POLICY BRIEF

4i TRACTION
innovation · investment
infrastructure · integration

Transformative change to achieve 1.5°C: an EU member state assessment

Main findings and recommendations:

This policy brief assesses 1.5°C compatible pathways for seven selected EU member states (Germany, Finland, France, Belgium, the Netherlands, Poland and Spain) and compares them with current national plans and targets. It finds that:

1. **All selected member states can cut their greenhouse gas emissions to at least 50% below 1990 levels by 2030** (excluding LULUCF), and in some countries up to 77%. Of the seven member states assessed, **none have legislated 2030 targets that align with domestic (national) mitigation pathways derived from globally cost-effective 1.5°C pathways**.
2. **In national 1.5°C-consistent pathways, rapid deployment of wind and solar enables the power sector to reach near-zero emissions in the 2030s.** In all seven member states, coal is phased out of the power sector by 2030. In the most ambitious pathways, fossil gas is phased out between 2028 and 2041.
3. **Widespread electrification is a central component of decarbonisation.** Electricity provides 52-73% of final energy in the seven countries in 2050. Electrification allows renewables to displace fossil fuels in the energy mix, but also strongly reduces final energy demand, due to the greater efficiency of electric technologies.
4. **Member states can achieve strong reductions in final energy demand via electrification, efficiency improvements and societal change.** Demand-side policies can help accelerate emissions reductions and reduce supply-side challenges, thereby acting as an 'enabler' of the 1.5°C energy-system transformation. In the seven selected countries, final energy demand falls by up to 58% in 2050, relative to 2019 levels.
5. **Renewables provide 40-47% of the countries' final energy demand in 2030**, rising to above 90% by 2050. Residual fossil fuel demand is largely concentrated in aviation and non-energy use, where synthetic fuels and renewable feedstocks represent the main source of competition.

Introduction

Achieving the Paris Agreement goals will require "rapid, far-reaching and unprecedented changes" in society (IPCC 2018). To limit warming to 1.5°C, global greenhouse gas (GHG) emissions need to fall rapidly in the 2020s, with net zero CO_2 emissions reached by mid-century (IPCC 2022). Every country in the world must undertake transformative change to achieve this goal.

The EU27 has the opportunity to play a global leadership role in delivering climate action. The bloc has recently updated its Nationally Determined Contribution (NDC), aiming to reduce emissions to 55% below 1990 levels by 2030. The REPowerEU plan further accelerates the EU27's energy transition. However, EU climate action depends on transformative change at the level of individual member states. The EU27 will succeed or fail, based on actions taken at the national level.

Are EU member states aligned with 1.5°C?

In this policy brief we explore how seven major EU member states can transform their energy systems to align with the 1.5°C limit. The countries selected are Germany, Poland, Finland, the Netherlands, France, Spain, and Belgium. We use the latest evidence assessed by the IPCC, selecting two global pathways produced by integrated assessment models (IAMs - Box 1), demonstrating the "highest plausible ambition" for the European continent. We downscale these pathways to the member state level (Methodology), assessing whether the climate action of each country aligns with 1.5°C and highlighting key policy implications.

A recent policy brief by the 4i-TRACTION consortium has emphasised that the EU could go further in reducing emissions by 2030 to at least 63% (4i-TRACTION 2022). This will

Box 1 – Integrated assessment models, pathways and feasibility

IAMs are global models which explore how the energy, land and economic systems could evolve together to meet the Paris Agreement goals.

The analysis is based on the analysis of two IAM pathways, called **HighRE** and **SusDev**. The HighRE pathway focuses on rapid renewables deployment and electrification to reduce emissions. The SusDev pathway focuses more broadly on achieving the sustainable development goals alongside the Paris Agreement's 1.5°C temperature limit. This particularly involves greater non-CO_2 emissions reductions from agriculture, which allows for a slightly slower transition in the energy system and a somewhat expanded carbon budget. For more detail, see Luderer et al. (2021), Soergel et al. (2021) and the section on Methodology.

These pathways are technically feasible and economically cost-effective. Technical considerations include constraints on the pace of technology deployment, renewable potentials, and power sector dynamics, such as storage requirements. IAMs do not assess the political feasibility of pathways or identify the regulatory challenges to achieving transformative change. However, identifying technically feasible pathways to higher ambition can raise the motivation to address barriers to their political feasibility.

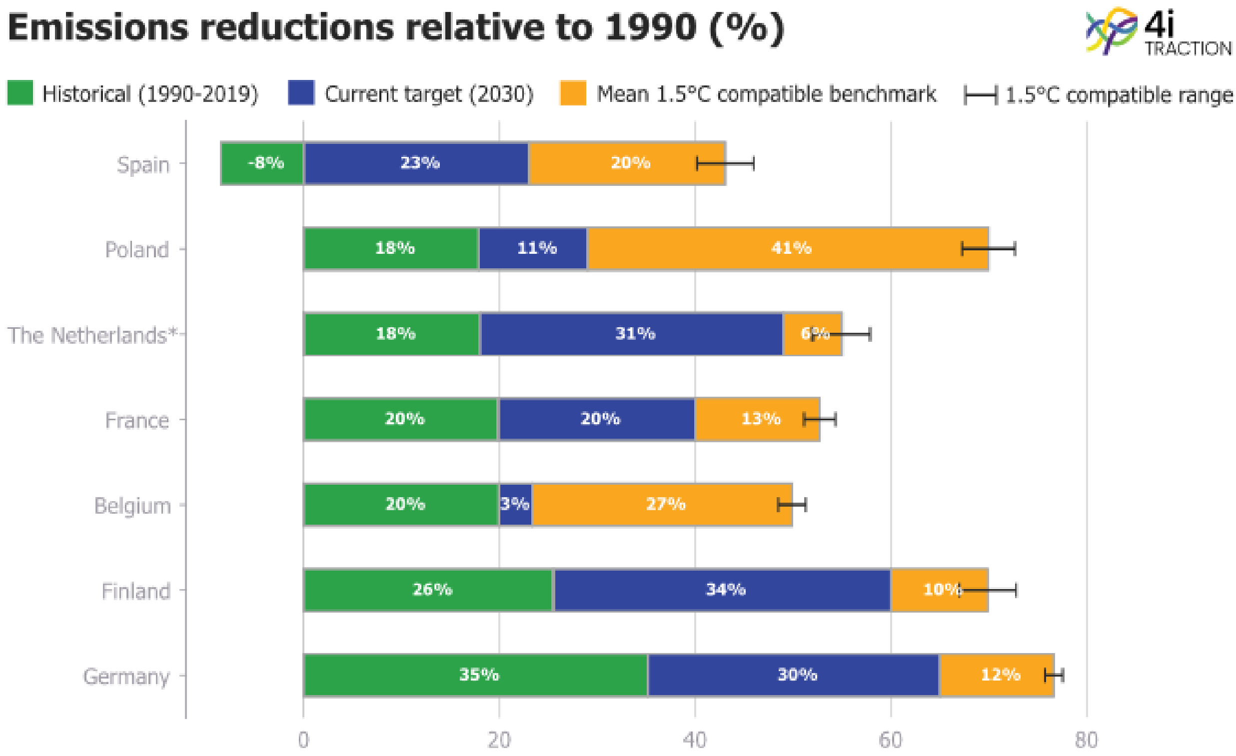

Figure 1 | 1.5°C compatible emissions targets for selected member states

Note: The figure shows the progress made to-date in reducing emissions (green), the additional reductions committed in 2030 targets (blue), and the further reductions required to align with cost-effective 1.5°C compatible benchmarks by 2030 (yellow). Error bars show the range of emissions reductions between the two illustrative pathways considered.

*The Netherlands' current 2030 target of a 49% reduction is not 1.5°C compatible. The coalition has recently proposed increasing this to 55%. This would align with the illustrative pathways, but remains below the Netherlands' fair share contribution to global mitigation (Climate Analytics, 2022). Along with all member states, the Netherlands would need to take additional action to reduce emissions at home and upscale climate finance to support decarbonisation in less wealthy countries, to meet its fair share obligations under the Paris Agreement (Fekete et al., 2022).

require accelerated decarbonisation at the member state level.

Current 2030 emissions targets vary across the seven countries, ranging from 65% relative to 1990 levels (Germany), to 23% (Belgium/Spain). However, **none of the seven member states assessed has a 2030 target for domestic emissions reductions which aligns with globally cost-effective 1.5°C compatible pathways.** We also note that to fully align with the Paris Agreement, member states will need to go beyond aligning with cost-effective pathways, particularly by providing climate finance to support emissions reductions in less wealthy countries (Box 2).

Figure 1 shows GHG emissions for each member state. It represents the progress made by 2019 in reducing emissions since 1990 (green), the current national target for 2030 (purple), and the 1.5°C compatible benchmark for 2030 (blue). These illustrative pathways demonstrate that there are technically feasible and cost-effective **pathways for all seven member states to reduce emissions by at least 50% below 1990 levels** (excluding LULUCF)**.**

Our methodology distributes emissions and energy consumption between different countries in a cost-effective manner (Methodology). This mirrors the internal logic of integrated assessment models but does not account for the effort sharing regulation (ESR) and other European policies that aim to distribute climate action between member states based on fairness, rather than cost-effectiveness. While it is unlikely that the EU will move away from the ESR entirely, cost-effectiveness analysis remains a valuable tool, as it identifies substantial mitigation potentials that could otherwise be overlooked. The cost-effective potential is particularly large in Poland and Germany, due to the high share of coal in their total energy mix. This can help inform the EU27's climate action as a whole and potentially unlock greater ambition in the 2020s. Existing and new funds, such as the Just Transition Fund and EU ETS revenues, can help enable an EU-wide energy system transition which is both cost-effective and fair.

Box 2 – Cost-effectiveness, equity and 1.5°C compatibility

This analysis focuses on whether a country's domestic emissions reductions align with globally cost-effective 1.5°C pathways. However, to be fully compatible with the 1.5° temperature limit as expressed in the Paris Agreement, countries need to make a fair contribution to global emissions reductions, reflecting "equity and the principle of common but differentiated responsibilities and respective capabilities (CBDR)" (UNFCCC, 2015, Article 2.2).

To do this, wealthier countries such as EU27 member states need to do more than align with domestic cost-effective pathways. They can do this by:

- Assisting less wealthy countries to reduce their emissions by providing greater climate finance (Climate Action Tracker, 2022). International climate finance flows from the EU27 are currently insufficient to align with 1.5°C (Climate Action Tracker 2021).
- Reducing their domestic emissions beyond the levels identified in this analysis.

How can member states achieve transformative change?

The analysis identifies key features of transformative change in the selected countries.

A clean power sector in the 2030s

Clean electricity is at the heart of transformation pathways for the EU27. In all selected member states, there is rapid deployment of renewables, particularly non-biomass renewables such as wind and solar, which provides 60-89% of electricity generation in 2030, and 82-99% in 2050. Total renewables account for 67-94% of electricity generation in 2030, and 89-100% in 2050 across all countries and pathways. Figure 2 shows the power sector transition for each country.

In the illustrative pathways assessed here, **coal-fired electricity generation is effectively phased out by 2030 at the latest in all seven countries.** Of the seven countries, France and Belgium have already effectively phased out coal in the power sector. Finland, Spain and the Netherlands have existing or proposed plans to phase out coal-fired generation by 2030, but should aim to accelerate this to the early- to mid- 2020s. Germany's current legislated target is to phase out coal by 2038, which is not compatible with 1.5°C. The coalition's aim to "ideally" phase out

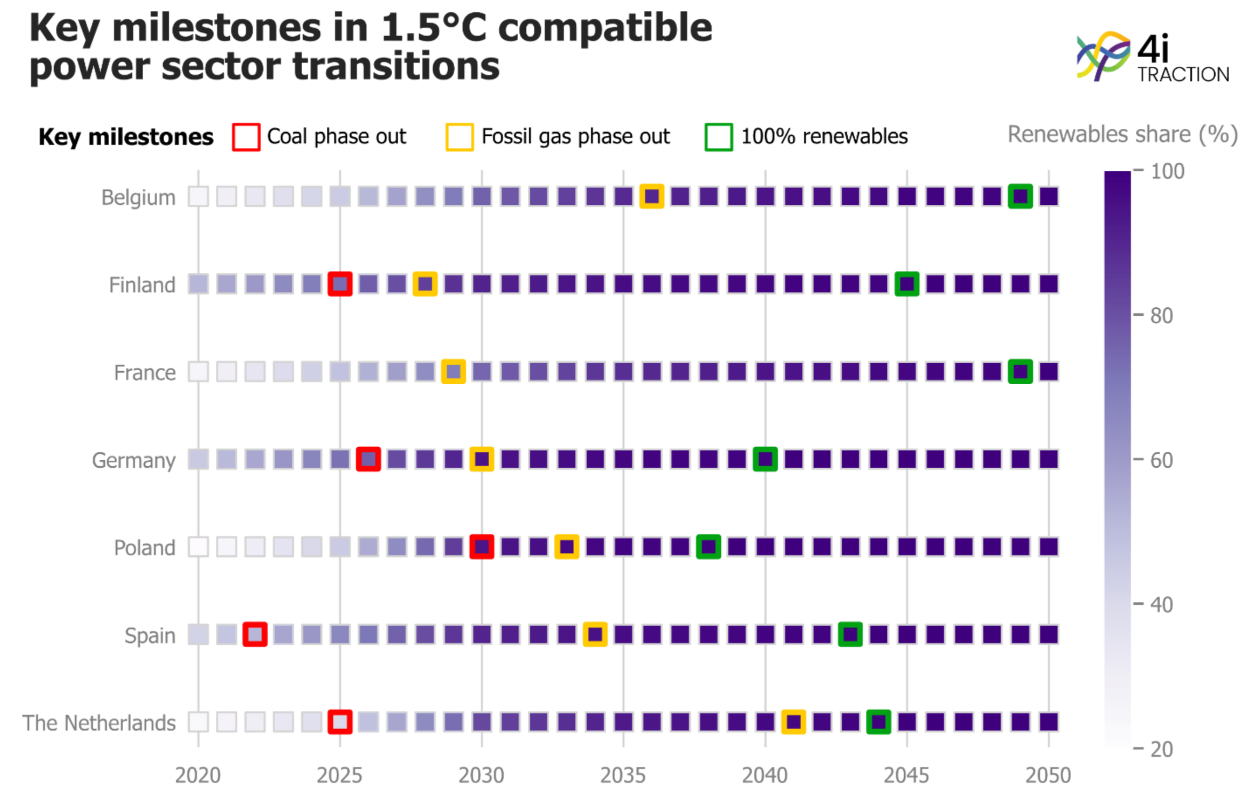

Figure 2|1.5°C compatible power sector transitions for selected EU member states.

Note: The figure shows the earliest date by which each country can effectively phase out coal (red), fossil gas (yellow), or achieve 100% renewables in the power sector (green), based on the two illustrative pathways used in this analysis. Effective phaseout dates are calculated as when a given technology provides under 2.5% of electricity generation (Climate Analytics, 2022). Short-term plans to increase coal generation in the next six to eighteen months are unlikely to affect eventual coal phaseout dates (Ember, 2022).

The 100% renewables milestone is calculated as when renewables provide over 99% of electricity generation, having phased out coal, fossil gas and nuclear from the power system.

coal by 2030 is the latest possible date that could be aligned with 1.5°C and should be brought forwards further where possible. Poland's latest energy plan envisages that coal will still provide 56% of electricity generation in 2030 (Polish Government 2021). The evidence is clear: Poland's plan for continued coal generation post-2030 has no place in a 1.5°C compatible pathway.

There are also strong reductions in fossil gas-fired electricity across all seven countries and both illustrative mitigation pathways. In the HighRE pathway, **fossil gas effectively exits the power system between 2028 and 2041** in all seven countries. This means they **achieve close to 100% clean power (>98%) in the 2030s.** However, at present, none of these member states has explicitly made a commitment to fully decarbonise the power sector in the 2030s. Yet it is clear, including from IPCC reports, that this is a key milestone in the transformation towards zero emissions.

The SusDev pathway does not completely phase out gas generation in every country, but in the EU27 as a whole, fossil gas contributes <3% of electricity generation post-2035. At this low level, fossil gas will be relegated to the role of a 'peak-supply technology', operating only to meet electricity demand on limited occasions. Other options to balance supply and demand could reduce this gas consumption to negligible levels. These include power grid digitisation, demand-side response, interconnection and energy storage.

In these 1.5°C compatible pathways, there is no need to expand nuclear or biomass electricity generation. **Nuclear is phased out before 2050**[1] in all member states and **biomass-based electricity generation remains flat or declines.** This is in stark contrast to existing plans which involve increasing biomass consumption considerably, via coal-to-biomass switching (Ember 2019). Over half of all the coal-to-biomass projects proposed are in the Netherlands, Germany, Spain and Finland, with the Netherlands accounting for over 25% alone. Expanding bio-electricity production is unnecessary for these seven countries to align with the 1.5°C temperature limit. Decision-makers should instead prioritise expanding wind and solar generation.

Electrification and energy efficiency

Wide-spread electrification is essential to the transformation of member states' energy systems. Currently, electricity provides around 18-30% of final energy in the seven selected countries. In the illustrative pathways, this rises to around 52-73% in 2050. There is also an increase in the share of biomass and other renewables (hydrogen and renewable-based district heating).

An electrified energy system is a more efficient system, as electric vehicles, heat pumps and electric heating technologies are much more efficient than their fossil fuel counterparts. As a result, electrification can reduce final energy demands, while providing the same level of energy service demand for consumers. **Electrification is energy efficiency.** In all countries except Finland, electrification coupled with incremental efficiency improvements reduces final energy demand by 20-40% in 2050, relative to 2019 levels. Ambitious lifestyle shifts (as modelled in the SusDev pathway) can then further reduce final energy demand to 40-60% below 2019 levels. Demand reduction can accelerate the pace of decarbonisation (Barrett *et al* 2022), reduce reliance on CO_2 removal (Grubler *et al* 2018) and have considerable wellbeing benefits (Creutzig *et al* 2022).

The greatest potential to reduce final energy demand in these pathways is found in Germany, where demand in 2030 is around 19% lower than in 2019. Finland has the lowest potential for demand reduction, with final energy in 2050 virtually unchanged from 2019 levels. This is because there is a smaller shift from fossil fuels to electricity in 1.5°C compatible pathways for Finland, which has already made progress in reducing fossil fuel demand. This is particularly true in buildings, where district heating and electric technologies (e.g., heat pumps) already provide over 75% of final energy, and fossil gas provides <1%. Without the potential to switch from gas boilers to heat pumps, the scope for efficiency gains via electrification in Finland is more limited.

A rapid reduction in fossil fuel consumption

Renewable-based electrification, sustainable biomass consumption, greater deployment of

[1] The illustrative pathways do not consider the potential for lifetime extensions on existing nuclear plants. This could enable a greater contribution from nuclear in the future.

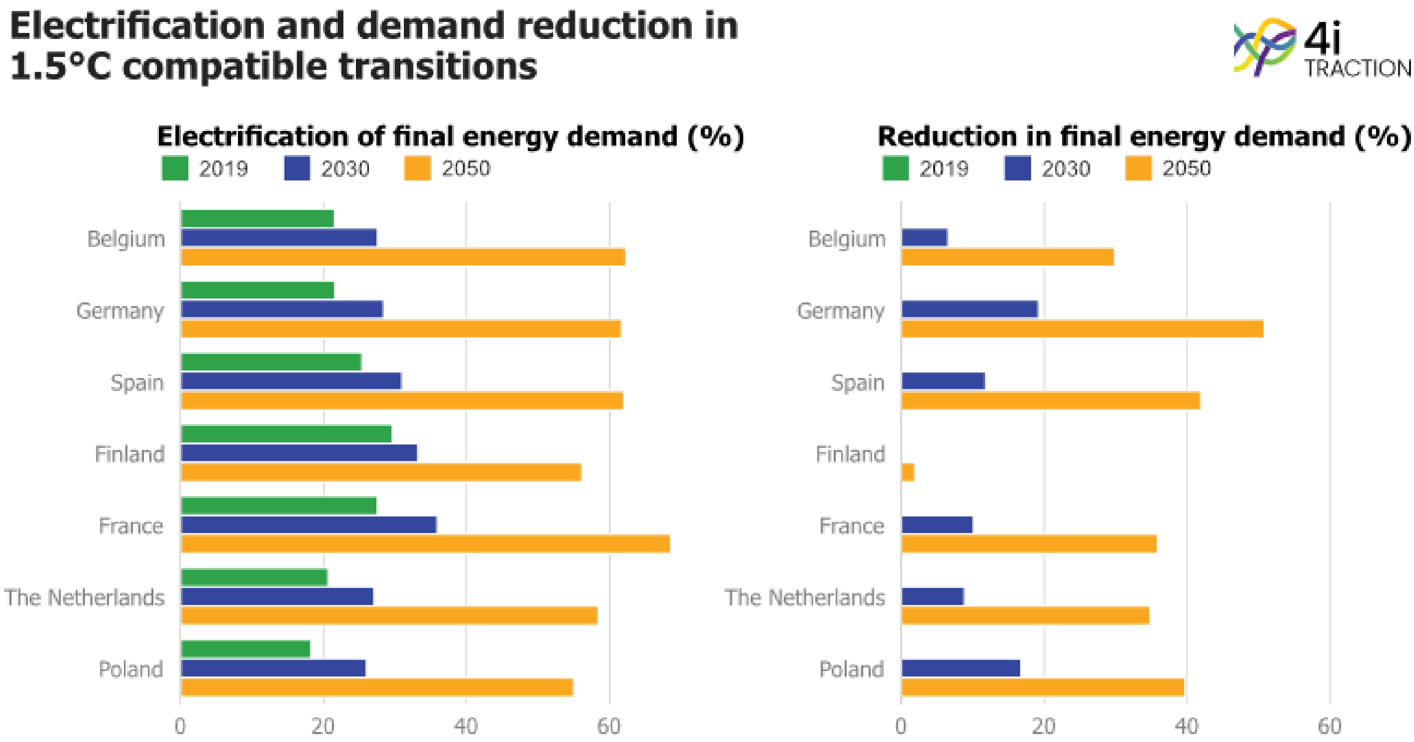

Figure 3|Electrification and energy efficiency in 1.5° compatible pathways for selected EU27 member states

Note: Chart shows the average level of electrification and demand reduction (from 2019 levels) across both illustrative pathways in 2030 and 2050.

hydrogen/renewable heat and reduced final energy demand all drive fossil fuels out of the energy mix.

Renewables provide 40-47% of the seven selected countries' final energy demand in 2030, rising to 91-96% in 2050. Fossil fuel demand falls rapidly across all member states. Figure 4 shows the average share of final energy provided by fossil fuels (including fossil-based electricity) across each member state in the 1.5°C compatible pathways.

In these pathways, unabated coal is almost entirely phased out of the energy system by 2030. This has particularly strong policy implications for industry. Coal-reliant sectors such as steel would need to make rapid steps towards fossil-free alternatives, such as hydrogen direct reduction, or risk locking in new fossil-based assets that will either become stranded on the path to net zero emissions, or increase reliance on carbon capture and storage. This highlights the need to move beyond coal, not only in the power sector but across the energy system.

Oil and gas demand also falls strongly in all seven member states, so that **fossil fuels provide less than 10% of final energy in 2050**. The remaining consumption is mainly oil consumption and is concentrated in feedstocks for the chemical industry and kerosene for the aviation sector. Developing synthetic fuels to replace kerosene, and renewable alternatives for fossil feedstocks in the chemicals industry, could enable an entirely fossil-free energy system by mid-century. These options are not modelled in the illustrative pathways.

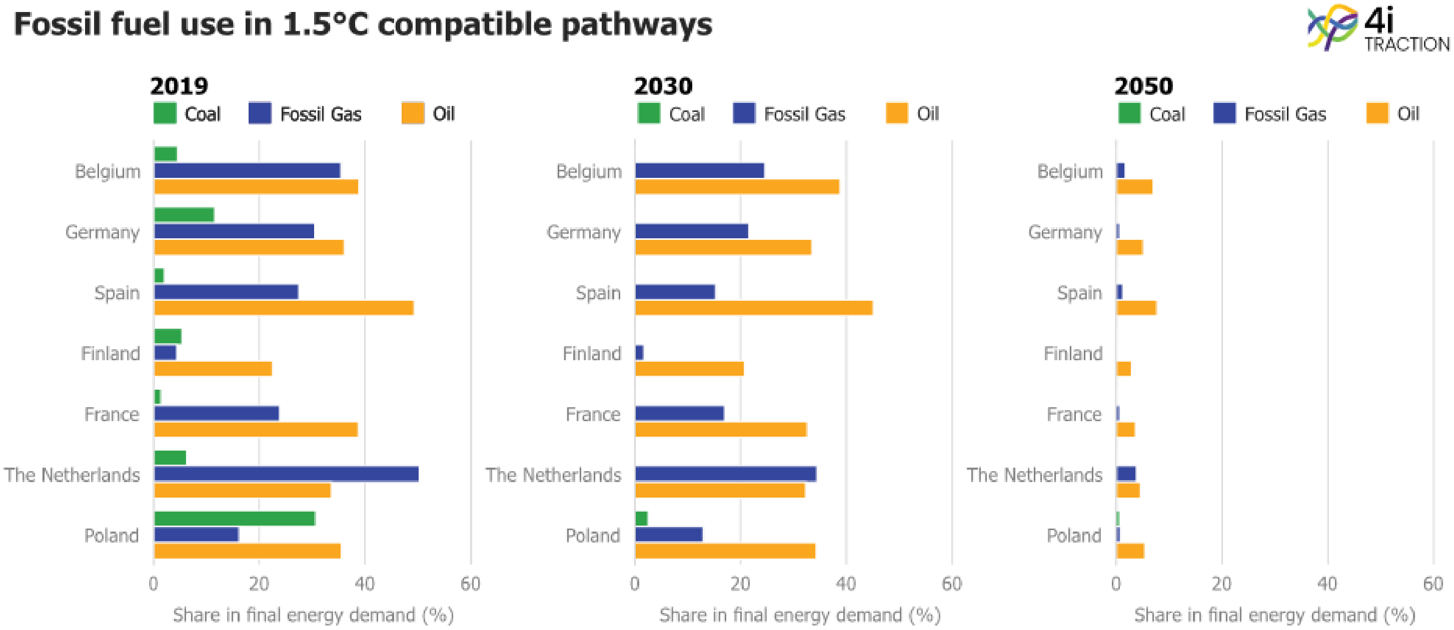

Figure 4|1.5°C compatible reductions in fossil fuel demand for selected EU27 member states

Note: Chart shows the average share of fossil fuels in the energy mix across both illustrative pathways, including fossil-based electricity.

Key benchmarks for member states and implications for the 4i's

Table 1 summarises a range of key 1.5°C compatible benchmarks for domestic mitigation in each of the selected member states. This again highlights the need for every country to take transformative change.

This transformation can be viewed within the lens of the 4i's: the need to foster **innovation**, shift **investment**, roll out **infrastructure** and achieve **integration** across sectors (Görlach *et al* 2022). This provides a conceptual framing to assess transformative change.

The pathways analysed here show that the first key area for transformation is the power sector. Achieving 100% clean electricity by the 2030s will require unprecedented levels of investment in wind and solar generation, and large-scale expansion of transmission and infrastructure and interconnectors. Permitting reform is one key step to accelerate renewables deployment in the 2020s (Bellona 2022). As well as infrastructure improvements, a highly renewable power sector will require demand-side innovation. Demand-side flexibility offers considerable potential in Europe to balance variable renewables at low cost, as 15–30% of the peak load can be shifted on average (Söder *et al* 2018).

Once the power sector has been largely decarbonised, the pathways use clean electricity as the foundation of a new energy system. This represents a highly integrated future, in which the end-use sectors of transport, industry and buildings are strongly coupled with the power sector via direct and indirect (green hydrogen-based) electrification. While growth in final electricity demand is modest in the 2020s, it rapidly accelerates in the 2030-2050 period. Infrastructure deployment to facilitate end use electrification therefore becomes key post-2030.

Country	2030 GHG reduction (relative to 1990)	Power Sector: Coal phase-out	Power Sector: Fossil gas phase-out	Final Energy: electricity share (2050)	Final Energy: renewables share (2050)	Final Energy Demand in 2050 (relative to 2019)
Germany	73-77%	2026	2030	58-65%	93-96%	-43 to – 58%
Finland	64-70%	2025	2028	53-59%	95-99%	+10% to -14%
France	42-57%	N/A	2029	65-73%	94-97%	-26% to -46%
Belgium	44-50%	N/A	2036	57-67%	87-95%	-21% to -39%
Poland	68-70%	2030	2033	52-58%	91-95%	-31% to -48%
The Netherlands	52-55%	2025	2041	53-64%	87-97%	-26% to -44%
Spain	46-51%	2023	2034	58-67%	88-94%	-34% to -49%

Table 1|1.5°C compatible benchmarks for selected EU27 member states

Note: Coal and fossil gas phase-out dates represent the earliest date by which these fuels are phased out of the system, based on the two illustrative pathways assessed. France and Belgium have already effectively phased out coal in the power sector.

As well as highlighting the timing and key focuses of transformation across the 4i's, the results highlight key areas where further breakthrough would be needed to achieve a fossil-free energy system. In the illustrative pathways, residual fossil demand is concentrated in long-distance transport and in non-energy use. Innovation into sustainable aviation fuels and renewable feedstocks are therefore promising avenues to displace remaining fossil fuels in 2050 and achieve a fossil-free European Union.

If EU member states are to align with 1.5°C, urgent, systemic, and large-scale transformation is necessary. Member states are due to revisit and update their national energy and climate plans (NECPs) in 2023. This provides a key opportunity for each country to demonstrate global leadership and accelerate transformative change. This policy brief and the accompanying report highlight key steps that each member state could take. The question then remains – will they deliver the action that is so urgently needed?

Methodology

This policy brief uses the latest evidence from pathways consistent with the Paris Agreement's long-term temperature goal, as assessed by the IPCC in the 6th Assessment Report (IPCC 2022). This provides an ensemble of 97 pathways produced by IAMs which limit warming to 1.5°C with no or low overshoot (Byers *et al* 2022). This ensemble was further filtered to select pathways which limit carbon dioxide removal to within sustainable levels (Fuss *et al* 2018), reach net zero GHG emissions globally in the second half of the century, as per Article 4.1 of the Paris Agreement, and provide the necessary data. This filtering process provides a set of eight pathways for analysis. From these, two illustrative pathways were taken – the '**HighRE**' and the '**SusDev**' pathways. They are chosen as they exhibit the highest level of emissions reductions by 2030 for the EU 27 as a whole. As such, they represent the greatest level of transformative change in the EU27, consistent with EU reducing emissions in line with the highest plausible ambition. For more detail, see Box 1 and the accompanying report.

These global pathways are produced by an integrated assessment model, REMIND-MAgPIE (Baumstark *et al* 2021). This model produces global decarbonisation pathways, showing how different regions can contribute towards the collective goal of limiting warming to 1.5°C.

This ensures member state pathways are part of a globally consistent pathway that limits warming to 1.5°C. These pathways are produced by cost optimisation, and do not explicitly account for effort sharing or equity considerations, under which the EU27 and individual member states would likely need to cut emissions faster still (van den Berg *et al* 2019). Key to the EU27 contributing its fair share to climate action will be supporting ambitious decarbonisation in other countries, particularly via upscaling climate finance, which is currently at insufficient levels (Climate Action Tracker 2022).(Climate Analytics 2022, UNFCCC 2015)

REMIND-MAgPIE disaggregates the global into eleven "macro regions", providing results for the European region as a whole. We use SIAMESE (Simplified Integrated Assessment Model and Energy System Emulator) to downscale energy consumption and energy-related CO_2 emissions to the member state level (Sferra *et al* 2019). SIAMESE allocates energy consumption to individual countries by equating marginal fuel prices across all countries. This provides a cost-effective allocation of energy consumption, which mirrors the internal logic of IAMs. To downscale non-CO_2 and non-energy CO_2 emissions to the national level, we use an intensity convergence algorithm which assumes that the ratio of emissions to GDP across all European countries will converge by 2100 (Gidden *et al* 2019). Combining these approaches gives economy-wide GHG emissions pathways.

IAMs often display a bias against complete decarbonisation and so fossil consumption does not always reach absolute zero (Climate Analytics 2019). Therefore, effective phase-out dates are calculated on the basis of when fossil fuels provide under 2.5% of electricity generation. These phase-out dates are driven by carbon pricing in the model, which does not actively model fossil fuel phase-out dates in the pathways. However, they show the date, given effort consistent with the 1.5°C target, that fossil fuels would effectively exit the power system.

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