476.6	-254.0	-837.8	-603.3	-1188.9
Latvia	-17.4	-20.0	-36.6	-49.6	-57.8	-79.7
Lithuania	-6.1	-18.1	-23.8	-45.1	-40.3	-71.7
Luxembourg	-0.8	-5.6	-5.5	-14.1	-7.7	-23.8
Malta	-0.2	-1.6	-1.0	-2.5	-1.4	-2.3
Netherlands	-48.1	-189.5	-123.0	-338.6	-266.4	-542.1
Poland	-1554.0	-1533.5	-3218.0	-2695.0	-4853.5	-4181.4
Portugal	-11.3	-23.9	-14.0	-37.8	-16.9	-48.5
Romania	16.6	-39.2	30.2	-67.9	55.3	-94.0
Slovakia	-7.9	-32.5	-22.4	-54.3	-46.3	-82.5
Slovenia	-40.8	-114.8	-175.2	-250.6	-173.3	-281.3
Spain	151.8	86.1	217.4	52.9	192.1	-37.4
Sweden	-204.8	-361.1	-341.9	-594.3	-493.7	-822.9
United Kingdom	-774.2	-1500.5	-1904.0	-2968.2	-2731.8	-4530.0

3.2.3 Subsidies

The following table shows the level of subsidies per country for building technologies as the differences between the increased-policies scenario or the new actor-related policies scenario and the current-policy scenario.

Table 7: Overview of differences of subsidies for building technologies in Mio EUR, difference (D2) between increased-policies scenario and current-policy scenario, difference (D3) between new actor-related policies scenario and current-policy scenario

	2020		2025		2030	
Country/scenario	**D2**	**D3**	**D2**	**D3**	**D2**	**D3**
Austria	258.3	263.1	274.9	277.7	286.1	277.7
Belgium	17.6	18.5	26.7	29.9	29.9	29.5
Bulgaria	156.6	206.9	189.7	243.5	219.4	274.8
Croatia	3.4	2.9	3.6	3.5	3.2	4.3
Cyprus	15.7	15.9	20.8	21.1	23.0	22.6
Czech Republic	133.9	193.9	193.1	279.4	255.0	299.5
Denmark	38.1	35.8	37.4	33.0	33.3	31.3
Estonia	39.3	41.0	41.1	41.2	40.8	43.1
Finland	-12.1	24.2	8.0	36.4	24.8	60.3
France	1253.6	1337.0	1709.1	1898.3	2001.0	2364.9
Germany	-237.5	-235.6	226.6	200.8	252.4	139.1
Greece	957.9	1044.9	679.8	694.2	302.1	315.4
Hungary	110.6	113.5	116.9	119.7	118.3	127.2
Ireland	470.2	508.6	566.9	623.1	603.6	655.7
Italy	88.0	118.4	84.4	120.3	56.8	130.0
Latvia	12.4	12.7	10.3	10.4	9.8	10.0
Lithuania	13.3	15.8	15.1	17.0	16.2	18.5
Luxembourg	0.9	1.2	1.3	2.0	1.4	1.7
Malta	14.7	15.7	18.1	18.8	20.3	21.5
Netherlands	146.2	153.7	154.1	158.3	177.9	169.6
Poland	329.2	322.2	271.0	282.4	211.5	227.5
Portugal	211.4	198.9	103.7	93.9	93.0	99.2
Romania	142.0	237.8	146.8	246.6	159.7	348.4
Slovakia	29.9	40.0	5.0	17.1	5.3	14.8
Slovenia	85.7	105.2	73.9	87.9	56.9	69.7
Spain	144.4	107.4	102.0	80.2	12.7	75.4
Sweden	93.6	110.3	126.3	130.1	114.4	117.3
United Kingdom	199.7	296.9	326.9	392.7	502.1	599.2

3.3 Exports of energy efficient technologies

Globally successful technological innovations are commonly established first in one country or region before being adopted internationally (Quitzow et al. 2014). Countries or entire regions such as the EU can establish demand and supply-based lead markets through dedicated policy action before the domestic demand for a technological innovation emerges. In the past, Europe has been very successful in this respect: Even if we eliminate Intra-EU trade, our analysis shows that Europe has been supplying 27.5 % of the world trade in technologies relevant for energy efficient appliances, and 19.5 % of world trade in technologies relevant for energy efficiency in buildings in 2014.[4] Within the lead market concept, it is argued that countries forging ahead can improve their competitiveness, and can realise higher export potential of the technologies involved. Thus, in the case of renewable energy, such lead market or first mover advantages were taken into account in modelling the employment effects of European RES policies (Duscha et al. 2014 and 2016).

Traditionally, it was thought that lead market suppliers originate mainly in traditional OECD countries. This concept has therefore strongly influenced European policy in the past and has focused research on activities related to lead markets (for the renewable sector, see Walz 2006, for the European Lead Market Initiative, see CSES and Oxford Research 2011, and for demand-led innovation policies, see Edler et al.2012). This concept is also one of the rationales behind European Flagship Initiatives such as "Resource Efficient Europe", which links increasing resource efficiency to securing growth and jobs for Europe, by stimulating innovation, improving competitiveness and opening up new export markets**.** The globalisation of innovations along value chains (Pietrobelli and Rabelotti 2011), and the success of various emerging economies in building up innovation capabilities can also be seen for green technologies (Walz et al. 2017). Therefore, the concept of lead markets from a demand and supply perspective has been broadened recently to include emerging economies (Cleff and Rennings 2012, Quitzow et al. 2014, Walz and Köhler 2014, Diederich 2016).

Indeed, the data shows that the lead of the EU in energy efficiency technologies on the world market is becoming smaller: Compared to the figures quoted above for 2014, the EU accounted for 30 % of energy efficient appliances in 2003, and 23.5 % of technologies relevant for energy efficient buildings. In order to build sound scenarios of future exports of energy efficiency technologies, it is important to reflect upon the most important mechanisms. For technology-intensive goods, which include energy efficiency technologies, high market shares depend on the innovation ability and the achieved learning effects of a national economy and its early market presence. Taking the globalisation of markets into account, this requires the establishment of competence clusters which build on specific national competitive advantages and are difficult to transfer to other countries with lower production costs. These competence clusters must consist of high technological capabilities linked to a demand which is open to new innovations and horizontally and vertically integrated production structures (Quitzow et al. 2014; Walz and Köhler 2014):

- Demand-based diffusion patterns of a technology may create price advantages for countries based on both economies of scale and learning (Beise-Zee and Cleff, 2004). It can also be expected that user-producer linkages increase if the technology diffuses through the (home) market. Widespread diffusion therefore also leads to the improvement of future technological capability. Demand advantages also allow to develop a market which takes up global demands earlier than others. Thus, it can be assumed that the increase in diffusion in

4 Data on world trade and patents of energy efficiency technologies were obtained from the Fraunhofer Lead Market Data base (see Walz and Eichhammer 2012).

energy efficiency technologies in the EU, which is assumed in the two scenarios compared to BAU, will also increase international competitiveness due to the demand advantages.

- International trade performance depends on technological capabilities (for an overview see Dosi and Soete 1988 or Fagerberg 1995). Thus, indicators which measure technological capability are also important with regard to competitiveness. A common indicator for technological advantage is patent specialisation (Walz and Eichhammer 2012). Our calculations reveal that the EU shows a worldwide patent share of 44 % for appliances and 38 % for building relevant energy efficiency technologies. This is above the share for all technologies. This results in a significant positive specialisation on these technologies, as shown by the RPA values.[5] Thus, the EU shows a substantial technological advantage. If the domestic diffusion increases, this will lead to further learning effects. Furthermore, if the diffusion policies assumed in the scenario are supported by policies which strengthen the research capabilities of the European actors, it can be assumed that the technological advantage in the diffusion scenarios will be higher compared to BAU.

- On the supply side, demonstration effects may create so called transfer advantages: If countries show a high level of successful technological applications, they will find it easier to export their products. The transfer effect works in favour of countries which enjoy a high technological reputation. Countries which already are active in exporting a technology, and who enjoy a competitive trade advantage, are more likely to be successful in the future, too. With growing division of labour on a worldwide basis, it can be assumed that trade specialisation will increase. As shown above, the EU enjoys a high export share. Perhaps even more important is that Europe is specialising on exporting technologies. It shows a positive Relative Trade Advantage (RXA) of 42 for appliances, and 8 for building technologies. Thus, the EU shows considerable strength in this area, and there is a good starting point that improvements in other advantages are supported by a transfer advantage.

The scenarios of future export of energy technologies have to reflect the changing nature of world trade. Prior to the financial crisis, the world exports for all goods were increasing by 7 % annually. After the financial crisis, this has slowed down to about 3 %. Forecasts do expect that there are also structural reasons, which will lead to export growth rates of merchandise on the order of magnitude of 3 % annually, with the center of exporting countries shifting more towards emerging economies. (PWC 2014; OECD 2014; HSBC 2016). For energy efficient appliances and building technologies, the tremendous growth rates (15-20 % annually) before the financial crisis have been reduced substantially to 6.5 % for appliances and 5 % for building technologies after the financial crisis. For the future, we assume that the difference in export growth rates for merchandise and energy efficient technologies will remain the same. The assumption that the growth rate for energy efficiency technologies remains higher than the average can be justified with the above average growth in markets for energy technologies, but also with trends to lower tariffs for energy efficiency technologies in relation with the Environmental Goods Agreement (Sugathan 2015). Thus, with an export growth rate of about

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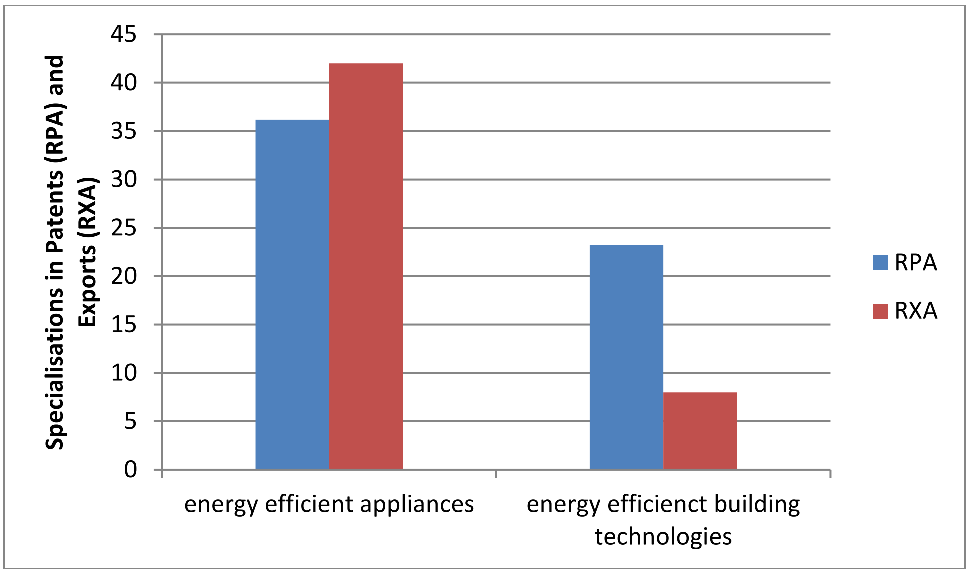
5 For every country i and every technology field j the Relative Patent Activity (RPA) is calculated according to: $RPA_{ij} = 100 * \tanh \ \ln [(p_{ij} / \sum_i p_{ij}) / (\sum_j p_{ij} / \sum_{ij} p_{ij})]$.

The Relative Export Advantage (RXA) is calculated in a similar way as the RPA, by substituting patents (p) by exports (x), respectively. All specialization indicators are normalized between +100 and –100). Positive values indicate an above average specialization in the analyzed technology; negative values show that the country is specializing more in other technologies.

3 % for merchandise exports on average until 2030, we assume future world exports to grow by 6.5 % annually for energy efficient appliances, and 5 % annually for building technologies.



Source: Calculations of Fraunhofer ISI, based on data from PATSTAT and UN COMTRADE

Figure 4: Specialisation of the EU on patents and exports of technologies relevant for energy efficient appliances and building technologies

For the BAU case, we assume that the trend of falling EU export shares will continue as has been the case between 2003 and 2014. This is in line with the forecasts that the share of emerging economies in exports of merchandise will continue to increase. The trend extrapolation until 2030 for BAU indicates that EU export shares for appliances will fall to 25.5 % and for building technologies to 11.4 %. In contrast, we assume for the D2 and D3 scenario that the EU will support the increasing demand advantage (see above) with innovation policies to strengthen the supply side and technological advantage. Furthermore, with a growing division of labour, countries will be especially successful in fields in which they are already specializing. Thus, it seems plausible that increased demand and technological advantages will lead to higher export shares in D2 and D3 compared to BAU. Therefore we assume in the D2 and D3 scenario that the EU will be able to hold its world export share in energy efficient appliances and building technologies at its 2014 level. This leads to additional exports compared to BAU of about 9 billion Euro. The additional exports were allocated to the EU countries according to their export share in 2014. The resulting technology export impulses for the countries are shown in Table 8.

Table 8: Overview of differences of technology exports for appliances and building technologies in Mio EUR, difference between increased-policies scenario/new actor-related policies scenario versus current-policy scenario

	2020		2025		2030	
Country/scenario	**appliances**	**buildings**	**appliances**	**buildings**	**appliances**	**buildings**
Austria	13.7	68.9	31.9	158.7	58.7	291.9
Belgium	24.1	66.3	55.9	152.7	102.7	280.9
Bulgaria	3.3	5.6	7.6	12.9	13.9	23.8
Cyprus	0.0	0.3	0.0	0.8	0.1	1.4
Czech Republic	18.9	98.1	44.0	225.8	80.9	415.4
Denmark	19.8	37.4	46.0	86.2	84.5	158.6
Estonia	1.4	10.6	3.3	24.4	6.0	44.9
Finland	12.2	23.9	28.2	55.1	51.9	101.4
France	55.6	123.8	129.2	285.2	237.5	524.6
Germany	180.3	442.4	418.7	1018.8	769.5	1874.2
Greece	0.6	4.1	1.3	9.5	2.4	17.6
Hungary	15.4	15.2	35.8	35.0	65.9	64.4
Ireland	1.9	9.6	4.4	22.0	8.0	40.5
Italy	120.8	237.7	280.5	547.4	515.5	1007.0
Latvia	0.5	4.6	1.2	10.6	2.2	19.5
Lithuania	2.8	11.9	6.5	27.3	11.9	50.3
Luxembourg	3.8	6.1	8.9	14.0	16.3	25.7
Malta	0.0	0.0	0.1	0.0	0.2	0.0
Netherlands	29.9	88.0	69.4	202.7	127.6	372.9
Norway	7.3	2.7	16.9	6.2	31.0	11.4
Poland	27.6	76.9	64.0	177.1	117.7	325.8
Portugal	6.4	10.1	14.9	23.3	27.4	42.8
Romania	2.7	5.6	6.3	12.9	11.5	23.8
Slovakia	2.7	31.6	6.2	72.8	11.3	133.9
Slovenia	3.8	12.4	8.8	28.5	16.2	52.5
Spain	19.8	35.3	46.0	81.3	84.6	149.5
Swiss	10.5	33.8	24.5	78.0	44.9	143.4
Sweden	19.9	19.3	46.3	44.5	85.0	81.9
United Kingdom	38.6	55.8	89.7	128.6	164.9	236.6

3.4 Overview of total impulses

Figure 5 gives an overview of all impulses which are used as input for the macroeconomic model. The impulses increase over time, however only slightly after 2025. The new actor-related scenario generally mobilizes higher impulses than the increased policies scenario. The green bars in Figure 5 represent the additional negative impulses, which are assumed for compensating the difference between positive investment and negative energy demand impulses. Nevertheless, in total, the positive impulses slightly exceed the negative ones. There are two reasons for this: First, the impulse of positive technology exports are not subject to the paradigm of positive impulses equaling negative ones. However, this effect is small. Second, we assumed that the subsidies from governments to finance energy efficiency also do not fall under the paradigm of positive impulses equaling negative ones. Thus, there is a Keynesian element in our analysis, by assuming that governments can raise these subsidies without inducing a crowding out effect. However, the ratio between these subsidies and the compensating effects is roughly between 25% and 35 %. Thus, with compensating effects being two to three times higher than Keynesian modelled subsidies, our analysis is more tilted towards neoclassical assumptions.

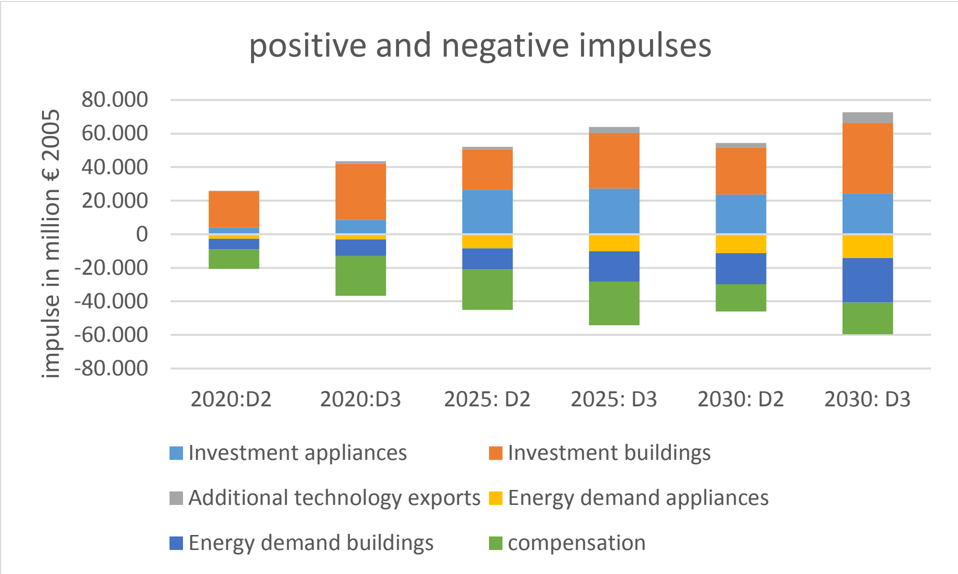


Figure 5: Overview of positive and negative impulses, difference (D2) between increased-policies scenario and current-policy scenario, difference (D3) between new actor-related policies scenario and current-policy scenario

4 Macroeconomic effects

The investment, energy expenditure, subsidy and export impulses serve as inputs for the macroeconomic model ASTRA, which is used for the assessment of macroeconomic effects. As described above, these impulses represent the difference between the increased-policies scenario (D2) or the new actor-related policies scenario (D3) and the current-policy scenario, which is also referred to as the business-as-usual (BAU) scenario. The simulation of macroeconomic effects is conducted for the period from 2012 to 2030. All monetary indicators are portrayed in real terms in 2005 €. Thus, the unit "€" henceforth refers to 2005 €. The model calculations are performed on a yearly basis. In order to increase readability, some macroeconomic results are presented as averages between the years 2012 and 2030.

The investment and export impulses have a positive effect on the sectors which provide investment goods in the form of appliances, efficiency technologies and insulation for buildings. The energy demand reduction has a negative effect on the energy sector. Depending on the relationship between the investment impulse and the energy expenditure impulse, a different reaction is supposed for final consumption. If the energy savings are higher than the investment impulse, the saved money is assumed to be spent on other goods, and aggregate consumption increases accordingly. If the investments in one country are higher than the associated energy savings, it is assumed that aggregate consumption has to be reduced accordingly. This consumption reduction is alleviated by subsidies, which however increase government expenditures that have to be alimented by the private sector. Thus, from a macroeconomic real goods perspective, the spending on energy efficient technologies has an investment character: in the year of the investment, there might be a crowding out of other elements of final demand, if the achieved reduction of energy consumption is not strong enough. However, in the following years, the energy efficiency technologies also lead to energy demand reductions, which enable higher consumption expenditures. In our D2 and D3 scenarios, there are flows of investment between 2012 and 2030. The effects of the investments taking place in later years also have a payback in form of reduced energy consumption which takes place after 2030. Thus, it has to be kept in mind that the modelling time frame does not cover all of the positive effects of the impulses.

Figure 6 illustrates that the overall effect on GDP and employment on the European level is relatively small in both scenarios. Over the entire simulation period, the average EU 28 GDP is 0.11 % above the current-policies scenario in the increased-policies scenario (D2), and 0.17 % above the current-policies scenario in the new actor-related policies scenario (D3). The effects on employment in full time equivalents (FTE) are even smaller: The results point towards an increase of 0.01 % in the increased-policies scenario and 0.013 % in the new actor-related policies scenario. In absolute terms, these changes equate to 17 billion € of additional EU 28 GDP per year in the D2 scenario and 25 billion € additional yearly GDP in the D3 scenario. The yearly changes in European employment are approximately 17.000 additional jobs in FTE in the D2 scenario and 26.000 additional jobs in FTE in the D3 scenario.

The development of the relative GDP change in both scenarios is relatively uniform across the entire simulation period, with a small increase in the growth rate towards the end of the simulation period (see Figure 7). The yearly change in employment does not increase so uniformly as the GDP change. It reaches a local maximum around 2020, declines slightly and then increases again similarly to GDP towards the end of simulation period.

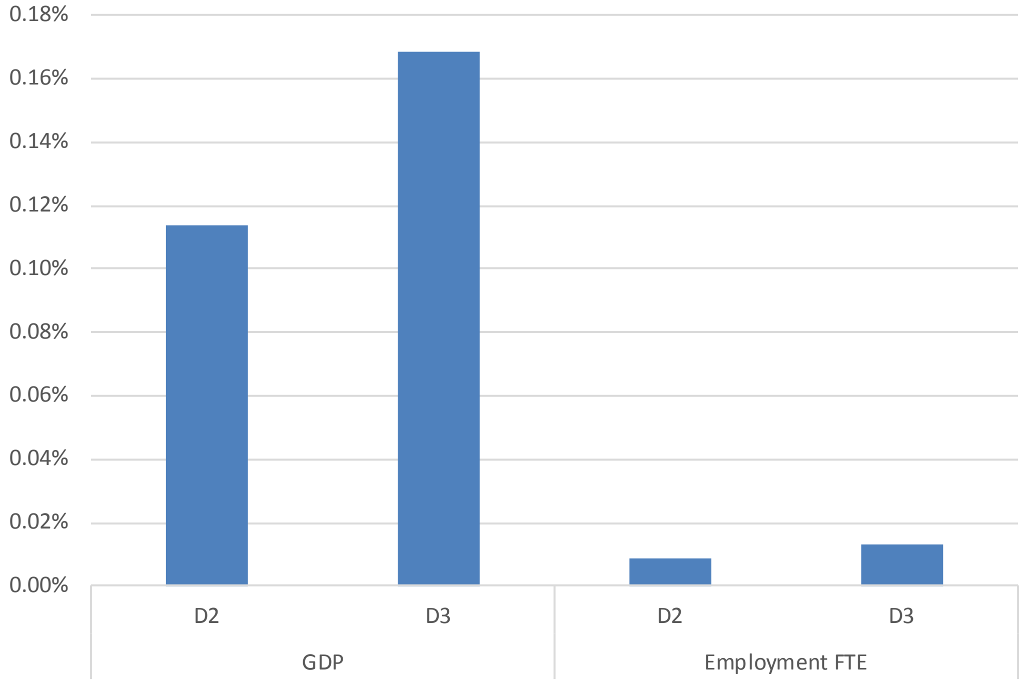


Figure 6: Relative yearly GDP and FTE employment change for EU 28 for the period from 2012-2030 for the increased-policies scenario (D2) and the new actor-related policies scenario (D3)

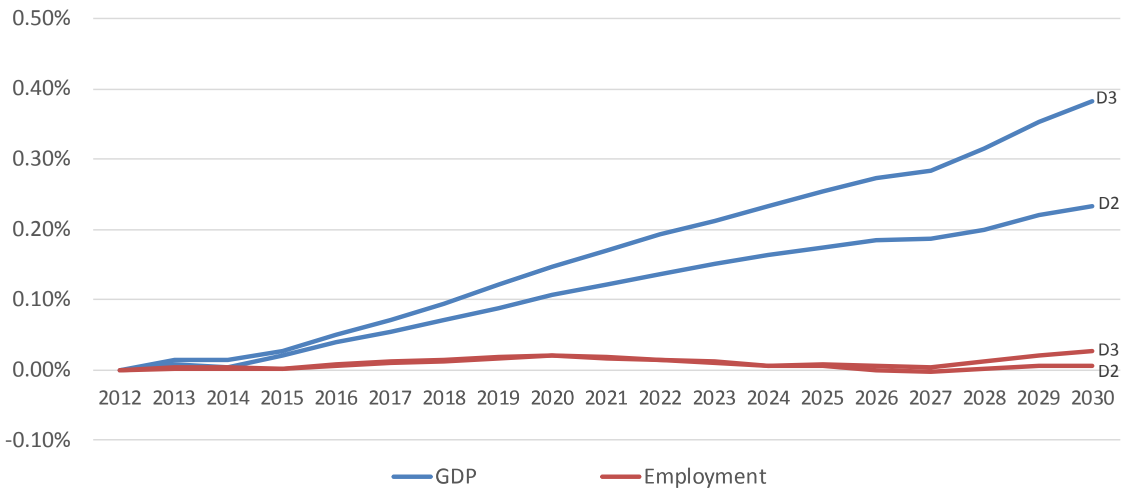


Figure 7: Relative GDP and FTE employment development in D2 and D3 scenarios with respect to the current-policy scenario

On a sectoral level, the results reflect the structure of the impulses. Figure 8 illustrates the EU 28 change in employment per sector for both scenarios. The manufacturing and construction sectors benefit from the investments in appliances and building technologies. The biggest gain in FTE employment relative to the baseline scenario is in the electronics sector with over 0.3 %. The second major winner among the sectors is construction. In contrast, the energy and minerals sectors (which also include fossil fuels) experience a decline in employment relative to the baseline scenario. The employment effects are also negative in some service sectors, due to the negative impulse on final consumption in the case of higher investment costs than energy savings. This negative effect is, however, comparatively small.

As described in the previous section, the results of the bottom-up energy modelling vary widely between scenarios and countries. This also translates into a range of country and scenario specific developments in the macroeconomic aggregates. The change in GDP is positive for most countries in both scenarios, as shown in Figure 9. Only Spain experiences negative GDP changes in both scenarios, while the GPD change for Poland and Slovenia is only negative in the D2 scenario but positive in the D3 scenario. Positive GDP changes in the other economies are due to the positive investment impulse and the parts of energy demand reductions which accrue to fossil fuel suppliers outside the EU. Thus, an import substitution effect takes place, reducing imports of fossil fuels into the EU. These impulses are particularly strong for the Czech Republic, Greece and Bulgaria, leading to strong positive GDP effects.

As Figure 10 illustrates, the employment effects are more heterogeneous. However, they are of a smaller relative magnitude with a maximum for Greece of about 0.15 % in the new actor-related policies scenario. Spain, Bulgaria, Estonia, Malta, Poland and Slovenia experience small negative employment changes in both scenarios. For a few other countries, the sign changes between scenarios.

The difference between the GDP and employment effects is mainly due to shifts between economic sectors with different labour productivities. The D2 and D3 scenarios represent a strategy in which energy is substituted for by capital (investment into energy efficient technologies), which temporarily have to be financed on the macroeconomic level by foregone consumption. As consumption is more strongly linked to service sectors than investment, the service sectors decline in importance. In general, the more manufacturing based sectors linked to the production of appliances and building technologies are more labour productive than service sectors. Thus, we see a trend that the employment results are somewhat less positive than the effects on GDP. This trend is especially strong for countries which are characterized by a lower ratio of energy cost reduction to investment on the one hand, and by labour intensities of the service sectors which considerably exceed thosein the manufacturing sectors. This might explain why especially in some Eastern European countries opposite signs of impact on GDP and employment can be observed.

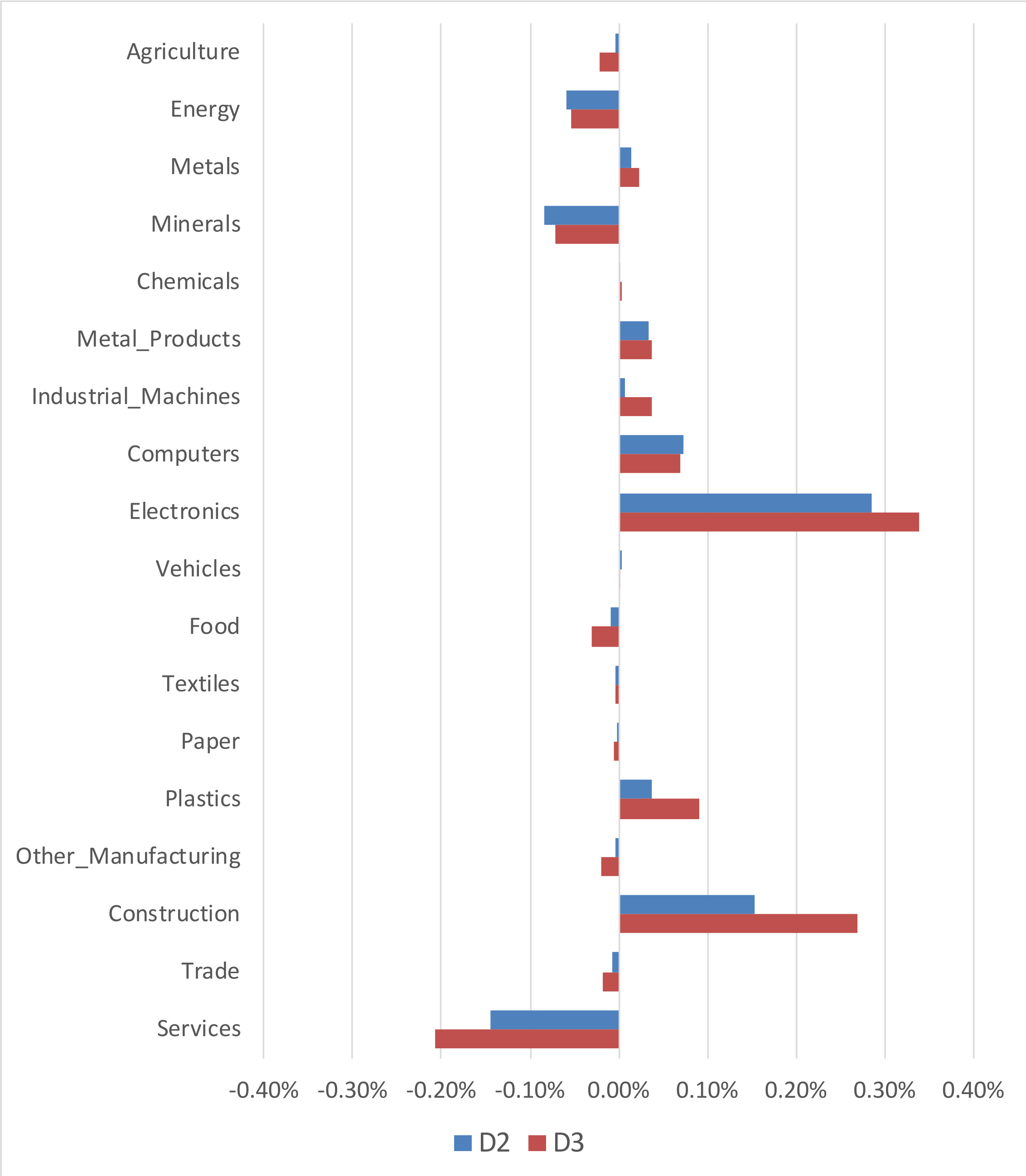


Figure 8: Relative sectoral FTE employment changes in the EU 28 for the D2 and the D3 scenario in the period 2012-2030

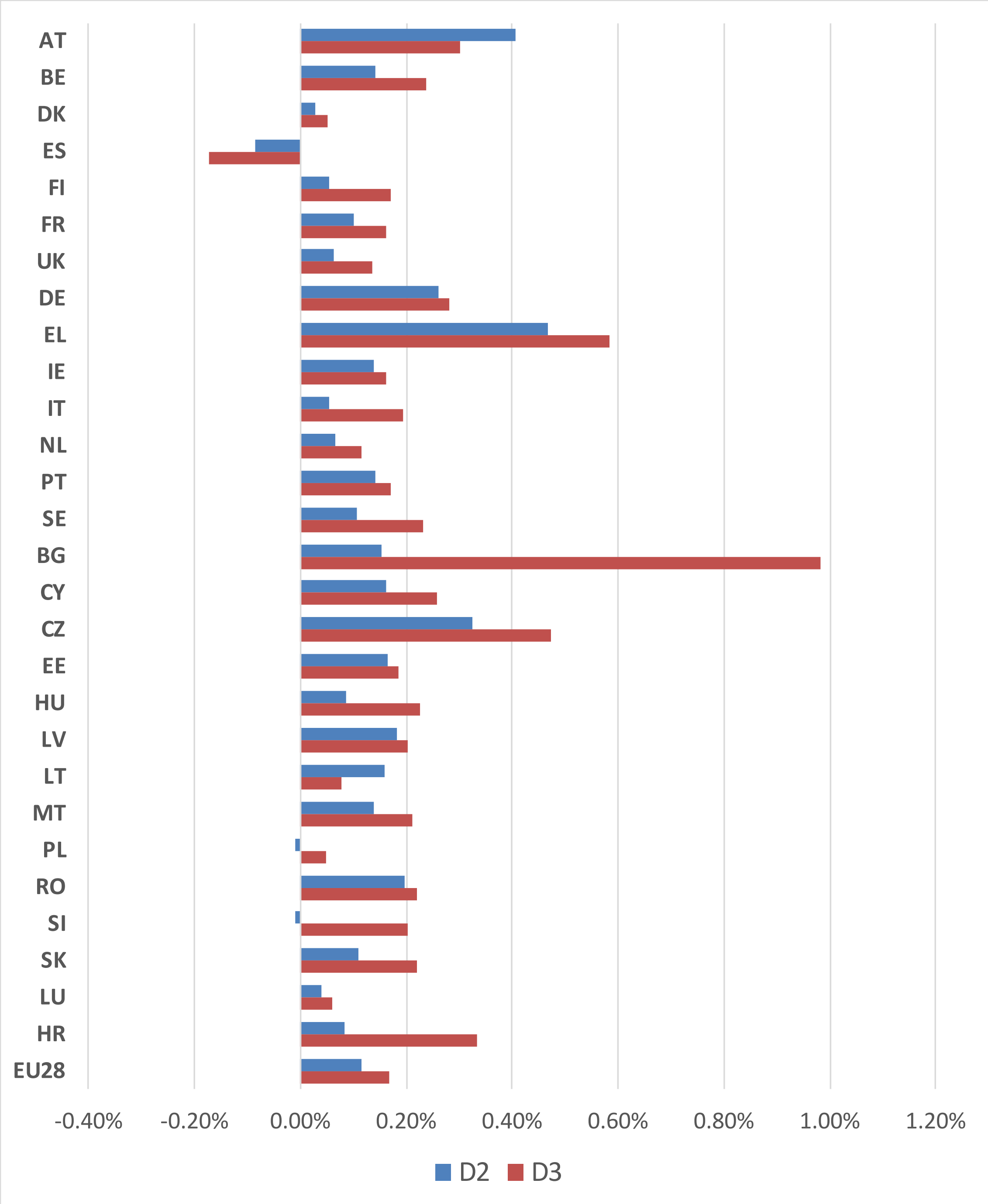


Figure 9: Country level relative yearly changes in GDP for the D2 and the D3 scenario in the period 2012-2030

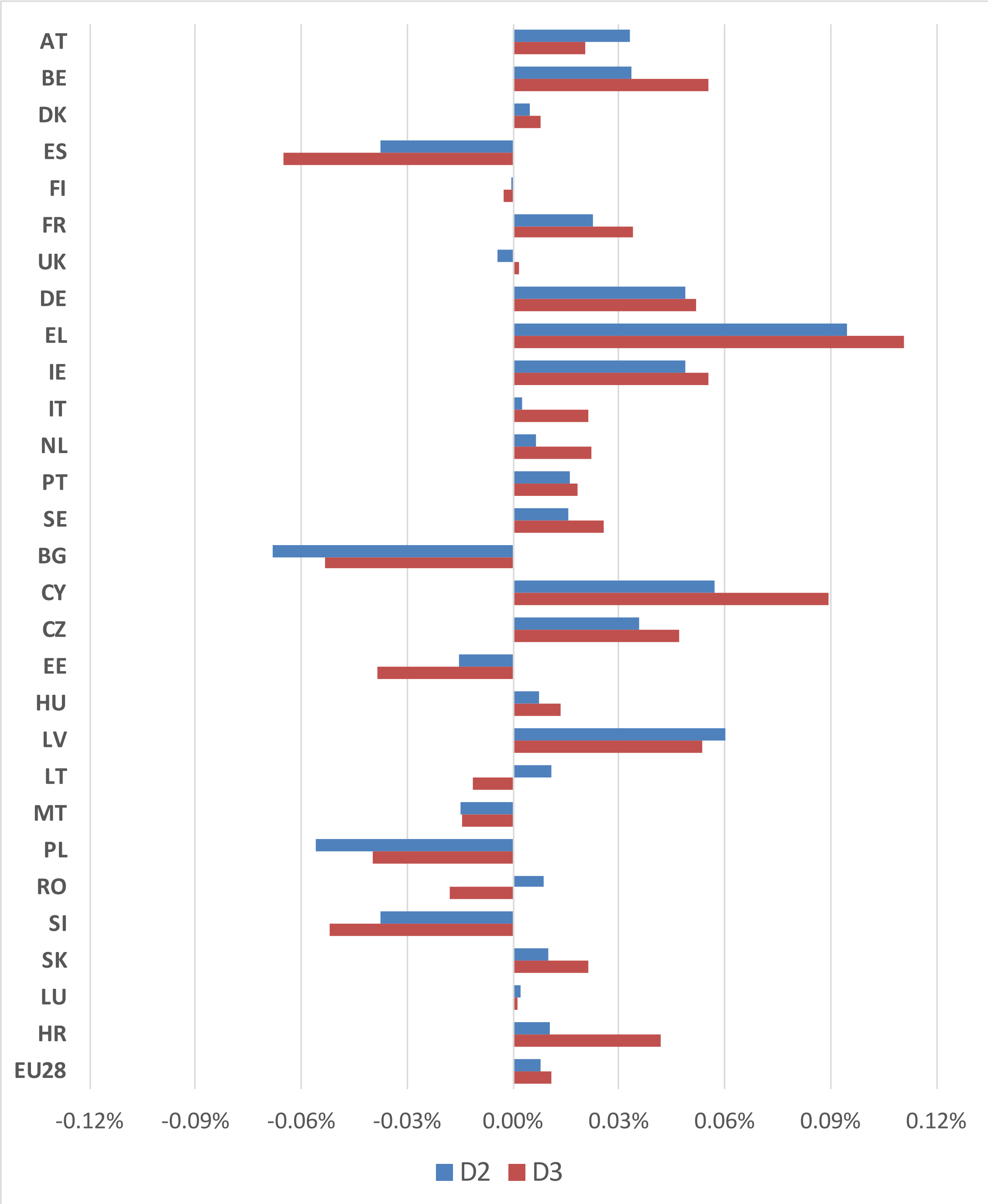


Figure 10: Country level relative yearly changes in FTE employment for the D2 and the D3 scenario in the period 2012-2030

5 Conclusions and outlook

The macroeconomic effects of energy efficiency are positive, albeit small in the short to medium term. Taken together, the macroeconomic impacts of the scenarios show characteristics of an investment into a modernization process: Investments into energy efficiency technologies have to be offset temporarily by a reduction in consumption. However, the investments drive a structural change, which increases overall macroeconomic productivity. This is not mainly due to productivity increases in the investing sector, but via a structural change towards sectors which are less labour intensive. With the push for additional investments ebbing off, and induced energy costs savings lagging behind, consumption is able to pick up in the long run. Differences in the macroeconomic effects can be explained by differences in the impulses and differences in the structural composition of the economy, which are expressed as differences in the labour intensity and value chains of the sectors affected by the economic changes.

A comparison with the results of other studies quoted in the introduction shows some similarities, but also some differences. Similar to these studies, we see positive, albeit modest positive economic impacts, which are driven by import substitution of energy carriers. Differences arise with regard to the sectorial composition. Here we see that some services might be also among the sectors losing employment. This is due to, among other things, the effect that the positive impulses (higher investments in energy efficiency) mainly accrue to manufacturing sectors. On the other hand, the effects of a reduced consumption, which are necessary to compensate for the difference between positive and negative impulses, mainly accrue to service sectors. Due to the higher labour intensity of services, it is therefore not surprising to see that in our results – in contrast to some other studies – the employment impacts are less strong than the GDP impacts. Our assumption that crowding out effects are (temporarily) taking place contributes substantially to these differences.

There are various caveats which have to be taken into account in interpreting these results. First, the positive effects of energy costs reductions cannot fully be accounted for within the time framework chosen, because they are lagging behind the investments. Second, the results depend on the results of the energy demand modelling, and especially on the order of magnitude of investments in relation to energy cost reductions. Third, as mentioned above, the results are influenced by our assumption that crowding out of private consumption is prevailing in the compensation of positive impulses exceeding negative ones. This is a rather cautious, neoclassical assumption. If a more Keynesian situation were assumed, in which underutilized capacity and idle capital can accommodate additional investments, the assumption of a strong crowding out of consumption by investment would not hold anymore. Under such assumptions, the additional investments lead to increase in a final demand impulse, which leads via multiplier effects to a higher increase in employment and GDP than is depicted in our model run. Taken together, this means that our results are not on the optimistic side of possible outcomes. They should be interpreted as a robust outcome, which shows that investments in energy efficiency will have at least modest positive economic impacts for the EU.

These caveats also lead to important conclusions for future modelling. The first relates to the time horizon of scenario building. In energy scenario modelling, the direct effects of energy technology diffusion on energy demand and emissions, and related costs, are of primary concern. Thus, typically a time horizon is chosen which reflects the effect of the last technology coming into the market. Thus, in the BRISKEE project, modelling of the scenarios spans until 2030. However, in the logic of macroeconomic modelling, the impulses of the strategy span until the last technology exits the market. The (negative) impulses only cease after this point in time. Thus, a simulation of macroeconomic effects of energy efficiency which covers all effects over time requires energy scenarios as input which span the complete time horizon until the phasing out of the last newly introduced technology. A second issue relates to the assumptions made with regard to compensation of differences between positive and negative impulses. Depending on the outlook on the persistence of a lack in demand, the importance to model the effects in a more Keynesian mode might increase. A third issue relates to the spending behaviour of private households. Following a more neoclassical approach, we have modelled a crowding out based on macroeconomic considerations, and there was no rational to differentiate between increased-policies scenario and new actor-related policies scenario. However, if we assume a stronger role of Keynesian assumptions, microeconomic considerations in financing decisions might become more important. Under these assumptions, it might make a difference on aggregate demand whether the households decide to finance efficiency investments out of savings or credits, or out of reduced spending on other consumption goods. In that case, we have to ask whether or not the differences with regard to discount rates also influence the microeconomic perspective of the actors involved with regard to financing and spending decisions.

The results on economic effects of energy efficiency also open up new avenues for modelling feedbacks between outcomes of policies and behaviour. Various theories and research perspectives focus on how behavioural outcomes can lead to redefinition of determinants and adjustments in future behaviour (e.g. self-perception theory by Bem 1972, dissonance theory by Festinger 1957, and research applied to environmental problems, e.g. Jones 2014; Klöckner 2015; Klintmann 2012; Sanatarius et al. 2016). However, by and large, these analyses take the socio-structural environment as given. On the other hand, neoclassical economists analyse optimal decision making under the assumption that "preferences are given". Behavioural and evolutionary economists look at how institutional settings influence behavioural output, as well as at bounded rationality and routines (Becker 2002; Diamond and Vartianen 2007; Nelson 2016). In the BRISKEE project, we have added an explicit step in focusing on the role of household preferences for time discounting and risk, accounting for possible differences by technologies, household types, and countries. Nevertheless, in general, norm activation, motivation and behavioural patterns are taken as given in economic analysis. However, using an integrated framework for explaining environmental behaviour (Figure 11), which draws on both the theory of planned behaviour and the norm activation model (Bamberg and Möser 2007; Klöckner 2013), there are various feedbacks which we have to account for. The following assumptions are the starting point for explaining them (see blue arrows in Figure 11):

- Changing behaviour impacts the diffusion of energy efficiency technologies. But diffusion also influences habits, routines which shape decisions, and indirectly also aspects of perceived behavioural control and social norms. Over time, these changes will influence lifestyles by inducing integration of values and attitudes, as well as behavioural patterns supporting energy efficiency. Thus, there is a positive feedback loop between diffusion of energy efficiency technologies and behaviour.
- Individual preferences and personal and social norms are influenced by socio-structural development. From economists' point of view, environmental quality can be seen as a superior good, which increases in importance with satiation of basic needs (Beckerman 1992; Baldwin 1995). Thus, if the future development of the economy, as depicted in the economic scenarios, shows increasing satiation of basic needs, this should also translate into increasing acceptance of environment driven energy efficiency strategies.
- Diffusion of energy efficiency results in economic and environmental impacts. These impacts also feed back into diffusion of energy efficiency technologies. Positive effects will increase legitimacy, and according to the policy feedback literature (e.g. Jordan and Matt 2014; Jacobs and Weaver 2014), winners of the strategy will become supporters of even more ambitious policies.
- The impacts of energy efficiency also affect behavioural costs. People are more likely to change towards sustainable consumption behaviour if they think that this will not threaten their economic well-being. New business opportunities arising from energy efficiency symbolize positive effects on economic well-being. Positive environmental effects enhance the perceived efficacy of behavioural alternatives and thus the motivation to act accordingly. If the impact of energy efficiency on economy and environment is positive, a positive feedback loop results, and vice versa.

Modelling such feedbacks will require the linking of a dynamic model of behavioural determinants with diffusion models of energy efficiency technologies and macroeconomic models. BRISKEE has demonstrated the feasibility and advantages of linking the latter two kinds of models. It will be up to future modelling exercises to enhance this approach by explicitly building and integrating empirical models of behavioural change.

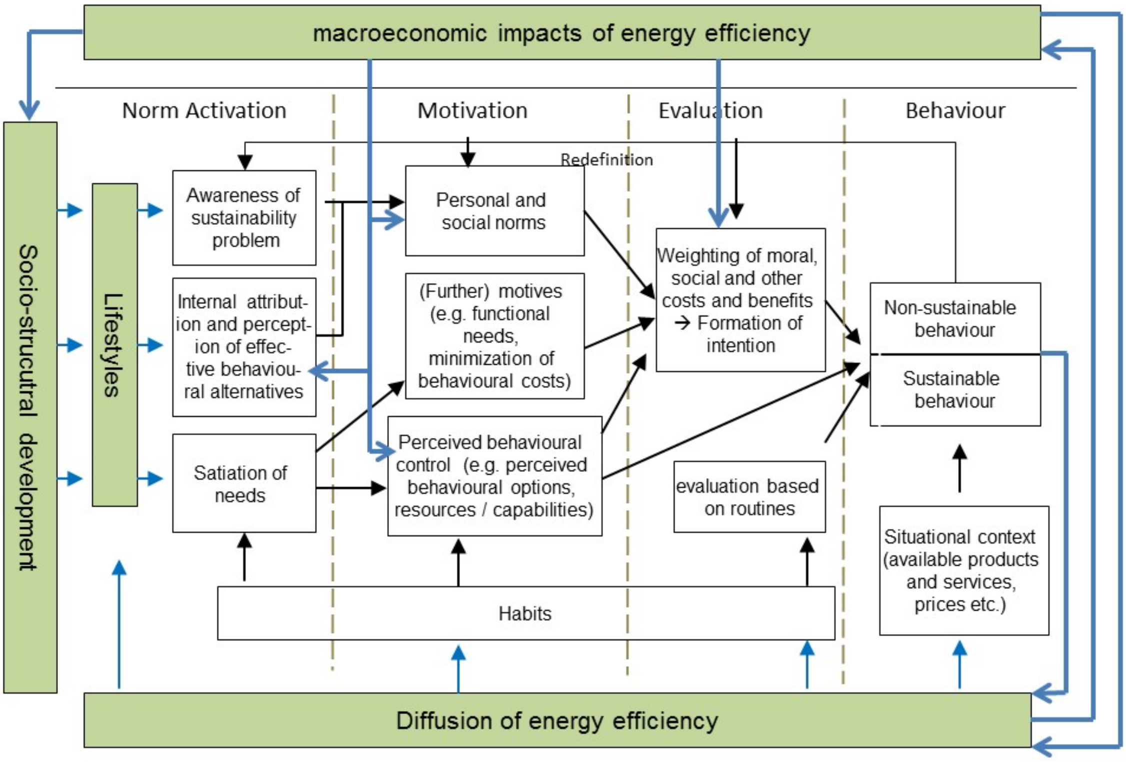


Figure 11 Conceptual approach of linking model of sustainable behaviour with socio-economic development and diffusion of CE innovations (drawn on integrated psychological models of sustainable behaviour based on meta-analyses by Bamberg and Möser 2007, and Klöckner 2013).

Publication bibliography

Baldwin, R. (1995): Does sustainability require economic growth? In: Goldin, I.; Wanter, L.A. (eds.): Economics of sustainable growth, Cambridge University Press, Cambridge, 51-77.

Bamberg, S; Möser, G. (2007): Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. Journal of Environmental Psychology (27), 14-25.

Barker, Terry; Alexandri, Eva; Mercure, Jean-Francois; Ogawa, Yuki; Pollitt, Hector (2015): GDP and employment effects of policies to close the 2020 emissions gap. In Climate Policy 16 (4). pp. 393–414. DOI: 10.1080/14693062.2014.1003774.

Barker, Terry; Ekins, Paul; Foxon, Tim (2007): The macro-economic rebound effect and the UK economy. In Energy Policy 35 (10). pp. 4935–4946. DOI: 10.1016/j.enpol.2007.04.009.

Becker, M.C. (2002): Organizational routines: a review of the literature. Industrial and Corporate Change 13, 643-677.

Beckerman, W. (1992): Economic Growth and the Environment. World Development 20 (4), 481-496.

Bem, D. J. (1972). Self-Perception Theory. In L. Berkowitz (Ed.), Advances in Experimental Social Psychology (Vol. 6, pp.1-62). New York: Academic Press.

Bernanke, Ben (2015): Why are interest rates so low? Part 3: The global savings glut. Brookings blog from Wednesday, April 1 2015, retrieved Jan. 7 2018 from: https://www.brookings.edu/blog/ben-bernanke/2015/04/01/why-are-interest-rates-so-low-part-3-the-global-savings-glut/.

Cleff, T. und Rennings, K. (2013): Are there any first mover advantages for pioneering firms? Lead market oriented business strategies for environmental innovation, European Journal of Innovation Management 15 (4), pp. 491-513

Croucher, Matt (2012): What is important when modeling the economic impact of energy efficiency standards? In Utilities Policy 22. pp. 50–57. DOI: 10.1016/j.jup.2011.12.002.

CSES and Oxford Research (2011): Final Evaluation of the Lead Market Initiative, Final Report, Luxembourg: Publications Office of the European Union

Diamond, P.; Vartianen, H. (eds.) (2007): Behavioral economics and its applications. Princeton University Press, Princeton.

Diederich, H. (2016): Environmental Policy and Renewable Energy Equipment Exports. Heidelberg: Springer.

Dosi, G.; Pavitt, K.; Soete, L. (1990). The Economics of Technical Change and International Trade, New York.

Duscha, V.; Ragwitz, M.; Breitschopf, B.; Schade, W.; Walz, R.; Pfaff, M.; Visser, E. de; Resch, G.; Nathani, C.; Zagamé, P.; Fougeyrollas, A.; Boitier, B. (2014) Employment and growth effects of sustainable energies in the European Union. Final Report. Contract no.: ENER/C1/428-2012. Brussels: European Commission, 2014, 199 S.

Duscha, V.; Ragwitz, M.; Resch, G.; Schade, W. Pfaff, M.; Fougyerollas, A.; Breitschopf, B.; Walz, R. (2016): Renewable energy deployment in Europe up to 2030 and the aim of a triple dividend. Energy Policy 95, S. 314–323.

Edler, J., Georghiou, L., Blind, K., Uyarra, E. 2012. Evaluating the demand side: New challenges for evaluation, Research Evaluation 21, 33–47

Eggertsson, Gauti B.; Mehrotra, Neil R; Summers, Lawrence H (2016): Secular Stagnation in the Open Economy. American Economic Review, 106(5): 503-07.

Eggertsson, Gauti B., Krugman, Paul (2012): Debt, Deleveraging, and the Liquidity Trap: A Fisher-Minsky-Koo Approach. The Quarterly Journal of Economics 127(3): 1469–1513,

European Commission (2010): Communication from the Commission. Europe 2020 - A strategy forsmart. sustainable and inclusive growth. COM(2010) 2020 final. Brussels.

European Commission (2011a): Communication from the Commission to the European Parliament. the Council. the European Economic and Social Committee and the Committee of the Regions. A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy. COM (2011) 21. Brussels.

European Commission (2011b): Communication from the Commission to the European Parliament. the Council. the European Economic and Social Committee and the Committee of the Regions. A Roadmap for moving to a competitive low carbon economy in 2050. COM(2011) 112 final. Brussels.

European Commission (2011c): Communication from the Commission to the European Parliament. the Council. the European Economic and Social Committee and the Committee of the Regions. Energy Efficiency Plan 2011. COM(2011) 109 final/2. Brussels.

European Commission (2011d): Communication from the Commission to the European Parliament. the Council. the European Economic and Social Committee and the Committee of the Regions. Energy Roadmap 2050. COM(2011) 885 final. Brussels.

Fagerberg, J. (1995b), Technology and Competitiveness, Oxford Review of Economic Policy, 12(3), pp. 39-51.

Festinger, L. (1957). A Theory of Cognitive Dissonance. Stanford: Stanford University Press.

HSBC (2016): Global Trade Report 2016. https://globalconnections.hsbc.com/downloads/trade_forecasts/global.pdf

IEA (2014): Capturing the multiple benefits of energy efficiency. Available online at http://www.iea.org/publications/freepublications/publication/Captur_the_MultiplBenef_ofEnergyEficiency.pdf.

Jacobs, A.M.; Weaver R.K. (2014): When Policies Undo Themselves: Self-Undermining Feedback as a Source of Policy Change. Governance 28 (4), Pages 441–457.

Jones, R. G. (2014). Psychology of sustainability: an applied perspective. Routledge.

Jordan, A. and E. Matt (2014): Designing Policies that intentionally stick: policy feedback in a changing climate. Policy Sciences, 47, 227-247.

Klintman, M. (2012). Citizen-consumers and evolution: reducing environmental harm through our social motivation: Palgrave Macmillan.

Klöckner, C. A. (2013): A comprehensive model of the psychology of environmental behaviour – A meta-analysis. Global Environmental Change

Klöckner, C. A. (2015). The psychology of pro-environmental communication: beyond standard information strategies. Springer.

Krugman, Paul (2014): Four observations on secular stagnation. Geneva Reports on the World Economy August 2014: 61-68.

Mirasgedis, S.; Tourkolias, C.; Pavlakis, E.; Diakoulaki, D. (2014): A methodological framework for assessing the employment effects associated with energy efficiency interventions in buildings. In Energy and Buildings 82. pp. 275–286. DOI: 10.1016/j.enbuild.2014.07.027.

Nelson, R.R. (2016): Behavior and cognition of economic actors in evolutionary economics. Journal of Evolutionary Economics, 26(4), pp. 737-751

OECD (2014); Trade Patterns in the 2060 world economy. OECD Economics department Working Paper No. 1142.

OECD/IEA (2012): Spreading the Net. The multiple benefits of energy efficiency improvements. OECD. Paris. Available online at https://www.iea.org/publications/insights/insightpublications/Spreading_the_Net.pdf.

Pietrobelli, C., Rabellotti, R., 2011. Global value chains meet innovation systems: are there learning opportunities for developing countries? World Development 39 (7), 1261–1269.

Pollitt, Hector; Alexandri, Eva; Chewpreecha, Unnada; Roso, Antonio De; Drost, Roel; Estourgie, Laurent et al. (2016): The Macroeconomic and Other Benefits of Energy Efficiency. checked on 7/6/2017.

PWC (2014): Global Economy Watch: Issue October 2014. PricewaterhouseCoopers LLP.

Quitzow, R., Walz, R., Köhler, J., Rennings, K. 2014: The concept of "lead markets" revisited: Contribution to environmental innovation theory Environmental Innovation and Societal Transitions Vol. 10, March 2014, pp. 4-19

Santarius, T., Walnum, J. H., Aall, C. (Hg.) (2016): Rethinking Climate and Energy Policies: New Perspectives on the Rebound Phenomenon. Cham: Springer International Publishing.

Saunders, Harry (2013): Is what we think of as “rebound” really just income effects in disguise? In Energy Policy 57. pp. 308–317. DOI: 10.1016/j.enpol.2013.01.056.

Sugathan, M. (2015): Addressing Energy Efficiency Products in the Environmental Goods Agreement. ICTSD Issue Paper No. 20..

Summers, Lawrence (2016): The age of secular stagnation. Foreign Affairs 95(2), pp. 2-9

Summers, Lawrence (2015): Demand Side Secular Stagnation. American Economic Review, 105(5): 60-65.

Turner, Karen (2009): Negative rebound and disinvestment effects in response to an improvement in energy efficiency in the UK economy. In Energy Economics 31 (5). pp. 648–666. DOI: 10.1016/j.eneco.2009.01.008.

Walz, R. (2006) Impacts of Strategies to Increase Renewable Energy in Europe on Competitiveness and Employment. Energy & Environment 17, pp. 951-975.

Walz, R., Eichhammer, W. 2012. Benchmarking Green Innovation. Mineral Economics 24 (1), 79-101.

Walz, R., Köhler, J. 2014: Using lead market factors to assess the potential for a sustainability transition. Environmental Innovation and Societal Transitions, Vol. 10, March 2014, pp. 20-41

Walz, R.; Pfaff, M.; Marscheider-Weidemann, F.; Glöser-Chahoud, S. (2017): Innovations for reaching the green sustainable development goals – where will they come from? International Economics and Economic Policy 14 (3), S. 684-695.

Walz, R.; Schleich, J.: The economics of climate policy: macroeconomic effects, structural adjustments, and technical change, Heidelberg: Physica 2009.

List of abbreviations

GDP	Gross Domestic Product
FTE	Full Time Equivalent
HVAC	Heating. Ventilation and Air Conditioning
ICT	Information and Communication Technologies
IO	Input-Output
NUTS	Nomenclature of Territorial Units for Statistics
NACE	European sector classification: Nomenclature generale des Activites Economiques dans les Communautes Europeennes
NACE-CLIO	Is the branch of NACE 1970 used for the compilation of input-output tables

A. Appendix: Description of the ASTRA-EC model

A.1 The modelling approach

The ASTRA-EC-EC model is based on System Dynamics methodology. System Dynamics does not focus on the analysis of specific fields like economy or transport. but is a general methodology that can be applied to any kind of system meeting some basic conditions. In brief. a System Dynamics model consists of a set of hypotheses on the relationship between causes and resulting effects. Hypotheses may be based on theory or only informed by theory. but empirical inputs from statistics. surveys or other observations may also be used.

Relationships are represented by equations that are written and solved by mathematical simulation. In other words. a System Dynamic model does not have a specific set of unknown parameters or variables whose value is estimated as a solution of the model. Instead, most of the model variables change dynamically over time as an effect of the interaction of positive or negative feedback loops. This can be considered as the most important characteristics of any complex systems. System Dynamics models consist of three main types of variables: level, flow and auxiliary variables. The state of a variable is mainly calculated within level variables changed over time by inflows and outflows that are driven by auxiliary variables. Mathematically, level variables are solved with differential equations. Since the solution of a system with a set of level variables is too complex, an approximation is applied by solving only the related difference equations. Nevertheless, the mathematical calculations in a large scale System Dynamics model like ASTRA-EC-EC are challenging and demanding on the computational equipment.

As opposed to computed general equilibrium models, reaching a steady state or equilibrium in each stage of the simulation is not foreseen in System Dynamics models. Dedicated software allows the development of System Dynamics models concentrating on the causal relationships by means of intuitive graphical interfaces.

The ASTRA-EC-EC model is therefore focused on the investigation of functional cause-and-effect relationships between the systems represented (transport, economy, environment) and connected through several feedback loops. The model is developed using Vensim® software.

A.2 Overview of the model structure

The model covers the time period from 1995 until 2050. Results in terms of main indicators are available on a yearly basis via a user interface. Geographically, ASTRA-EC-EC covers all EU28 member states plus Norway and Switzerland.

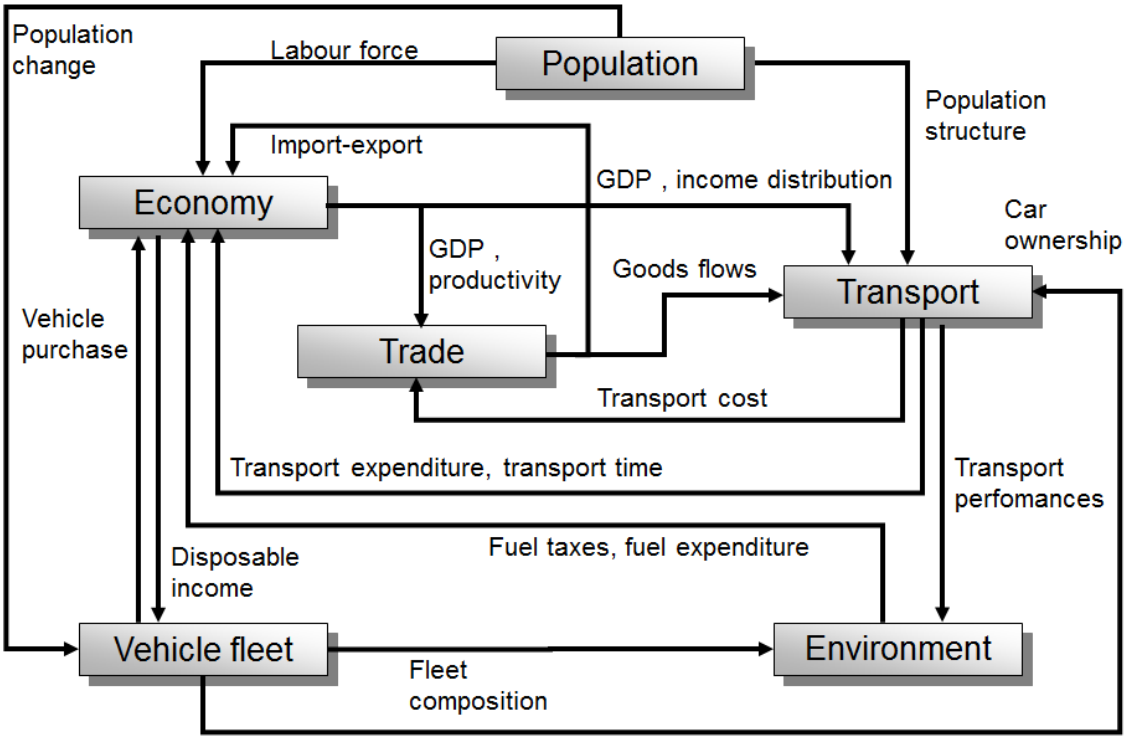
ASTRA-EC-EC consists of different modules, each related to one specific aspect, such as the economy, the transport demand, the vehicle fleet. The main modules cover the following aspects:

- Population and social structure (household types and income groups).
- Economy (including input-output tables, government, employment and investment).
- Foreign trade.
- Transport (including demand estimation, modal split, transport cost and infrastructure networks)
- Vehicle fleet (road).
- Environment (including pollutant emissions, CO_2 emissions, fuel consumption).

A key feature of ASTRA-EC-EC as an integrated assessment model is that the modules are linked together. Changes in one system are thus transmitted to other systems and can feed back to the original source of variation. For instance, changes in the economic system immediately feed into changes of the transport behaviour and alter origins, destinations and volumes of European transport flows. In turn, via some micro-macro bridges (see below), the changes in the transport system feed back into the economic system e.g. adapting the consumption behaviour of households or the sectoral interchange of intermediate goods and services.

Since all modules are part of the same dynamic structure, the whole model is simulated simultaneously. The most appealing consequence is that there is no need of iterations to align the results of the various modules. All parts of the model are always consistent to each other throughout the whole simulation.

An overview on the modules and their main linkages is presented in Figure 0-1.



Source: TRT - Fraunhofer-ISI

Figure 0-1: Overview of the linkages between the modules in ASTRA-EC-EC

A.3 Geographical scope and zoning system

Different levels of spatial categorizations are applied in parallel in ASTRA-EC-EC:

- The first categorization is based on the country level spatial differentiation, applied in all the modules of the model;

- The second categorization is founded on the NUTS I zones level, which is applied in the transport module to represent national trips;
- The third categorization is built on the NUTS II zones level, applied in the transport modules (for trips generation) as well as for population;

Further differentiation within NUTS II zones is provided in some modules like e.g. the transport module. Finally, for intercontinental trade and transport demand an aggregated zoning system is applied to non-European areas, including the following world regions: Arab-African Oil Exporters, Asian Oil Exporters, Brazil, China, East Asia, India, Japan, Latin America, North America, Oceania, Russia, South-Africa, South-Asia, Turkey, Rest-of-the-World.

At the European level, each country is treated separately in the model, resulting in a total of 30 states. The specific application of spatial categories in the modules of ASTRA-EC-EC is shown in the following table.

Table 0-1: Summary of spatial categorizations used in different modules of ASTRA-EC-EC

Spatial category	**Population**	**Macro-economic**	**Trade**	**Transport**	**Vehicle fleet**	**Environment**
Country	X	X	X	X	X	X
NUTS I	X			X		
NUTS II	X			X		
Urban context				X		
World regions			X	X		

Source: TRT / Fraunhofer-ISI

As highlighted in the table above, the transport module includes the most detailed level of spatial categorization, while in the other modules (except the population module) the variables are mainly defined at country level.

It would be desirable that the same level of spatial detail is available also for the other modules, but this is not feasible within a System Dynamics model calculating each variable for every time step from 1995 to 2050. When NUTS I and NUTS II level is used to describe transport demand, the size of the model becomes already quite big. Using the same detail throughout the model would lead to unsustainable computational problems due to the overall model size.

Therefore, the implementation of more detailed spatial categorizations only in the transport module results from a balanced judgment of factors: model requirements, soft- and hardware capabilities, and data availability. Outside the transport module, the NUTS level is used only for selected socio-economic indicators.

A.4 Sectoral differentiation

Sectoral disaggregation in ASTRA-EC-EC is based on the concept of *NACE-CLIO* sectoral coding system where NACE stands for the general industrial classification of economic activities within the European communities and CLIO for Classification and nomenclature of input-output. Both are used Eurostat statistics, though the CLIO system is especially designed to generate harmonised input-output tables for the EU25 countries since each country used its own national system e.g. in Germany with 59 sectors or in the United Kingdom with 102 sectors.

Table 0-2: Differentiation into 25 economic sectors in ASTRA-EC-EC

Nr.	**IOSector**	**TradeSector**
1	Agriculture	T Agriculture
2	Energy	T Energy
3	Metals	T Metals
4	Minerals	T Minerals
5	Chemicals	T Chemicals
6	Metal Products	T Metal Products
7	Industrial Machines	T Industrial Machines
8	Computers	T Computers
9	Electronics	T Electronics
10	Vehicles	T Vehicles
11	Food	T Food
12	Textiles	T Textiles
13	Paper	T Paper
14	Plastics	T Plastics
15	Other Manufacturing	T Other Manufacturing
16	Construction	not included
17	Trade	T Other Services
18	Catering	T Other Services
19	Transport Inland	T Transport Services
20	Transport Air Maritime	T Transport Services
21	Transport Auxiliary	T Transport Services
22	Communication	T Other Services
23	Banking	T Other Services
24	Other Market Services	T Other Services
25	Non Market Services	T Other Services

Source: Fraunhofer-ISI

The NACE system corresponds to international classifications like *ISIC* (International Standard Industrial Classification), such that also data following these categorisations could be used, and is available as NACE with 17, 25 or 44 sectors. Three main reasons suggest using the NACE-CLIO version with 25 sectors (see following table): firstly, in ASTRA-EC-EC the use of harmonised input-output tables for the EU27+2 countries is of significant importance to reflect the economic interactions that are induced in all sectors of the national economies by influences of policies in those sectors that are directly related to transport demand. Eurostat provides such tables for most of the EU27 countries plus Norway and Switzerland for 1995. Values for 1995 are required as the sectoral interweavement is initiated by data. Input output tables of upcoming years are endogenously calculated based on changing final use. They are not calibrated against input output tables of following years. Secondly, the split into 25 sectors offers five sectors that are directly related to transport demand changes and that would be affected by transport policies. These sectors are sector 2 Refined petroleum products and Electric power, gas, etc. influenced by private expenditures for fuel; sector 10 Transport Equipment affected by private car purchase and investments in any other kind of vehicles; sector 16 Building and Construction driven among others by investments in transport facilities (e.g. container terminals or stations) and transport networks; sector 19 Inland Transport Services influenced by expenditures for bus, rail, road freight transport and inland waterway transport; sector 20 Maritime and Air Transport Services affected by ocean ship transport and air transport. Thirdly, among the 25 sectors are already 9 service sectors which enable the model to take account of the ever increasing importance of services for the European economies. A conversion table from the NACE Revision 2 classification of economic sectors (65 sectors) to the NACE-CLIO version called IOSector (25 sectors) is provided below.

Table 0-3: Conversion factors from NACE Rev. 2 CPA 65 classification to ASTRA-EC-EC NACE-CLIO 25 classification

NACE Rev.2	**Sector Name**	**IOSector**	**Conversion**
A_01	Products of agriculture, hunting and related services	Agriculture	1
A_02	Products of forestry, logging and related services	Agriculture	1
A_03	Fish and other fishing products; aquaculture products; support services to fishing	Agriculture	1
B	Mining and quarrying	Metals	0.43
B	Mining and quarrying	Minerals	0.21
B	Mining and quarrying	Energy	0.36
C_10-12	Food products. beverages and tobacco products	Food	0.9
C_10-12	Food products. beverages and tobacco products	Other Manufacturing	0.1
C_13-15	Textiles. wearing apparel and leather products	Textiles	1
C_16	Wood and of products of wood and cork. except furniture; articles of straw and plaiting materials	Other Manufacturing	1
C_17	Paper and paper products	Paper	1
C_18	Printing and recording services	Paper	0.5
C_18	Printing and recording services	Other Manufacturing	0.5
C_19	Coke and refined petroleum products	Energy	1
C_20	Chemicals and chemical products	Chemicals	1
C_21	Basic pharmaceutical products and pharmaceutical preparations	Chemicals	1

C_22	Rubber and plastics products	Plastics	1
C_23	Other non-metallic mineral products	Minerals	1
C_24	Basic metals	Metals	1
C_25	Fabricated metal products. except machinery and equipment	Metal_ Products	1
C_26	Computer. electronic and optical products	Computers	1
C_27	Electrical equipment	Electronics	1
C_28	Machinery and equipment n.e.c.	Industrial Machines	1
C_29	Motor vehicles, trailers and semi-trailers	Vehicles	1
C_30	Other transport equipment	Vehicles	1
C_31-32	Furniture; other manufactured goods	Other_ Manufacturing	1
C_33	Repair and installation services of machinery and equipment	Trade	1
D	Electricity, gas, steam and air-conditioning	Energy	1
E_36-37	Natural water; water treatment and supply services	Energy	1
E_38-39	Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	Non Market Services	1
F	Constructions and construction works	Construction	1
G_45	Wholesale and retail trade and repair services of motor vehicles and motorcycles	Trade	1
G_46	Wholesale trade services, except of motor vehicles and motorcycles	Trade	1
G_47	Retail trade services, except of motor vehicles and motorcycles	Trade	1
H_49	Land transport services and transport services via pipelines	Transport Inland	1
H_50	Water transport services	Transport Air Maritime	1
H_51	Air transport services	Transport Air Maritime	1
H_52	Warehousing and support services for transportation	Transport Auxiliary	1
H_53	Postal and courier services	Communication	1
I	Accommodation and food services	Catering	1
J_58	Publishing services	Other Market Services	1
J_59	Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services	Other Market Services	1
J_60	Telecommunications services	Other Market Services	1
J_62-63	Computer programming, consultancy and related services; information services	Other Market Services	1
K_64	Financial services, except insurance and pension funding	Banking	1

K_65	Insurance, reinsurance and pension funding services, except compulsory social security	Banking	1
K_66	Services auxiliary to financial services and insurance services	Banking	1
L	Real estate services	Other Market Services	1
L_68	Of which: imputed rents of owner-occupied dwellings	Other Market Services	1
M_69-70	Legal and accounting services; services of head offices; management consulting services	Other Market Services	1
M_71	Architectural and engineering services; technical testing and analysis services	Other Market Services	1
M_72	Scientific research and development services	Other Market Services	1
M_73	Advertising and market research services	Other Market Services	1
M_74-75	Other professional, scientific and technical services; veterinary services	Other Market Services	1
N_77	Rental and leasing services	Other Market Services	1
N_78	Employment services	Other Market Services	1
N_79	Travel agency, tour operator and other reservation services and related services	Catering	1
N_80-82	Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	Other Market Services	1
O	Public administration and defence services; compulsory social security services	Non Market Services	1
P	Education services	Non Market Services	0.8
P	Education services	Other Market Services	0.2
Q_86-87	Human health services	Non Market Services	0.8
Q_86-87	Human health services	Other Market Services	0.2
Q_88	Social work services	Non Market Services	1
R_90-91	Creative. arts and entertainment services; library, archive, museum and other cultural services; gambling and betting services	Non Market Services	0.1
R_90-91	Creative arts and entertainment services; library, archive, museum and other cultural services; gambling and betting services	Other Market Services	0.9
R_92-93	Sporting services and amusement and recreation services	Other Market Services	1
S_94	Services furnished by membership organisations	Non Market Services	1
S_95	Repair services of computers and personal and household goods	Other Market Services	1
S_96	Other personal services	Other Market Services	1
T	Services of households as employers; undifferentiated goods and services produced by households for own use	Other Market Services	1

U	Services provided by extraterritorial organisations and bodies	Other Market Services	1

Source: Fraunhofer-ISI