Pathways towards a European Low Emission Society
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Mitigating GHG Emissions through Agriculture and Sustainable Land Use

An Overview on the EUCalc Food & Land Module

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Headlines

- Several options are available for evaluating potential agriculture and land use interventions by 2050, including: climate smart production systems for crops, livestock and forestry products, land management, alternative protein sources for livestock, bioenergy, and the management of organic wastes and residues.
- Agriculture and land use can either help mitigate GHG emissions through enhancing the net land carbon sink or exacerbate emissions by emitting more GHGs than are taken up overtime.
- With combined action at the highest levels of mitigation ambition in the food (supply and demand) and agricultural sectors, we estimate that over 1 000 Million tonnes of CO_2 removals per year could be generated by 2050. This would require systemic, sustained and transformative change in the levels of technological and behavioural innovation applied in all EU Member States.
- Changes in diet are a significant driver that enable and/or disable the range and extent of the sustainable mitigation options for the agricultural production system. Agroecology is a suitable option for the European agriculture production system, only when a dietary shift occurs that reduces demand for high emission agricultural products.
- Agricultural intensification can 'free up' the land needed, expanding forests and grasslands, but there are inherent limits for achieving sustainable intensification without causing major impacts on animal welfare, biodiversity and natural resources such as water and plant nutrients.
- The EU international food trade balance (imports vs. exports) has and will continue to have a significant impact on land use dynamics inside and outside Europe.
- Climate change mitigation efforts on Land Use, Land Use Change and Forestry (LULUCF) and sustainable biomass provision are fundamental components in achieving a net zero-emission pathway, when carefully implemented along with ambitious levels of mitigation in the transport, manufacturing, buildings, and power sectors.

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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 and policy framework

The current efforts for climate change mitigation in agriculture and land use have not been enough to avoid a dangerous increase in the global mean surface temperature in the coming decades. At the same time, the global population and the demand for food, forest and bioenergy products keep increasing, including in Europe. The challenge is: how to promote sustainable land use, whilst also achieving food and energy security, health and prosperous lifestyles, water and biodiversity conservation, and carbon mitigation by 2050 and beyond?

Behavioural changes, policy decisions and market regulation can directly affect the capability and capacity of agriculture and land use to contribute to climate change mitigation targets. The EU has been trying to address these issues through several directives and regulations, in addition to national and local efforts carried out in its different Member States. The report of the High-Level Panel of the European Decarbonization Pathways Initiative [1], for example, proposes a circular approach to agriculture, land use and the bioeconomy, from which it would be possible to restore soil fertility and decarbonise the economy. Sustainable land use practices and nutrient recycling (e.g. via composting) can help achieve circularity, especially in agroecological and integrated land use schemes such as agroforestry, rather than linearity, which is often observed in conventional agriculture, based on the intensive use of agricultural inputs (fertilisers, pesticides). These issues align with the EU's proposed 2019-2024 agenda launched by the current president of the European Commission, Ursula von der Leyen [2], with the ambition of Europe becoming the first carbon-neutral continent. More recently, the European Commission submitted a Communication (ref. COM (2019) 640 final), to the European Parliament, the European Council, the Council, the European Economic and Social Committee, and the Committee of the Regions for a 'European Green Deal' [3]. Hence, land and food are in the core of the EU policy agenda on carbon mitigation and sustainable development.

The European agricultural production system is mostly driven by the EU's Common Agricultural Policy (CAP). Its agricultural emissions account for approximately 438 MtCO2eq per year, which is equivalent to around 10% of the total GHG emissions in the EU, with crop cultivation representing about 40% and livestock about 60% of these emissions in 2015 [4]. In contrast, the EU's Land Use, Land Use Change and Forestry (LULUCF) sector has a net negative GHG emissions balance, with greater rates of carbon captured than emitted in the recent past, primarily because Europe continues to expand its forest area and decrease deforestation rates. Therefore, LULUCF is a key pillar for enabling net-zero emission pathways as zero emissions by 2050 in all the other sectors of the economy is extremely unlikely. Thanks to the natural carbon cycle, the world's oceans, lands and forests constitute major natural carbon sinks that are currently offset CO2 emissions. Whilst most of the EU's forests are commercial and actively managed, in 2016, they captured 419 MtCO2eq, representing almost 8% of its total GHG emissions [4].

Bioenergy, the production of liquid fuels (e.g. ethanol, biodiesel, and hydrotreated vegetable oil - HVO) as well as solid biomass (e.g. wood pellets, logs and chips) and biogas for heating and electricity, has all increased in Europe. In particular, the EU's bioelectricity generation capacity, about 28 TWh in 2015, continues to increase driven by the need to rapidly phase-out coal generation. However, concerns about direct and indirect land use change effects have recently influenced EU policy which is now aimed at reducing the risk of major environmental impacts arising from bioenergy expansion inside and outside Europe's boundaries. In 2018, a revised Renewable Energy Directive – RED II (2018/2001/EU), entered into force, 'recasting' renewable energy, particularly bioenergy, policy through to 2030. The EU also has a common legislation for waste management, e.g. the Waste Framework Directive (2008/98/EC), comprising both waste prevention and recovery, among other initiatives, which is also under review.

Agriculture and Land Use Dynamics

Agriculture and land use are one of the most complex sectors of the economy to be modelled robustly, because of the large number of variables and uncertainties involved. However, specialist models are often too complex to be understood by non-expert audiences and usually are not integrated with models from other sectors to drive whole-systems models targeted at meeting the needs of decision makers, nor are they available in open access forms. Thus, in the EUCalc, a novel, simplified, scientifically consistent, transparent and robust modelling framework was developed for this sector in order to offer an accessible tool for a non-expert audience. This simplified format also facilitates its use as a communication platform, including for environmental education in schools and higher education.

The EUCalc land & food module of the EUCalc model is based on seven 'levers', each of them with four 'levels' of growing climate mitigation ambition through to 2050. This model is an original approach which was developed building on previous experiences with the Global Calculator [5] and the EU Land Use Futures module [6], using a system dynamics approach [7] based on MS Excel and Knime. The module was calibrated using a broad range of academic and applied literature sources, such as FAO reports [8][9][10][11] and EU-specific papers [12][13][14][15], among many other sources. The module was also calibrated using the outputs from an expert stakeholder consultation workshop, which was held at Imperial College London in 2019. Further references and explanations on this EUCalc module are available online as a supplementary technical document for agriculture and land use (WP4 document) from the EUCalc website (see weblink in the end of this policy brief).

The EUCalc levers on land and food:

- **Climate smart crop production:** this lever covers how intensive agriculture and agroecology systems may evolve in Europe through to 2050. It addresses practices that are used for crop production (e.g. agroforestry, crop-rotation), including crop yields and the use of fertilisers, pesticides and energy. The lever also addresses food waste and losses at the farm level.
- **Climate smart livestock production:** sets the land transition matrix (a 6x6-way matrix) enabling the relative competitive land dynamics to be accounted for, for example, when settlements / urban infrastructure increases at the expense of cropland expansion on forestland, wetlands, grasslands, protected land, etc. In some EUCalc pathways, Europe may require much less productive land than it currently uses and thus, land may become available for other purposes overtime. This lever provides the user with the option to assess how to allocate these freed-up areas to alternative uses e.g. abandoned land, afforestation/reforestation, and calculate the resulting GHG emissions.
- **Climate smart forestry:** comprises a set of enhanced management practices, such as coppicing and implementing sustainable harvesting rates. This lever affects the gross biomass increment, natural losses (including resilience to natural disturbance) and the harvest rate.
- **Land management:** this lever is about the use of potential freed-up lands and sets the extent of land-use dynamics. In some EUCalc pathways, Europe may require much less productive land than it currently uses and, thus, land may be available for other purposes overtime. This lever gives the user the option to decide how to allocate these freed-up areas in terms of use (e.g. abandoned land, afforestation/reforestation), which has impacts on GHG emissions as well. In addition, this lever partially sets some other relative dynamics for land use e.g. if the user

projects an increase in settlements' area, then cropland may be expanded over forestlands or grasslands; thus, this lever sets a land transition matrix, which is adapted considering other projected land demands in the EUCalc.

- **Bioenergy capacity:** changes the expansion dynamics of bioelectricity and heating, biogas from digestors, landfill, wastes, sewage treatment and thermally generated gases, also liquid biofuels, such as biogasoline, biodiesel, and biokerosene for aviation (bio-jet fuel). In the EUCalc, if the user projects an over consumption of food by 2050 without major increases in agricultural yields and food imports, then the domestic capacity to produce energy crops would be reduced over time. On the other hand, the use of agricultural and animal residues and food wastes for bioenergy production remains an option.
- **Hierarchy for biomass end-uses:** directs / allocates biomass towards possible markets (e.g. biofuel, livestock feedstuffs), and enables or disables food-crop based feedstock-use for non-food purposes. It follows the European food waste hierarchy, firstly prioritizing recovery options (e.g. combustion, bioenergy feedstock), then focusing on waste prevention (e.g. pet food, livestock feed) and recycling options (e.g. fertiliser, composting).
- **Alternative protein sources (for livestock):** insect farming and algae-based meals are promising, land-efficient alternative sources of animal feed. This lever considers the animal health and food output quality to set the maximum alternative feed intake for each type of livestock (e.g. cattle, pig, chicken, fish). The lever also raises the potential for bioenergy provision (e.g. microalgae oil) and organic fertilisers (e.g. insect manure).

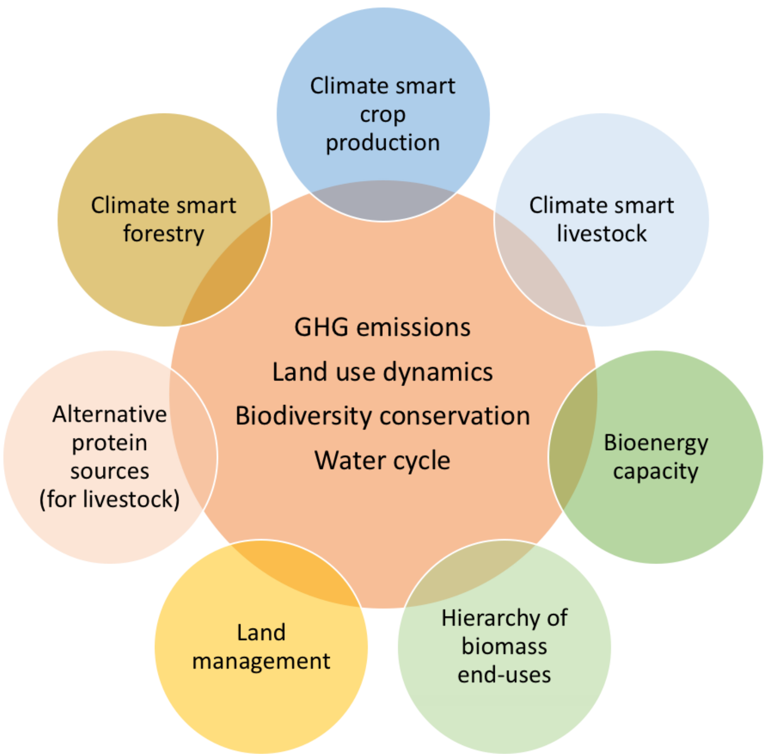

Figure 1: Agriculture and Land-Use Levers in the EUCalc.

As illustrated in Figure 1, by using these seven levers, the EUCalc can calculate the associated GHG emissions and changes in land use distribution, as well as the effects on the water cycle. Interconnections with other sectors (transport, building, manufacturing, power) in terms of energy, materials and carbon dynamics are also included.

As a regional tool, EUCalc must also be able to account for any significant transboundary effects. Changes in European supply and demand in the land use sector will have impacts overseas and vice-versa. For example, if the European population keeps eating more meat per capita, but does not increase agriculture and livestock productivity at the same pace, and in parallel wants to increase its forest area for biodiversity conservation and carbon sequestration, it may be necessary to increase either meat or animal feed imports, depending on the projected levels of intensification and changes in food consumption patterns. Under these circumstances, carbon and land use footprints outside Europe will occur. We note that for some crops / agricultural commodities, higher efficiency or lower impact production might be possible outside Europe, due to different climatic, management and agronomical conditions. Alternatively, the EU could increase its agriculture and livestock productivity whilst also achieving lower impact dietary patterns (e.g. through decreased meat consumption) and increasing biodiversity conservation altogether, without necessarily increasing food or feed imports.

Thus, there are many possible pathways that can be simulated by selecting different levels of carbon mitigation efforts in EUCalc's levers on land and food. The international food, feed and bioenergy dynamics associated with the EU market and their respective impacts were also discussed in publications [16][17] and models, such as GLOBIOM model from the International Institute for Applied Systems Analysis – IIASA (Austria), and the GTAP model coordinated by the Purdue University (United States).

Sustainable Pathways for Food & Land

Given the complexity of the land use sector, there is a very broad range of scenarios that can be developed to mitigate carbon emissions. We use three example pathways:

1. 'EU Reference': a low to moderate carbon mitigation effort scenario, action across all sectors;
2. 'Behaviour and Land-Food': assumes a very ambitious level (level 4) of carbon mitigation effort through sustainable agriculture and land use, alongside significant behavioural changes (e.g. diet, consumption pattern, home and travel), whilst also maintaining 'EU Reference' levels of effort in all other sectors; and
3. 'Ambitious': uses an extremely ambitious mitigation effort across all sectors, including substantial negative emissions coming from LULUCF.

As shown in Figure 2, total EU GHG emissions from all sectors gradually decline through to 2050 by 38% and 77% respectively for the 'EU Reference' and 'Behaviour and Land-Food' example pathways, whereas under the 'Ambitious' example pathway, it would be possible not only to obtain a zero-emission scenario in the EU by 2050, but also a negative emission.

It is worth noting that the GHG emission reduction obtained from agriculture and land use alone would not be be much different from the 'EU Reference' pathway, but when it comes combined with behavioral changes, specially changes in dietary patterns (e.g. a lower consumption of meat products), the total reduction would be very substantial by 2050.

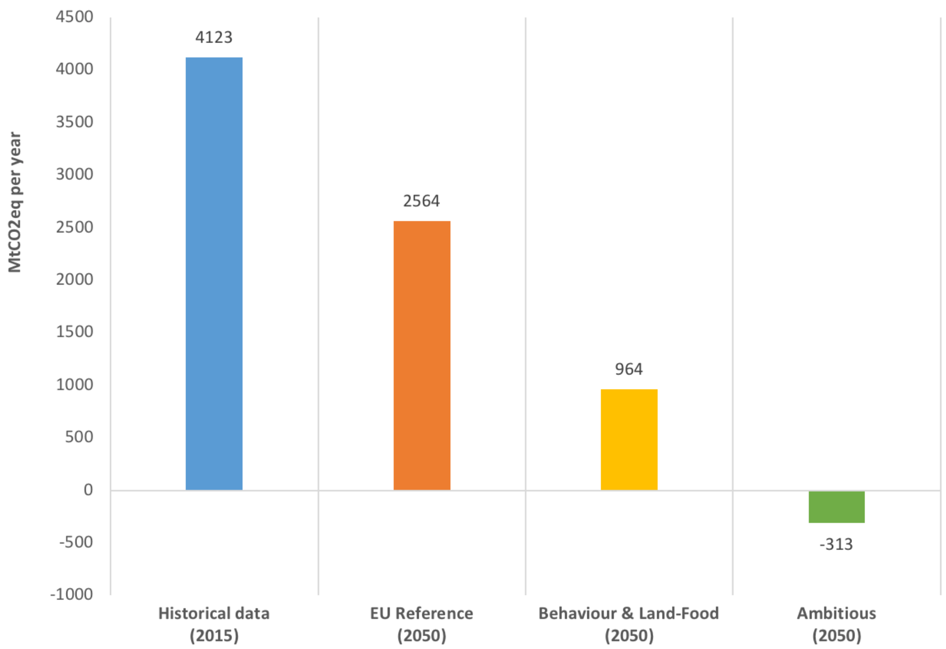

Figure 2: Total GHG emissions in Europe under three different example pathways in the EUCalc.

Significant GHG emission reductions are only achieved when all the sectors of the European economy achieve major reductions. However, realising either a net-zero or a negative emission pathway is only possible when the land and food levers are set to deliver a highly ambitious level of effort. Figure 3, Figure 4 and Figure 5 (followed by a common legend for these three figures) show only the LULUCF emissions for the same three example pathways already discussed. Under both the 'Behaviour and Land-Food' and the 'Ambitious' pathways, net total negative emissions coming from LULUCF would be almost twice current levels. However, it is worth noting that this pathway would require an unprecedented, transformative, effort on climate change mitigation, when compared to current trends.

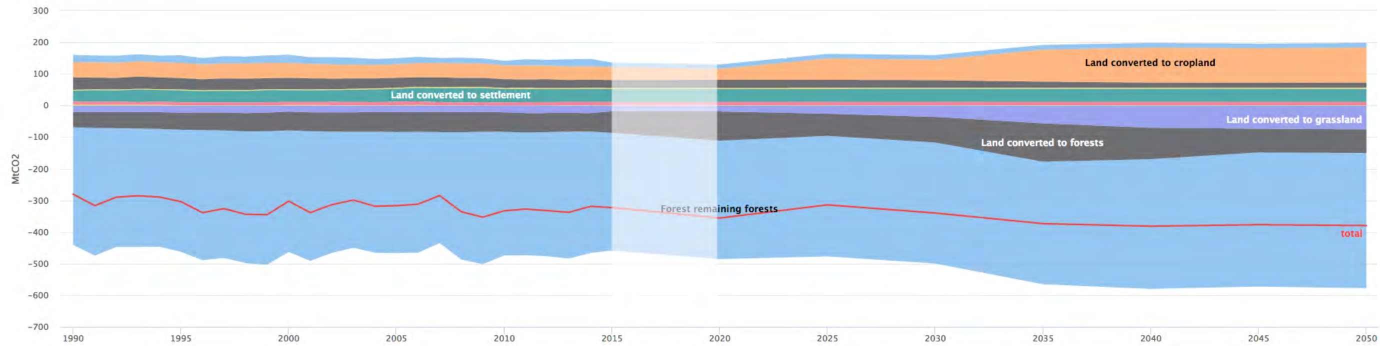

Figure 3: Europe's LULUCF GHG emissions under 'EU Reference' (EUCalc example pathway).

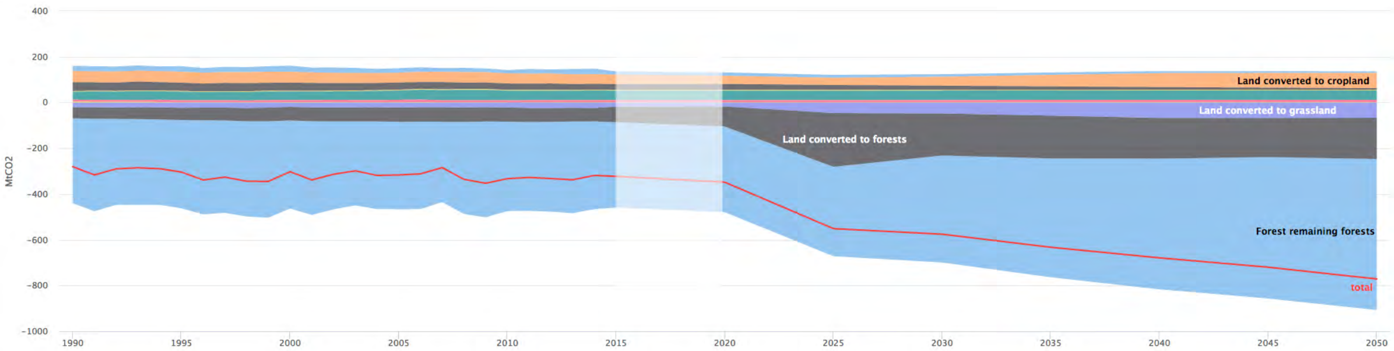

Figure 4: Europe's LULUCF GHG emissions under 'Behaviour and Land-Food' (EUCalc example pathway).

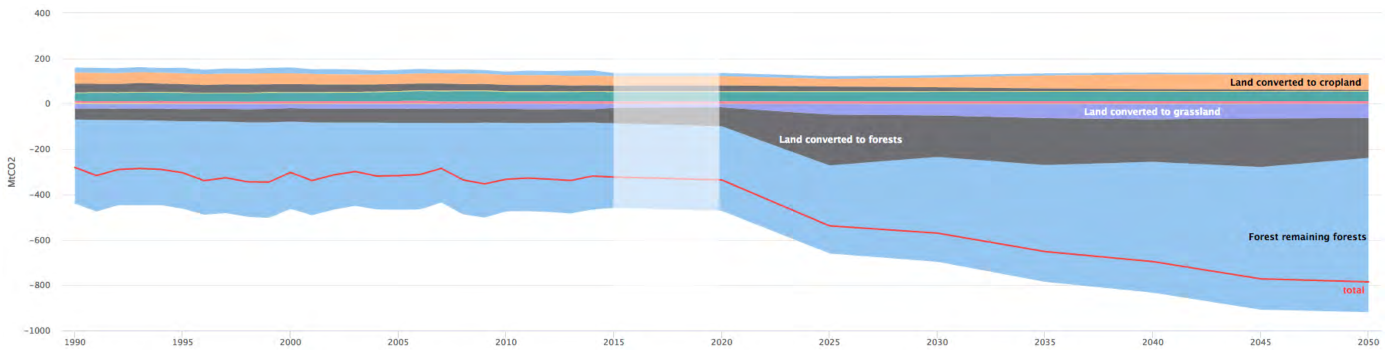

Figure 5: European LULUCF GHG emissions under 'Ambitious' (EUCalc example pathway).

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Common legend for Figure 3, Figure 4 and Figure 5:

- Forest remaining forests
- Land converted to cropland
- Settlement remaining settlement
- Land converted to wetland
- total
- Land converted to forests
- Grassland remaining grassland
- Land converted to settlement
- Other lands remaining other-lands
- Cropland remaining cropland
- Land converted to grassland
- Wetland remaining wetland
- Land converted to other-lands

The emission impacts, co-benefits and trade-offs arising from changes to land & food levers can be visualised using the Transition Pathways Explorer webtool, the EUCalc model user interface. The webtool provides detailed information on land use distribution, forestry production, livestock population, meat production, crop use and production, livestock feed, and bioenergy dynamics as well as on the interactions with other sectors of the European economy. The simulations shown here demonstrate that EUCalc can successfully simulate a wide range of carbon mitigation pathways and provide policy makers, business leaders, NGOs and users from the general public with a tool viable and sustainable transition pathways for Europe, by enabling the user to evaluate the full range of options available in the agriculture and land use sectors.

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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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