Ref. Ares(2020)1963111 - 07/04/2020

EUCALC

Explore sustainable European futures

Library of input for the employment module and analysis of the impact on employment and GDP for EU and per MS

D6.6

February/2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730459.

Project Acronym and Name	EU Calculator: trade-offs and pathways towards sustainable and low-carbon European Societies - EUCalc
Grant Agreement Number	730459
Document Type	Report
Work Package	WP6
Document Title	Library of input for the employment module and analysis of the impact on employment and GDP for EU and per MS
Main authors	Boris Thurm, Marc Vielle
Partner in charge	EPFL
Contributing partners	PIK, CLIMACT, BPIE, Imperial College, OEGUT, PANNON, TUD
Release date	February 2020
Distribution	*Public*

Short Description
This deliverable first describes the methods used to generate the library of inputs for the employment module, and in particular, the Input-Output tables for the EUCalc reference scenario. Second, the employment impacts of different decarbonisation pathways are analysed, and policy recommendations are offered to illustrate how the EUCalc model can help policy makers take informed decisions regarding Europe's decarbonization and employment policies.

Quality check	
Name of reviewer	**Date**
Luis Costa	06/04/2020

Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Use
CGE	Computable General Equilibrium
EU	European Union
EU28	European Union 28 countries (as of 31st December 2019)
EU28+1	European Union 28 countries + Switzerland
EUCalc	European Calculator project
EUref	EU-Reference Scenario 2016
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GTAP	Global Trade Analysis Project
IO	Input-Output
LFS	Labour Force Survey
LULUCF	Land Use, Land-Use Change, Forestry
OPEX	Operative Expenditure
TPE	Transition Pathway Explorer
UK	United Kingdom
WP	Working Package

1 Executive summary

This deliverable first describes the methods and assumptions used to generate the library of inputs for the employment module. The main inputs for the employment module are Input-Output tables representing the state of the economy in a reference scenario for each of the EU28 Member States and Switzerland. These tables are constructed using: (1) historical Input-Output tables extracted from the Exiobase database; (2) simulation of the reference scenario in the CGE model GEMINI-E3; (3) inputs from other EUCalc modules for the reference scenario.

Second, the EUCalc model, and in particular the employment module, is used to assess the employment impacts of different decarbonisation pathways in 2050, with respect to the reference scenario. The impacts on different category of workers (e.g. demand for skilled workers, evolution of wages) are also assessed.

The results show that the objectives of decarbonisation and job creation can go hand in hand. The simulated pathways are expected to entail positive impacts on employment due to the higher investment in sustainable infrastructures or to the reallocation of income towards services. Nonetheless, decarbonisation pathways are associated with large sectoral shift in employment, which could create job instability. It is therefore crucial to develop education and training programs to facilitate the transition and to ease the reclassification of workers. Moreover, policy makers should be careful that the transition does not widen social inequalities. Indeed, in some pathways, the gap between the average wages of unskilled and skilled workers is expected to increase which could lower the public acceptance of decarbonisation measures. This outcome could also endanger the transition because financially-constrained individuals would not have the ability to modify their lifestyles and to purchase sustainable products. Policy makers should thus implement redistribution policies to assist those in needs.

Consequently, these results shed light on the trade-offs behind different decarbonisation pathways and illustrates how the EUCalc online model can help policy makers take informed decisions regarding climate and employment policies.

2 Introduction

Decarbonisation and unemployment reduction are two of the most important challenges facing by Europe. Are these objectives conflicting, or could European countries make use the structural changes required for decarbonisation to enhance the creation of jobs? The European Calculator project (EUCalc) can help answer this question by offering the possibility to simulate a large range of decarbonization pathways and to visualize their associated environmental and socio-economic impacts.

There are many possible pathways to reach the same level of reduction of greenhouse gas emissions. Some rely on technology development, other on behavioural changes. These pathways not only differ with respect to their impacts on total employment, but also on the economic sectors and category of workers affected. For instance, individuals without tertiary education may be more vulnerable to a transition towards sustainable societies.

Understanding the trade-offs behind different decarbonisation pathways is crucial to guide Europe in a desired direction and to alleviate the potential negative impacts of the chosen pathway. The objective of this deliverable is to show how the EUCalc model can help policy makers take informed decisions regarding climate policies by presenting a set of selected scenarios and their associated economic impacts.

In EUCalc, the employment indicators (total and sectoral employment; employment and evolution of wages per educational attainment level) are computed in the employment module. The economic model and methodology used is described in detail in Deliverable 6.8 (Thurm and Vielle, 2019). In short, the employment module receives inputs from the sectoral modules (e.g., lifestyle, buildings, transport, industry, agriculture, and electricity supply) to modify a reference scenario and to reproduce the pathway designed by the user in a macroeconomic model. These inputs include changes in consumption (e.g., food, energy), in industrial activities, and in investment patterns. The employment impacts are then calculated with respect to the reference scenario.

Consequently, the employment module needs input information about the state of the economy in the reference scenario. This information is obtained by constructing reference Input-Output (IO) tables. Therefore, before analysing the economic impacts of several decarbonisation pathways, this report details the processes to generate the library of inputs for the employment module. Part of the methods used were already described in Deliverable 6.1 (Thurm et al., 2018), in which a preliminary methodology to implement employment impacts in the calculator is suggested. When this is the case, this report will only focus on the updates brought to the methodology.

The rest of the document is organized as follows. A brief overview of the trends and evolution of employment in Europe is provided in Section 3. The data and methods to obtain historical IO tables are described in Section 4. The simulation of the reference scenario and the construction of future IO tables for this reference scenario are explained in Section 5. The socio-economic impacts of a set of selected decarbonisation pathways are analysed in Section 6. Finally, we conclude in Section 7 with some policy recommendations.

3 Trends and evolution of employment in Europe

In 2018, 227.8 million people are employed in the European Union representing about 60.4% of the working age population, i.e., persons aged 15-64 (Source: Eurostat, EU Labour Force Survey[1]). There are 133.8 million economically inactive persons, which stay outside the labour market due to education and training, retirement, staying at home to look after children, illness or incapacitated dependency. Of the 246.7 million economically active persons, 6.8% are unemployed in 2018, which is close to the level before the 2008 economic crisis, as illustrated in Figure 1.

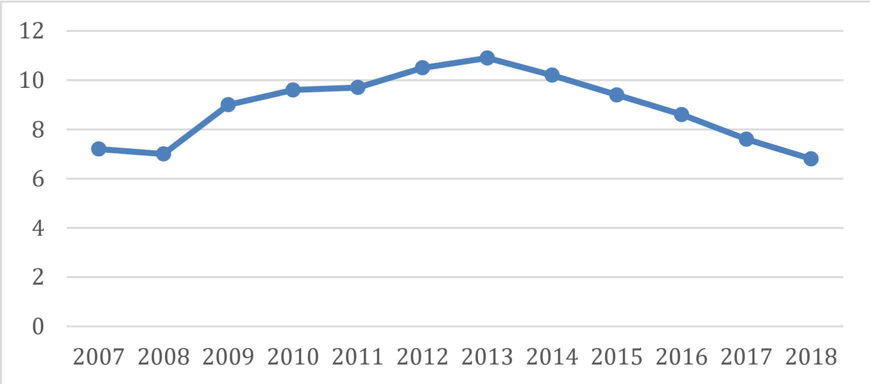


Figure 1 - Evolution of unemployment rate (in % of active population) in EU28 countries (Source: Eurostat, Labour Force Survey)

However, the unemployment rate varies substantially between countries, ranging from 2.2% (Czech Republic) to 19.3% (Greece), as highlighted in Figure 2. There are several determinants that explain such differences, such as employment protection legislation, union density and tax on wages. Decreasing unemployment is a policy priority of the European Commission. Therefore, the decarbonizing actions of European countries could be an opportunity to increase employment following the “double dividend paradigm”. In this paradigm, which was debated in the nineties, the revenue coming from an environmental taxation is recycled through a decrease on social contributions that stimulates job creation at the same time. Other channels can link the transition towards low-carbon economy and employment. For example, increasing energy efficiency can lead to a substitution of energy intensive goods with labour intensive goods. Furthermore, investing in the transition can also stimulate economic growth and create jobs. There is an extensive literature on the topic, which tends to support the idea that an energy transition has positive employment impacts (see for instance Lehr et al., 2012; Cambridge Econometrics, 2015; Pollitt et al., 2015; Hartwig et al., 2017; and Fragkos and Paroussos, 2018).

[1] Description of the EU Labour Force Survey: https://ec.europa.eu/eurostat/web/microdata/european-union-labour-force-survey

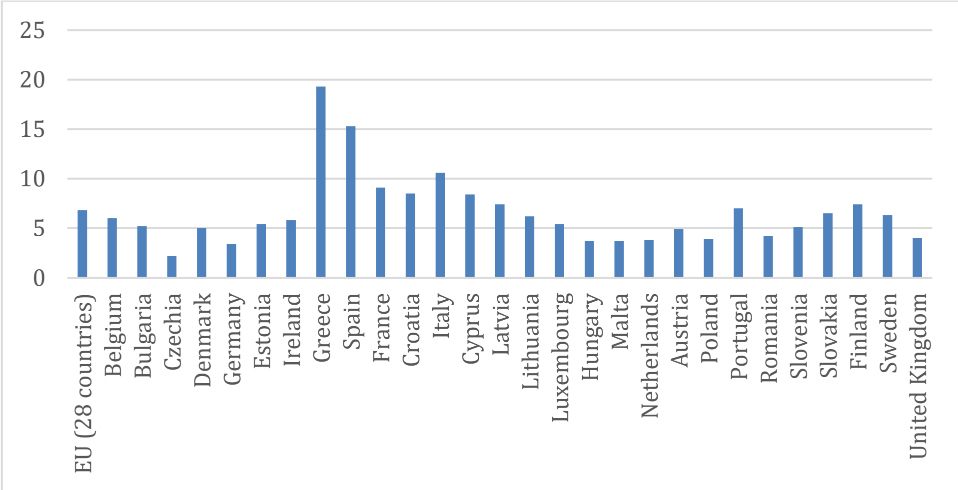


Figure 2 - Unemployment rate (in % of active population) per Member State in 2018 (Source: Eurostat, Labour Force Survey)

Looking at a more detailed picture, employment participation greatly varies depending on the educational attainment level of workers. In Figure 3, the employment rate is shown for three groups classified in function of their educational attainment level.[2] The employment rate is defined as the number of employed people within the age group 25-64 years. This indicator gives information about the difficulties that people with different levels of education face in the labour market. In 2018 in the EU28 countries, the employment rate is only 56.8% for persons with primary education while it is 82.6% for persons having achieved tertiary education. A similar trend is observed in all EU28 Members States.

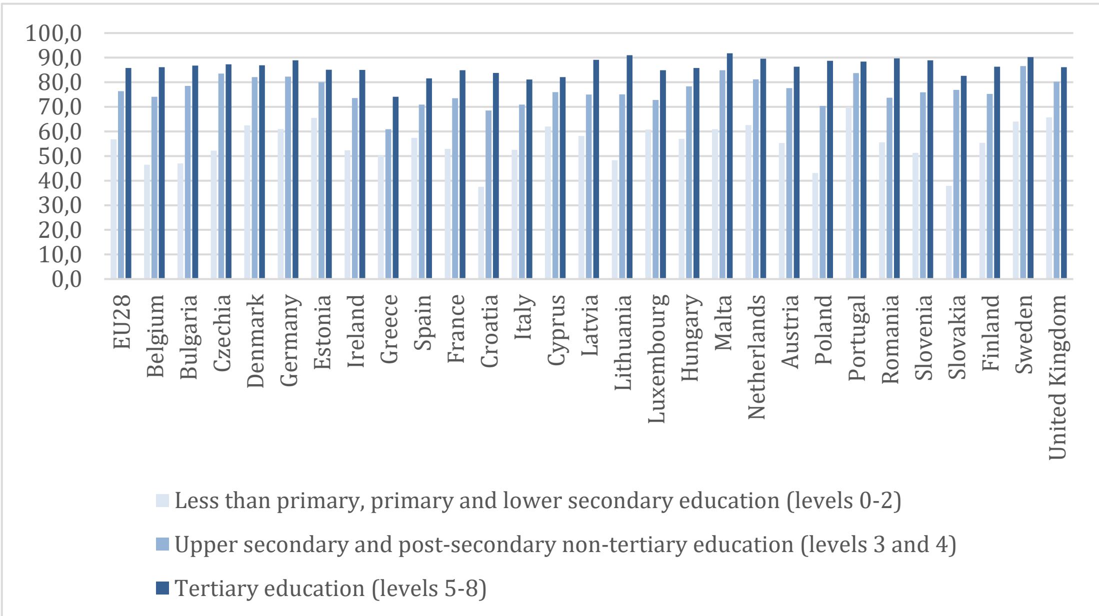


Figure 3 - Employment rate per educational level in EU28 Member States in 2018 (Source: Eurostat, Labour Force Survey)

[2] The educational attainment level is coded according to the International Standard Classification of Education (ISCED), see UNESCO Institute for Statistics (2012).

The European Commission also promotes equal economic independence for women and men with the aim to increase female participation in the workforce, to reduce the gender pay gap and to increase female entrepreneurship and self-employment. In 2018, the female employment rate is 69.1% on average in the EU, while it is 81.3% for men. Gender equality refers to several dimensions. Figure 4 displays the shares of men and women employed (aged 20 to 64 years) for each EU28 Member State. In 26 countries the share of women is lower than 50%, and even lower than 45% in Malta, Greece, Italy, Romania and the Czech Republic. Finally, the gender pay gap (i.e., the difference between the average gross hourly earnings of male and female employees as a percentage of male gross earnings) is 16.2% in 2016 on average across EU28 countries, ranging from 5.2% in Romania to 25.3% in Estonia.

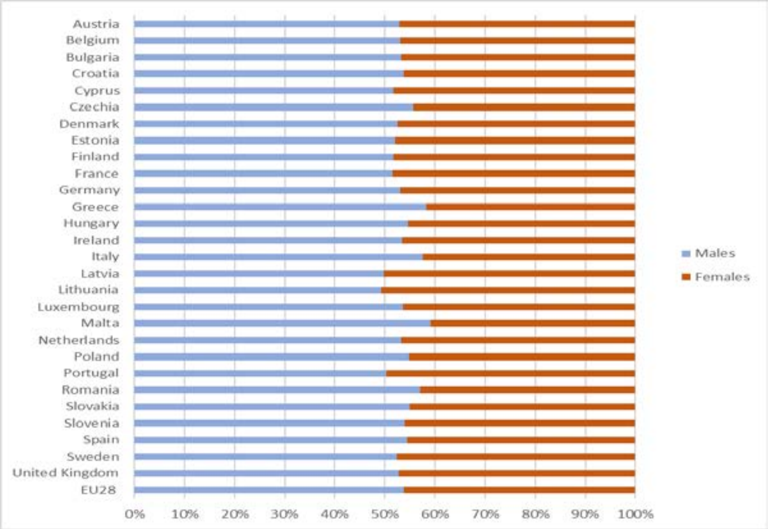


Figure 4 – Share of men and women employed per EU28 Member States in 2018 (Source: Eurostat, Labour Force Survey)

4 Historical database

The historical IO tables, the evolution of the Gross Domestic Product (GDP) and employment data are extracted from the Exiobase[3] version 3 (Tukker et al., 2009). This database provides IO tables for the EU28 countries and Switzerland between 1995 and 2011. It also includes data on employment, disaggregated per educational level and gender.

The Exiobase industrial classification (163 sectors) is modified to obtain the 56 sectors detailed in Table 1. More information about the choice and definition of the economic sectors in the employment module is available in Deliverable 6.8 (Thurm and Vielle, 2019).

Table 1 – Industrial classification used in the employment module

EUCalc WP6 Sectors		Exiobase Correspondence	EUCalc WP6 Sectors		Exiobase Correspondence
01	Crops, Vegetables & Fruits	1-8	29	Glass	65, 66
02	Livestock	9-17	30	Cement	69, 70
03	Forestry	18	31	Other non-metallic mineral	67, 68, 71
04	Fish	19, 45	32	Iron and steel	25, 72, 73
05	Processed crops and vegetables	39, 41, 42, 43	33	Aluminium	28, 76, 77
06	Processed animal products	35, 36, 37, 38, 40	34	Copper	26, 80, 81
07	Beverage	44	35	Other metal	29-31, 74-75, 78-79, 82-86
08	Coal	20, 56	36	Mineral mining	24, 32, 33, 34
09	Crude oil	21, 23	37	Construction	113, 114
10	Petroleum product	57, 58, 116	38	Rail transport	120
11	Gas	22, 110	39	Road transport	121
12	Electricity distribution	107, 108, 109	40	Water transport	123, 124
13	Coal power	96	41	Air transport	125
14	Gas power	97	42	Transport nec	122, 126
15	Nuclear power	98	43	Transport machinery	91, 92, 115
16	Hydropower	99	44	Appliances	87, 88, 89, 90
17	Wind power	100	45	Other consumption good	46, 47, 48, 49, 93
18	Oil power	101	46	Trade	117, 118
19	Biomass power	102	47	Hotels and restaurants	119
20	Photovoltaics	103	48	Education	137
21	Solar thermal power	104	49	Health	138
22	Marine power	105	50	Recycling	94, 95
23	Geothermal power	106	51	Waste incineration	139-145
24	Wood manufacture	50, 51	52	Biogas	146, 147, 148
25	Water	111, 112	53	Composting	149, 150
26	Pulp and paper	52, 53, 54, 55	54	Wastewater	151, 152
27	Chemicals, plastic, rubber	59, 60, 63, 64	55	Landfill	153-158
28	Fertilizer	61, 62	56	Other services	127-136, 159-163

[3] More information on Exiobase: https://www.exiobase.eu/

In addition, to be consistent with the other EUCalc modules, we need to adjust the Exiobase data in the electricity industry branches. In Exiobase, the electricity sector is disaggregated between *Electricity Transmission and Distribution* and 11 sectors related to electricity production. However, the electricity production sectors also include part of the transmission. In EUCalc, *Electricity Transmission and Distribution* corresponds to the electricity consumed in each module (e.g. Buildings, Transport, Industry, Agriculture) while the production is computed in the Electricity supply module. Consequently, we modify the original Exiobase IO tables so that all the electricity consumed by firms, households and government is provided by the sector *Electricity Transmission and Distribution*.

In an IO table, a column details the inputs needed to produce a good, while a row details the intermediate demand (demand of firms) and final demand (demand of households and government). Since we consider that the power sectors (#13 to 23) only includes the electricity production, the inputs of electricity should only come from the *Electricity Transmission and Distribution* (#12) sector. Thus, for each sector (column), we sum the electricity consumed (sectors #12 to 23) into *Electricity Transmission and Distribution* (#12). We proceed similarly for the electricity consumption of households and government. The column *Electricity Transmission and Distribution* (#12) describes the inputs needed to produce electricity. Hence, the electricity mix is represented in this column by the inputs in electricity production (rows #13 to 23). We modify the cells corresponding to the electricity mix (column #12, rows #13 to 23) by replacing their value with the sum of the intermediate and final demand of electricity production. This ensures that the table is balanced, i.e., that the supply of a product is equal to its demand.

As a result, we obtain the historical IO tables for each country, which in turn allows to find the historical input shares and the GDP evolution.

Methodology update (with respect to Deliverable 6.1):

The industrial classification defined in Deliverable 6.1 was adjusted in two ways:

1. *The original plan was to use the GTAP 9 database. However, we decided to switch to Exiobase because this database is open-source, it provides historical data (from 1995 to 2011), and its classification is closer to the sectoral EUCalc modules, allowing for a closer interface. For instance, the rail and road transport are two separate sectors in Exiobase while they are aggregated in the GTAP 9 database.*
2. *The number of sectors was increased (from 39 to 56) to better fit with the sectoral modules representation.*

More information about the choice and the definition of the industrial classification is available in Deliverable 6.8 (Thurm and Vielle, 2019).

5 Reference scenario

The socio-economic impacts of decarbonisation pathways are evaluated with respect to a reference scenario. The demographic and economic assumptions behind the reference scenario are detailed in Deliverable 7.1 (Yu and Clora, 2018). These assumptions mainly build on the EU-Reference Scenario 2016 (Capros et al., 2016; European Commission, 2014; 2015).

To compute the employment indicators, the employment module needs input information about the state of the economy in the reference scenario. This information is obtained by constructing reference Input-Output (IO) tables, which requires several steps:

1. Construction of historical IO tables (see Section 4);
2. Simulation of the reference scenario in a Computable General Equilibrium (CGE) model (Section 5.1);
3. Simulation of the reference scenario in the calculator by carefully selecting the appropriate values for each lever (Section 5.2);

5.1 Simulating the reference scenario in a CGE

The reference scenario is simulated for the period 2011-2050 with yearly timesteps using the Computable General Equilibrium (CGE) model GEMINI-E3. GEMINI-E3 is a worldwide multi-country, multi-sector, CGE model, which has been specifically designed to assess energy and climate change policies. A detailed description of GEMINI-E3 and of the methods to simulate the reference scenario are available in Deliverable 6.1 (Thurm et al., 2018).

GEMINI-E3 runs allow to compute reference IO tables considering not only economic growth but also changes in the economic structure. However, due to the complexity of a CGE model and to the vast number of regions (30), GEMINI-E3 simulations require a limited number of economic sectors, as shown in Table 2.

Therefore, the industrial classification used in GEMINI-E3 differs from the one of the employment module. Additional information is thus needed to construct reference IO tables with the representation of the employment module. It is obtained by simulating the reference scenario in the calculator.

Table 2 – Industrial classification in GEMINI-E3

Sector	
01	Coal
02	Oil
03	Natural gas
04	Petroleum products
05	Electricity
06	Agriculture
07	Energy intensive industries
08	Other goods and services
09	Transport

5.2 The reference scenario in EUCalc

The EU-Reference Scenario 2016 (abbreviated EUref in the following) (Capros et al., 2016) is reproduced in the calculator by selecting the appropriate levers' values. A description of the matching rationale is provided below. This exercise is sometimes challenging, due to the differences in granularity between the EUCalc model and the information available in the EUref scenario. In the absence of specific information, a continuation of historical trends (level 1 or 2) was generally assumed.

Key behaviours

Travel

Passenger distance The best approximation of the distance travelled by passengers is level 1, resulting in a total of 8,660 billion person-kilometer for EU28 countries, about 4.3% below the demand in the EUref scenario. The main reason for this difference lies in the fact that passenger travel demand is determined taking into account the age factor in EUCalc. Indeed, the transport demand of elderly is lower than the one of younger persons (see Deliverable 1.3, Costa et al. 2018, for a full documentation of the lifestyle module). Thus, due to the relative ageing of European population between 2020 and 2050, the trajectories for passenger distance in EUCalc are below the EUref scenario.

Mode of transport In EUref, there is a slight decrease in the modal share of road transport (from 74% to 66%). This correspond to an ambition level 1.9 in EUCalc: the car modal share accounts for 67% of the total.

Occupancy There is no specific information about the utilization of vehicles in EUref. Therefore, we assume that this lever is on level 1, which represents a status quo in 2050 with respect to 2015.

Car own or hire Due to the absence of specific information regarding the utilization of vehicles in EUref, we assume a moderate increase in car sharing represented with level 2.

Homes

Living space per person There is no explicit quantification of the living space per person in EUref. Therefore, a continuation of the past trends (level 1) is assumed.

Percentage of cooled living space There is no explicit quantification of the residential floor area subjected to cooling in EUref due to the higher granularity of the EUcalc model. A moderate increase is thus assumed, which corresponds to level 2.

Space cooling & heating As above, due to the higher granularity of the EUCalc model, no information is available regarding the cooling and heating habits of the population, and we assume that level 2 is the best fit.

Appliances owned The evolution of the appliances ownership is inferred from the evolution of the electricity demand from appliances. In EUref, this electricity demand increases, even though there is a decoupling between the appliances stock and the associated energy consumption. Accordingly, the best fit in EUCalc is level 1.5, reflecting an increase in appliances ownership.

Appliances used There is no specific quantification in EUref regarding the number of hours appliances are used. For a matter of consistency, the level chosen is the same as for the *Appliances owned* lever, i.e. 1.5. This ensures that the increase in electricity demand is caused by an increase in the appliances stock and by an increase of the hours of use in the same proportion.

Diet

Calories consumed For this lever, the granularity of the EUCalc model surpasses the information available in EUref. Given that the biophysical requirements in EUCalc are a function of the age structure, the calories consumed are assumed to follow the population and a level 2.1 is assumed.

Type of diet Although the EUref does not explicitly report dietary choices, information about the agricultural activity is available. The changes in diet that would best represent the changes in agricultural activity as reported in the EUref is obtained with the level 1. Under this level, the calories from pigs decrease by 9% in 2050 in EUCalc (vs. 5% drop of pigs farming in EUref), the calories from sheep decrease by 14.2% in 2050 in EUCalc (vs 15% drop of sheep farming in EUref), the calories of bovine meat decrease by 8% in 2050 in EUCalc (vs a slight decrease of non-dairy cattle and 25% decrease of dairy cows in EUref). Similar information does not exist for other food groups.

Consumption

Use of paper and packaging Since no specific information is available in EUref, a continuation of historical trends is assumed, i.e., level 1.

Product substitution rate As above, the granularity of EUCalc surpasses the information available in EUref regarding the product substitution rate of appliances. A level 2 is assumed, i.e., appliances are replaced once they reach the end of their technical lifetime.

Food waste at consumption level In EUref, there is no quantitative information about the food waste level in households. However, the CH4 emissions from municipal and industrial solid waste are reduced by more than 70% in 2030 due to the implementation of the EU landfill directive. Translating this decrease in emissions in EUCalc would result in a level 4 ambition, i.e. the, EU would comply with the most stringent food waste target already in 2030. Since this trajectory seems very unrealistic for a reference scenario, we assume that the food waste lever takes level 1, keeping constant the current food waste. In other words, we assume that the 70% reduction in CH4 emissions is caused by increasing energy efficiency in landfills, and not by behavioural changes.

Freight distance In EUref, the freight traffic is strongly correlated with GDP growth until 2030, resulting in about 57% increase of the freight distance between 2010 and 2050. The best match in EUCalc is obtained with an ambition level 1, i.e., an increase of 49% of freight distance between 2015 and 2015.

Technology and fuels

Transport

Passenger efficiency The best approximation of the improvement in the vehicles' energy efficiency is obtained with a level 2.2, corresponding to a 29% efficiency increase between 2015 and 2050 and following an S-curve shape. In EUref, the vehicles' energy efficiency improves by 17% in 2020 and by 29% in 2030 with respect to 2010, before stabilizing. Hence, the evolution is delayed in EUcalc, but the 2050 values are similar.

Passenger technology In EUref, the electric vehicles emerge around 2020 to reach 36% of the activity share in 2050. Therefore, an ambition level 2.5 is assumed. With this level, the share of electric vehicles in new vehicles sales is 32.5% in 2043, which corresponds to around 30% of electric cars in the total fleet by 2050.

Freight efficiency Due to the absence of specific information regarding freight vehicles' energy efficiency, a level 2 is assumed, a similar ambition than for the *Passenger efficiency* lever.

Freight technology In EUref, diesel continues to be the primary fuel for heavy duty vehicles. Hence, we assume that this lever is on level 1.1, i.e., diesel engines represent 71% of heavy duty vehicles in 2050 (vs. 98% in 2015).

Freight mode The best fit for this lever is level 1, corresponding to a status quo. In EUref, the road freight experiences a marginal reduction in its modal share, while the rail freight modal share increases from 15% in 2010 to 18% in 2050.

Freight utilization rate Due to the absence of specific information regarding the utilization of vehicles in EUref, we assume an ambition level of 1, i.e., a status quo with respect to 2015.

Fuel mix This lever controls the evolution of the share of biofuels in internal combustion engines. In EUref, this share is not expected to increase after 2020. We therefore assume a level 1, which corresponds to a slight increase (from 4 to 7%) in the biofuels share in road transport between 2015 and 2050.

Buildings

Building envelope In EUref, there are large gains in energy efficiency in buildings in the residential and tertiary sectors due to the implementation of the Energy Efficiency Directive. For instance, the energy for heating in the residential sector gradually decreases from 156 kWh/sqm in 2010 to 85 kWh/sqm in 2050. Although the granularity of the EUCalc buildings module surpasses the information available from EUref, such an evolution corresponds to an intermediate ambition level. Hence, we assume a level 1.5, with for instance an annual renovation rate of about 1.25%.

District heating share While the district heating output is expected to remain relatively constant after 2020 in EUref, the decrease in the energy demand induces a moderate increase in the district heating share. We thus assume a level 1.5 for this lever.

Technology and fuel share The consumption of solids and oil sharply declines in EUref. While the consumption of gas is relatively constant, its market share decreases in the tertiary sector. On the contrary, the electricity gains share, in particular due to the development of heat pumps. These evolutions are best represented by an ambition level 1.5, even though the decrease in gas and the increase in solid bioenergy are overestimated in EUCalc.

Heating and cooling efficiency Following a similar rationale as for the *Building envelope* lever, we assume a level 1.5. Hence, the expected increase in energy efficiency in buildings is represented in EUCalc by additional renovations and by an increase in efficiency of boilers and ventilation systems.

Appliances efficiency As mentioned for the *Appliances owned* and *Appliances used* levers, there is a decoupling between the appliances stock and the associated electricity consumption in EUref. For consistency, we also assume a level 1.5 for this lever.

Manufacturing

Material efficiency There is no specific quantification of the increase in material efficiency in EUref. This lever is set at level 2.5, corresponding to an improvement rate between 5.5% and 20.5% for the different industrial sectors. This level allows to obtain a reduction in the energy demand of industrial sectors of 23% in 2030, the same as in EUref.

Material switch In the absence of information regarding the substitution of materials for more sustainable ones, we assume a level 2.5 to ensure consistency with other manufacturing levers. This means that lightweight materials will replace carbon-intensive materials in the building and transport sector by 15%.

Technology efficiency Following historical trends, there is a decoupling between industrial activities and energy demand in EUref. This results in a steady decline in the energy intensity of the industrial sectors, by almost 40% between 2015 and 2050. This trend is not only due to the fastest growth of non-energy intensive growth, but also to projected investment in new and more efficient productive equipment between 2020 and 2030. However, the investment in new technologies is not maintained after 2030. In addition, EUref does not include recent initiatives promoting a circular economy (e.g., the 2015 Circular Economy Package) while the EUCalc *Technology efficiency* lever also controls the amount of recycled materials for instance. Therefore, we assume a level 2.5 to represent these patterns, corresponding to an average share of the recycling route of 19.5%. While this level results in similar ambition in 2050, the changes in EUCalc are more gradual than the “fast-slow” investment cycle projected in EUref.

Energy efficiency The matching of this lever follows the same rationale as the *Technology efficiency* lever and we thus assume a level 2.5. This represents an intermediate level of energy efficiency, between 6.5% (wood products) and 20.5% (food, beverages and tobacco).

Fuel mix In EUref, the shares of coal and oil sharply decrease, the share of gas remains approximately constant, and the shares of electricity and bioenergy increase. This evolution is best represented with a level 2.5 in EUCalc.

Carbon Capture in manufacturing There is no information regarding carbon capture for manufacturing in EUref. Hence, we assume that this lever takes level 1, i.e., there are no commercially viable carbon capture technology options (for the manufacturing industry) by 2050.

Carbon Capture to fuel This lever controls the share of the carbon captured that is stored (CCS) or used (CCU). In EUref, only CCS is mentioned. We therefore assume a level 1, i.e., all the carbon captured is stored.

Power

Coal phase out Electricity generation from coal power plants significantly decreases in EUref due to the phasing out of coal power plants. Although ambitious, this trend corresponds to a level 1 in EUCalc.

Carbon Capture ratio in power In EUref, the generation plants equipped with carbon capture technologies represent between 0% (in most countries) and 21.4% (in Poland) of the electricity produced by thermal power plants. In most countries (except Austria, the Netherlands and the UK), there are no generation plants with carbon capture before 2045. This pattern is best represented by a level of 1.5, for which investment in carbon capture technologies start in 2030 to reach about 10% of emissions captured on average in the EU in 2050.

Nuclear The installed capacity of nuclear power plants decreases in the EUref scenario, from 114 GW in 2020 to 93 GW in 2050, due to nuclear phase-out policies. Hence, the best fit is a level 4, resulting in 101 GW installed in 2050.

Wind Wind capacities sharply increase in EUref, from 86 GW in 2010 to 367 GW in 2050, supplying 14.4% of the net electricity generation. In EUCalc, this best corresponds to an ambition level 1, i.e. 315 GW in 2050.

Solar Photovoltaics capacities are expected to increase from 30 GW in 2010 to 183 GW in 2030 and to 299 GW in 2050 in EUref. In EUCalc, this trajectory is best represented with an ambition level 1 (166 GW in 2030 and 246 GW in 2050).

Hydro, geo & tidal In EUref, the share of hydro generation remains relatively constant, with only 19 GW increase in installed capacity. Geothermal and tidal electricity generation stay below 0.2% of the total production. The best fit in EUcalc is therefore level 1, i.e., a continuation of current trends resulting in an increase in the total hydro, geothermal and marine capacities of about 20 GW by 2050.

Balancing strategies In EUref, balancing strategies such as pumped hydroelectric storage plants are not included. We thus assume an ambition level of 1.

Charging profiles This lever controls the charging patterns of electric vehicles. Since there is no specific information available in EUref, we assume an ambition level of 1.

Resources and land use

Land and food

Climate smart crop production This lever sets the ambition regarding the crop production system and reflects the transition from an intensive to an agroecology approach. The agriculture sector description is neither explicit nor highly detailed in the EUref scenario. As a benchmark, we considered the N_2O emissions from fertilizer-use (-4% compared with 2005) as well as land-use as cropland (122Mha, circa 8 Mha less compared with 2005). Neither agroforestry nor agroecology options are detailed, leading to prioritize the ambition levels between A and B. We thus assume level A.4, the best match to reproduce the decrease of the N_2O emissions from fertilizer-use. In this setup, conventional crop production practices remain dominant.

Climate smart livestock This lever sets the ambition regarding the livestock production system and reflects the transition from an intensive to an agroecology approach. In EUref, the dairy-cows population decline by 17% in 2030 with respect to 2005, while the dairy-cows yield increase by 42%. The grassland in 2050 decreases by circa 5 Mha. These patterns are best represented with a level C. However, CH_4 emissions are nearly constant in EUref, despite the tremendous increase in dairy-cows yield. This induces a mismatch of about 1.5 $MtCH_4$ between the emissions in EUCalc and in EUref.

Bioenergy capacity In EUref, the use of biomass and waste combustion in thermal power plants increases from 17.3% in 2020 to 31.5% in 2050. Moreover, pure biomass plant capacities reach 57.3 GW in 2050. Finally, biogas and biofuels increase by circa 150%. This scenario was used as a benchmark to define the level of ambition 2.

Alternative protein source This lever controls the share of insect and microalgae-based meals for livestock. Due to the absence of information in EUref regarding livestock meals, we assume that animal feed compounds remain the same as in 2015, i.e., no deployment of insect and microalgae-based meals occurs, which corresponds to a level 1.

Forestry practices In EUref, the forestry sector includes the deployment of coppice and the development of enhanced productivity, leading to a wood production up to 688 Mm3 by 2050, while the emissions associated with deforestation represent 8 MtCO2e by 2050. Given the dropping carbon sink described in EUref, we assume a level 1: the climate-smart-forestry practices are not deployed and no enhanced management is conducted. In this setup, the harvest rate, natural losses, and growing stocks are following the historical trends.

Land management This lever controls the allocation of free lands between natural prairies and forests. In EUref, about 6 Mha are turned into settlements, and 10Mha into new forests, while 7.5 and 5 Mha are lost for cropland and grassland respectively. This dynamic corresponds to a level 2.7, which assumes that freed land is mostly allocated to forest and to grassland to a lower extent. However, EURef only considers the dynamics of grassland, cropland and forests while EUCalc includes settlements, wetlands and other lands dynamics. This results in a mismatch in LULUCF emissions (275 $MtCO_2e$ in EUref vs 325 $MtCO_2e$ in EUCalc).

Hierarchy for biomass end-uses In EUref, there is a gradual development of anaerobic digesters treating manure to recover heat and electricity. This evolution is best represented by an ambition level B. This is a business as usual scenario that considers the use of energy-crops, and a share of industrial and agricultural byproducts to produce bioenergy, feed and biomaterials.

Boundary conditions

Demographics & Long-term

Population In EUref, the EU28 population reaches 522 million inhabitants in 2050 due to increases in fertility rates and life expectancy and a decline in net migration. The best fit for this lever is level B.1, which results in a EU28 population of 522.9 million inhabitants.

Urban population There is no specific assumptions regarding urban population in EUref. We thus assume a level B, i.e., a moderate increase in urbanization following current trends.

Domestic supply

Food production EUref does not report on the changes in food import and export. Hence, the matchmaking was derived using information on the fertilizer use (4% decrease in 2050 vs 2005), on land-use (cropland and grassland are allocated to 122 and 88 Mha in 2050), and on livestock population (decreasing ruminant population, increasing non-ruminant one). This corresponds to a continuation of historical trends, i.e. a level B.3, meaning that self-sufficiency ratio follows historical trends.

Product manufacturing This lever is set on level B, which corresponds to the value computed by the GTAP-EUCalc CGE model (i.e., the model used for trade analysis in EUCalc) when simulating the EUref scenario.

Material production As above, this lever is set on level B, which corresponds to the value computed by the GTAP-EUCalc CGE model when simulating the EUref scenario.

The ambition levels corresponding to the reference scenario are summarized in Table 3. It is worth noting that the EUref scenario is a lowly ambitious scenario in EUCalc, most levers’ reference levels being between 1 and 2.

Table 3 – Ambition levels corresponding to the reference scenario

Headline	Group	Lever	Reference level
Key behaviours	***Travel***	*Passenger distance*	1
		Mode of transport	1.9
		Occupancy	1
		Car own or hire	2
	Homes	*Living space per person*	1
		Percentage of cooled living space	2
		Space cooling & heating	2
		Appliances owned	1.5
		Appliances used	1.5
	Diet	*Calories consumed*	2.1
		Type of diet	1
	Consumption	*Use of paper and packaging*	1
		Product substitution rate	2
		Food waste at consumption level	1
		Freight distance	1
Technology and fuels	***Transport***	*Passenger efficiency*	2.2
		Passenger technology	2.5
		Freight efficiency	2
		Freight technology	1.1
		Freight mode	1
		Freight utilization rate	1
		Fuel mix	1
	Buildings	*Building envelope*	1.5
		District heating share	1.5
		Technology and fuel share	1.5
		Heating and cooling efficiency	1.5
		Appliances efficiency	1.5
	Manufacturing	*Material efficiency*	2.5
		Material switch	2.5
		Technology efficiency	2.5
		Energy efficiency	2.5
		Fuel mix	2.5
		Carbon Capture in manufacturing	1
		Carbon Capture to fuel	1
	Power	*Coal phase out*	1
		Carbon Capture ratio in power	1.5
		Nuclear	4
		Wind	1
		Solar	1
		Hydro, geo & tidal	1
		Balancing strategies	1

		Charging profiles	1
Resources and land use	***Land and food***	*Climate smart crop production systems*	A.4
		Climate smart livestock	C
		Bioenergy capacity	2
		Alternative protein source	1
		Forestry practices	A
		Land management	2.7
		Hierarchy for biomass end-uses	B
Boundary conditions	***Demographics & long-term***	*Population*	B.1
		Urban population	B
	Domestic supply	*Food production*	B.3
		Product manufacturing	B
		Material production	B

Thanks to this simulation exercise, each sectoral module can send the input variables corresponding to the reference scenario to the employment module. In turn, the employment module is using this information to create indicators of transition (see Deliverable 6.8 for more details) and to construct reference IO tables.

5.3 Constructing reference IO tables

GEMINI-E3 simulations (Section 5.1) provide reference IO Tables between 2011 and 2050 with the industrial classification of Table 2 (p. 12). Based on this information, reference IO tables are reconstructed with the industrial representation of the employment module (Table 1, p. 10).

The methodology consists of modifying the historical 2011 IO tables (Section 4) based on the following steps:

1. The intermediate and final consumption are modified:
   a. Each component of the final demand (i.e., households' consumption, government spending, investment, exports) is multiplied by the change with respect to the year 2011 computed by GEMINI-E3, at the aggregated level;
   b. The structure of the final demand components is updated. When the classification of the employment module corresponds exactly to the one used by GEMINI-E3, it is done directly. For example, coal, crude oil, petroleum product, gas, and electricity consumption are represented both by the employment module and by GEMINI-E3. When it is not the case, the changes at the aggregated level are considered. For example, the share of the consumption of agricultural goods in the reference IO tables (i.e., sectors #1 to #4 in the employment module) is assumed to follow the share of the good *Agriculture* (#06, Table 11) computed by GEMINI-E3;
   c. The intermediate consumption is adjusted to consider variations computed by GEMINI-E3, either at the sectoral level or at the aggregated level depending on the concordance between the representations. In addition, the inputs from the sectoral modules (Section 5.2) are used to better account for sectoral shifts not

modelled in GEMINI-E3. For instance, the evolution of the electricity mix is computed using OPEX inputs from the electricity supply module;

2. The imports of each good are adjusted based on the results of GEMINI-E3 simulations, either at the sectoral level or at the aggregated level depending on the concordance between the representations;
3. Finally, a RAS algorithm (Lecomber, 1975) is used to balance the new IO tables, i.e., to equilibrate the supply and the demand in all sectors.

This procedure gives the reference IO tables for each country, which are consistent with the reference scenario simulated by GEMINI-E3 and by the calculator, and which consider not only economic growth but also changes in the economic structure.

5.4 Input data of the employment module

The employment module is using three sets of inputs:

- the input variables from each sectoral module (Lifestyles, Buildings and District Heating, Transport, Agriculture, Industry, CCUS) for the reference scenario. The simulation of the reference scenario in EUCalc was detailed in section 5.2. The detailed input variables are described in Deliverable 6.8 (Thurm and Vielle, 2019);
- information about the state of the economy in the reference scenario, extracted from the reference IO tables (see section 5.3). More precisely, the final demand is directly obtained from the reference IO tables, while the technical coefficients are computed by dividing the sectoral input with the corresponding domestic production;
- the model parameters, such as the elasticity of substitutions, which are described in Deliverable 6.8 (Thurm and Vielle, 2019).

All the inputs are made accessible with the following link and password:

Link: https://cloud.pik-potsdam.de/index.php/s/nMitJ7LKTMSJj3N
Password: ulFh8d25

The naming of each input file as well as the metadata provided follow the EUCalc standards, as detailed in the project's Data Management, Deliverable 11.2 (Costa et al., 2017).

6 Socio-economic impacts

The employment module enables to assess the employment impacts of different decarbonisation pathways. In this section, we discuss the results obtained for a few scenarios to help the users understand how to read these results.

6.1 Scenarios

We will explore four scenarios, ranging from a continuation of past trends to large behavioural and technological changes:

- *Past trends*: This scenario portrays a Europe in which behaviours, technologies and fuels, and land and food largely evolve following past observed trends. Travel demand continues to rise, as does the amount of living space per person. Diets change little beyond a slow decline in bovine meat and a moderate shift towards eating more vegetables. The number of appliances per household increases and so does the demand for packaging. On the technology side, although cars become 20% more fuel efficient by 2050, 98% of new cars have internal combustion engines. The renovation rate of buildings tops out at 1% a year and the depth of renovation is shallow. In industry, energy efficiency gains top out at 5% in 2050.
- *Key behaviours*: This scenario portrays a Europe following the maximum ambition level in EUCalc regarding behavioural changes. Individual travel demand is contained and slightly decreased taking advantage of tele-working/study and remote access to services. Diets European-wide converge to a flexitarian diet with low animal calorie input and food waste is reduced by 50%. Smaller living spaces are favoured and environmental-conscious attitudes rule purchasing decisions for appliances and packaging.
- *Tech and land-food*: This scenario portrays a Europe following the the maximum ambition level in EUCalc regarding technological change, agriculture practices and land management. There is unconstrained progress towards electrification of road transport and the shift to biofuels in aviation. The renovation of buildings towards improved energy standards results in 66% energy saving by 2050. The efficiency of industry process and the switch to new materials makes use of the full technical potential available. There is a strong deployment of renewable and a coal phase out, and the use of bioenergy capacity is fully explored. The whole European agricultural production system follows the agroecology standards. Free land is reforested, and the carbon pool potential is maximised.
- *Ambitious*: This scenario portrays a Europe in which an unparalleled historical change takes place, with a major shift to sustainable lifestyles and huge investment in transformational technologies and fuels. Individual travel demand is contained and slightly decreases. Across Europe, people adopt flexitarian diets low in animal calories, and food waste is reduced by 50%. People favour smaller living spaces and make environmentally conscious buying decisions when it comes to appliances and packaging. There is unconstrained progress towards electrification of road transport and a shift to biofuels in aviation. The renovation of buildings towards improved energy standards results in a 66% energy saving by 2050. The efficiency of industrial processes and the switch to new materials reach

their maximum technical potential. There is strong deployment of renewable energy, and coal is phased out. Intensification of crop and livestock production remains limited, but bioenergy capacity is fully explored. Alternative feed sources for livestock, like insects and microalgae, are fully developed.

The lever position corresponding to each of these scenarios is detailed in the Appendix 9.1, Table 8.

The *Ambitious* and the *Tech and land-food* scenarios entail the largest GHG emissions reduction: net zero is reached in 2039 in the former and in 2047 in the latter, while the 2050 emissions are around -900 $MtCO_{2e}$ and -175 $MtCO_{2e}$ respectively. The *Key behaviours* scenario experience drastic GHG emissions reduction but fail to reach net zero in 2050 (around 1'250 $MtCO_{2e}$). By contrast, the GHG emissions are still largely positive in 2050 in the *Past trends* scenario, more than 3'600 $MtCO_{2e}$, a mere reduction of 500 $MtCO_{2e}$ with respect to 2015.

6.2 Impacts on employment

The four simulated pathways portrait very different future societies. What will the economy look like in 2050, and what will be the consequences for employment?

The results displayed below are computed in the employment module, using inputs from the sectoral modules. All the numbers refer to the year 2050, with respect to the EUref scenario (see section 5.2). The *Key behaviours*, *Tech and land-food*, and *Ambitious* scenario entail drastic changes in the European economic structure. The *Past trends* pathway is closer to EUref and thus leads to moderate changes. The complete results are available in Appendix 9.2, Tables 9, 10, 11 and 12.

The total employment change for each country and scenario is illustrated in Figure 5. An increase of this indicator implies an increase in the total number of hours worked by the whole (active) population in 2050.

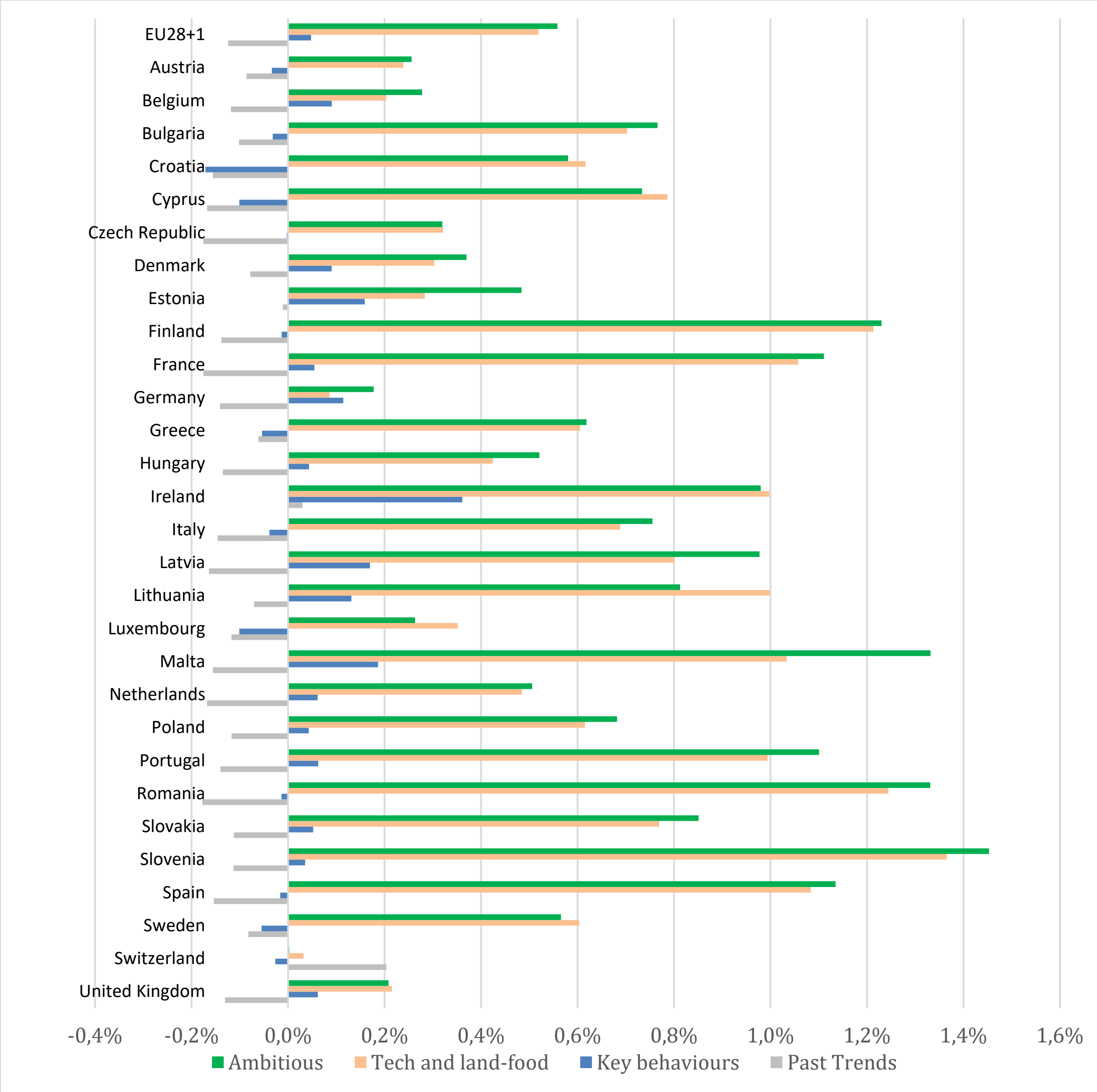


Figure 5 - Change in employment in 2050 (with respect to the EUref scenario, number of hours worked by the active population)

We first observe that the *Ambitious* and the *Tech and land-food* pathways have positive impacts on employment in all countries. The results for the *Key behaviours* scenario are more contrasted, but still positive at the EU28+1 scale (European Union 28 member states + Switzerland). The *Past trends* scenario leads to negative impacts in all countries. Hence, decarbonisation and job creation are not antinomic objectives.

A closer look at the sectoral impacts allows to better understand the drivers behind the employment changes. For clarity, the 56 sectors used in the employment module are aggregated into 5: Agriculture (includes fisheries and the forestry industry), Electricity (production, transmission and distribution), Industry, Transport, and Services. These sectors were chosen to keep consistency with the sectoral modules. The links between this new industrial classification, used to display results in the Transition Pathways Explorer (TPE), and the one used in the Employment module are presented in Table 4.

Table 4 - Industrial classification used in the Transition Pathways Explorer

TPE sector	Employment module sectors
Agriculture	01, 02, 03, 04
Electricity	12-23
Industry	05-11, 24-37, 43-45
Transport	38-42
Services	46-56

The sectoral changes in employment for EU28+1 are displayed in Figure 6. While the overall impacts were relatively small (between -0.12% in the *Past trends* scenario and +0.56% in the *Ambitious* scenario), the sectors experience large and differentiated changes in the decarbonisation pathways (*Key Behaviours*, *Tech and land-food* and *Ambitious*).

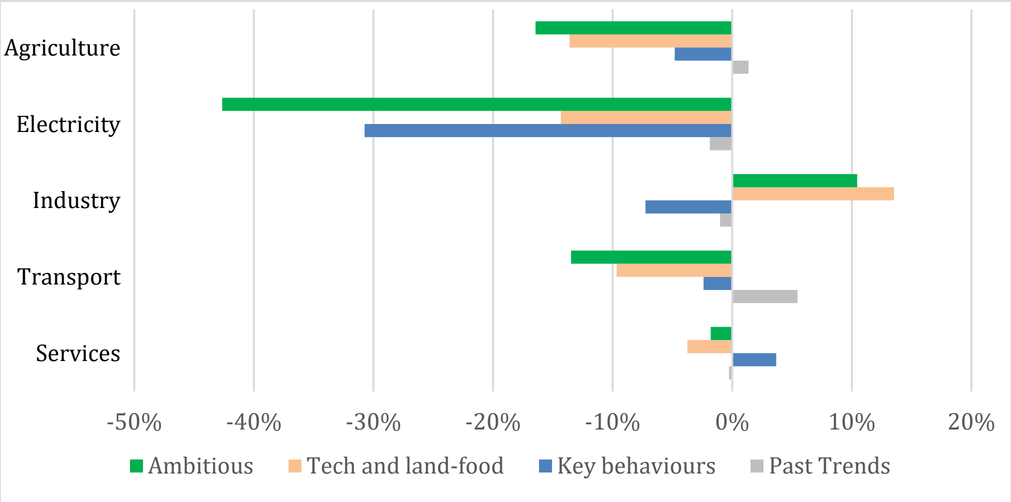


Figure 6 - Sectoral employment changes in 2050 for EU28+1 (with respect to the EUref scenario, number of hours worked by the active population)

When looking at Figure 6, we note that the impacts on employment are negative in all sectors except Services in the *Key behaviour* scenario. Still, the overall impacts are positive in most countries. The reason is that the Services sector represent the largest share in value added, as shown in Figure 7. Hence, an increase in employment in the Services sector can compensate larger decrease in Industry, Transport, Electricity and Agriculture. By contrast, in the *Tech and land-food* and *Ambitious* pathways, the substantial growth in Industry (second sector in terms of value added and employment) compensates for the drop in the other sectors.

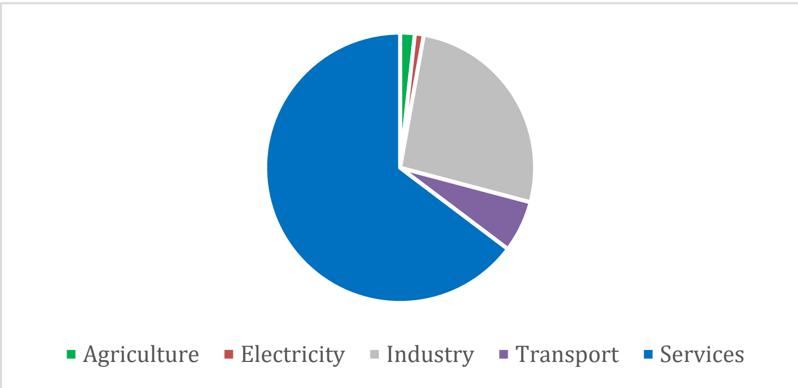


Figure 7 - Repartition of value added between sectors in 2050 for EU28+1 in EUref scenario

In the Agriculture sector, employment decreases in the *Key Behaviours*, *Tech and land-food* and *Ambitious* scenarios because of a drop of livestock and crop production. This is due to changes in diet (less calorie and meat consumed) in the *Key Behaviours* pathway, and to a more efficient production system (increase in yield, reduction of waste) in the *Tech and land-food* pathway. The *Ambitious* scenario combines these effects and thus experience a larger decrease of the agricultural workforce. In addition, there is a decline of forestry due to the lower needs of wood for construction either because of a reduced activity (behavioural changes) and/or a greater efficiency of industrial processes (technological progress).

In the Electricity sector, less employment is expected because the electricity demand decreases. This could arise from a change in lifestyles (e.g., less appliances used and owned) or technological progress (e.g., increased appliances efficiency). The shift in electricity demand (and employment) is stronger in the *Key behaviours* pathway than in the *Tech and land-food* pathway. One reason is the deployment of electric vehicles in the latter.

In the Industry sector, employment decreases in the *Key behaviours* scenario because of a lower activity in industrial sectors. Individuals own less vehicles and appliances, they consume less food and energy and they need less living space. This results in less construction and a lower production of appliances, transport machinery, materials (cement, steel, wood, etc.), processed food and petroleum products. By contrast, employment increases in the *Tech and land-food* pathway. The production of materials, processed food and petroleum products still decrease, but this drop is compensated by higher investment in the construction sector. For instance, even though the electricity demand decreases, the widespread installation of renewables requires substantial investment. As before, the *Ambitious* scenario combines the different effects, and is thus in-between. However, it is worth noting that the *Tech and land-food* and *Ambitious* pathways generate an oversupply of electricity (as indicated by a warning in the online interface). This over-investment therefore inflates the gain in employment. On the other hand, this effect is partly compensated by the lack of investment in renovation in 2050. Indeed, the ambitious setting of the building envelope lever results in a complete renovation around 2043 for most building types, and double renovations are not conducted in the model because the renovations are assumed more sustainable.

In the Transport sector, the impacts on employment are negative in the three decarbonization pathways. Indeed, the distance travelled by households and the demand for freight transport shrink in the *Key behaviours* scenario, while the transportation system improves its efficiency (increased load factor and vehicle efficiency) in the *Tech and land-food* pathway.

The impacts on employment in the Services sector depend on what is happening in the other branch of the economy. For example, the wholesale and retail trade are indirectly affected by the needs for food and materials. In addition, depending on the household consumption of other goods, they can allocate more or less income to leisure activities, e.g., going to bars, restaurants, cinemas, theatres, etc. This explains the positive impacts observed in the *Key behaviours* scenario.

A look at some countries' results is provided in Table 5 (*Tech and land-food*) and Table 6 (*Key behaviours*).

Table 5 – Sectoral impacts in the Tech and land-food scenario (with respect to the EUref scenario, selected countries)

	Austria	Belgium	France	Netherlands	Poland	Portugal
Agriculture	-18.1%	6.2%	-21.3%	0.3%	-18.8%	-9.7%
Electricity	-12.9%	14.8%	-30.9%	-39.0%	-29.8%	-25.9%
Industry	4.5%	3.5%	39.1%	15.7%	13.5%	49.9%
Transport	-10.4%	-7.1%	-11.1%	-12.2%	-12.0%	-20.0%
Services	-0.6%	-0.6%	-10.3%	-3.3%	-6.2%	-14.7%
Overall	***0.2%***	***0.2%***	***1.1%***	***0.5%***	***0.6%***	***1.0%***

Table 6 - Sectoral impacts in the Key behaviours scenario (with respect to the EUref scenario. selected countries)

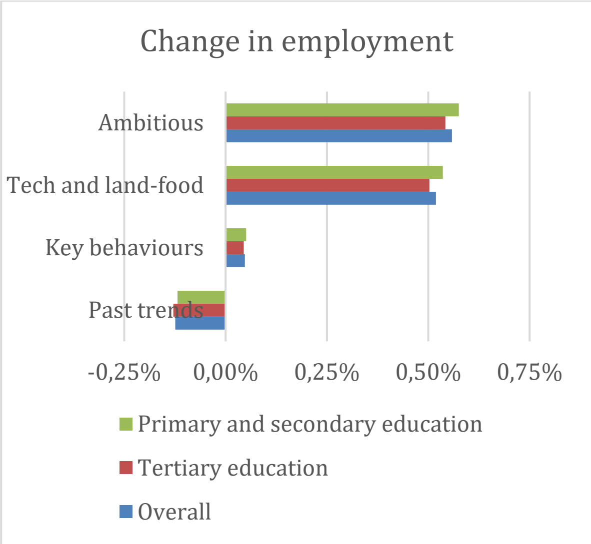
	Croatia	Germany	Hungary	Italy	Ireland	Sweden
Agriculture	12.4%	-5.1%	0.7%	-9.3%	-14.8%	-13.3%
Electricity	-11.6%	-24.8%	-21.9%	-34.1%	-34.1%	-43.3%
Industry	-10.9%	-5.1%	-6.7%	-6.8%	-4.4%	-6.7%
Transport	-2.9%	-2.1%	-3.6%	-14.0%	-0.2%	-4.5%
Services	4.3%	3.9%	4.3%	5.0%	2.9%	4.0%
Overall	***-0.17%***	***0.11%***	***0.04%***	***-0.04%***	***0.36%***	***-0.05%***

Each country is differently affected by the transition. Not only does the intensity differs, but also the signs. For instance, in Belgium, the employment in the Electricity sector is expected to increase in the *Tech and land-food* pathway because the additional electricity demand for electric vehicles more than compensates the increased efficiency of appliances and of industrial processes.

Although there are positive impacts on total employment in the three decarbonisation pathways, the important shifts observed at the sectoral level highlight a key challenge of the transition: the needs for education and training. Moving from one sector to another is not immediate, and workers will need reskilling while educational program should adjust to the new demand.

The decarbonisation pathways not only have differentiated impacts on sectors, they also affect workers differently depending on their skill level. The changes in employment and in average wage per educational level (primary and secondary, tertiary) for EU28+1 are presented in Figure 8. The changes in employment for each skill group follow the one of the total workforce. However, the impacts on wages vastly differ: positive for the *Tech and land-food* and *Ambitious* pathways, negative for the *Key Behaviours* pathway. In addition, the unskilled[4] workers are more affected, either positively or negatively, because the sectors employing more unskilled workers (e.g., construction) are on average more impacted by the transition.

[4] For the sake of brevity, we use the term "unskilled workers" to denote the individuals with primary and secondary education, and the term "skilled workers" for the individuals with tertiary education.



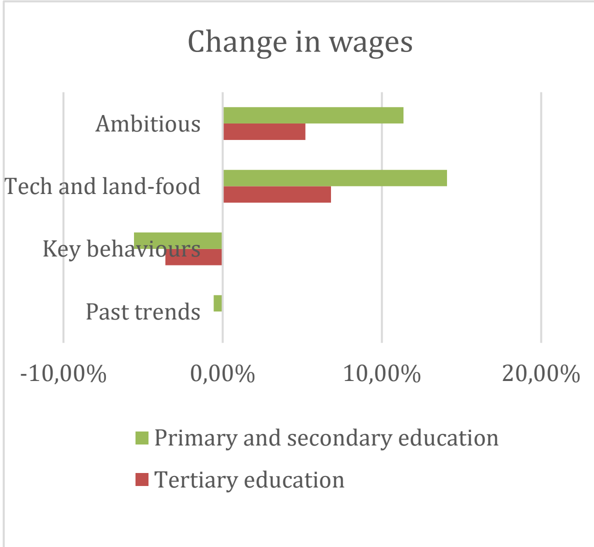


Figure 8 - Impacts on employment in 2050 depending on the educational level of workers for EU28+1 (with respect to the EUref scenario)

Looking at the countries' results, we observe that there can be four different cases, illustrated in Table 7:

1. The employment decreases while the wages increase: individuals can satisfy their needs by working less since they get a higher income for each hour worked. Due to the increase in labour cost, firms are less inclined to hire workers. They might substitute labour with relatively cheaper inputs such as capital, which intensifies the decrease in hours worked.
2. The employment and the wages decrease (most countries in the *Past trends* scenario): individuals get a lower income for each hour worked, they would thus rather work less and enjoy more leisure. Since the labour cost decreases, firms are willing to hire more workers, which mitigates the decrease in hours worked.
3. The employment increases while the wages decrease (most countries in the *Key behaviours* scenario): individuals need to work more hours to satisfy their needs because they get a lower income for each hour worked. Due to the decrease in labour cost, firms are willing to hire more workers, which intensifies the increase in hours worked.
4. The employment and wages increase (most countries in the *Ambitious* and *Tech and land-food* scenarios): since individuals get a higher income for each hour worked, they have some incentives to work more at the expense of their leisure time. With the increase in labour cost, firms are less inclined to hire workers, which mitigates the increase in hours worked.

These patterns are the results of two opposite effects. On the one hand, when the wages increase, individuals have the incentives to work more to get a higher income. This is called the substitution effect, observed in cases 2 and 4. On the other hand, as the wages increase, individuals can enjoy more leisure and still maintain their income. This is the income effect, observed in cases 1 and 3. Which effect dominates depend on preferences between consumption and leisure, on the wages' level, on the economic structure, and on the intensity of structural economic changes.

Table 7 - Impacts on employment in 2050 depending on the educational level of workers (with respect to the EUref scenario)

Country	Scenario	Employment change		Change in wages	
		Skilled	Unskilled	Skilled	Unskilled
UK	Past trends	-0.13%	-0.13%	0.66%	0.62%
Czech Republic	Past trends	-0.18%	-0.18%	-1.23%	-1.47%
Germany	Ambitious	0.18%	0.18%	-4.73%	-6.62%
Finland	Ambitious	1.21%	1.21%	27.56%	43.32%

The price effects play an important role in the results, by either intensifying or mitigating the impacts on the total number of hours worked. For instance, in the UK in the *Past trends* scenario, the average wage of skilled workers increases more than the one of unskilled workers. Due to this relative difference in labour cost, firms are willing to substitute skilled with unskilled workers. As a result, the employment changes are similar for the two groups. Without the price effects, unskilled workers would be more negatively affected than skilled workers.

Finally, the comparison of the changes in wages between educational levels can inform about the vulnerability of each group towards the transition. In Germany, in the *Ambitious* scenario, the average wage of unskilled workers decreases more than the one of skilled workers. Hence, there is a risk of widening inequalities that could endanger the transition if individuals are financially constrained. Indeed, individuals might have the will but not the ability to adopt potentially more expensive lifestyles or to invest in sustainable appliances, in renovation, etc. Worse, the creation of inequalities could decrease the public acceptance of decarbonisation measures. However, this negative outcome can be alleviated thanks to redistribution policies.

The different pathways studied lead to very distinct impacts on employment. What will be the impacts in your pathway? You can find out by using the online version of the calculator.[5]

6.3 Limitations

Although the results derived in the Employment module allow to gain some valuable insights on the socio-economic impacts of decarbonization pathways, the model also has some clear limitations to keep in mind.

6.3.1 Limitations in the sectoral module inputs

In the EUCalc model, the users can explore a wide range of pathways, including some inconsistent ones. When this is the case, a warning informs the users about the inconsistency, and some advices are offered to fix the issue. For example, in the *Tech and land-food* and *Ambitious* pathways, the large deployment of renewables coupled with efficiency gains generate an oversupply of electricity. But since the Employment module receives the inputs without any adjustment, the over-investment in power plants engenders an artificial stimulation of the activity, and in turn the positive impacts on employment are overestimated. Therefore, the users should also pay attention to the warnings in the online interface when exploring the impacts on employment.

[5] EUCalc online tool: http://tool.european-calculator.eu/intro

In addition, the investment patterns, available online in the Cost tab, are computed in the sectoral modules and then sent to the Employment module. In the current version of the model, the capital expenditures to construct a power plant or for renovation activities are fully allocated at the time of the commissioning instead of being distributed throughout the duration of the project. This assumption could lead to an overestimation of the investment needs. Nonetheless, this drawback is alleviated in the Employment module by using the relative changes in capital expenditures (with respect to the EUref scenario) instead of the absolute numbers.

6.3.2 Limitations of the employment module

The indicator retained to compute employment changes is the number of hours worked. Hence, it is not possible to draw lessons on the level of unemployment. Indeed, an increase in hours worked could be explained by more persons being hired, or because already employed persons are working a few more hours each week. The actual level of unemployment is thus dependent on the implemented labour policies, e.g. labour taxes, weekly working hours, minimum wages, financial compensation of extra hours, etc.

The model also makes the unrealistic but commonly-adopted assumption of a perfect labour mobility between sectors (e.g., Bernard & Vielle, 2008; Capros et al., 2013; Pollitt et al., 2015). However, there are barriers preventing workers from moving freely between the different economic sectors, such as skill mismatches or geographic constraints. A more realistic setup would strengthen the price effects (i.e., larger variation in wages) due to the additional constraints on labour availability. It could also curtail some of the positive impacts observed in the decarbonisation pathways. Education and training are thus key to facilitate the important sectoral shifts in employment and to alleviate their negative effects.

Next, the share of skilled and unskilled individuals is fixed in the model, based on the EUref scenario. The implementation of an “education and training” lever was considered but left for future improvement of the model. Such a lever would let the user modify the share of skilled and unskilled workers by controlling the societal investment in education and training.

The analysis of skills suffers from another important limitation. Due to data constraints, the unskilled and skilled categories were defined based on the education level of workers. Hence, many jobs requiring specific skills are wrongly allocated in the unskilled group, for instance building trade activities (electricity, masonry, woodwork, carpentry, painting, etc.). In addition, the aggregation of workers into only two groups, while necessary due to data and computation time constraints, is hiding more specific needs: the individuals in one group are not all substitutable. Similarly, this granularity cannot represent the development of skills needed for particular jobs. For example, the growth of electric vehicles will affect the tasks of mechanics. Therefore, the results on employment change per educational level should be taken with care.

Another issue involves the changes in wages. The current indicator is the change with respect to the EUref scenario. However, a more appropriate indicator should account for a price index, which would allow to discuss the changes in purchasing power. Such a feature is foreseen in future improvement of the model but could not be implemented in this version due to time constraints. Consequently, more important than the variations in wages are the differences between workers depending on their level of education. As discussed in section 6.2, this comparison enables to gain insights on the vulnerability of each group towards the transition and on the potential widening of inequalities.

Automation processes are not included in the model (except when they imply a direct modification of the economic activity such as autonomous vehicles). In other words, the level of automation is assumed the same than in the EUref scenario. The links between automation and decarbonization, although interesting, is left for further research.

Likewise, the changes in labour intensity due to decarbonisation are only portrayed via the price and substitution effects: a relative increase in labour cost decreases the labour intensity. Thus, the changes in labour needs due to changes in production practices are not included. For example, the change of agriculture practices, from an intensive production system to agroecology, will modify the number of workers needed per unit produced. This link between agriculture practices and labour intensity will be implemented in future improvement of the model.

Last but not least, it should be stressed out that the employment module does not offer predictions. Instead, it provides a comparison between what would happen in the user scenario with respect to what happens in the EUref scenario. Therefore, the sign and the size of the effects matter much more than the actual numbers.

7 Policy recommendations

The results of Section 6 illustrate that decarbonisation is not opposed to the creation of jobs, quite the contrary.

Pathways relying on technological progress are expected to experience positive impacts on employment due to the higher investment in the construction and maintenance of sustainable buildings and infrastructures. However, this transition cannot happen without the appropriate policy support. Indeed, not all individuals have the financial ability to renovate their buildings or purchase a more efficient car. The policy schemes should thus assist those in needs. Enforcing binding policies without helping poorer households could only lower the public acceptance of decarbonisation measures.

Pathways drawing on behavioural changes could benefit from a reallocation of income towards services. It is worth pointing out that the analysis of the impacts widely differs between lifestyles- and technology-oriented pathways. In pathways with substantial lifestyle changes, a decrease in employment – not observed in the simulated scenarios – would not necessarily be a negative signal. Indeed, such pathways imply a complete change of paradigm. Individuals decide to consume less food, less energy and less products. Hence, their needs decrease, and they could decide to work less and to enjoy more leisure and non-pecuniary activities. Nonetheless, policy makers should be careful that this transition does not exacerbate the social and ideological inequalities between individuals that have the financial capacity to modify their lifestyles and those that cannot.

The simulated decarbonisation pathways result in very important sectoral shift in employment. Hence, despite the overall positive employment impact and the new job opportunities, there is a high risk of job instability. Policy makers should focus on developing education and training programs to facilitate the transition and to ease the sectoral reallocation of workers. Measures promoting continuous training and reskilling should be implemented to help workers deal with the adoption of new technologies. Educational programs that provide the skills needed for the chosen pathway should be supported. Moreover, policy makers should identify the strategic industries for decarbonisation – which are pathway-dependent – and promote them to avoid outsourcing.

Finally, the gap between the average wages of unskilled and skilled workers is increasing in some pathways (most countries in the *Key behaviours* scenario; Germany and Switzerland in the *Tech and land-food* scenario). This risk of widened inequalities could endanger the transition by preventing some individuals from adjusting their lifestyle and from purchasing sustainable equipment and by decreasing the public acceptance of decarbonisation measures. Consequently, policy makers should keep an eye on this potential negative outcome, which they can alleviate by designing redistribution policies.

8 References

Bernard, A., & Vielle, M. 2008. GEMINI-E3, a general equilibrium model of international–national interactions between economy, energy and the environment. *Computational Management Science*, 5(3), 173-206.

Cambridge Econometrics. 2015. Assessing the Employment and Social Impact of Energy Efficiency. Final report available at: https://ec.europa.eu/energy/sites/ener/files/documents/CE_EE_Jobs_main%2018Nov2015.Pdf

Capros, P., Van Regemorter, D., Paroussos, L., Karkatsoulis, P., Fragkiadakis, C., Tsani, S., ... & Abrell, J. 2013. GEM-E3 model documentation. *JRC Scientific and Policy Reports, 26034*.

Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., ... & Paroussos, L. 2016. EU Reference Scenario 2016-Energy, transport and GHG emissions Trends to 2050.

Costa, L., Matton, V., Staniaszek, D. 2017. Deliverable 11.2: Data management plan for the EU calculator project – Public deliverable of the EUCalc project

Costa, L., Baudry G., Taylor, E., Matton, V., Pradhan, P., Kochat, J. 2018. Deliverable 1.3: Lifestyles in Europe: Perspectives and scenarios – Public deliverable of the EUCalc project

European Commission (DG ECFIN) & Economic Policy Committee (AWG) 2014. The 2015 Ageing Report Underlying Assumptions and Projection Methodologies. *European Economy Report No. 8*.

European Commission (DG ECFIN) & Economic Policy Committee (AWG) 2015. The 2015 Ageing Report Economic and budgetary projections for the 28 EU Member States (2013-2060. *European Economy Report No. 3*.

Fragkos, P., & Paroussos, L. 2018. Employment creation in EU related to renewables expansion. *Applied energy*, 230, 935-945.

Hartwig, J., Kockat, J., Schade, W., and Braungardt, S. 2017. The macroeconomic effects of ambitious energy efficiency policy in Germany–Combining bottom-up energy modelling with a non-equilibrium macroeconomic model. *Energy*, 124, 510-520.

Lecomber, J. 1975. A Critique of Methods of Adjusting, Updating and Projecting Matrices. In *Estimating and Projecting Input-Output Coefficients*. London. Input-Output Publishing Company. Pages 1–25.

Lehr, U., Lutz, C., and Edler, D. 2012. Green jobs? Economic impacts of renewable energy in Germany. *Energy Policy*, 47, 358-364.

Pashaei Kamali F., Thurm B., Rankovic A., Vielle M., Posada J. and Osseweijer P., 2018. Deliverable 6.3: Identification of the parameters relevant to assess socio-economic impacts and consultation workshop – Public deliverable of the EUCalc project

Pollitt, H., Alexandri, E., Chewpreecha, U., and Klaassen, G. 2015. Macroeconomic analysis of the employment impacts of future EU climate policies. *Climate Policy,* 15(5), 604-625.

Thurm, B. Spierenburg L. and Vielle M. 2018. Deliverable 6.1: Documentation on the GEMINI-E3 module and interface and on the way the library is generated – Public deliverable of the EUCalc project

Thurm, B. and Vielle M. 2019. Deliverable 6.8: New EUCalc module on socio-economic impacts – Public deliverable of the EUCalc project

Tukker, A., Poliakov, E., Heijungs, R., Hawkins, T. Neuwahl, F. Rueda-Cantuche, J., Giljum, S., Moll, S., Oosterhaven, J. Bouwmeester, M. 2009. Towards a global multi-regional environmentally extended input–output database, *Ecological Economics*, 68(7):1928-1937.

UNESCO Institute for Statistics. 2012. *International standard classification of education: ISCED 2011*. Montreal: UNESCO Institute for Statistics.

Yu, W. and Clora, F. 2018. Deliverable 7.1: Formulation of baseline projections and documentation on modeling approach review – Public deliverable of the EUCalc project

9 Appendix

9.1 Ambition levels

Table 8 - Ambition levels for each studied scenario

Headline	Group	Lever	EUref	Past trends	Key Behaviours	Tech and land-food	Ambitious
Key behaviours	***Travel***	*Passenger distance*	1	1	4	1	4
		Mode of transport	1.9	1	4	1.3	4
		Occupancy	1	1	4	1.3	4
		Car own or hire	2	1	4	1.3	4
	Homes	*Living space per person*	1	1	4	1.5	4
		Percentage of cooled living space	2	1	4	2	4
		Space cooling & heating	2	1	4	1	4
		Appliances owned	1.5	1	4	1,8	4
		Appliances used	1.5	1	4	1.8	4
	Diet	*Calories consumed*	2.1	1	4	2	4
		Type of diet	1	1	4	1	4
	Consumption	*Use of paper and packaging*	1	1	4	2	4
		Product substitution rate	2	1	4	1	4
		Food waste at consumption level	1	1	4	3	4
		Freight distance	1	1	4	1	4
Technology and fuels	***Transport***	*Passenger efficiency*	2.2	1	1.3	4	4
		Passenger technology	2.5	1	1.1	4	4
		Freight efficiency	2	1	1.1	4	4
		Freight technology	1.1	1	1.1	4	4
		Freight mode	1	1	1.3	4	4
		Freight utilization rate	1	1	1.3	4	4
		Fuel mix	1	1	1.3	4	4
	Buildings	*Building envelope*	1.5	1	1.5	4	4
		District heating share	1.5	1	1.5	4	4
		Technology and fuel share	1.5	1	1.5	4	4
		Heating and cooling efficiency	1.5	1	1.5	4	4
		Appliances efficiency	1.5	1	1.5	4	4
	Manufacturing	*Material efficiency*	2.5	1	1.5	4	4
		Material switch	2.5	1	1.5	4	4
		Technology efficiency	2.5	1	1.5	4	4
		Energy efficiency	2.5	1	1.5	4	4
		Fuel mix	2.5	1	1,5	4	4
		Carbon Capture in manufacturing	1	1	1.5	4	4
		Carbon Capture to fuel	1	1	1	1	4
	Power	*Coal phase out*	1	1	1	4	4
		Carbon Capture ratio in power	1.5	1.5	1.5	4	4
		Nuclear	4	4	4	4	4

		Wind	1	1	1	4	4
		Solar	1	1	1	4	4
		Hydro, geo & tidal	1	1	1	4	4
		Balancing strategies	1	1	1	4	4
		Charging profiles	1	1	1	4	4
Resources and land use	***Land and food***	*Climate smart crop production*	A.4	B	B	D	B
		Climate smart livestock	C	B	A	D	B
		Bioenergy capacity	2	1	1	4	4
		Alternative protein source	1	1	1	4	4
		Forestry practices	A	A	A	D	D
		Land management	2.7	1	1	4	4
		Hierarchy for biomass end-uses	B	B	B	D	D
Boundary conditions	***Demographics & long-term***	*Population*	B.1	B.1	B.1	B.1	B.1
		Urban population	B	A	B	B	D
	Domestic supply	*Food production*	B.3	B	B	B	B
		Product manufacturing	B	B	B	B	B
		Material production	B	B	B	B	B

9.2 Results

Table 9 - Employment impacts in 2050 in the Past trends scenario (with respect to the EUref scenario)

Country	Total	Agriculture	Electricity	Industry	Transport	Services	Skilled	Unskilled	Wage skilled	Wage unskilled
Austria	-0.1%	-0.8%	-4.2%	-0.6%	8.3%	-0.5%	-0.1%	-0.1%	-0.2%	-0.2%
Belgium	-0.1%	1.9%	-10.0%	-2.2%	5.0%	0.3%	-0.1%	-0.1%	-0.6%	-1.1%
Bulgaria	-0.1%	1.9%	-19.5%	-2.6%	6.5%	0.5%	-0.1%	-0.1%	-0.6%	-1.3%
Croatia	-0.2%	1.5%	4.8%	-2.2%	2.8%	0.3%	-0.2%	-0.2%	-2.2%	-2.4%
Cyprus	-0.2%	5.0%	37.9%	-10.2%	11.3%	1.1%	-0.2%	-0.2%	-1.5%	-3.9%
Czech Republic	-0.2%	-0.6%	4.5%	-1.1%	6.4%	-0.2%	-0.2%	-0.2%	-1.2%	-1.5%
Denmark	-0.1%	0.8%	-19.7%	-1.8%	9.1%	-0.2%	-0.1%	-0.1%	-0.7%	-1.0%
Estonia	0.0%	-0.1%	-14.6%	-1.1%	4.3%	0.1%	0.0%	0.0%	-0.7%	-1.1%
Finland	-0.1%	-2.6%	16.9%	-2.2%	6.5%	0.1%	-0.1%	-0.1%	-0.5%	-0.9%
France	-0.2%	1.8%	-13.6%	-2.3%	4.6%	0.1%	-0.2%	-0.2%	-0.3%	-1.3%
Germany	-0.1%	-1.9%	-7.4%	0.1%	6.6%	-0.9%	-0.1%	-0.1%	0.9%	0.7%
Greece	-0.1%	2.0%	7.2%	0.3%	5.9%	-0.6%	-0.1%	-0.1%	0.5%	0.2%
Hungary	-0.1%	0.5%	-6.7%	-2.0%	2.3%	0.5%	-0.1%	-0.1%	-1.0%	-1.8%
Ireland	0.0%	-1.2%	-4.8%	-3.0%	9.4%	0.3%	-0.1%	0.1%	-2.0%	-3.3%
Italy	-0.1%	4.9%	-8.6%	-2.5%	5.5%	0.2%	-0.1%	-0.1%	-0.1%	-1.0%
Latvia	-0.2%	0.6%	2.4%	-1.9%	5.4%	-0.5%	-0.2%	-0.2%	-0.5%	-1.7%
Lithuania	-0.1%	1.8%	-26.7%	-0.5%	4.2%	-0.4%	-0.1%	-0.1%	0.0%	-0.4%
Luxembourg	-0.1%	0.1%	-3.4%	-6.9%	12.3%	0.1%	-0.1%	-0.1%	-1.8%	-2.7%
Malta	-0.2%	-1.3%	600.7%	-2.2%	-5.7%	-1.8%	-0.2%	-0.2%	-0.8%	-1.4%
Netherlands	-0.2%	1.4%	-3.3%	-1.6%	5.1%	-0.2%	-0.2%	-0.2%	-0.4%	-0.8%
Poland	-0.1%	-0.4%	-19.9%	-0.8%	6.1%	-0.1%	-0.1%	-0.1%	-0.2%	-0.6%
Portugal	-0.1%	4.4%	-21.3%	-3.9%	6.2%	0.7%	-0.1%	-0.1%	-0.7%	-2.0%
Romania	-0.2%	2.6%	-6.7%	-1.1%	4.3%	-0.6%	-0.2%	-0.2%	-0.4%	-0.2%
Slovakia	-0.1%	-3.6%	-8.7%	-2.4%	2.9%	1.5%	-0.1%	-0.1%	-1.3%	-2.4%
Slovenia	-0.1%	3.7%	-0.3%	-3.4%	5.5%	0.9%	-0.1%	-0.1%	-1.9%	-2.6%
Spain	-0.2%	0.8%	10.1%	-2.4%	6.1%	0.1%	-0.2%	-0.2%	-0.4%	-1.2%
Sweden	-0.1%	0.4%	-4.1%	-0.5%	3.7%	-0.2%	-0.1%	-0.1%	0.2%	0.0%
Switzerland	0.2%	0.7%	2.1%	-2.8%	8.7%	0.9%	0.1%	0.3%	-1.6%	-3.5%
United Kingdom	-0.1%	2.1%	7.8%	1.3%	3.6%	-0.9%	-0.1%	-0.1%	0.7%	0.6%
EU28+1	-0.1%	1.4%	-1.9%	-1.0%	5.5%	-0.3%	-0.1%	-0.1%	0.0%	-0.6%

Table 10 - Employment impacts in 2050 in the Key behaviours scenario (with respect to the EUref scenario)

Country	Total	Agriculture	Electricity	Industry	Transport	Services	Skilled	Unskilled	Wage skilled	Wage unskilled
Austria	0.0%	-3.8%	-33.4%	-7.0%	-1.2%	4.0%	0.0%	0.0%	-3.8%	-5.5%
Belgium	0.1%	-5.2%	-36.7%	-6.9%	-7.3%	3.6%	0.1%	0.1%	-3.5%	-5.2%
Bulgaria	0.0%	-8.1%	-86.5%	-4.0%	-10.3%	4.0%	0.0%	0.0%	-3.2%	-5.6%
Croatia	-0.2%	12.4%	-11.6%	-10.9%	-2.9%	4.3%	-0.2%	-0.2%	-4.7%	-7.4%
Cyprus	-0.1%	-9.6%	-10.5%	-19.0%	-0.2%	5.0%	-0.1%	-0.1%	-3.6%	-7.8%
Czech Republic	0.0%	-1.3%	-31.5%	-3.8%	8.4%	2.6%	0.0%	0.0%	-2.6%	-3.8%
Denmark	0.1%	-3.2%	-42.3%	-4.5%	-20.8%	3.4%	0.1%	0.1%	-1.9%	-3.7%
Estonia	0.2%	-7.2%	-37.0%	-3.8%	-3.1%	3.7%	0.2%	0.2%	-2.7%	-5.2%
Finland	0.0%	-18.0%	-37.8%	-4.8%	-16.6%	5.3%	0.0%	0.0%	-3.3%	-6.3%
France	0.1%	-3.4%	-42.0%	-10.4%	4.8%	3.4%	0.1%	0.1%	-4.6%	-5.8%
Germany	0.1%	-5.1%	-24.8%	-5.1%	-2.1%	3.9%	0.1%	0.1%	-4.1%	-5.9%
Greece	-0.1%	-7.6%	-37.1%	-14.5%	6.8%	3.2%	-0.1%	-0.1%	-3.0%	-5.6%
Hungary	0.0%	0.7%	-21.9%	-6.7%	-3.6%	4.3%	0.0%	0.0%	-4.1%	-6.7%
Ireland	0.4%	-14.8%	-34.1%	-4.4%	-0.2%	2.9%	0.2%	0.5%	-2.2%	-3.5%
Italy	0.0%	-9.3%	-34.1%	-6.8%	-14.0%	5.0%	0.0%	0.0%	-5.1%	-8.3%
Latvia	0.2%	-2.3%	-10.4%	-3.9%	-20.5%	6.4%	0.2%	0.2%	-5.0%	-8.5%
Lithuania	0.1%	3.7%	-42.3%	-6.4%	-9.1%	6.8%	0.1%	0.1%	-5.1%	-8.0%
Luxembourg	-0.1%	2.0%	-59.4%	-13.6%	1.2%	2.5%	-0.1%	-0.1%	-2.4%	-4.9%
Malta	0.2%	-15.2%	-100.0%	-5.2%	-2.3%	3.2%	0.2%	0.2%	-2.4%	-4.0%
Netherlands	0.1%	-4.5%	-30.7%	-7.1%	3.1%	2.5%	0.1%	0.1%	-2.2%	-3.6%
Poland	0.0%	-14.3%	-46.1%	-6.2%	3.6%	4.3%	0.0%	0.0%	-3.7%	-6.7%
Portugal	0.1%	-18.1%	-58.9%	-9.3%	-3.1%	4.4%	0.1%	0.1%	-4.6%	-7.2%
Romania	0.0%	-6.2%	-26.8%	-7.2%	-2.0%	8.5%	0.0%	0.0%	-7.3%	-13.3%
Slovakia	0.1%	-0.5%	-31.4%	-3.6%	1.1%	3.0%	0.1%	0.1%	-2.9%	-4.3%
Slovenia	0.0%	-12.3%	-24.8%	-4.3%	-14.2%	4.6%	0.0%	0.0%	-3.9%	-6.5%
Spain	0.0%	2.9%	-32.3%	-10.8%	-9.8%	4.9%	0.0%	0.0%	-4.7%	-7.7%
Sweden	-0.1%	-13.3%	-43.3%	-6.7%	-4.5%	4.0%	-0.1%	-0.1%	-2.7%	-5.5%
Switzerland	0.0%	12.4%	-14.3%	-4.3%	2.8%	1.7%	0.0%	0.0%	-1.1%	-2.7%
United Kingdom	0.1%	-0.8%	-28.5%	-9.0%	1.6%	3.0%	0.1%	0.1%	-2.6%	-3.5%
EU28+1	0.0%	-4.8%	-30.7%	-7.3%	-2.4%	3.7%	0.0%	0.1%	-3.6%	-5.6%

Table 11 - Employment impacts in 2050 in the Tech and land-food scenario (with respect to the EUref scenario)

Country	Total	Agriculture	Electricity	Industry	Transport	Services	Skilled	Unskilled	Wage skilled	Wage unskilled
Austria	0.2%	-18.1%	-12.9%	4.5%	-10.4%	-0.6%	0.2%	0.2%	2.0%	3.3%
Belgium	0.2%	6.2%	14.8%	3.5%	-7.1%	-0.6%	0.2%	0.2%	0.9%	2.1%
Bulgaria	0.7%	-6.0%	-34.7%	19.6%	-18.0%	-7.0%	0.7%	0.7%	12.0%	20.3%
Croatia	0.6%	-10.1%	-23.8%	14.0%	-8.9%	-3.5%	0.6%	0.6%	12.0%	15.0%
Cyprus	0.8%	-5.2%	-85.9%	52.8%	-14.2%	-10.7%	0.8%	0.8%	11.4%	27.3%
Czech Republic	0.3%	1.5%	-29.3%	2.2%	-11.2%	0.5%	0.3%	0.3%	2.4%	3.0%
Denmark	0.3%	10.9%	2.2%	10.5%	-14.1%	-1.8%	0.3%	0.3%	3.7%	6.8%
Estonia	0.3%	-10.9%	8.1%	9.2%	-10.4%	-2.5%	0.3%	0.3%	5.3%	9.3%
Finland	1.2%	-31.5%	-72.5%	37.5%	-17.1%	-14.3%	1.2%	1.2%	27.6%	43.3%
France	1.1%	-21.3%	-30.9%	39.1%	-11.1%	-10.3%	1.1%	1.1%	19.8%	35.2%
Germany	0.1%	-3.7%	2.0%	-3.4%	-6.6%	3.0%	0.1%	0.1%	-3.0%	-4.3%
Greece	0.6%	-17.1%	-49.9%	33.2%	-9.0%	-5.3%	0.6%	0.6%	7.8%	17.8%
Hungary	0.4%	-9.5%	-24.0%	10.0%	-4.4%	-3.0%	0.4%	0.4%	5.0%	9.0%
Ireland	1.0%	-2.3%	7.0%	24.9%	0.1%	-9.4%	1.0%	1.0%	18.6%	35.0%
Italy	0.7%	-18.2%	182.2%	21.5%	-15.6%	-6.8%	0.7%	0.7%	9.9%	20.0%
Latvia	0.8%	-14.3%	-12.7%	25.4%	-18.3%	-6.2%	0.8%	0.8%	11.9%	24.3%
Lithuania	1.0%	56.1%	12.6%	9.4%	-20.5%	-2.9%	0.9%	1.1%	4.1%	12.1%
Luxembourg	0.4%	9.1%	-31.1%	19.6%	-12.2%	-2.2%	0.4%	0.4%	5.2%	9.7%
Malta	1.0%	-6.3%	-100.0%	10.1%	5.3%	-1.7%	1.1%	1.0%	3.9%	6.9%
Netherlands	0.5%	0.3%	-39.0%	15.7%	-12.2%	-3.3%	0.5%	0.5%	5.4%	10.1%
Poland	0.6%	-18.8%	-29.8%	13.5%	-12.0%	-6.2%	0.6%	0.6%	8.0%	14.9%
Portugal	1.0%	-9.7%	-25.9%	49.9%	-20.0%	-14.7%	1.0%	1.0%	18.3%	36.5%
Romania	1.2%	-23.5%	19.7%	20.1%	-9.1%	-7.9%	1.2%	1.3%	27.3%	36.9%
Slovakia	0.8%	-16.6%	-27.8%	22.1%	-11.2%	-11.4%	0.8%	0.8%	13.4%	23.2%
Slovenia	1.4%	-42.1%	-31.6%	45.5%	-15.1%	-18.7%	1.4%	1.4%	37.6%	55.6%
Spain	1.1%	-20.7%	-36.3%	42.6%	-16.8%	-12.0%	1.1%	1.1%	18.0%	36.2%
Sweden	0.6%	-13.7%	-61.6%	16.6%	-10.3%	-5.7%	0.6%	0.6%	9.7%	17.1%
Switzerland	0.0%	-4.4%	-11.8%	-2.2%	-6.3%	1.6%	0.0%	0.0%	-1.0%	-2.0%
United Kingdom	0.2%	-2.3%	-36.0%	0.4%	-4.0%	0.8%	0.2%	0.2%	-0.1%	0.7%
EU28+1	0.5%	-13.6%	-14.3%	13.5%	-9.7%	-3.8%	0.5%	0.5%	6.8%	14.1%

Table 12 - Employment impacts in 2050 in the Ambitious scenario (with respect to the EUref scenario)

Country	Total	Agriculture	Electricity	Industry	Transport	Services	Skilled	Unskilled	Wage skilled	Wage unskilled
Austria	0.3%	-17.9%	-50.6%	2.0%	-12.7%	1.3%	0.3%	0.3%	0.6%	1.3%
Belgium	0.3%	3.7%	-26.7%	-0.2%	-14.1%	1.8%	0.3%	0.3%	-1.2%	-1.3%
Bulgaria	0.8%	-15.8%	-90.6%	20.5%	-27.9%	-5.5%	0.8%	0.8%	12.1%	19.7%
Croatia	0.6%	3.4%	-34.3%	11.3%	-17.4%	-1.9%	0.6%	0.6%	11.6%	13.9%
Cyprus	0.7%	-14.7%	-92.8%	40.7%	-18.7%	-7.0%	0.7%	0.7%	8.6%	20.3%
Czech Republic	0.3%	-1.1%	-49.8%	0.6%	-3.9%	1.4%	0.3%	0.3%	2.8%	3.1%
Denmark	0.4%	10.5%	-51.8%	7.6%	-32.9%	0.9%	0.4%	0.4%	2.5%	4.0%
Estonia	0.5%	-16.7%	-32.8%	9.1%	-14.5%	-0.7%	0.5%	0.5%	4.3%	7.3%
Finland	1.2%	-45.4%	-89.3%	37.2%	-35.0%	-11.4%	1.2%	1.2%	26.8%	40.2%
France	1.1%	-23.0%	-63.5%	34.7%	-11.3%	-8.5%	1.1%	1.1%	17.4%	31.8%
Germany	0.2%	-5.4%	-26.7%	-5.7%	-8.1%	5.0%	0.2%	0.2%	-4.7%	-6.6%
Greece	0.6%	-21.9%	-64.4%	27.9%	-9.0%	-3.9%	0.6%	0.6%	7.4%	16.5%
Hungary	0.5%	-9.1%	-41.1%	8.7%	-9.6%	-1.2%	0.5%	0.5%	4.1%	7.4%
Ireland	1.0%	-13.7%	-24.6%	21.2%	-8.9%	-6.5%	1.0%	1.0%	16.3%	30.9%
Italy	0.8%	-23.7%	88.5%	21.0%	-27.5%	-4.8%	0.8%	0.8%	8.3%	17.2%
Latvia	1.0%	-19.0%	-9.9%	27.9%	-38.2%	-2.9%	1.0%	1.0%	9.7%	20.9%
Lithuania	0.8%	49.2%	-21.5%	7.6%	-26.9%	0.2%	0.8%	0.9%	2.2%	9.0%
Luxembourg	0.3%	3.2%	-67.7%	5.3%	-12.0%	0.5%	0.3%	0.3%	2.1%	3.1%
Malta	1.3%	-15.5%	-100.0%	2.8%	5.4%	1.4%	1.4%	1.2%	1.8%	2.7%
Netherlands	0.5%	-4.5%	-54.7%	12.3%	-10.9%	-2.0%	0.5%	0.5%	4.7%	8.7%
Poland	0.7%	-27.9%	-55.7%	12.0%	-12.7%	-4.7%	0.7%	0.7%	7.2%	13.2%
Portugal	1.1%	-27.0%	-64.0%	47.9%	-24.3%	-13.0%	1.1%	1.1%	15.7%	32.1%
Romania	1.3%	-30.5%	16.1%	17.6%	-15.2%	-3.0%	1.3%	1.3%	25.4%	30.2%
Slovakia	0.9%	-16.0%	-52.3%	22.1%	-15.0%	-10.5%	0.9%	0.8%	13.1%	22.8%
Slovenia	1.5%	-45.7%	-47.0%	46.8%	-33.0%	-17.0%	1.5%	1.5%	37.1%	54.0%
Spain	1.1%	-18.4%	-55.1%	39.0%	-27.0%	-9.7%	1.1%	1.1%	15.2%	31.4%
Sweden	0.6%	-23.8%	-93.6%	12.8%	-16.8%	-2.9%	0.6%	0.6%	8.6%	13.7%
Switzerland	0.0%	9.9%	-25.4%	-4.1%	-5.2%	2.2%	0.0%	0.0%	-0.7%	-2.1%
United Kingdom	0.2%	1.6%	-61.2%	-5.2%	-3.8%	2.7%	0.2%	0.2%	-1.5%	-1.4%
EU28+1	0.6%	-16.5%	-42.6%	10.5%	-13.5%	-1.8%	0.5%	0.6%	5.2%	11.4%