NET ZERO BY 2050: FROM WHETHER TO HOW

ZERO EMISSIONS PATHWAYS TO THE EUROPE WE WANT

CLIMACT

SEPTEMBER 2018

ACKNOWLEDGEMENTS

We are grateful to the following organisations for their expertise and insight.

Model testers - the following organisations supported the analytical team in testing the model, which is itself derived from the ClimateWorks Foundation's Carbon Transparency Initiative (CTI):

Agora-Energiewende, Climate Strategy, The Coalition for Energy Savings, Friends of the Earth (FoE) UK, Grantham Research Institute - London School of Economics, Iberdrola, Institute for European Environmental Policy (IEEP), Institute for Sustainable Development and International Relations (IDDRI), Third Generation Environmentalism (E3G), UK Department for Business, Energy and Industrial Strategy (BEIS), and the World Wide Fund for Nature (WWF) European Policy Office.

Members of these organisations tested the model during the summer of 2018 and explored a variety of decarbonisation pathways. These scenarios have informed our conclusions but were not used directly.

Other organisations were consulted on sector specific discussions:

Agora Verkehrswende, Aviation Environment Federation (AEF), Buildings Performance Institute Europe (BPIE), the Energy and Climate Intelligence Unit (ECIU), Ecofys, EuroACE, the European Consumer Organisation (BEUC), the European Federation for Transport & Environment (T&E), FERN, Fraunhofer ISI, International Federation of Organic Agriculture Movements – EU (IFOAM-EU), International Institute for Systems Analysis (IIASA), Öko-Institut, Imperial College London (ICL), Open Exp, Stefan Scheuer, and Vrije Universiteit Brussel (VUB) – Institute for European Studies (IES).

Grateful thanks also to the many members of staff from the European Climate Foundation (ECF) who have provided input throughout the process, and to ClimateWorks Foundation for their support and encouragement.

The views expressed in this paper are attributable only to the authors, and not the organisations that have supported or advised on its development.

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FOREWORD

Laurence Tubiana
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The 2015 Paris Agreement marked the moment when the global community committed to decisive climate action to keep warming well below 2°Celsius (°C). This will require transformational change – all countries, rich and poor, must reach carbon neutrality. Net-zero needs to be our goal, our direction of travel, and our rallying cry.

This is a challenge, but also an opportunity – for the EU and its Member States, it is an opportunity to demonstrate global leadership by charting a path to reach carbon neutrality by 2050. But in order to reach our goal, we need a plan – we need to know the pathways to net-zero, including the growth and innovation opportunities it presents, the trade-offs that may need to be made, and the policy designs we will need to get there.

The European Climate Foundation's collaboration on the CTI 2050 Roadmap Tool shows that while it is not easy, Europe can design these pathways – and the advantages far outweigh the difficulties. The project seeks to answer the question of 'how' we achieve the required transition.

The research makes it clear that the move forward must be holistic – all sectors must play their part in reducing emissions. The good news is that there are interdependencies that can and must be used to deliver maximum speed and efficiency of mitigation. There are major opportunities and need for technological innovation and investment, and enabling policies – this will be fundamental to achieving the required reductions quickly.

Net-zero is technically and economically possible. But the key driver of success will be political will, creative policy implementation, and societal understanding and ambition. This project shows that there are many compelling reasons to expect that a net-zero world will be cleaner, healthier, more prosperous, more equitable, and happier – not least because it will avoid the massive costs of large-scale climate impacts on food, infrastructure, health, and migration. The costs of transition are dwarfed by the costs of dealing with climate impacts in a scenario where we fail to reach net-zero by 2050. Setting net-zero as a clear direction of travel will help to achieve many of the societal goals we have set ourselves.

The "Europe we want" is one that protects its citizens from global threats such as climate change, which no one country can tackle on its own; and creates a safer, cleaner world. Net-zero is a path to a sustainable Europe in which prosperity and well-being are delivered alongside a clean and healthy environment.

METHODOLOGY & SCENARIOS OVERVIEW

This project has developed and used a simulation model of European emissions and the mitigation options available now and in the future, analysing possible pathways to reach net-zero greenhouse gas (GHG) emissions. The emissions scope of the model encompasses all sectors of the economy and all GHG emissions sources covered by national inventories, including international aviation, shipping, and Land Use, Land-Use Change and Forestry (LULUCF).

It is a techno-economic simulation model; pathways illustrated in this report are designed as a combination of ambition levels across all GHG emitting sectors and mitigation options. The model was extensively discussed and tested with the wide range of stakeholders listed above. It relies on an extensive literature review and stakeholder consultation.

For each sector of the EU economy that emits GHGs (Power production, industry, buildings, transportation, and Agriculture, Forestry and Land-Use (AFOLU)), the GHG emissions drivers and means of reducing them – referred to as 'levers' – were modelled. Examples of levers include shifting from cars to softer modes of transport, deep retrofits of buildings to reduce their energy consumption, enhancing the circular economy with longer-lived assets, shifting to renewable forms of electricity production, and shifting to healthier diets to free up land for increasing forest covers.

Rather than calculating optimal pathways, the model allows the user to choose the ambition level of each individual lever (from a reference level up to maximum technical ambition) and thereby explore different scenarios or pathways to 2050. The costs of each pathway are estimated by adding the annual capital expenditures (e.g., new infrastructures or assets), operational costs (e.g., maintenance) and fuel costs. Other externalities (such as improved air quality, reduced noise, climate change damages, or biodiversity conservation) are not accounted in the cost estimates but discussed based on a literature research (see Section 3, p.14).

More details on the modelling and its scope can be found in the Appendix.

THREE MAIN NET-ZERO GHG EMISSIONS SCENARIOS ARE USED IN THE REPORT AND AVAILABLE ONLINE

More than 10 scenarios were modelled by the organisations who supported the model testing, while other scenarios were elaborated by the project team to explore the net-zero opportunities and trade-offs. Out of these scenarios, three typical pathways were selected to illustrate the conclusions of this report. All three reach net-zero emissions by 2050.

1. *The "Shared efforts" scenario: A comparable level of effort is maintained across sectors and levers, i.e., there is no emphasis on any specific mitigation option. Where conclusions are illustrated in the text with only one scenario, it is the Shared efforts scenario unless otherwise indicated.*
2. *The "Technology" scenario: Emphasises efficiency and innovative technological options by raising their ambition to the highest levels (e.g., energy efficiency, electrification, hydrogen, carbon capture, and storage (CCS)). It leads to -41% energy demand in 2050.*
3. *The "Demand-focus" scenario: Demand-side levers are used here to reduce the overall demand further, e.g., for energy (-64% by 2050), products, or meat, which implies that technological levers can be reduced compared to the Shared efforts scenario.*

These scenarios are used in the graphics of the report, but they can also be explored in more detail online. Additional scenarios are also available on the website.

One of the objectives of this work is to increase the analytical basis available to define the adequate political framework for the low-carbon transition, increasing model transparency, ease of use, the comparability of existing scenarios, and ultimately the access of policy makers to the most useful information for decision making. In this logic, a version of the model directly based on the full simulation model is accessible online. This allows for the pathways used in the analysis to be explored in much greater details, as well as to test additional pathways.

The webtool can be found at: *https://stakeholder.netzero2050.eu*

Hyperlinks are included as just above in the report text where relevant, so that readers can easily navigate between the report and the three main scenarios online.

EXECUTIVE SUMMARY

Impacts of climate change are already being felt today around the globe, including in Europe, and urgent action is now required by all countries. The Paris Agreement[1] states an objective of limiting global warming to "well below 2°C" above pre-industrial levels, but also of making all possible efforts to achieve the goal of 1.5°C climate stabilisation.

On the basis of the scientific underpinning of these goals provided by the Intergovernmental Panel on Climate Change (IPCC), signatories to the Paris Agreement also committed to ensure that global GHG emissions fall to net-zero as early as possible in the second half of this century, before going negative. This means developed economies such as the European Union's (EU), will need to achieve net-zero emissions by 2050, or even earlier. Numerous countries have already set goals consistent with this.[2]

This is the starting point taken by the CTI 2050 Roadmap Tool project, which seeks to explore the feasibility and implications for the EU of reaching net-zero GHG emissions by 2050 at the latest. It finds that not only is it technically possible, but that the net-zero future is likely to be both economically beneficial, and desirable on many other grounds. However, it requires a collective commitment to transformational action and without delay.

1 REACHING NET-ZERO GHG EMISSIONS BY 2050 IS FEASIBLE

BUT REQUIRES ROBUST ACTION ACROSS ALL SECTORS, AND WIDENING THE RANGE OF LOW-CARBON OPTIONS USED FOR THE TRANSITION

Planning for net-zero GHG emissions requires a new way of thinking – more innovative, cross-sectoral, and beyond business-as-usual. It means ensuring that GHG emissions are reduced close to zero in all sectors, and that these remaining emissions are compensated by carbon sinks like forest growth or sustainable biomass coupled with carbon capture and storage (CCS).

Social patterns, societal organisation and energy efficiency are key to make it easier to reach net-zero (the contributions of each lever group relate to how ambitious the reference is (EU-REF16)).

(GHG emissions, [$MtCO_2e$])

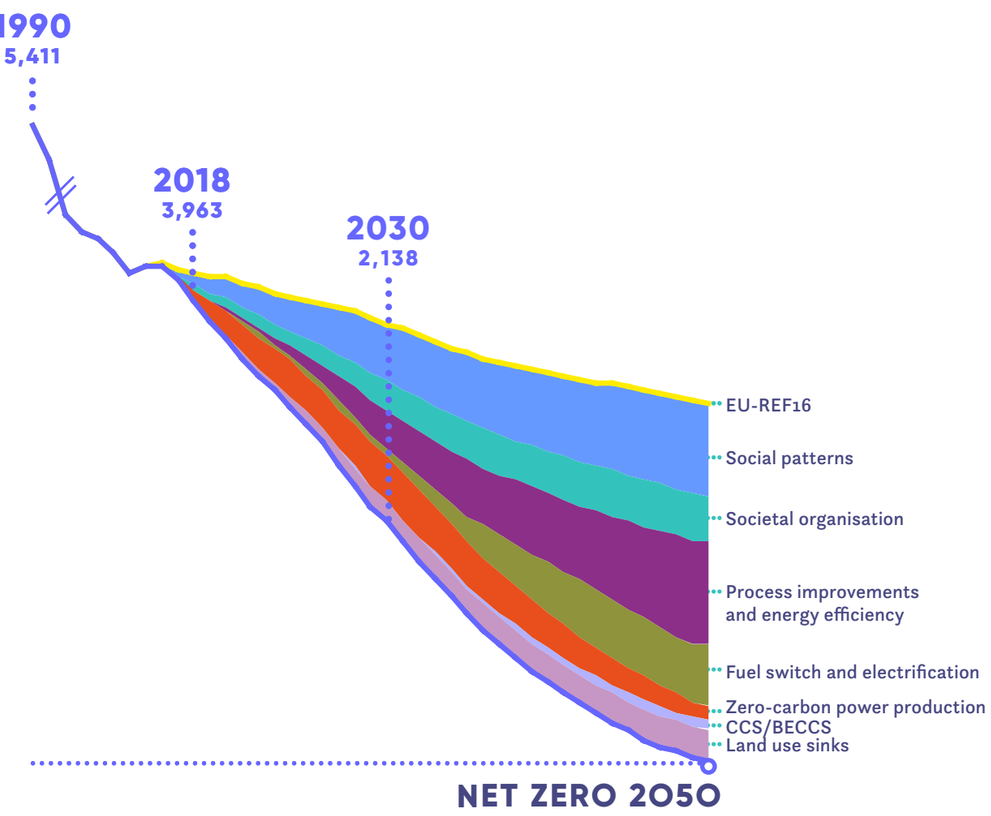


FIGURE 1. *GHG emission reductions by lever types in a Shared efforts (See the section on the "Analytical basis" p.7 to read on the various scenarios used in this report.) net-zero scenario [$MtCO_2e$]*

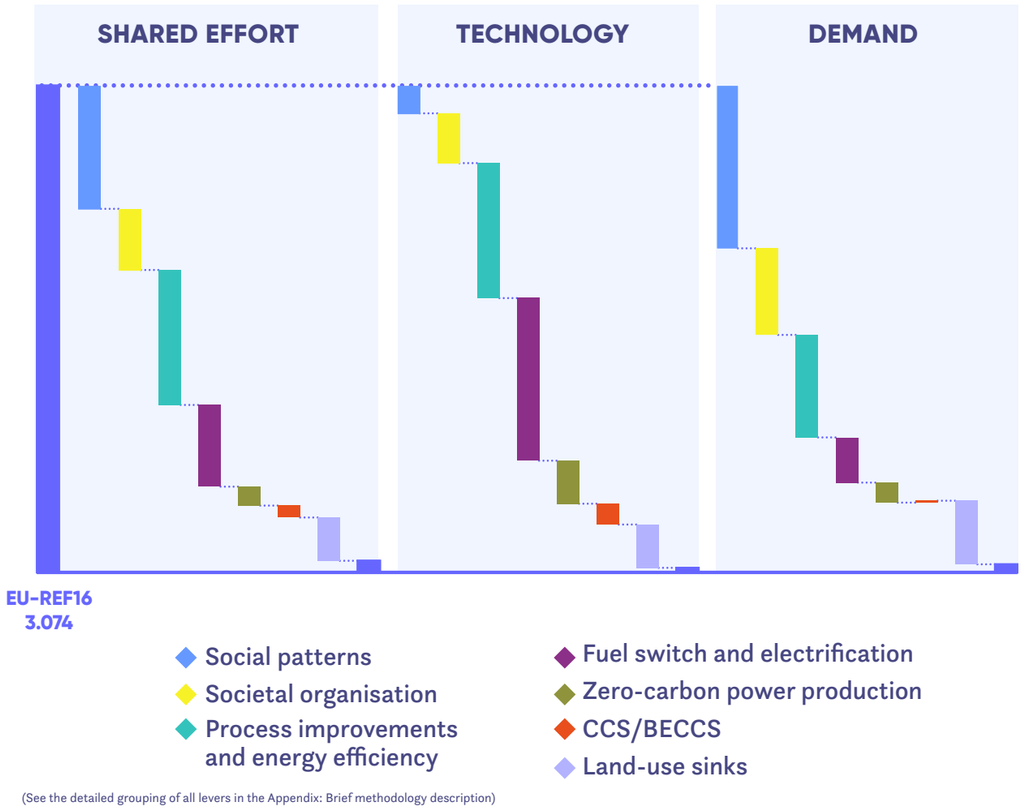
Planning to reach net-zero by 2050 at the latest means no sector can be left aside. We need to widen the range of options being used, including by putting more focus on how we operate as a society. Innovation in our consumption patterns and increasing potential natural carbon sinks need to be combined with the more typical technical options such as energy efficiency, fuel shift, zero-carbon power production and electrification.

Figure 1 illustrates the contribution of the various lever groups to reducing emissions over time and shows that actions of many types are involved in delivering the required emission reductions. This includes actions related to technology choices, but also about how society is organised, consumption patterns, and the impact of the circular economy principles, with better and more innovative product design leading to longer lifetimes and greater recycling and reuse of raw and processed materials. **All these demand-side choices have a major trickle-down effect on the entire value chain.**

While Figure 1 illustrates the "Shared efforts" scenario, which leverages all levers to a similar ambition, other pathways with different focuses can also lead to net-zero. Figure 2 shows how the key lever groupings differ across the three studied scenarios. This also connects to large differences across European countries in their approaches to the low-carbon transition. **Our research shows that there is not one way to decarbonise: each country, region, city or local authority has to define its own transition with the global objective in mind.**

The impact of key lever groups differs significantly across the three scenarios

(GHG emissions, [$MtCO_2e$])



(See the detailed grouping of all levers in the Appendix: Brief methodology description)

FIGURE 2. *Impact of each lever group on GHG emissions reductions for each scenario in 2050 [$MtCO_2e$]*

This transition means using all the best practices that are already being applied across Europe, and applying them at a much greater scale, as well as increasing investment and putting policies in place to ensure widespread uptake of more transformational solutions – in technical, business model, societal, and governance arenas. **A review of the scenarios points to the fact that commercially available solutions can already take us about 75% of the way to net-zero if deployed at scale. The remaining 25% can be achieved based on known approaches and technologies for which further scaling up and commercialisation is needed. This includes the wider implementation of innovative business models that frontrunners are already starting to use.**[3]

Net-zero requires increased deployment of efforts and solutions as well as upscaling the commercialisation and deployment of new technologies, and innovation in business models

(GHG emissions, [$MtCO_2e$])

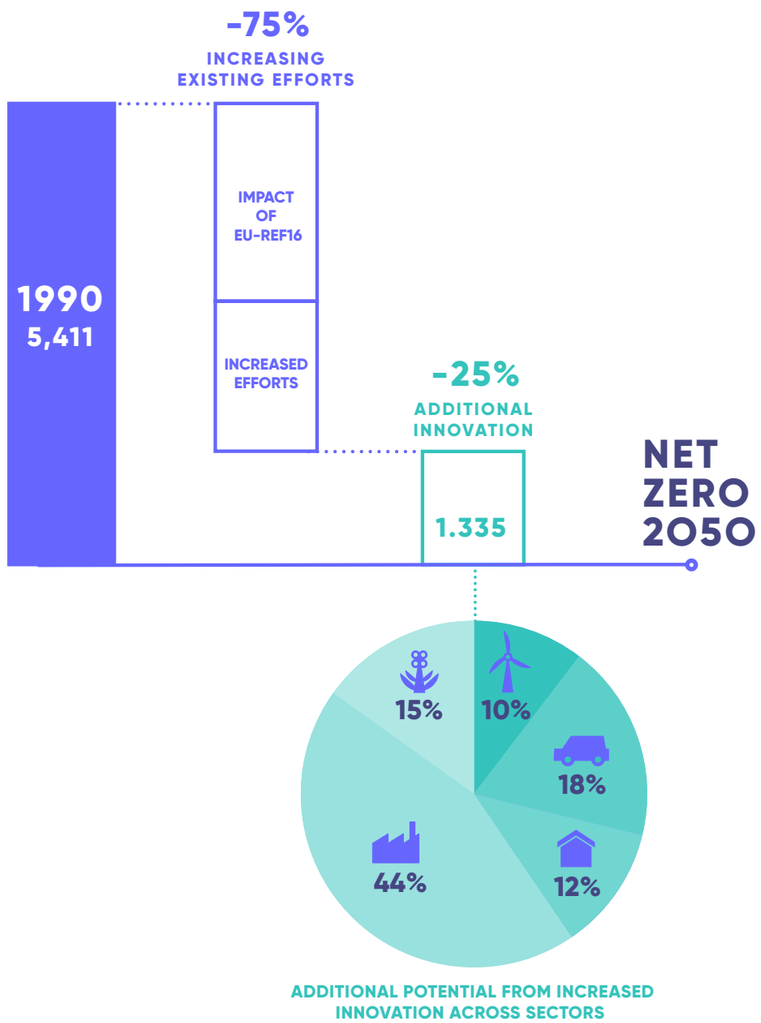


FIGURE 3. *GHG emission reductions split between increased efforts and additional innovation (see end note[3])*

Setting a firm and clear direction of travel, which is required to ensure that near-term choices are aligned with long-term goals, will help to ensure the required investment in scaling up these solutions. It is likely to also unleash further creativity regarding technologies and social developments, which can widen the range of options available for reaching net-zero.

Our work also highlights the importance of deploying all mitigation actions possible including land-use sinks and other options for removal of GHG from the atmosphere. In our three scenarios, improved land-use practices could support around 600 megatonnes of CO_2 equivalent ($MtCO_2e$) per year of GHG sinks, which amounts to about 10% of 1990 emissions and can help us reach net-zero by 2050. Other options to remove GHG from the atmosphere (e.g., biomass use combined with CCS) have significant limitations as well. However, the European carbon emissions budget is very tight and reaching net-zero by 2050 is unlikely to be sufficient. **Europe will need to compensate for some of its emissions by going net-negative after 2050. Therefore these limited natural sinks and other carbon dioxide removal (CDR) options will not be an alternative for the emitting sectors. Each sector needs to reach close to zero emissions around mid-century or shortly after.**

2 NET-ZERO GHG EMISSIONS IN 2050 REQUIRES RAISING THE 2030 AMBITION LEVEL

TO SET EUROPE ON THE RIGHT TRAJECTORY

2050 matters because of the guide it provides for near-term choices. It evidences the need to increase action now in order to leverage all the no-regrets options available and to avoid locking-in to the wrong technologies and processes. Not doing enough, or not anticipating correctly by 2030, will limit our options in the future and simply 'doing a bit more' after 2030 will not work since not all pathways will remain open. **This study finds that to be on a trajectory to net-zero by 2050, GHG emissions will need to be reduced from about 55–65% compared to 1990 levels (including LULUCF) by 2030.**

The 2030 ambition needs to be increased to be in line with net-zero scenarios

(GHG emissions, [$MtCO_2e$])

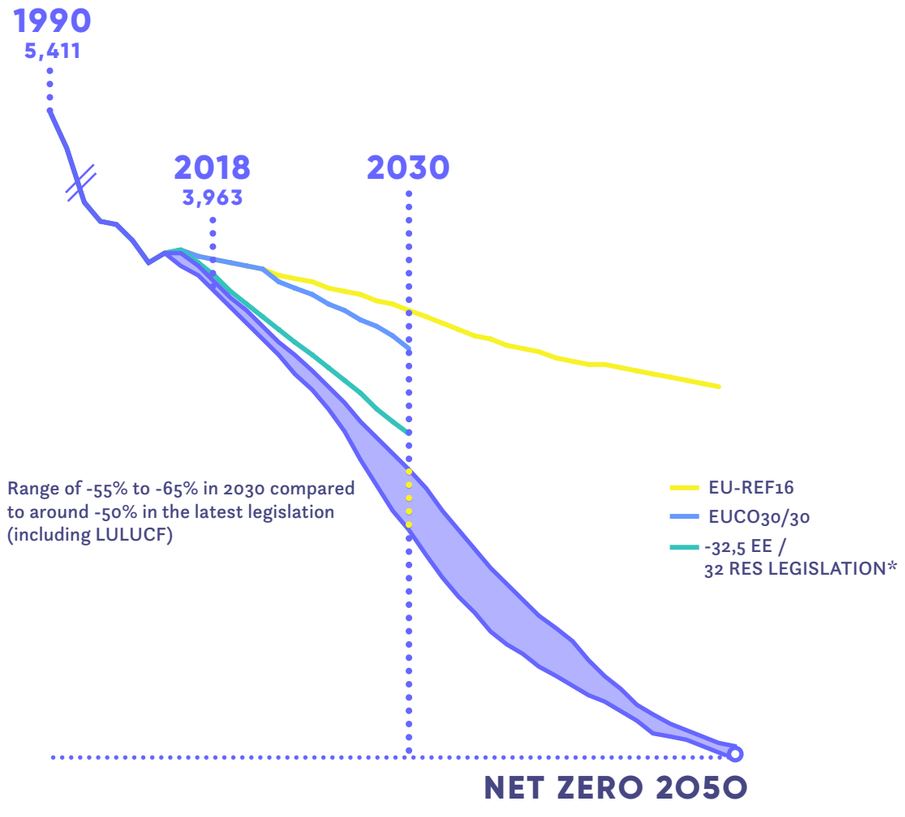


FIGURE 4. *GHG emission reduction range in net-zero scenarios compared to the EUCO scenario and the impact of the latest 32.5% energy efficiency and 32% renewables targets based on the non-paper by the EU Commission*

* This scenario is based on the latest « Non paper on complementary economic modelling undertaken by DG ENER regarding different energy policy scenarios » and is using the 33% RES / 33% EE figure for 2030, with a linear interpolation from 2016, so it slightly overestimates the latest legislation

This finding contradicts the current EU target[4] which leads to only 40% GHG reductions (including LULUCF, 35% excluding it) in 2030. It also contradicts the latest adopted EU legislation that gives targets of 32.5% on energy efficiency and 32% for renewables, which is estimated to lead to about 46% excluding LULUCF (or 50% reductions including them) in 2030. This would keep us still far from the range of reductions needed to set Europe on the required trajectory to net-zero just 20 years later.

Our findings, as well as the latest scientific evidence, tell us that the next 10 years are crucial if Europe and the world are to avoid the worst consequences of climate change. Our analysis identifies a set of "no-regrets" actions[5], which need to be taken in this time span. "No regrets" actions are those required in all zero emissions pathways, regardless of the emphasis they set on the various levers or sectors, and regardless of the 2030 ambition level:

TRANSPORT

By 2030, the focus must be to ensure transport demand is stabilised to today's levels, and that the modal shift away from cars has started in earnest. Car share should be down to 70% from around 80% today. After stabilisation of demand and modal shift, vehicle efficiency is the third key lever in the short term, with efficiency needing to improve by at least 15% for cars and even beyond 20% improvement for trucks. The support for Zero-Emission vehicles (ZEVs) must be reinforced so that Europe innovates in ZEV production and the actual penetration in the fleet starts to increase at a fast pace after 2030. Note that several countries, including those with relevant automotive sectors, have announced bans on sales of new conventional internal combustion cars, notably Ireland and Slovenia (2030), and France and the UK (2040). The Netherlands aims to have all new cars emission free by 2030. These can be effective policies to drive this shift. Charging infrastructure investment and deployment is also crucial to drive the shift toward ZEVs.

BUILDINGS

Significantly renovating 3% of the buildings each year with deep retrofits to improve energy efficiency to near-zero energy levels, and fully decarbonising heat by 2050 at the latest. Current annual renovation rates are below 1%. New constructions must be energy-positive "smart" buildings already in the decade to 2030 to avoid having to renovate those again until 2050.

INDUSTRY

By 2030, significantly reducing the demand for materials and products (5-10% by 2030, above 40% by 2050) by boosting the functional economy(Increase the products lifetime by 5%), the circular economy(Increase product utilisation by 5%, switch to more efficient material (e.g., 8% of steel switched to carbon fibres in automotive), reduced material intensity, increased share of recycled materials), and associated innovation. While deploying best practices in industrial processes (electrification, fuel switching) is expected to begin soon, the adoption of new innovative technologies is currently mostly expected in the 2030-2050 time horizon.

POWER

Close to complete phase-out of coal. Wind and solar should reach at least 50% of power production by 2030, around 60% by 2050, and 75% of the demand-side management (DSM) potential is being exploited by 2050. About half of the flexibility needed to compensate seasonal and daily intermittency is covered by a mix of zero-carbon flexibility options (storage, inter-connections, biomass-firing), which reduces the role of gas even as coal phases-out.

AGRICULTURE, FORESTRY AND LAND USE (AFOLU)

*Before 2030 land-use must fully integrate climate change considerations: policies and business models must be convincing to restore degraded forests and to reforest most surplus and abandoned land[6]. Incentives should effectively support a change of agriculture practices to boost land multi-use, stopping land degradation. On average, in 2030, meat consumption must be reduced by 25% (and at least halved by 2050) without increasing consumption of dairy products. Trends are already going in this direction.**

FINANCE

Sufficient investments in innovation is a fundamental requirement for this economy-wide decarbonisation, to accelerate lab-to-market for innovative net-zero technologies and the co-development of new products, businesses and services. These investments can be shaped by the public sector through flagship research and innovation programmes like Horizon Europe, but also require the strong engagement of European businesses.

*https://www.eea.europa.eu/data-and-maps/indicators/13.2-development-in-consumption-of-2/assessment-1

3 NET-ZERO PATHWAYS CAN COST LESS THAN BUSINESS-AS-USUAL

AND BUILD A MORE PROSPEROUS, RESILIENT SOCIETY

Reaching ambitious GHG emissions reductions is economically attractive. If all available levers are actioned, particularly on the demand side, the total energy system costs (Investment costs + operational expenditures + fuel costs) will be lower than in a business-as-usual scenario (here taken as the EU-REF16 scenario from the EU Commission). Essentially a net-zero society uses its resources much more efficiently across all sectors: products with longer lifetimes and increased asset utilisation (e.g., using fewer cars but using them more than the 5% of the time that is currently the case). Figure 5 illustrates these system costs in the Shared efforts scenario grouped by action type. **It shows how strong the impact of improving the way our society is organised can be.**

Net-zero pathways can cost less than business-as-usual, with a strong impact from the demand-side levers

Undiscounted cumulated total energy system costs by lever category [x10³ billion €]

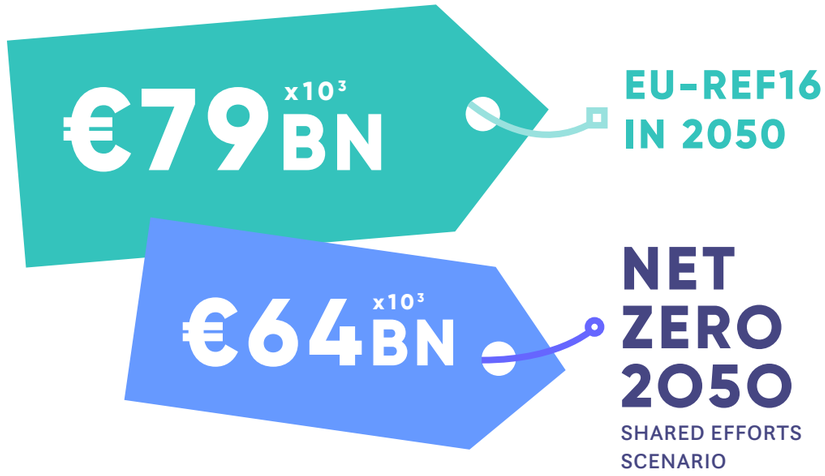


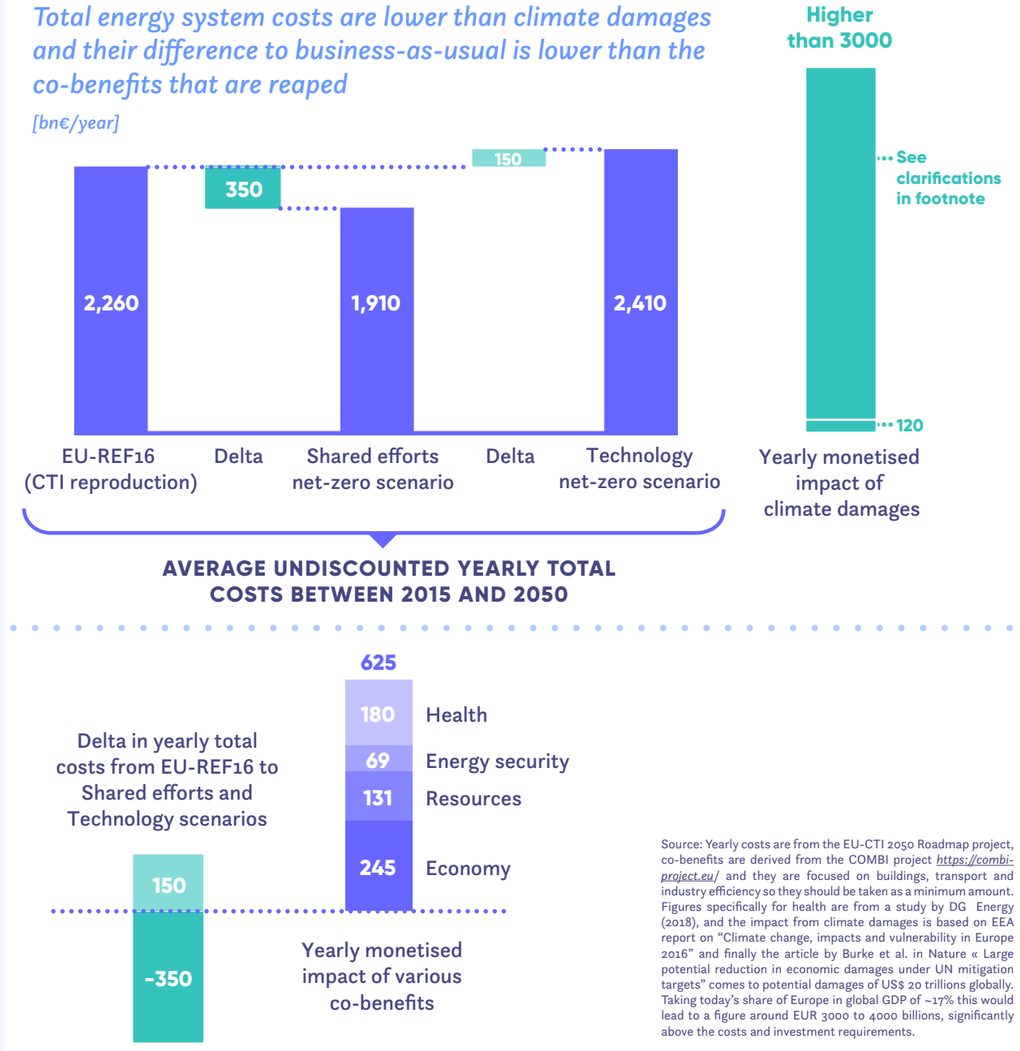
FIGURE 5. *Difference in total system costs by lever group between the EU-REF16 and the Shared efforts net-zero scenario*

Many of the 'net-zero' choices will also take us closer to other goals Europeans have set for themselves. A net-zero society can bring an attractive quality of life to its citizens, with a wide range of additional benefits and lower costs – e.g., cleaner air, less traffic and city congestion, better living environments, less money spent on fuels and more on infrastructure and innovation in Europe, leading to a more resilient economy with more and better jobs, more durable goods, higher biodiversity, and better forests.

Figure 6 shows how the latest estimates in the literature indicate that the difference in potential climate damages in a 2°C scenario compared to a 1.5°C scenario are foreseen to be much higher than the total costs of any scenario, low-carbon or not, and whether more technology-focused or not. The many co-benefits identified are also higher than the cost delta of the Technology scenario compared to the EU-REF16. **Clearly the low-carbon transition is attractive "on average", which does not take away the complexity of the substantial investments required, nor the strong variations in cost impacts across sectors. This can be addressed by having a vision and planning for a climate-proof, resilient and future-oriented society.**

Total energy system costs are lower than climate damages and their difference to business-as-usual is lower than the co-benefits that are reaped

[bn€/year]



Source: Yearly costs are from the EU-CTI 2050 Roadmap project, co-benefits are derived from the COMBI project *https://combi-project.eu/* and they are focused on buildings, transport and industry efficiency so they should be taken as a minimum amount. Figures specifically for health are from a study by DG Energy (2018), and the impact from climate damages is based on EEA report on "Climate change, impacts and vulnerability in Europe 2016" and finally the article by Burke et al. in Nature « Large potential reduction in economic damages under UN mitigation targets" comes to potential damages of US$ 20 trillions globally. Taking today's share of Europe in global GDP of ~17% this would lead to a figure around EUR 3000 to 4000 billions, significantly above the costs and investment requirements.

FIGURE 6. *Costs and investments compared to the potential impact of co-benefits and climate damages*

ABOUT THE PROJECT

PROCESS

This paper is the outcome of a year-long effort of deep analytical work and active stakeholder engagement. It builds on the model developed as part of the Carbon Transparency Initiative (CTI) by the *ClimateWorks Foundation* and has been extended and upgraded for Europe with the support of the *European Climate Foundation* (ECF), in consultation with other experts in the field. This consultative process took place between September 2017 and September 2018, and was concluded over the summer of 2018 with the testing of the model by a range of experts who have developed their own low-carbon scenarios to explore and develop the policy options under consideration.

ClimateWorks FOUNDATION

European Climate Foundation

OUTPUTS

The CTI 2050 Roadmap Tool project has two major outputs:

This Report and Summary for Policy Makers, which provide a perspective on the feasibility and the implications of reaching net-zero emissions by 2050 at the latest. It describes the key changes required and highlights potential net-zero trajectories and their implications in terms of both costs and co-benefits. This is intended as an input to the preparation of the European Union (EU)'s Long Term Strategy, as required under Article 14 of the Paris Agreement. It also gives a perspective on near-term actions needed to get on track to net-zero, which has relevance for ongoing discussions on EU Member States' National Energy and Climate Plans required under the EU Governance Regulation, and the EU's Nationally Determined Contribution (NDC) under the Paris Agreement.

A webtool version of the model featuring:

- A range of scenarios that online users can explore to better understand the results.
- An option to switch to a live version of the webtool, which stakeholders are invited to use to explore, design, and propose their own pathways.
- These are available at: *https://stakeholder.netzero2050.eu*
- Sectoral presentations to explain the assumptions and model logic in more detail.
- These can be found at: *https://europeanclimate.org/net-zero-2050/*

ENDNOTES

1. https://unfccc.int/sites/default/files/english_paris_agreement.pdf
2. Including: Denmark, Finland, France, Iceland, Luxembourg, Sweden, New Zealand, Norway, and Portugal. Brazil, Colombia, Costa Rica, Ethiopia, Finland, France, Germany, Iceland, Luxembourg, Marshall Islands, Mexico, Netherlands, New Zealand, and Portugal – as well as thirty-two cities – have signed up to a statement to develop long-term pathways to transition to net-zero emissions as part of the carbon neutrality coalition.
3. Note on innovation: According to formal definitions, the points discussed above – scaling up deployment of existing commercially available solutions and increasing the uptake and technology readiness of other known solutions – can be referred to as 'innovation', and as requiring 'innovation support'. An informal understanding of the word 'innovation' may however risk misinterpretation that the solutions required to reach net-zero are as yet unknown. Our research finds that this is not the case. To avoid possible confusion, the concept of innovation is not used extensively in the Executive Summary but detailed further in the body of the text. We refer readers to the text around Figure 13 p21 where there is a more thorough and precise discussion of what is implied.
4. See the details of the EU Reference Scenario 2016 and the EUCO scenarios at https://ec.europa.eu/energy/en/data-analysis/energy-modelling, and the non-paper on increased energy efficiency and renewables targets as summarised and downloadable in the following Euractiv article https://www.euractiv.com/section/energy/news/leaked-eu-analysis-makes-case-for-higher-renewables-energy-saving-goals/
5. In this report, 'no-regret actions' are defined as emissions reduction actions that are common to all our net-zero scenarios and hence appear as "must do" irrespective of chosen pathway. This definition may differ from other studies where "no-regret" means having a short financial payback or a negative marginal abatement cost.
6. Afforestation/reforestation being based on a mix of species guaranteeing high biodiversity. New forests must also not lower the albedo of the land in order to avoid a negative net climate impact.

https://europeanclimate.org/net-zero-2050/
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