Pathways towards a European Low Emission Society
Policy Briefs from the EUCalc project funded by the European Union's Horizon 2020 research and innovation programme

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Impacts of European air pollution on human health

A brief assessment of the EUCalc scenarios

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Headlines

- With current technologies, trends and policy measures, there will be a decrease in annual mortalities attributable to air pollution of PM2.5 in 2050.
- European Union Member States show very different levels of air pollution related health impacts due to differences in emissions and demographics.
- Action to reduce greenhouse gas (GHG) emissions and improve air quality are mutually reinforcing in most cases. There are significant benefits of deeper decarbonisation ambition that can lead to even greater reductions to air pollution impacts.
- Reducing air pollution has a direct effect on improving human health in the EU and it is not dependent on choices made in the rest of the world.
- Policy makers can intensify and accelerate improvements in air pollution with ambitious decarbonisation policies that lead to lifestyle and technological changes.
- Different sectoral contributions and demographics mean that Member States should carefully evaluate the most appropriate policies for their citizens.
- The EUCalc model allows policy makers and politicians to evaluate the air pollution impacts of different climate change mitigation strategies in different sectors. This provide insights on synergies and possible tensions between solutions for climate change mitigation (decarbonisation) and health impacts.

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The EUCalc model and the Transition Pathways Explorer

The EUCalc model user interface - the Transition Pathways Explorer - is a tool that allows users to build a pathway to a net-zero carbon future at European and Member State level. Its scientific mission is to provide a sophisticated, yet accessible, model to fill the gap between integrated climate-energy-economy models and the practical needs of decision-makers. The model relates emission reduction with human lifestyles, the exploitation and/or conservation of natural resources, job creation, energy production, agriculture, costs, etc. in one highly integrative approach and tool which enables decision-makers to get real-time policy support underpinned by comprehensive trade-off analyses.

Politicians, innovators and investors can use the EUCalc Transition Pathways Explorer to create their own pathways to a low-carbon future online, in real-time and together. This tool can help policy makers in the EU28 + Switzerland explore the routes they can take to delivering climate protection, whilst securing energy and other important policy priorities.

Background

Role of the EU Calculator

Reducing climate change and its impacts is one of the biggest priorities within the European Union (EU). Many different pathways have been considered to reduce GHG emissions in manufacturing, building, energy production and transport sectors, in form of innovation in production technologies as well as lifestyle changes. Projections of expected emission reductions are used as a basis to suggest policies to support such transitions strategies. The EUCalc is a model designed to provide such information based on validated data and expert advice. However, choosing the best options is not straightforward as each pathway also brings about other effects and potential trade-offs. It is important to consider potential trade-offs in policy making to avoid undesirable and unintended consequences. While building the EUCalc model, sectoral experts, policy makers and other stakeholders were consulted on which other impacts were most desired and perceived feasible to include in the model. Air pollution was chosen by the stakeholders for its health importance to the European population. Consequently, EUCalc has integrated the effects on air pollution resulting from different sectoral decarbonisation transition and lifestyle choices. This policy brief aims to inform the debate on air pollution and its effect on human health as a consequence of various decarbonisation pathway choices.

Air pollution and health

Air pollution can lead to a range of serious adverse outcomes. Epidemiological studies have shown that there are a large number of adverse health effects associated with air pollution, particularly with particulate matter with a diameter of less than 2.5 microns, called $PM_{2.5}$ (EEA, 2019; WHO, 2016).

Definition of $PM_{2.5}$:

Tiny solid or liquid particles less than 2.5 μm wide, including soot and aerosols formed from gaseous pollutants such as sulphur dioxide, nitrogen oxides and ammonia. Their very small size allows them to enter the air sacs deep in the lungs where they may cause adverse health effects. (UNECE, 2016)

Exposure to air pollution has both long-term and short-term effects. The long-term effect on health relates to premature mortality due to cardiopulmonary (heart and lung) effects. In the short-term, high pollution episodes can trigger increased admissions to hospital and contribute to the premature death of people who are more vulnerable to daily changes in levels of air pollutants.

$PM_{2.5}$ can be directly emitted and formed as secondary $PM_{2.5}$ in the air from gaseous precursors including sulphur oxides (SO_x), nitrogen oxides (NO_x), ammonia (NH_3) and non-methane volatile organic compounds (NMVOCs). The health effects of air pollution, expressed as premature deaths attributable to air pollution, are dependent on the changes in $PM_{2.5}$

concentrations in different Member States and how many people are exposed to the pollution (i.e. the population density); in other words the number of people that would be breathing in more or less $PM_{2.5}$ as a result of policy decisions.

In EUCalc, the outputs for all sectors, including population, are used to calculate the number of premature deaths (mortalities) for each Member State and for Europe in total. In the method, validated data from the IIASA GAINS model provides sectoral population-averaged $PM_{2.5}$ exposure factors (Amann et al, 2011; Wagner et al, 2019). The predicted mortality figures for each Member State and chosen pathway are shown in the Transition Pathways Explorer.

Policies for reducing air pollution

Air pollution resulting from $PM_{2.5}$ has been declining due to the introduction of policies to reduce emissions. Total emissions of all main air pollutants (SO_x, NO_x, NH_3, NMVOCs and primary $PM_{2.5}$) have decreased considerably since 1990. For example, compared with the baseline year ($PM_{2.5}$: 2000; other pollutants: 1990) emissions of NH_3 and NO_x in the EU-28 (European Environment Agency, 2018b) had decreased by 23% and 91% in 2016, respectively. Stricter regulation from the National Emission Ceilings Directive (NECD, 2012 - amended Gothenburg Protocol) included an emission ceiling and emission reduction commitments in 2020 and 2030 of primary $PM_{2.5}$, SO_x, NO_x, NH_3 and NMVOCs. (European Environment Agency, 2018b). Ambient concentrations of SO_2, NO_2 and other nitrogen oxides, PM_{10} and $PM_{2.5}$, lead, benzene (C_6H_6), carbon monoxide (CO) and ozone are regulated under the Directive 2008/50/EC. The directive also sets out two additional targets for $PM_{2.5}$, the exposure concentration obligation and the national exposure reduction target (NERT) (European Environment Agency, 2018a).

Domestic energy sources and agriculture are largest contributors to air pollution

PM2.5 air pollution stems from various activities and hence differs is each country. On average for Europe in 2015, air pollution was most prominently caused by the building sector (25.7%), driven to a large extent by domestic heating, followed by the agriculture sector (25.6%), the electricity sector (12.2%), the transport sector (10.5%) and the industrial sector (6.3%) as illustrated in Figure 1. District heating only counts for 0.3% of overall emissions. Energy consumption through solid biomass is responsible for 75% of the emissions related to the building sector. Nitrogen fertilizer and livestock for dairy acount for 49% and 19% of the agriculture sector. Agriculture is a key emissions source of ammonia associated mainly with fertiliizer application, which is an important precursor of $PM_{2.5}$. The control of ammonia emissions is regarded as one of the most effective control strategies in mitigating the $PM_{2.5}$ concentrations (Pozzer et al., 2017; Schiferl et al., 2014).

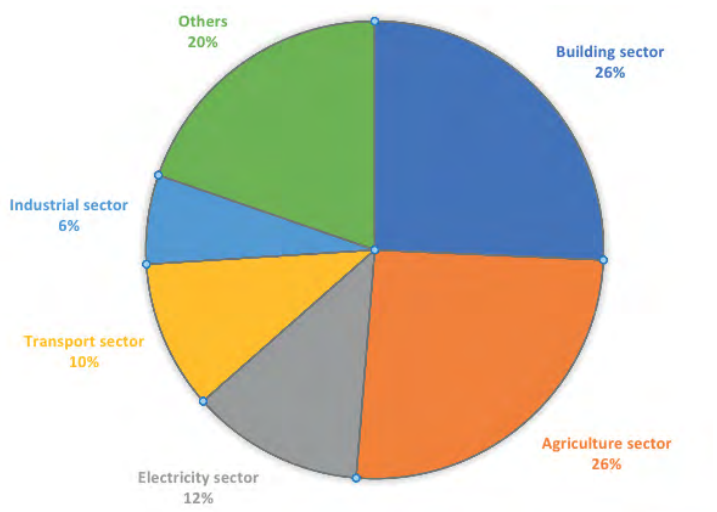

Figure 1: Air pollution sources in Europe, 2015 (Åström, S., 2015).

Present day air pollution health impacts

In 2015, according to the EU Reference (EURef) scenario, there were 252,000 deaths in the EU 28 Member States plus Switzerland (EU28+1) attributable to $PM_{2.5}$ exposure, varying from 50,000 in Germany to less than 100 in Malta and Cyprus (Capros P. et al., 2016). Germany and Italy had the highest number of mortalities (above 40,000 deaths), followed by Poland, France and the UK (Figure 2).

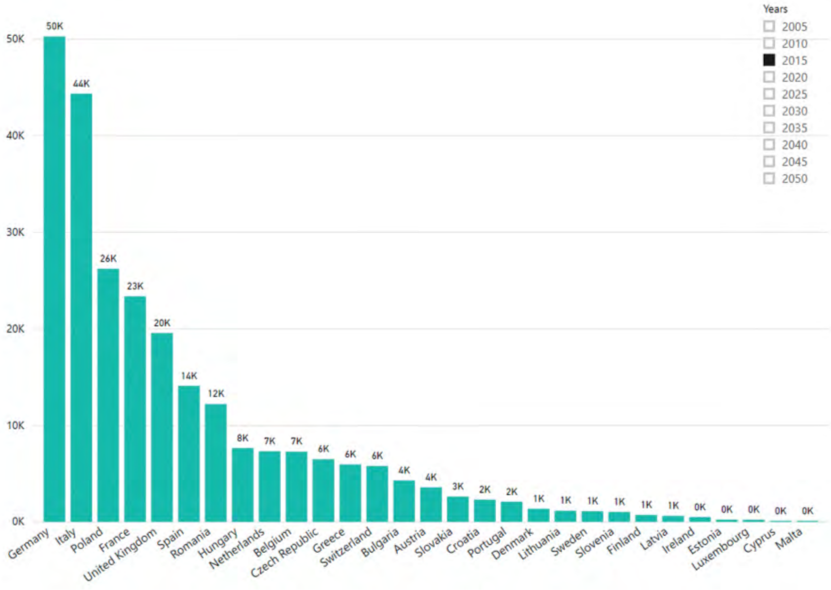

Figure 2: PM2.5-attributable premature mortalities (number of deaths) in each EU28+1 country in 2015, EUCalc.

Results from the EUCalc compared to other models

Comparing the mortality estimates in the EURef scenario (252,000) to the latest estimate of $PM_{2.5}$-attributable premature mortalities from the European Environment Agency (EEA) for 2016 (EEA, 2019) of 378,000 for the EU28+1, the EUCalc health model captures 2/3 of the total. This is within the 95% confidence interval of 248,000 - 489,000, which reflects potential differences in emissions and uncertainties in the concentration response function. Comparing the top five countries with the highest mortalities, EUCalc estimates agree with the EEA in determining that the largest health impacts, and their ranking, are in the countries with the highest populations: Germany, Italy, Poland, France and the UK. The lower estimates from EUCalc of mortality attributed to $PM_{2.5}$ compared to the EEA is likely due to: (i) the spatial resolution of the model, which is at the Member State level, compared to the higher resolution pollution and population maps used by the EEA; and (ii) the propagation of lower average population-weighted exposure at the Member State level, which is then propagated through to a non-linear concentration-response function.

Impacts on human health resulting from decarbonisation pathways in Europe

Under business as usual (BAU), there is a declining trend in air pollution impacts on health in Europe to 2050 as a result of improvements in emissions control technologies stimulated by existing EU policies. In the EURef scenario, which represents BAU, mortalities due to air pollution in Europe decrease from 253,000 in 2015 to 145,000 in 2050, a decline of 43%.

However, there are significant benefits of decarbonisation that lead to even greater reductions to air pollution impacts. Simply, greater decarbonisation ambition leads to greater air pollution benefits, as shown in Figure 3.

Combinations of technological and lifestyle changes lead to the greatest reductions. This can be shown by analysing the results of different scenarios, which are described in Appendix 1. Under the ‘Middle of the Road’ scenario, which portrays a Europe in which behavioural changes are prioritised over the adoption of sustainable practices but without reaching the full level of possible ambition, annual air pollution attributable mortalities are reduced to 119,000 in 2050 – 18% lower than in the scenario. Under the 'Ambitious' scenario, in which there are unprecedented changes towards sustainable lifestyles and the deployment of transformational technologies and fuels, annual air pollution attributable mortalities are reduced to 94,000 in 2050 – 35% lower than in the scenario.

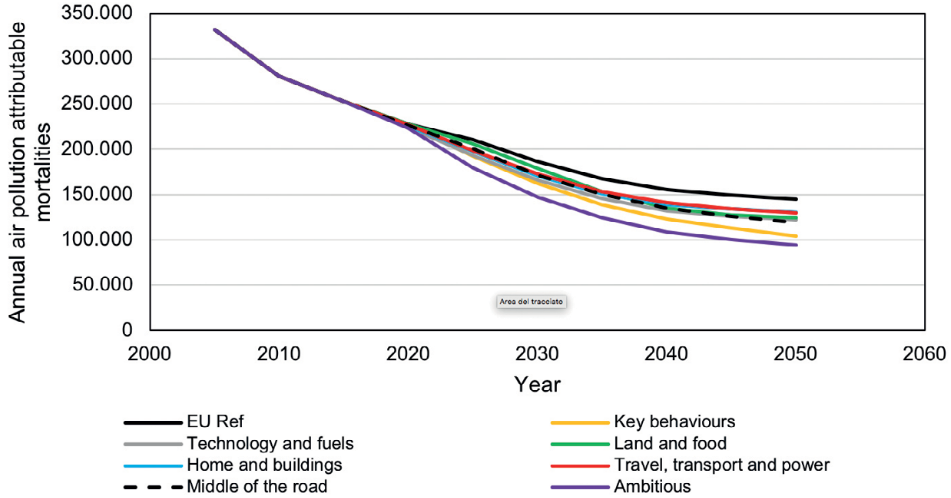

Figure 3: Air quality impacts under different decarbonisation pathways (in number of deaths per year, regarding PM2.5).

Challenges in policy choices

There are different sectoral contributions to air pollution impacts in different Member States, revealing the sectors that need to be addressed in each Member State, and providing insight into the implications of the European Green Deal.

The European Green Deal (European Commission, 2019) recognises that decarbonisation and air pollution are interlinked. The evidence from EUCalc is that greater action to decarbonise the economy has significant benefits for air quality and health: that they are 'mutually reinforcing'. EUCalc can provide insight into two areas of the European Green Deal in particular:

- 'From 'Farm to Fork': designing a fair, healthy and environmentally-friendly food system' recognises impacts of agriculture on air pollution in the Green New Deal. The 'Land and food' scenario demonstrates that efforts to make European Land and Food 'climate-smart' could reduce air pollution impacts relative to the reference scenario – annual air pollution attributable mortalities are 14% lower than the scenario is 2050.
- 'Accelerating the shift to sustainable and smart mobility' includes ambition for modal shift onto cleaner and more sustainable modes (including multi-modal transport options), alternative fuels, and to make transport in cities less polluting. The 'Travel, transport and power' scenario captures changes in lifestyle choices as well as improvements in technologies. This shows that significant improvements in health result from decarbonisation of transport sector – annual air pollution attributable mortalities are 10% lower than the scenario by 2050. As part of the new Green Deal, more stringent emissions standards on combustion-engine vehicles will be proposed from 2021. This illustrates that policy is heading in the right direction, and that since the policies will lead to reductions in air pollution impacts, policy makers can create more significant benefits by introducing the policies more rapidly.

What are the transboundary issues?

Reducing climate change impact through decarbonisation in Europe is critically important. However, the effects of European efforts to reach net-zero carbon emissions globally are highly dependent on the choices in other continents.

While air pollution is a transboundary phenomenon, the majority of air pollution impacts are caused by emissions in Europe. In EUCalc, transboundary effects in Europe are considered and previous literature showed that air pollution impacts in Europe are pre-dominantly caused by emissions within Europe; <5% of $PM_{2.5}$ of the total mortality impact in Europe is attributed to extra-regional emissions (Anenberg et al., 2014; Zhang et al., 2017).

This indicates that reducing air pollutant emissions in Europe will have significant and direct benefits to the health of European citizens.

The United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution covers most of the northern hemisphere, from the United States of America and Canada across Europe and the Russian Federation to Central Asia, and is the only multi-lateral, legally binding instrument on transboundary air pollution. This convention is the right forum for further development of transboundary effects of pollution.

What are the consequences of reducing air pollution in Europe?

Air pollution impacts will decrease in time due to the effect of policies that are already in place. Decarbonisation and air pollution are mutually reinforcing, and greater ambition in decarbonisation will lead to lower air pollution impacts and will achieve them more rapidly. Policy makers can intensify and accelerate air pollution improvements by implementing decarbonisation policies that combine technological and lifestyle changes.

There will be some differences in the most appropriate policies for different Member States as a result of different sectoral contributions and demographics. EUCalc provides policymakers with a tool to quickly evaluate the changes in air pollution resulting from different policy choices.

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Appendix 1
Description of selected decarbonisation pathways (from the EUCalc Transition Pathways Explorer)

EU Reference: the combination of lever positions under this scenario reproduces, as far as possible, the main sectoral assumptions and outputs of the EU Reference scenario as detailed in Capros et al. (2016).

Key behaviours: maximum ambition level in the EU Calculator regarding Key behaviour, which lead to a more substantial lifestyle change than that considered in the 1.5LIFE scenario. In this scenario Technology and fuels, and Land and food default to those of the EU Reference scenario.

Technology and fuels: maximum ambition level in the EU Calculator for Technology and fuels while Key behaviours and Land and food evolve as those in the EU Reference scenario.

Land-food: reflecting the ongoing debate that brought about the IPCC Special Report on Climate Change and Land approved in August 2019 (IPCC, 2019), this scenario represents a Europe where Land and Food become climate-smart (which might not always result in lower GHG emissions). In this scenario Key behaviours and Technology and fuels evolve as in the EU Reference scenario.

Tech and land-food: this scenario is and extension of the "Max ambition in land-food " by further pushing maximum ambition in Technology and fuels. In this scenario Key behaviour evolves as in the EU Reference scenario.

Behaviour and land-food: maximum efforts in Key behaviour and Land and food are undertaken and where efforts in Technology and fuels evolve as in the EU Reference scenario.

Behaviour and tech: maximum efforts Key behaviour and Technology and fuels are undertaken and where efforts in Land and food evolve as in the EU Reference scenario.

Travel, transport and power: maximum ambition in decarbonizing the Transport sector is undertaken. The effort takes place not only on the side of Key behaviours, namely on changes in travel distance, mode and occupancy rates, but also on the side of Technology and fuels, with a shift to higher efficiencies and changes in the fuel mix. Accordingly, maximum ambition in the power sector in order to accommodate the expected demand in electricity is also undertaken. The remaining levers are set to the EU Reference scenario.

Homes and buildings: maximum ambition in decarbonizing the Buildings sector is undertaken. The effort takes place not only on the side of Key behaviours, namely on changes in living space per person, but also on the side of Technology and fuels, with a shift phase out of fossil fuel use in buildings and aggressive renovation rates toward higher energy efficiency The remaining levers are set to the EU Reference scenario.

Past trends: this scenario portraits a Europe in which both behavioural change and technologies and fuels largely evolve following past observed trends. Travel demand continues to rise and so does the amount of living residential are per person. Diets change very little apart from the 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, sales of vehicles with internal combustion engines make up 98% of new car sales. The renovation rate of buildings tops at 1% a year and the depth of renovation is shallow. In Industry energy efficient gain top at 5% in 2050.

Middle of the road: behavioural changes prioritize the adoption of sustainable practices but without reaching the full level of possible ambition. Individual travel demand slows down but does not decline, the adoption of less-carbon intensive diets is left half the way to that entailed in WHO health recommendations, the amount of residential living space per person remains constant. On the technology and fuels largely side, there is considerable progress towards the deployment of electrification of transport, new energy standards in buildings, improved industrial processes and strong deployment of renewables. On the side of land and food the level of intensification of both crop and livestock production remains limited. The use of alternative protein sources for livestock like insects and microalgae reaches up to 10% of required ration. At the same time, any free land is converted mostly to prairies.

Ambitious: an unparalleled historical change takes place both on the side of behavioural changes prioritizing the adoption of sustainable lifestyle, and the deployment of highly costly transformational technologies and fuels. 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. On the technology and fuels 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 stitch to new materials makes use of the full technical potential available. There is a strong deployment of renewable and a shift coal phase out. On land and food the level of intensification of both crop and livestock production remains limited but the use of bioenergy capacity is fully explored. In addition, potential of alternative protein sources for livestock feeding, like insects, is fully developed.

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Further information on the EUCalc project:

The EUCalc project aims at providing a highly accessible, user-friendly, dynamic modelling solution to quantify the sectoral energy demand, greenhouse gas (GHG) trajectories and social implications of lifestyle and energy technology choices in Europe.

The novel and pragmatic modelling approach is rooted

between pure complex society-energy systems and

integrated impact assessment tools. The EUCalc model with its user interface - the Transition Pathways Explorer – has been designed to be both accurate but also accessible to decision-makers and practitioners. It covers all sectors and can be used by one or many people. The model is also open source so that experts can refine the model itself. The tool will have an e-learning version, the "My Europe 2050" tool as well as a Massive open online course (MOOC). See more on the EUCalc project, its scientific reports and all other outputs and access the Transition Pathways Explorer at:

www.european-calculator.eu

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Policy Briefs - Pathways towards a European Low Emission Society

The Policy Briefs on Pathways towards a European Low Emission Society, summarises key finding of the EUCalc project with a clear policy orientation, which provides practical climate change mitigation insights to both EU and individual Member States decision-makers. These policy briefs cover the following topics:

No. 1	The role of lifestyles changes in EU climate mitigation - Insights from the European Calculator
No. 2	Innovation and technology development - Decarbonisation pathways for manufacturing & production sector
No. 3	Long-Term Renovation Strategies: How the building sector can contribute to climate neutrality in the EU
No. 4	Avoid, shift, improve - Decarbonisation pathways for the transport sector in Europe
No. 5	Mitigating GHG Emissions through Agriculture and Sustainable Land Use - An Overview on the EUCalc Food & Land Module
No. 6	Decarbonizing the EU electricity sector - From ageing powerplants to renewable energy futures
No. 7	Implications of decarbonizing the EU economy on trade flows and carbon leakages - Insights from the European Calculator
No. 8	Impacts of European air pollution on human health - A brief assessment of the EUCalc scenarios
No. 9	Pathways towards a fair and just net-zero emissions Europe by 2050

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