

Bridging the Planning Gap

Transforming European NECPs to Deliver on Climate Targets

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CLEAN AIR TASK FORCE

About this Report

This report posits that the National Energy and Climate Plan (NECP) revision process is a critical opportunity to transform Europe's current climate and energy policy ambitions into policy action that enables an energy secure, net-zero Europe by 2050. This report elaborates CATF's vision of the NECPs as valuable tools to maximise the medium-term planning potential of the Governance Framework, and recommends Member States include areas of research, collaboration, deployment, and investment in their NECPs beyond what is included in the European Commission's NECP update guidance document and in previous NECP submissions. The report includes recommendations for key "components" that policymakers can imbue into NECPs to ensure these plans are fit for purpose.

This report is part of CATF's work in Europe focused on "An Options Based Strategy For Europe." CATF hopes this report can empower national actors across Europe to engage more openly in the NECP process and inspire out-of-the-box thinking to meet Europe's targets more quickly, efficiently, and cost effectively. This publication seeks to enhance understanding of the implications and opportunities of the NECP framework as a planning and investment tool to reach net-zero and provide specific recommendations to a broad range of institutional stakeholders through 2023-2024 as country-level NECPs are drafted and made public.

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Executive Summary

Achieving climate neutrality in Europe by 2050 is an ambitious goal. Doing so, while strengthening Europe's energy independence, building up domestic net-zero industry, improving energy resilience, and ensuring affordability for homes and businesses in the face of shifting geopolitical headwinds, ratchets up the difficulty. Fortunately, ongoing updates to European Union (EU) Member State National Energy and Climate Plans (NECP) provide an opportunity to chart a course through these perilous waters — if Member States raise the bar on their planning processes.

In the past few years, Europe has introduced important energy and climate policies, including the Fit for 55 Package, the Net Zero Industry Act, the electricity market reform, and the REPowerEU Plan. Successfully implementing this bevy of policies and connecting them to the EU's long-term net-zero goals will require intentional, strategic, and comprehensive planning. Fortunately, Europe already has a planning framework in place that can help. Passed in 2018, the Governance Regulation required Member States to develop an integrated NECP that details how countries will achieve energy security, renewables deployment, emissions reductions, interconnection, and research and innovation ambitions between 2021 and 2030. Given the shake up of the energy system and increased bloc-wide climate ambition, the EU is requiring Member States to update their NECPs by June 2024 (with initial drafts due in June 2023).

Member States have not yet leveraged the full potential of the NECPs – the European Court of Auditors and the European Commission found that the 2019 NECP process provided insufficient policy and investment clarity, consistency, and detail, and was not ambitious enough to facilitate climate neutrality. Fortunately, the 2023 NECP revision offers a fresh start and a unique opportunity to reflect the realities of the transformed geopolitical landscape; to tailor climate and energy strategies to simultaneously advance the related aims of energy security, affordability, and reliability; and to put forth ambitious, forward-thinking, and options-based policy and technology solutions.

To ensure this round of revisions unleashes the full potential of the NECPs to connect the Europe of today to the Europe of 2030 and 2050, CATF recommends Member States incorporate the following concepts into their submissions:

Hedge technology bets. Renewable sources of electricity are critical to the energy transition, but zero-carbon fuels, carbon capture and removal technologies and practices, and clean firm energy technologies like advanced nuclear and superhot rock geothermal broaden the option set for decarbonisation. In their NECPs, Member States should follow an options-based climate strategy that identifies high-value end uses for clean fuels and advances a wide range of clean technologies, especially those in early stages of development, to increase the likelihood of successfully decarbonising within their unique national contexts.

Provide certainty to investors and direct funds where most needed. NECPs should promote investor confidence and drive capital to where it is most needed by articulating clear, transparent, and unambiguous Member State priorities. NECPs can provide additional financial transparency by estimating costs and defining funding sources through 2030 and beyond. Member States should also encourage financing mechanisms like carbon contracts for difference and power purchase agreements, as well as research funding for early-stage technologies.

Facilitate regional and international solutions. Reaching Europe's climate and energy security goals will require scaling zero-carbon fuels, building cross-border infrastructure, and diversifying energy supply by exploring new options for energy imports. Member States should develop energy import strategies to serve critical end uses and evaluate the need for cross-border infrastructure in coordination with their neighbours and trading partners. These strategies and projects should be reflected in their NECPs. Member States should also evaluate opportunities for bilateral or multilateral contracts with other regions to use their purchasing power to seek emissions reductions from imported products and clean fuels, ensuring a level playing field domestically and internationally.

Enable implementation to meet 2030 and 2050 goals. Even the best laid plans cannot succeed without political and community buy-in, accountability, and a skilled workforce to administer, facilitate, and build projects. Member States should include implementation frameworks that speed necessary infrastructure deployment in their NECPs and should set deadlines for and track progress of infrastructure, investment, and emissions reduction milestones against 2030, 2040, and 2050 goals. Policymakers should use the NECP process to envision a net-zero 2050 and consider the policy and investment decisions needed between today and 2030 to enable that future. At the same time, Member States cannot expect that each piece of their plans remains relevant and rigid as time goes on. NECPs should help Member States bake in opportunities to recalibrate and adapt as lessons are learned, technology developments advance, and broader social, political, and economic contexts inevitably change.

Europe is currently in a situation where its detailed plans for 2030 are out of step with geopolitical and geoeconomic realities, not to mention real-world emissions reductions. Even worse, the path from those 2030 targets to EU-wide climate neutrality in 2050 is barely sketched out – an issue at the heart of what CATF calls Europe's "planning gap." Used to their full potential, the NECPs could address this as interim plans that ensure Member States achieve 2030 targets while also preparing for full decarbonisation by 2050.

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Introduction

Europe's climate ambition has never been greater. After the Paris Agreement, the bloc enshrined in law the climate neutrality objective by 2050 and set an intermediate target of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. To aid in meeting these climate and energy targets, all Member States were required by the Governance Regulation[1] to develop a National Energy and Climate Plan (NECP) spanning the ten years between 2021 and 2030. European Union (EU) countries drafted their first NECPs and submitted final versions in 2019.

Soon after their submission, however, NECPs were outdated due to new EU policies, such as the EU Green Deal and increased emissions reduction targets by 2030 through the Fit for 55 package.[2] Other significant external shocks followed the adoption of the NECPs, including the COVID-19 pandemic, the war in Ukraine, and a gas and energy crisis. More recently, competing energy policies like the U.S. Inflation Reduction Act (IRA) have presented additional trade and foreign policy implications.

These events fostered new policy developments and added urgency to build energy independence and strengthen energy security, as attempted via REPowerEU and other mechanisms. They also led to substantive discussion around the net-zero industrial and manufacturing ecosystem needed in Europe, spurring the Critical Raw Materials Act,[3] the Net Zero Industry Act,[4] and a new electricity market design vision.[5]

Though Europe is moving in the right direction, critical climate milestones are rapidly approaching. Significant work must be done to get Europe on a decarbonised, energy secure, independent, and industrially and economically competitive path and develop, construct, and deploy the clean energy system needed to do so. To bring about this 2050 net-zero vision, Europe must start planning now. But interim climate plans and policies, including the 2019 NECPs, have historically fallen short in ambition and failed to put forth a detailed, actionable trajectory between today, 2030, and 2050, jeopardising Europe's ability to adapt and achieve long-term goals in this new global context.[6]

In this dynamic environment, the EU has required that Member States update their NECPs by June 2024. This revision process offers a unique opportunity to reflect on the realities of a radically transformed policy, industrial, and geopolitical landscape, and to realise the full potential of the NECPs as interim plans that can ensure Member States achieve 2030 goals while preparing for a fully decarbonised future. Ambitious 2030 climate goals, a net-zero 2050 vision, and energy security concerns will require forward-thinking, diverse, and ambitious options-based policy and technology solutions that can ensure cross-sectoral emissions reductions while maintaining reliability and affordability across diverse national contexts. The urgency of all this change necessitates rapid build out of infrastructure that will require the buy-in of local communities, country-level planning and administrative capacity, and regional coordination. Europe will need all the tools at its disposal to reduce reliance on energy imports and deliver emissions reductions efficiently and cost-effectively. And countries must not lose sight of workforce development needs, community engagement, tracking, and other elements critical to the successful implementation of climate goals.

Fit for purpose NECPs can connect ambition to action, accelerating Europe's decarbonisation pathway by facilitating an options-based climate strategy, considering short-, medium-, and long-term investments needed to achieve climate goals, fostering collaboration with other countries and regions, and assessing infrastructure needs and barriers to deployment. Well-planned NECPs would support Member States in implementing new policies and strategies while allowing for adaptation and flexibility in the face of unknown geopolitical, technological, and economic developments ahead. The planning potential of the NECPs goes beyond EU borders, with countries like Ukraine poised to use this instrument for both reconstruction and the renaissance of a clean post-war future.[7] By unleashing the potential of its NECPs, Europe can be certain in its ability to achieve its climate, energy security, and infrastructure goals.

SECTION 2

NECPs in Context

The EU 2050 climate neutrality target is clearly articulated and legally binding. The path to achieving that target, however, is not as clear, and there is limited acknowledgment of the scale of the infrastructure challenge ahead. In response to shifting geopolitics and a global move toward net-zero industrial policy over the past several years, Europe proposed a set of policies promoting energy security and protecting and boosting green manufacturing. While these policies point Europe in the general direction of a 2050 net-zero future, they do not provide a clear roadmap to get there.

To be certain that it is moving steadily toward a net-zero future resilient to changing global dynamics, the EU needs a planned, comprehensive, and coordinated policymaking and planning process involving Member States, the private sector, local communities, civil society, and other key stakeholders. Only a couple of decades from now, Europe will need a plethora of renewable and clean energy resources commercialised and built, as well as cross-border infrastructure to carry fuels, carbon, and power. The planning, preparation, financing, labour, construction, and administrative support required to implement the net-zero energy system is unprecedented. Shorter-term plans and projects are essential to mobilising actors across the economy, and successfully completing these smaller-scale efforts day in and day out, learning from experience, and adapting and perfecting processes over time will eventually result in the deployment of a more secure, decarbonised energy system.

European policymakers can develop new tools to coordinate this short-, medium-, and long-term planning, but one underutilised, Member State-level mechanism already exists today: National Energy and Climate Plans (NECPs). NECPs lay out each country's integrated climate and energy plans between 2021-2030. Member States submitted the first round of draft NECPs in 2019 but must submit and finalise updated drafts between June 2023 and June 2024. This NECP update could allow Member States to leverage the full potential of the NECPs to meet the new geopolitical moment and develop interim plans to better connect the dots between the Europe of today and the Europe of 2050. And with policymakers at the EU and national levels debating the European response to the global trend of green industrial policy, now is an ideal time to develop ambitious updated NECPs that reflect the scale and complexity of the infrastructure challenge ahead with a more options-based set of policy and technology solutions.

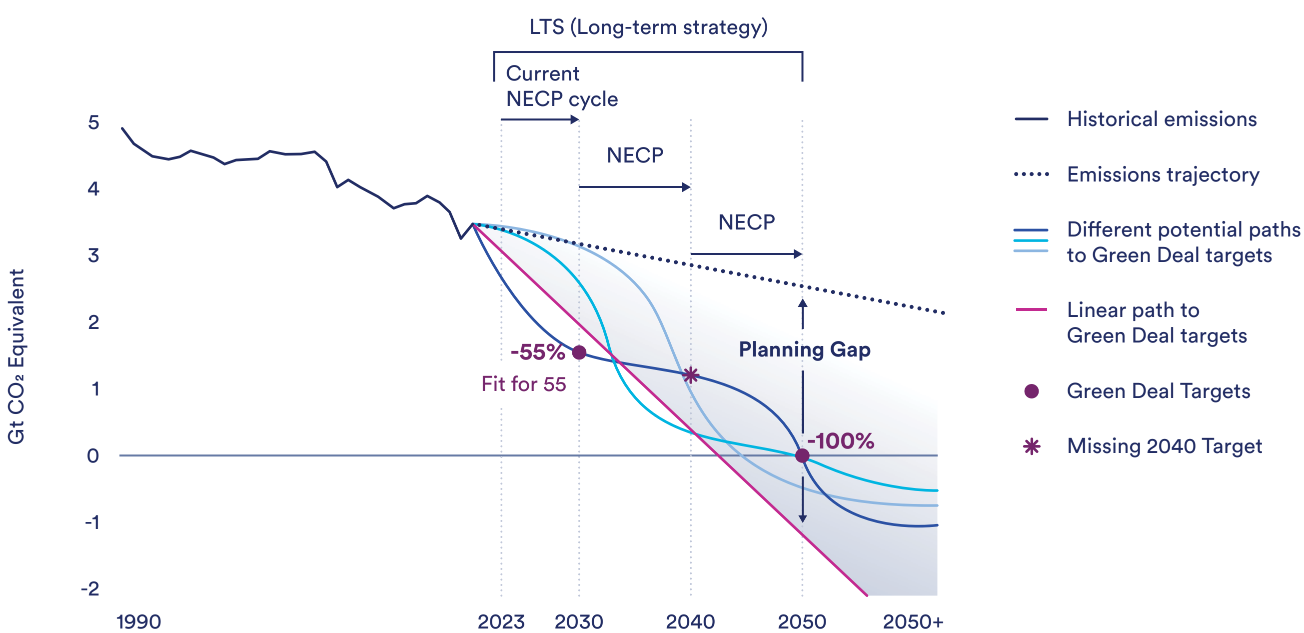
The new geopolitical reality facing Europe

Europe has long led on climate action. The EU developed and implemented the world's first international emissions trading scheme with country-level emissions caps on power and industrial emissions.[8] The region pioneered offshore wind and has deployed renewable technologies *en masse*. And after the Paris Agreement, the bloc enshrined in law the climate neutrality objective by 2050 and set an intermediate target via Fit for 55 of reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

However, historic leadership does not necessarily beget a continued leadership role. According to a recent EU Auditors report,[9] there is currently no guarantee that the ambitious EU targets stemming from the Green Deal will spur the action needed to achieve climate targets. This inconvenient truth reaffirms that the EU will not meet its 2030 climate targets, nor its climate neutrality objective in 2050, if it continues at current deployment and financing speed. There is also no credible plan to address the deployment gap between 2030 and 2050 since current policies, such as Fit for 55 and REPowerEU, do not go far enough to map out Europe's long game for clean energy security in a multi-polar and uncertain world (Figure 1).

Figure 1: NECPs can fill planning gaps between broader decadal targets[10]

The 2040 target is one missing milestone on the EU's pathway to 2050 Climate Neutrality. The European Commission is expected to propose an interim climate target for 2040 in the first half of 2024 to guide EU climate policy making beyond 2030



A quickly changing world has complicated Europe's ability to drive toward net-zero. Recent unprecedented events, such as the COVID-19 pandemic, the war in Ukraine, and the global energy crisis, shook the geopolitical foundation of European climate and energy policy. The war in Ukraine brought to the forefront an economy-wide overreliance on Russian natural gas and oil, exposing how dependent the EU remains on external suppliers for its energy supply.[11]

These events abruptly called into question Europe's energy security, the design of its electricity market, its economywide heavy reliance on imports, and the speed of its energy transition away from fossil fuels. They also served as a stark reminder that Europe, despite its historic climate leadership, has not successfully enabled an energy system transformation that accounts for energy and economic security.

The global trend toward green industrial policy adds a competitive dimension to the energy transition. The United States (U.S.) passed a trio of legislation, namely the Energy Act of 2022, the Infrastructure Investment and Jobs Act (IIJA) and the Inflation Reduction Act (IRA), representing the country's largest ever investments in addressing climate change and providing financial incentives for renewables, nuclear energy, carbon capture and storage, hydrogen, and other next-generation net-zero energy technologies that support these technologies from the lab bench to deployment. Japan, India, the United Kingdom (UK), China, and Canada have also released investment strategies focused on net-zero technologies and manufacturing.[12, 13]

The global shift toward net-zero industry has also highlighted Europe's specific overreliance on critical raw material imports. These materials are often concentrated in a limited number of third countries – and sometimes in just one country – that can control up to 90% of total supply.[i] High geographical and market concentration of critical raw materials in limited areas contributes to Europe's supply security challenges and could lead to future dependencies on other countries and regions, similar to Europe's historical hydrocarbon dependency on Russia.[14]

Europe is now centre stage in a global economic and geopolitical paradigm shift. EU policymakers have been quick to react to these changing dynamics, though not always in a coordinated manner. Initially, misaligned national responses to these crises strained and threatened a broader, organised EU response. Some countries returned to dirtier fuels to maintain energy security and affordability, and the European Commission relaxed state aid rules,[15] allowing Member States to preference and support their domestic industries. However, policymakers increasingly recognise a new energy reality unfolding across Europe that requires a more coordinated response to decarbonise and strengthen the European economy. New policy roadmaps, such as REPowerEU, emerged to end reliance on Russia and build energy independence with more ambitious renewable deployment and hydrogen procurement goals. Over the past several months, governments have agreed to higher renewable deployment targets and stricter energy efficiency measures, stemming from the flagship initiatives of the Fit for 55 package, to provide more certain targets and initiatives that can turbocharge the clean energy transition (Figure 2).

Figure 2: Fit for 55 package updated several 2030 targets

All of the below represent increases or decreases from 1990 data.

	GHG Emission Reduction Target	Renewable Energy Share	Energy Efficiency Improvment	Carbon Removal Target (LULUCF Regulation)	Interconnection Target
Previous EU 2030 Targets	at least 40% cut in GHG emissions	at least 32% share	at least 32.5% improvement	225M Tons of CO_2e	15%
Updated EU 2030 Targets (what Member States should reflect on)	at least 55% cut in GHG emissions	at least 42.5% share	at least 36% improvement (binding target)*	310M Tonnes of CO_2e	15%

[i] This is the case for light rare earths, heavy rare earths, gallium, and magnesium in China, and boron in Turkey.

Features of new EU net-zero industrial policy

The European Commission presented in February 2023 its Green Deal Industrial Plan which aims to enhance the competitiveness of Europe's net-zero industry and accelerate the transition to climate neutrality. It does so by creating a more supportive environment for scaling up the EU's manufacturing capacity for the net-zero technologies and products required to meet Europe's ambitious climate targets. To support this, the European Commission presented both the Net Zero Industry Act and the European Critical Raw Materials Act.

Key features: Net Zero Industry Act Vs Critical Raw Materials Act

Net-Zero Industry Act

- **Setting enabling conditions:** Simplifying the rules for net-zero technologies (lowering administrative burden and streamlining permitting)
- **Accelerating CO2 storage:** Remove a major barrier to developing CO2 capture & storage as an economically viable climate solution
- **Enhancing skills:** Ensure there is a skilled workforce supporting the production of net-zero technologies in the EU
- **Fostering innovation:** Member States can set up regulatory sandboxes to test innovative net-zero technologies and stimulate innovation

European Critical Raw Materials Act

- **Setting clear priorities for action:** Clear benchmarks for domestic capacities along the strategic raw material supply chainand to diversify EU supply by 2030
- **Creating secure & resilient EU critical raw materials supply chains**
- **Ensuring that the EU can mitigate supply risks**
- **Investing in research, innovation and skills**
- **Improving circularity & sustainability of critical raw materials**
- **Diversifying the Union's imports of critical raw materials**

And the EU has reconsidered the clean energy technology and industrial manufacturing ecosystem needed on the continent, spurring the Net Zero Industry Act (NZIA)[16] and the European Critical Raw Materials Act,[17] both presented in March 2023, as well as a new electricity market design vision.[18]

With this flurry of positive policy developments comes the hard task of planning for and implementing adopted policies. Major climate milestones are fast approaching, and much more needs to be done to fulfil a long-term European vision for energy security and economic growth in a changing world. For Europe to truly participate in this emerging new energy economy and move towards industrial independence and competitiveness, industrial strategies will have to both build on domestic opportunities and actively identify strategic partnerships.[19] Member States must think expansively about the solutions needed for a climate-aligned future and how the greater, evolving industrial and geopolitical landscape affects them. The goal is to transition to a net-zero, energy secure economy by 2050 and move towards an energy system that is radically different from that of today – one that is completely decarbonised, is more independent, and enables industrial and economic growth and competitiveness. This system must integrate a broad range of net-zero enabling technologies deployed in an efficient and environmentally friendly manner, reuse or repower existing infrastructure, connect demand centres to low-cost energy or fuel production sites, and consider social and land use trade-offs.

To achieve this energy system vision, European countries require a better understanding of what is needed to fill policy and technology gaps to go beyond 2030 targets. It will also require asking hard questions to determine if current national energy and climate policies are fit for purpose, developing comprehensive and bespoke sectoral and technology roadmaps informed by industry needs, and aligning with on the ground realities. With the right policy tools and political engineering, Europe can safeguard its position as a climate leader and marry climate action with global industrial and economic growth. The next few years will determine whether Europe continues to inch along with incremental actions that may or may not add up to a net-zero future, or if it will pivot to a strategy fit for the long-term.

Planning is key to building the net-zero economy

To achieve this net-zero 2050 energy system, Member States need to start planning today. The carbon-free energy systems that Europe needs to develop, commercialise, and deploy in the coming years are complex, interconnected, and capital-intensive. These systems require not only significant renewable resources, but also electricity transmission lines, long-duration energy storage, clean firm[ii] power, distributed generation resources, carbon capture, transport and storage, and low-carbon fuels, among other solutions. Three decades is a very short period to permit, renew, upgrade, install, and secure key infrastructure needed within and across Member State borders. Workforce shortages, social resistance, slow permitting processes, bureaucratic red tape, and unclear processes all threaten to cause project delays and costs that Europe cannot afford; delays or failure in one part of the system at any point in the transition ripple through the rest, threatening to slow progress, increase costs, and degrade reliability.

Member States lay out visions for 2050 in their "long-term climate strategies" (LTS).[20] These strategies are meant to align with Paris Agreement goals and provide an overarching framework to reduce emissions and get to net-zero. While these LTSs can be directionally helpful, they do not detail the steps needed to get zero-carbon technologies off the ground, permit critical infrastructure in a timely manner, train a generation of skilled labourers, identify least-harm sites for new generating resources, attract investor attention to specific needs at the right times, hold parties accountable for the achievement of any interim goals, and accomplish myriad other tasks and initiatives along the way that add up to success by 2050.

Interim plans can break these longer-term goals into manageable pieces, delegate responsibility for discrete tasks over shorter timeframes, facilitate buy-in and engagement on near-term objectives, and allow for recalibration if and when wider contexts shift or plans change. The EU and its Member States need more ambitious, well-thought out and consistent short- to medium-term interim plans that sum to the longer-term strategies for climate neutrality. To do this, Europe will need to take its energy system planning endeavours to 2030, 2040, and 2050 seriously and identify and address barriers more proactively.

The NECP as a timely and critical interim planning mechanism

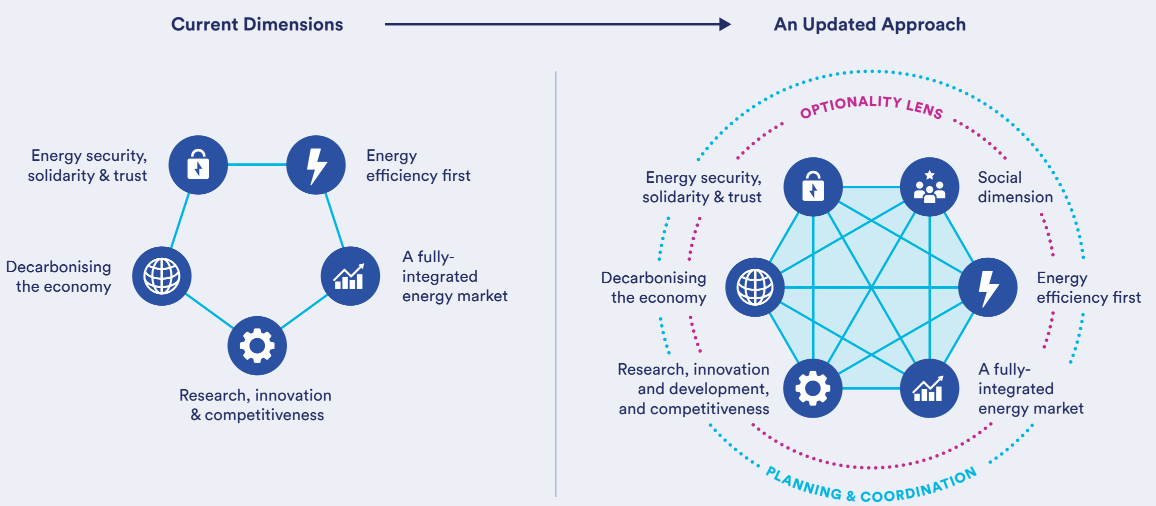
To help the EU reach its 2030 climate and energy targets, the Regulation on the Governance of the Energy Union[21] sets common rules for planning, reporting, and monitoring to ensure that the five dimensions of the Energy Union Strategy – energy security; internal energy market; energy efficiency; decarbonisation; and research, innovation, and competitiveness – are implemented coherently across the Union. It also allows synchronisation of EU planning and reporting with the ambition cycles under the Paris Agreement.

[ii] Clean firm capacity refers to generation resources that can control their power output and are not dependent on weather-related variables, such as geothermal, gas power with carbon capture and storage, and nuclear.

Updating the Energy Union Dimensions

The NECPs outline how the EU countries intend to address the five dimensions of the Energy Union, which are key for advancing on climate and energy objectives. This approach requires a coordination of purpose across all government departments and supports planning. However, much has changed since the publication of the Governance Regulation in 2018. New climate and energy regulations and targets have been introduced and the geopolitical priorities of the EU have shifted, changing the scope of the NECP framework. Five years ago, security of supply, while certainly a pillar of the Energy Union, was not a dimension covered in the NECPs. Today, it has become a crucial element for all EU countries. The policy landscape has evolved, and elements such as energy infrastructure, the internal energy market, and energy poverty have become more important, strengthening the case for including additional reinforcing dimensions, such as the social dimension. Other dimensions, such as the research and innovation (R&I) dimension, lack mention of development – a key component for the deployment and scale up of carbon-free technologies in this decade. This dimension should be further strengthened to encompass research, development, and innovation in all stages of the technology commercialisation cycle. The upcoming review of the Governance of the Energy Union in 2024 should consider broadening and adapting the dimensions that govern the NECP framework to fit current socioeconomic and geopolitical contexts.

Figure 3: Current and potential interlinked and mutually supportive dimensions of the Energy Union[22]



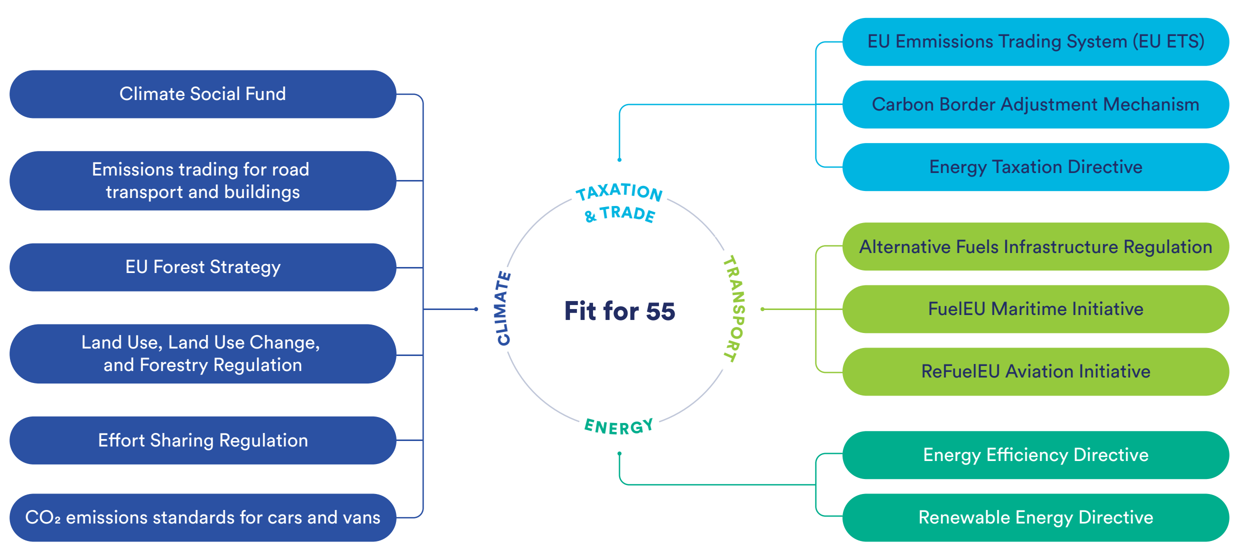
At the centre of the regulation lies the NECP,[23] a ten-year, Member State-specific integrated plan for the 2021-2030 period that details energy efficiency, renewables, emission reduction, interconnection, and research and innovation ambition. These plans should be coherent with EU and national planning documents, including their LTSs, which also stem from the Governance Regulation.

In theory, the NECPs already provide Member States a useful interim planning mechanism to bridge the gap to 2050. However, Member States submitted NECPs in 2019, and a European Commission assessment found that this first attempt fell short of expectations. Fundamentally, the Commission noted that Member States did not take advantage of the opportunity for these documents to serve as interim plans.[24,25] The plans lacked policy detail and long-term consistency, failed to provide long-term predictability, did not efficiently assess funding sources nor investment needs, failed to design policy frameworks that provide support across the entire technology lifecycle, and did not seize the full potential of regional cooperation.[26] Additionally, the Commission found that Member States provided the public insufficient opportunity to participate in the development of both draft and final NECPs.[27] As part of the adjustment to more ambitious climate and energy policies and the new geopolitical and economic realities in Europe, Member States have to update their NECPs, submit new drafts in June 2023, and submit final revised versions in June 2024. This process will necessarily induce Member States to update the objectives and 2030 targets set out in their initial NECPs and the policies and measures for attaining them, particularly in the dimensions of decarbonisation (which includes renewable energy), energy efficiency, and the internal energy market. To support countries in this endeavour, the Commission published a guidance document in December 2023. All in all, this guidance listed 43 new EU laws, policies, and legislative proposals that will need to be incorporated in the updated NECPs.

This upcoming revision process is a once-in-a-generation opportunity to leverage the potential of NECPs as valuable interim planning tools that tie current, 2030, and 2050 climate goals together. Well-designed NECPs can also align Member State plans and actions with updated European industrial and economic policies and energy security goals. Member States can use the updated NECPs to promote new innovations, policies, funding mechanisms, and strategies that can enable affordable carbon-free energy at scale to meet the climate challenge. To have truly fit for purpose NECPs, these plans will have to set a clear roadmap based on technology optionality, innovation, robust modelling and analysis, and ambitious clean tech funding and deployment. And with the right tracking and collaborative tools, NECPs can support continuous learning at the Member State and EU levels, helping to streamline and optimise the climate, economic, and social transition through 2050.

Figure 4: Overview of the Fit for 55 package, European Green Deal[28]

Fit for 55 refers to the EU's target of reducing net greenhouse gas emissions by at least 55% by 2030. The below policies and regulations have been put forth and revised to bring EU legislation in line with the EU 2030 climate target.



SECTION 3

Fundamental Components of NECPs Fit for Purpose

Fit for purpose NECPs can provide Member States with a critical tool to achieve an energy secure, economically strong, and climate-neutral Europe, delivering a blueprint for achieving net-zero emissions that promotes technology optionality and supports global decarbonisation. NECPs also provide the opportunity to map out the clean energy transition through 2030 while laying important groundwork for the journey to net-zero. Ideally, these documents should clearly articulate and feed into a long-term, options-based vision reflecting Europe's new policy, energy security, and geopolitical realities, the cultural and social environments of its Member States, and constraints on its land availability. They should attract investor and public attention to key emerging, clean energy technologies, particularly to decarbonise "no-regrets" sectors that are difficult to decarbonise and have hard-to-abate end uses. These plans should initiate and strengthen beneficial infrastructure and trade collaborations between Member States and with other countries and regions. And they should create the conditions for successful policy implementation by promoting policymaker accountability, social buy-in, tracking progress, and developing the net-zero workforce.

CATF identified five key components of well-planned NECPs built for net-zero that reflect these ideals. Through the recommendations provided, these characteristics can be imbued in NECPs to support Member State success in achieving 2030 and 2050 decarbonisation goals.

- **Hedge technology bets**
- **Clean energy in place and context**
- **Inspire investors confidence**
- **Look beyond borders**
- **Enable implementation**

Hedge technology bets

Policies like the revised Renewable Energy Directive, REPowerEU, and emergency permitting timelines for renewable energy projects reaffirm Europe's commitment to renewables and the criticality of these resources for achieving the region's policy goals. However, wind and solar should not be the only zero-carbon, clean energy resources in the toolbox. Studies by the Intergovernmental Panel on Climate Change,[29] the International Energy Agency,[30] and other leading climate research institutions find that multiple decarbonisation technology options are needed over the coming decades to decarbonise at the right scale and pace. Many countries, including those of the EU, have incorporated non-renewable, clean resources into their Nationally Determined Contributions (NDCs), underscoring the anticipated need out to 2050 for alternative options.[31] And varying rates of renewable deployment among Member States, differences in legacy energy systems among countries, and the unique social, economic, and resource circumstances of each Member State imply that a one-size-fits-all approach will not suffice – a broader, customised portfolio of climate solutions and technology options can and should be deployed to deliver on energy and climate targets while improving resilience to unexpected developments and events, security of supply, reliability, and affordability.

Several non-renewable power generating resources, carbon dioxide (CO_2) removal, capture, and storage technologies, and clean fuels poised to play an important role in the energy transition are in early stages of development today. Member States open to emerging technologies, such as superhot rock geothermal energy and advanced nuclear energy, should consider them in their NECPs to fast-track decarbonisation and improve energy security. To maximise the chances of timely commercial viability for these net-zero technologies, the next round of NECPs should identify critical end uses and applications for this broader suite of new technologies and start planning now for deployment at scale.

Encourage the production and use of hydrogen and zero-carbon fuels in high-value end uses

In 2050, and certainly in 2030, some hard-to-abate sectors, including oil refining, aviation, maritime shipping, steel production, long-distance trucking, and petrochemical industries, will be unable to fully eliminate emissions through power sector decarbonisation alone. Many of these industries today rely heavily on fossil fuels and release carbon pollution through unabated combustion or process emissions. They also use fossil fuel by-products, sometimes as feedstocks, to produce essential, commonly used products. Such products include transport and cooking fuels and oils, lubricants, plastics, detergents, fertilisers, pesticides, dyes, paint, fabrics, fibres, adhesives, construction materials, and pharmaceuticals. Some industrial processes demand heat sources far hotter than electricity can provide, and others demand energy density far greater than electricity storage alone can provide. Hydrogen is also a crucial industrial feedstock needed to produce fertilisers, fuels, and chemicals.

There are very few, if any, feasible pathways for decarbonisation in these sectors without the use of zero-carbon fuels. These fuels that produce no emissions when consumed or combusted, such as hydrogen and ammonia, can be developed today for applications that can reduce or eliminate otherwise unavoidable emissions. And new uses for hydrogen as an industrial feedstock, including in the production of synthetic fuels and biofuels, are emerging. However, hydrogen produced and used today typically has very high associated emissions, due to the process of producing the molecules. Hydrogen specifically is rarely found in a naturally abundant state and therefore must be liberated from a compound form. Most of the hydrogen produced today is via steam or autothermal reforming of methane (CH_4) from natural gas, with a small fraction produced through coal gasification. Additionally, hydrogen can be produced via water-based (H_2O) electrolysis, but little hydrogen today is produced via this method. To make hydrogen low-carbon, producers can install carbon capture technology and impose strict methane emissions controls onto the methane reforming process, or they can use electrolysis powered by clean firm or renewable energy, such as wind, solar, nuclear, or other emerging technologies (e.g., superhot rock geothermal).

Europe has limited domestic resources available to produce enough of its own hydrogen. The region has short supply of domestic natural gas to produce low-carbon hydrogen, and although European renewable capacity is increasing, the clean electricity these resources generate that could be used to produce hydrogen via electrolysis will be in high demand as other end uses continue to electrify. Because significant energy is needed to liberate hydrogen molecules from carrying compounds, and the properties of hydrogen make it difficult to transport and store efficiently and effectively, hydrogen should be viewed as a precious molecule and prioritised for use in the aforementioned hard-to-abate sectors where hydrogen specifically is needed.

Ammonia (NH_3), another compound that carries hydrogen, could also be "cracked" with significant energy input to liberate its hydrogen. However, ammonia is also highly valuable in and of itself as a low-carbon fuel, with applications in these hard-to-abate sectors. It is also more stable to transport and store than hydrogen, making it a more flexible decarbonisation option. If ammonia is produced under strict emissions controls, it could replace some demand for hydrogen in key sectors at cost and efficiency benefit.

At present, low-carbon fuels, and particularly hydrogen, are considered for use in sectors that have viable alternative decarbonisation options. For example, some facilities plan to co-fire hydrogen with natural gas for power production when those facilities could instead be replaced by a mix of non-emitting power plants that do not require expensive and scarce hydrogen fuel. The technical and economic realities of hydrogen production demand that it be used for only circumstances where there are few or no viable decarbonisation options.

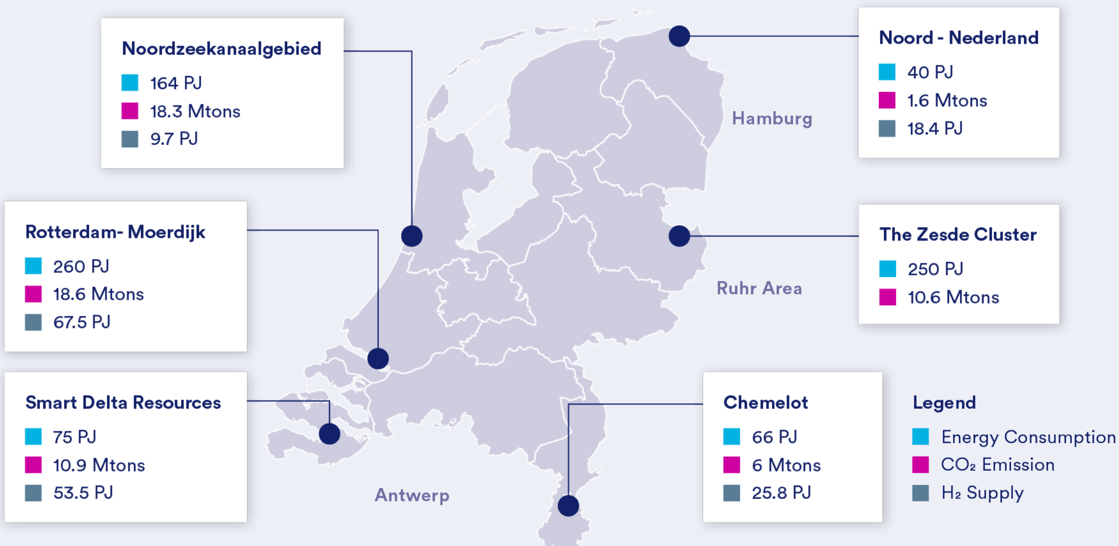
As mentioned, hydrogen can be produced through different pathways, using renewable-generated electricity, clean electricity from nuclear energy or other clean firm energy sources, or from fossil fuels with carbon capture and storage and strict methane controls. While renewable hydrogen is not available in substantial quantities to fully support the European hydrogen demand, EU Member States and their industries must be empowered to make use of a full array of clean hydrogen production pathways where hydrogen specifically is needed based on proven, low-carbon technologies to rapidly ramp up hydrogen production capacity at scale and bridge any existing gaps in hydrogen demand. And where possible, low-carbon ammonia should be explored as a viable and advantageous option to decarbonise hard-to-abate sectors, such as maritime shipping, more quickly.

Hubs can reduce industrial emissions and support development of an efficient CO_2 transport and storage network

The "hub" concept for CO_2 storage is growing in popularity, and early adopters are eager to deploy these hubs to reduce hard-to-abate emissions from industrial processes. These shared decarbonisation hubs allow emitters to utilise an interconnected transport network of CO_2 pipeline infrastructure to store CO_2 in secure geologic storage facilities.[32] This shared network minimises administrative, financial, and logistical barriers for industries interested in carbon storage, allowing emitters to plan projects focused on carbon reduction activities rather than investing in the full range of carbon capture, removal, and storage infrastructure. Because suitable geological storage does not exist in every European country, a shared service for transporting and storing CO_2 allows a much wider range of industrial sites across Europe, including iron, steel, cement, and chemical production facilities, to reduce emissions. The coordination of investments at these hubs enables more efficient deployment of CO_2 transport and storage infrastructure, as well as more rapid uptake of these technologies by emitters.

In the Netherlands, six key industrial clusters (Figure 5) producing "grey hydrogen," or hydrogen derived from natural gas without carbon capture, contribute significantly to the country's industrial emissions profile.[33] The Netherlands is developing a broad policy framework under the Hydrogen Programme to decarbonise hydrogen production and build demand for this resource among its chemical, petrochemical, and refining sectors. As part of its strategy, the country plans to rapidly scale up low-carbon hydrogen production in these industrial clusters through CCS and eventually through electrolysis powered by Dutch offshore wind energy resources. These clusters are intended to serve as "hubs" in the future – the Dutch energy network operator is developing a national hydrogen network to connect these clusters to end users and storage areas, and carbon capture facilities will connect to a planned CO_2 transport and storage network.

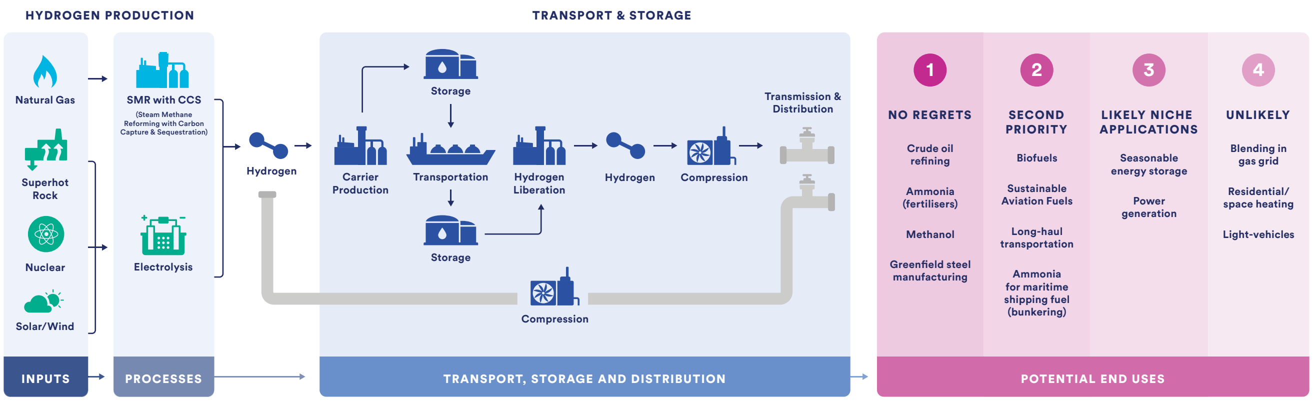
Figure 5: Industrial decarbonisation clusters in the Netherlands[34]



Fragmenting investor, policy, and technology development focus across end uses for hydrogen and zero-carbon fuels limits commercialisation and deployment of these technologies. Planners and policymakers should fully account for the technical and economic realities of hydrogen and zero-carbon fuels in their NECPs by prioritising the use of these scarce resources to in-country sectors with otherwise unavoidable emissions. Member States should identify and specify, together with industrial stakeholders, the most critical end-use sectors for hydrogen and zero-carbon fuel technologies in their NECPs and jointly develop plans to stimulate their deployment. Where hydrogen is required for industrial processes, NECPs should support its development across multiple pathways to speed the decarbonisation of these key end uses, but NECPs should also explore the feasibility of ammonia as an input in current and future national industry.

Figure 6: Hydrogen value chain and downstream sectors prioritisation[35]

Hydrogen takes significant energy to produce, transport, store, and distribute, making it a highly valuable molecule. It should be applied and used selectively in particular end uses.



Advance carbon dioxide removal

Achieving net-zero will depend primarily on steep and sustained emission reductions in the coming decades. There is consensus, supported by the findings of the IPCC 6th Assessment Report, that additional, complementary, and large-scale removal of carbon already in the atmosphere is also required to:

1. Further reduce net emissions in the near term
2. Counterbalance residual emissions to achieve net-zero targets by 2050
3. Reach and sustain net-negative emissions after 2050 to address historic emissions and potential global temperature overshoot[36]

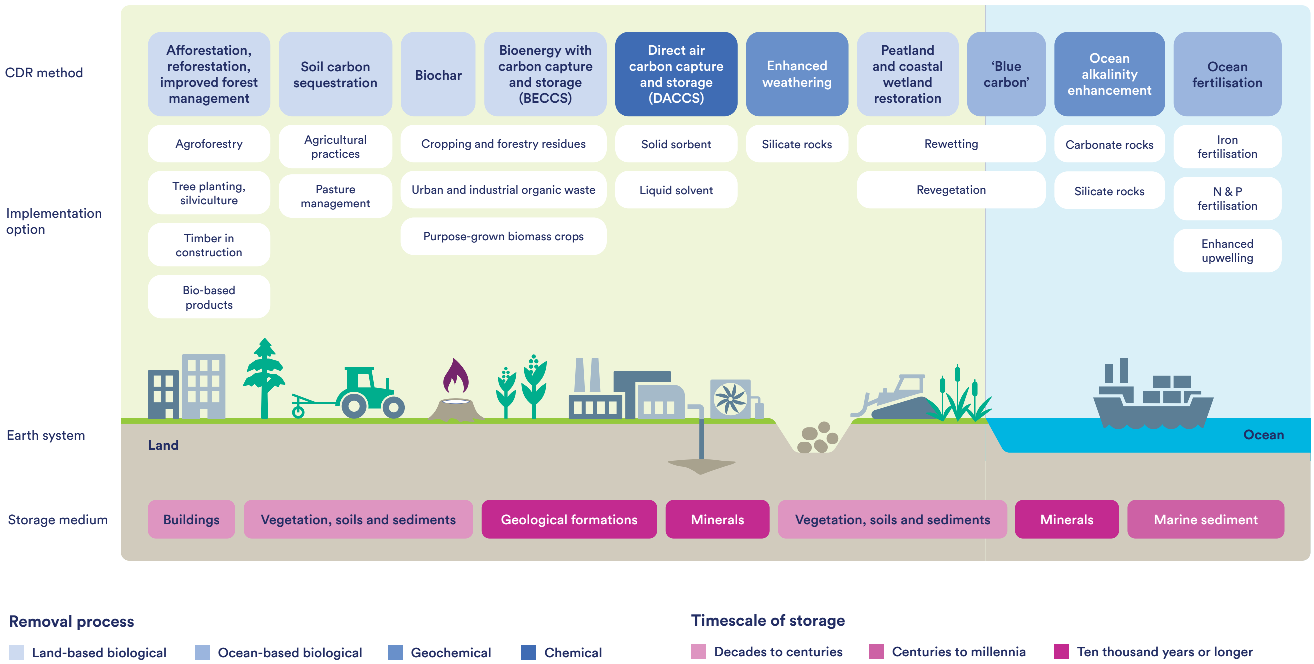
To stand at least a 50% chance of limiting global warming to 1.5°C with no or limited overshoot, pathways project the need for 20 to 60 gigatons of net negative CO_2 emissions globally until 2100.[37] Supportive policy mechanisms are needed to ensure that removals reach this scale.

Carbon dioxide removal (CDR) refers to anthropogenic activities that remove CO_2 from the atmosphere and store it durably in geological, terrestrial, or ocean reservoirs, or in products. As shown in Figure 7, various means of atmospheric capture and storage of CO_2 exist. Short-cycle removal methods, such as storing carbon in terrestrial reservoirs and living biomass, are typically more vulnerable and can store carbon for shorter periods (on the order of decades to centuries), while long-cycle removal methods that pair the removal of CO_2 from the atmosphere with geological storage can keep carbon stored for millennia.[38]

A shift toward carbon removal methods like direct air capture (DAC) with long-term geological storage potential that can reduce anthropogenic CO_2 in the atmosphere would enable Europe to become a leader on the path to a net-negative emissions economy.[40] Therefore, it is critical that NECPs enable the conditions for the development of DAC and similar carbon removal technologies, including the development of CO_2 infrastructure and availability of clean, affordable energy, to best ensure that deployment leads to net climate benefits.

High-quality nature-based solutions to CDR to increase net removals in the land use, forestry, and agriculture sectors should also be considered when updating Member State NECPs. Such solutions include, but are not limited to, improved forest management, avoided deforestation, enhanced rock weathering, and pyrolysis of biomass feedstocks such as corn stover with geologic storage. These solutions should be paired with appropriate use cases to ensure that low-cost nature-based CDR does not hinder achievable emissions reductions. Well-planned, thoughtful, and integrated nature-based approaches can dually support environmental

Figure 7: Overview of CDR methods, their storage media, and storage timescales[39]



and climate objectives by restoring and protecting ecosystems, safeguarding biodiversity, mitigating emissions, and limiting natural resource depletion.

In their 2019 NECPs, not only did few Member States set forth a strategic and comprehensive approach to CDR, but many countries insufficiently distinguished CDR from reducing emissions from processes or energy generation.[41] CDR and emission reductions are distinct climate mitigation methods that perform separate but necessary roles in achieving net-zero, with critical differences in how climate benefits are quantified. Therefore, it is important that Member States clearly define and differentiate these methods in the NECP revision process, as noted by the European Commission in its NECP guidance document.[42]

Distinctions between emissions reductions and the different methods of CDR are also increasingly important in the context of new public certification frameworks and policies that scale up carbon removal activities in the EU (e.g., EU carbon removal certification framework).[43] That said, distinguishing between emissions reductions and removals in the land sector can be challenging as the same activity or project can produce both reductions and removals and measurement challenges can hamper quantification of these changes. NECPs can also direct attention to these methodological challenges, encourage continued dialogue and study, and facilitate Member State engagement with universities and academia.

Support the development of carbon capture and storage

Carbon capture and storage (CCS) is another technology that Europe needs to reach climate neutrality. CCS can tackle CO_2 emissions from processes where CO_2 is generated by fossil fuels, biomass, or feedstocks. This technology can significantly reduce emissions in key industrial sectors, such as cement, waste-to-energy, refinery crackers, and steel production, as well as in the power sector. CCS can also unlock the potential of zero-carbon fuels – carbon capture applied to hydrogen produced using natural gas can deliver clean fuels while reducing competition for renewable electricity between the power sector and renewable hydrogen producers.[44]

CCS infrastructure can be deployed at individual power or industrial facilities. It can also be integrated into low-carbon hubs in major industrial zones across the continent that link to large-scale CO_2 storage facilities. Storage sites are currently under development in the North Sea, while others are in the planning stages in Southern, Central and Eastern Europe.[45] This includes the ANRAV project in Bulgaria,[46] which is supported by the EU Innovation Fund and aims to connect CO_2 capture facilities at the Devnya Cement Plant in Bulgaria with CO_2 storage in a depleted gas field in the Black Sea through a pipeline network. The project will result in the avoidance of 95% of emissions that would have otherwise been emitted during the first ten years of the plant's operation.

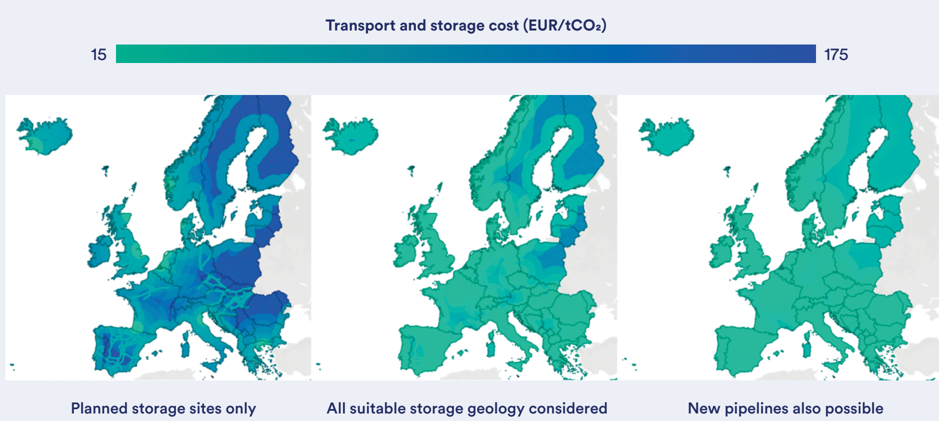
While 20 Member States indicated a role for CCS in their initial NECPs, only three developed dedicated strategies and funding commitments for the deployment of this technology at large scale by 2030.[47] For the upcoming presentation of the draft NECPs, Member States now have available best practices from pioneering countries and a ground-breaking EU-level focus on expanding European storage and transport capabilities via the NZIA proposal.[48] Member States should be explicit with funding commitments and deployment plans for carbon management infrastructure for critical applications and should consider developing or participating in cross-border low-carbon hubs.

The NZIA and NECPs can provide a strong foundation for the CCS industry

The Net Zero Industry Act (NZIA) proposal sets a first of its kind target to achieve an operational injection capacity of 50 million tonnes of CO_2 per year in the EU by 2030. It also requests that countries make publicly available where CO_2 storage sites can be permitted on their territory. This recognition of CCS and publication of current and future CCS infrastructure is critical to the commercialisation of this technology needed to decarbonise Europe's industrial sector.

Understanding where CO_2 storage sites will be located, for example, offers individual emitters and investors considering CCS technologies greater transparency into CCS cost drivers. Figure 8 shows the anticipated cost of carbon capture, transport, and storage for all emitting facilities in Europe by assessing the distance to the nearest suitable CO_2 storage site and the mode of CO_2 transport that is most accessible to the emitter (e.g., rail, pipeline, river barge, or sea-going ship). As shown in the figure, the cost of CCS varies considerably across Europe, but access to and availability of CO_2 transport and storage is the main cost-reducing factor. Transport costs could be dramatically reduced if storage sites are developed in areas where the geology and current regulations allow.

Figure 8: Mapping the cost of carbon transport and storage in Europe[49]



Based on current estimates and CATF analysis, 21 Member States have the capacity to store their own industrial emissions for at least 100 years, and there are many promising areas with unknown capacity due to lack of exploration and limited access to geological data held by the private sector. Data sharing enabled by the NZIA will provide greater insight into ideal areas for development.

The NECP revision process can build on the groundwork laid by the NZIA, help the European Commission further understand existing and planned CO_2 storage sites in the EU, and provide a more concrete estimation of potential CCS demand. Member States should include in their draft NECPs the status of CCS projects, where CO_2 will be stored, and how it will be transported. Furthermore, draft NECPs should also detail current and intended measures to support CCS project development. Collaboration with industry stakeholders will also be key to understand the full potential CO_2 storage capacity that can be made operationally available annually.

Promote emerging clean firm generation resources to decarbonise on time and complement renewable deployment

As Europe decarbonises through 2050, its demand for power is expected to increase by two to four times due to the electrification of end uses across the economy and increased production of green hydrogen.[50, 51] Therefore, decarbonising electricity generation in a manner that is low-cost, reliable, and energy secure is critical to meeting climate targets. Government subsidies and cost declines for wind, solar, and batteries have made variable renewables economically competitive with traditional energy sources in many markets. While developing as many of these resources as quickly as possible is high priority, their low costs do not account for whether or how these resources meet the comprehensive set of needs, risks, and uncertainties of a fully decarbonised system. Electrification will require not only the decarbonisation of existing systems but also the expansion of systems in a way that does not increase emissions and has limited impact on land and ecosystems. Critical mineral supply must increase significantly, unprecedented buildout of generation and transmission capacity will be necessary, and long-duration storage technology costs would need to drop substantially to offset the variability of renewables across days and seasons.[52]

As such, adding clean firm capacity to complement variable renewables can support the successful deployment of a fully decarbonised power system. Clean firm generation technologies can generate electricity on demand and are not dependent on weather. They can be located near demand centres or make use of the infrastructure from retiring emitting resources, which lowers the need for new (and often contentious) transmission. They are substantially more energy dense, which can reduce overall land use needs to achieve a decarbonised grid. Most clean firm resources also require substantially fewer critical minerals than renewables and batteries, reducing supply chain security concerns.

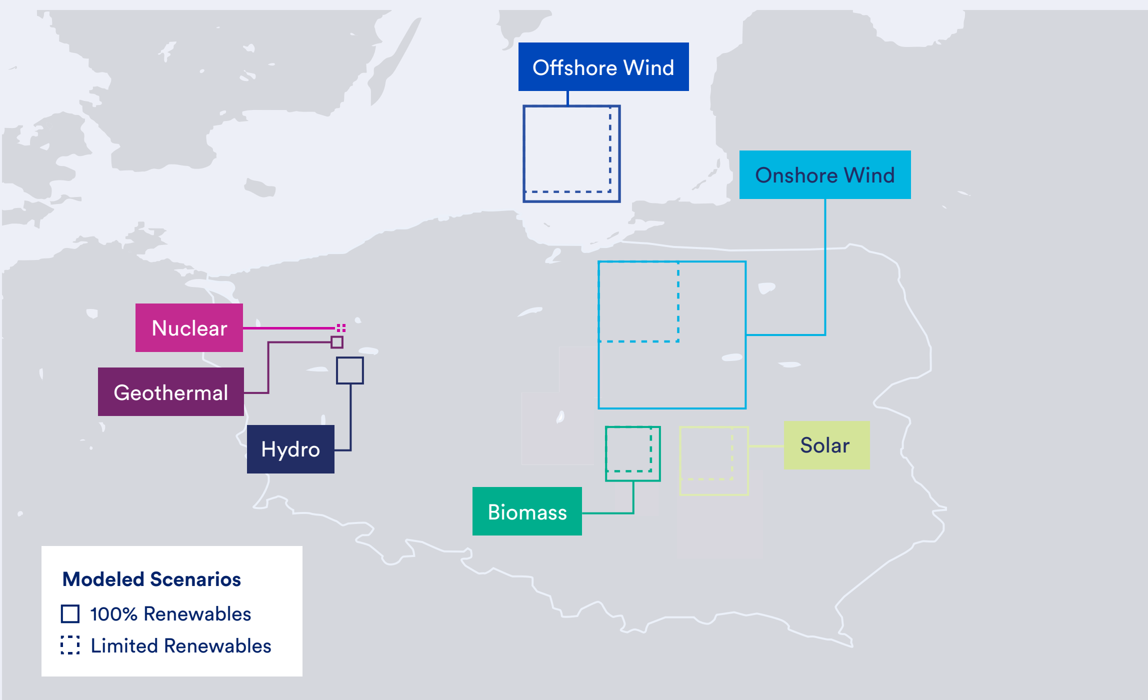
Considering energy source land use intensity in NECPs

Meeting net-zero in 2050 will require a threefold increase in renewables like wind and solar this decade.[53] To maximise security of supply, these installations can be complemented with clean firm generating resources. However, all resources have a land use footprint and face technical and regulatory constraints on their deployment. Siting these resources must also meet the requirements of ambitious and strict land use, nature protection and restoration laws[54] put forward by the European Commission and should be done in consultation and collaboration with local communities. Since energy infrastructure takes decades to be built, it is crucial that policymakers think strategically about the interactions and trade-offs of different technologies in land use planning and land availability for other competing purposes. Since renewables generally have lower energy density than clean firm power sources, their land use footprints can be much larger than those of other carbon-free energy sources. At the same time, these non-renewable resources may face more intense local opposition and be difficult to build to the needed scale.

To get it right, Member States will have to evaluate the amount of land that energy sources require per unit of electricity, based on a life-cycle assessment approach, and consider these trade-offs in their NECPs. They should also be empowered to consider different scenarios in their NECPs, from a 100% renewable scenario to scenarios where onshore wind and solar are replaced by more offshore wind and nuclear. Further studies on land use and power density of zero-carbon fuel production, electricity storage, and negative emissions technologies are needed to assess the total footprint of the future electricity system.

Figure 9: Land use intensity of Poland's 2050 electric capacity mix[55]

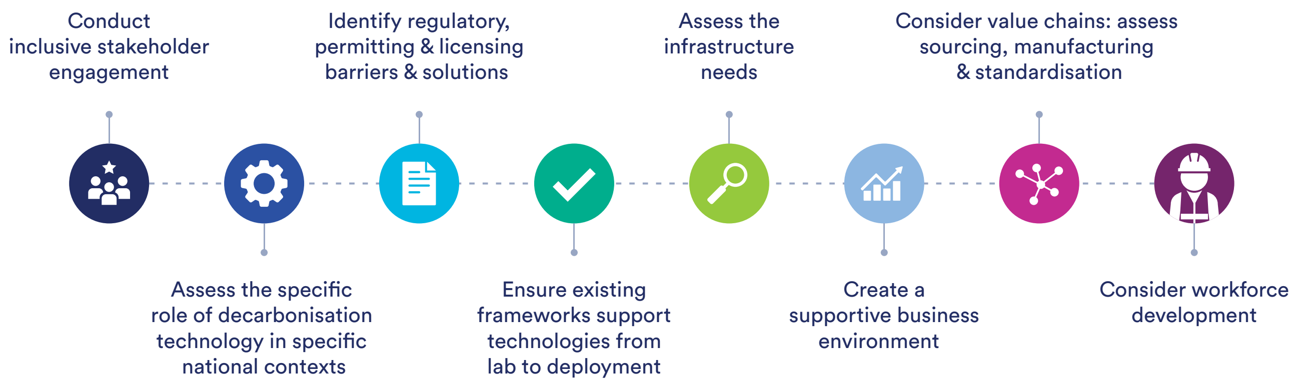
Squares depict total surface area covered by each electricity source in two scenarios from [Carbon Free Europe] modelling results: the "100% Renewables" scenario where all fossil fuels are eliminated and nuclear power plants are retired, and the "Limited Renewables" scenario where renewable electricity development is restricted to reflect land use constraints and growing opposition to large-scale solar PV and onshore wind projects. Each square is calculated using land use intensity values (ha/TWh/year) found in Lovering et al. 2022. The resulting land areas are mapped by converting the calculated planar area to geodesic area in ArcGIS.



Given current projections, the EU is forecast to have over a 100 gigawatt (GW) firm capacity gap by 2035.[56] Emerging clean firm generation technologies that complement widescale renewables and battery storage deployment while hedging against factors that can partially or fully delay decarbonisation are therefore critical to successful economywide decarbonisation. Two such power generation resources – advanced nuclear energy and superhot rock geothermal energy – can play important roles but are in early stages of development. Through their NECPs, Member States can support timely commercialisation of these clean firm generation technologies needed to achieve net-zero goals (Figure 10). Demonstration and early-stage deployments are urgently needed to make these technologies available quickly and affordably enough to support climate policy goals. In some cases, the costs, risks, and complexity of demonstrations will require collaboration across multiple countries. Member States should consider the critical role of low-carbon firm generation technologies in their specific national contexts.

Figure 10: Planning for an options-based technology strategy

To support an options-based technology strategy, Member States should proactively address these key considerations in the drafting stage of their NECPs.



Advanced nuclear energy technologies, including small modular reactors (SMRs) and Advanced Generation IV reactors, are innovative new designs that differ from conventional reactors in size, materials, output temperatures, and other operating characteristics. The economies of scale and new business models these technologies make possible would address and alleviate high capital costs and long construction times often associated with larger legacy reactors. These improvements will allow nuclear power plants to be mass produced in factories and to be deployed quickly and cost effectively, including at retiring fossil fuel sites. Their enhanced flexibility and operating characteristics would allow nuclear energy to ramp up and down quickly to support the variability of weather-dependent renewables.

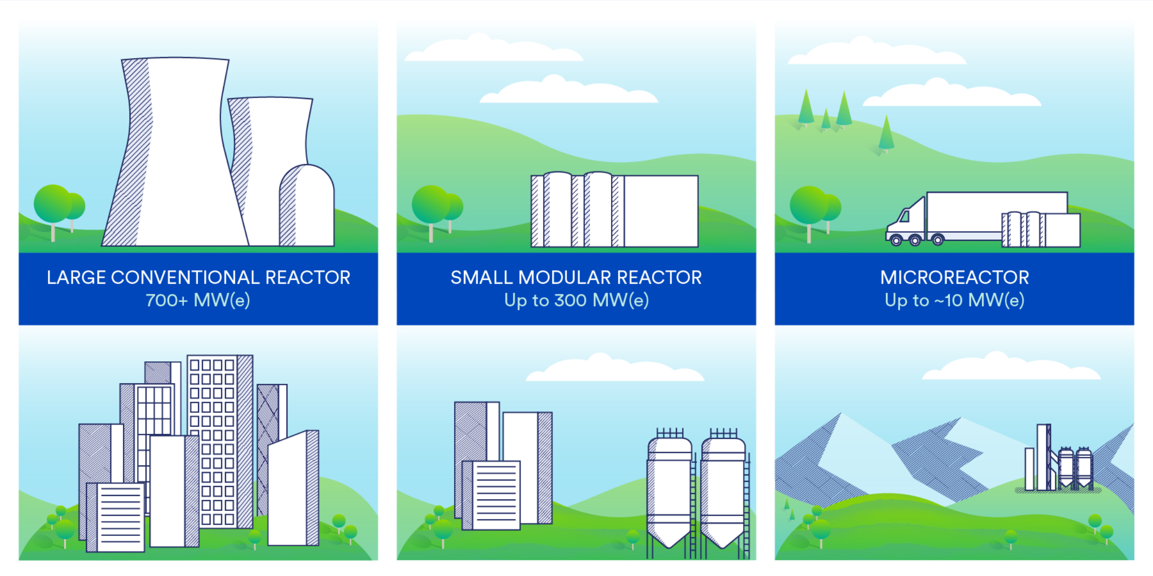
Scaling up emerging technologies like advanced nuclear starts with understanding how such technologies move through development stages. Typically, technology development starts with research and ends with market commercialisation. In the next round of NECPs, Member States, if desiring to deploy nuclear, should set up the research and enabling conditions needed to successfully commercialise these advanced nuclear energy technologies. First, NECPs can facilitate strategic partnerships with the private sector and collaborations with national laboratories and research institutions, which have been and will remain indispensable to effectively researching, developing, and demonstrating advanced nuclear technologies globally, as well as to conducting safety evaluations and accessing vital research facilities. For example, the U.S. Advanced Reactor Technologies

(ART) Program, started in 2015 as a consolidation of three U.S. Department of Energy (DOE) nuclear energy programs – Next Generation Nuclear Plan, Small Modular Reactors, and Advanced Reactor Concepts – aims to develop new advanced reactor designs to advance the state of reactor technologies, improve competitiveness, and support meeting the country's energy, environmental, and national security needs. This program is funded by DOE across four national laboratories. Member States could look to this collaborative approach in the U.S. and facilitate a similarly collegial RD&D environment in the European context through their NECPs.

Overview of advanced nuclear energy technologies

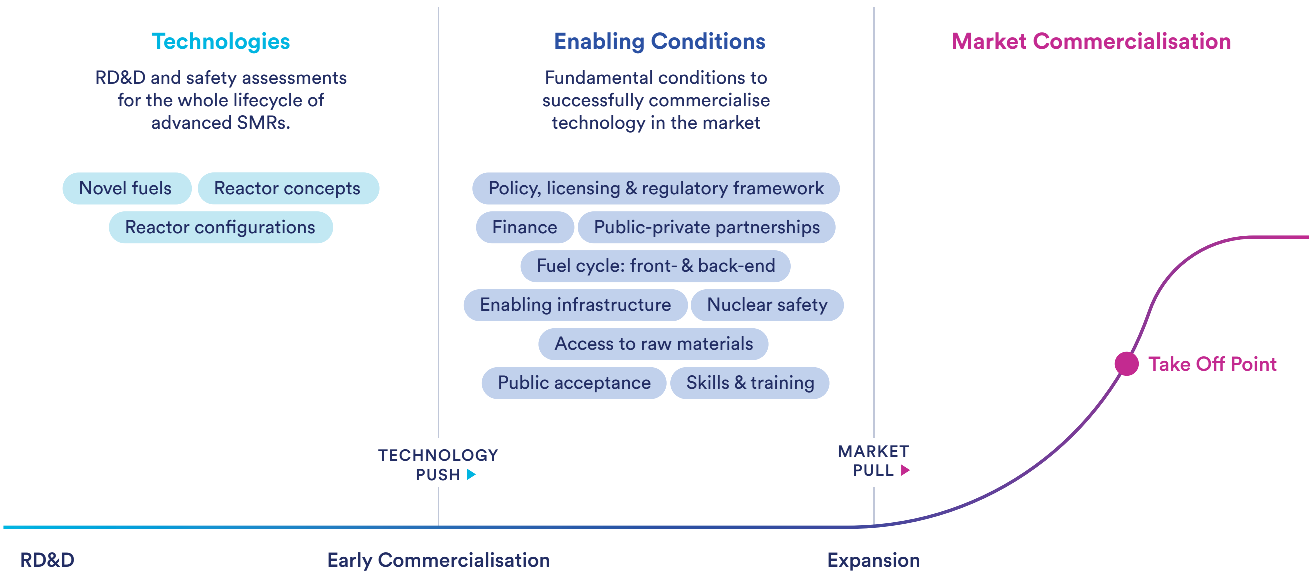
Advanced Generation IV reactors incorporate new reactor technologies, materials, and manufacturing techniques into advanced and innovative designs that make nuclear power plants not only less expensive but also safer than conventional reactors.[57] These advanced reactors can not only help to replace fossil-generated electricity, but also can provide sufficient electricity and high temperature process heat for industrial applications. Some advanced reactors will be able to provide process heat in excess of 600°C, enabling low-carbon production of products like hydrogen, pulp, paper, and methanol. This is a step up from currently commercialised nuclear technologies, which typically operate at temperatures around 300°C and can only provide district heating and process steam for desalination (which only require about 150°C).

Very small advanced reactors called Micro Modular Reactors – usually less than 20 megawatts – could even replace diesel generators to power remote villages or mining operations. Since advanced reactors share many of the same energy and siting requirements as fossil fuel plants, they can replace retiring unabated coal and gas plants, reducing the need for new transmission and providing sustained economic benefits and jobs in the surrounding communities. In some cases, advanced reactors may even be able to reuse some existing steam plant equipment. One case study of Polish coal plants, for example, estimated replacing coal with nuclear energy could save 28% to 35% in capital costs and reduce levelized cost of electricity by 9% to 28% compared to greenfield installation.[58]



Source: International Atomic Energy Agency (Adapted by CATF)

Figure 11: From the lab to the market: conditions to support advanced nuclear technology development[59]



Then, NECPs should connect these technologies with the market demand for new nuclear energy, looking beyond research to address demonstration, early commercialisation, and expansion so that these advanced technologies reach a "take-off" point (Figure 11). If the take-off point is reached, costs have been sufficiently reduced and the technologies can scale globally and contribute to climate neutrality ambitions. Arguably, European incentives for solar and offshore wind have helped these technologies reach this "take-off" point – NECPs should consider a suite of enabling policy, regulatory, and financial conditions to support today's emerging technologies as well.

Superhot rock geothermal is a nascent type of geothermal energy that taps into much higher heat than geothermal systems can today. If commercialised, superhot rock geothermal can access heat in more places beneath the Earth's surface and provide abundant, clean, firm electricity generation. In addition to power production, this energy source can create high quality advanced heat streams adequate to produce hydrogen for use in hard-to-abate industries. Europe is already a leader in engineered geothermal systems (EGS), a precursor technology to superhot rock systems. EGS projects are underway in the upper Rhine Valley and Iceland. Additionally, superhot rock geothermal energy can be demonstrated with today's drilling technologies where heat is relatively shallow (i.e., 4-7 kilometres).[60]

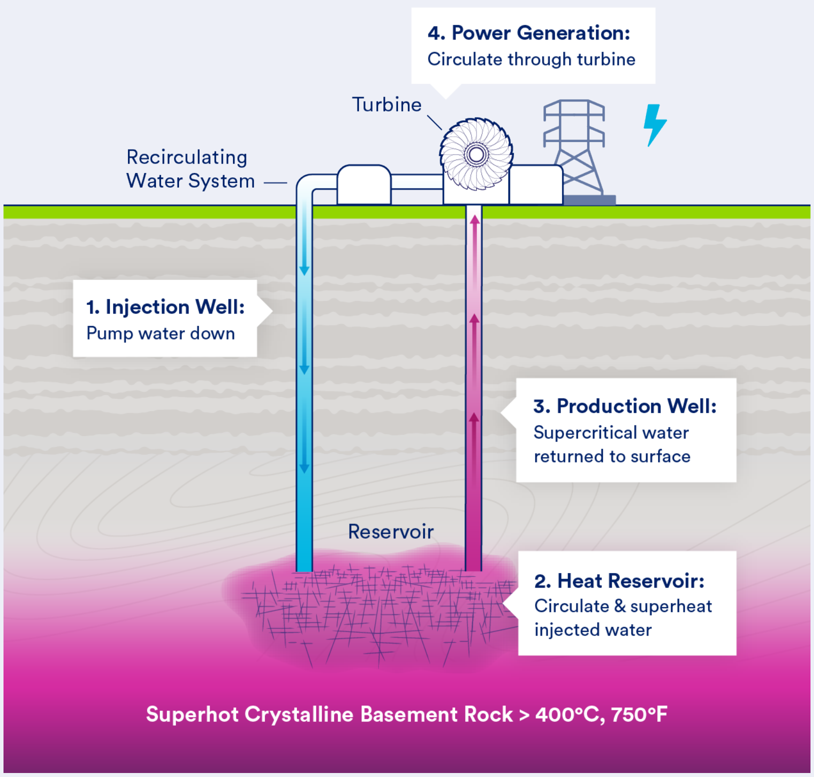
Demonstration and early-stage deployment efforts are urgently needed to develop superhot rock geothermal energy on time to support climate policy goals at affordable cost. In some cases, the costs, risks, and complexity of demonstrations will require collaboration across multiple countries. Through their NECPs, Member States can support timely commercialisation of superhot rock geothermal energy and build upon the legacy of geothermal collaboration to broaden their decarbonisation toolkits with this high-potential technology.

Superhot rock geothermal energy

Superhot rock geothermal technology circulates water through deep, hot dry rock systems where temperatures exceed 400°C. This injected water turns into a "supercritical" state that can carry five to ten times the energy produced by geothermal systems today to the Earth's surface (Figure 12).[61]

Figure 12: How does a superhot geothermal energy system work?[62]

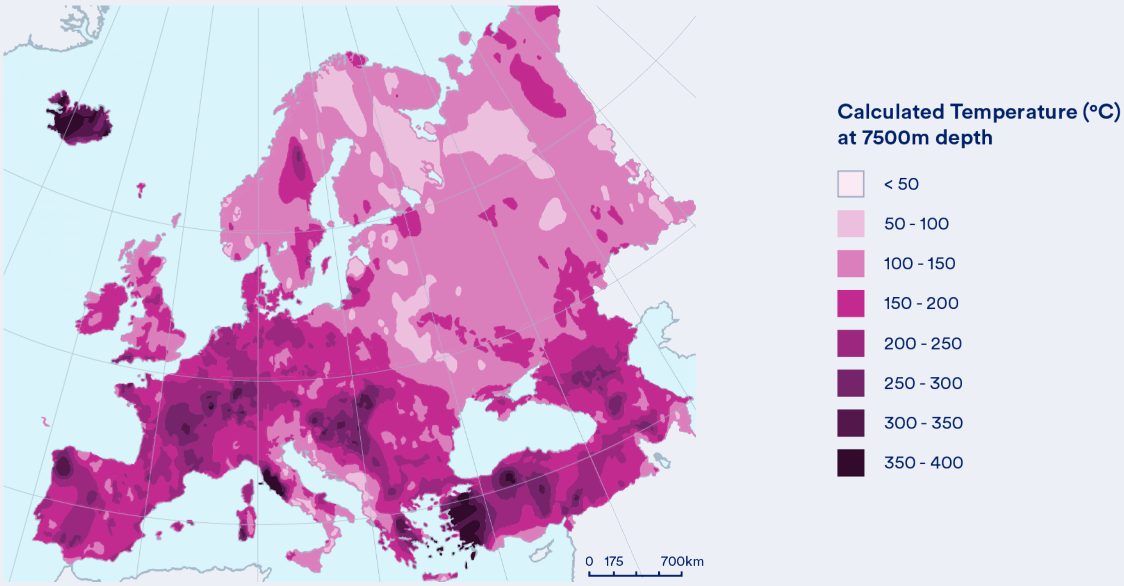
Not to scale. Underground flow conduits for water may either involve below-ground piping or fracture networks (pictured).



The depths required to reach 400°C+ superhot rock vary – in some places, sufficient heat can be found only three to five kilometres[63] below the surface, while in others, depths reach 10 to 20 kilometres. Superhot rock geothermal is an emerging technology in demonstration stages and at middling technological readiness levels (TRL) today. Reaching the required depths will require new drilling technologies, like plasma torch drills currently under development by a Slovakian company.[64]

Identifying early demonstration locations for superhot rock geothermal energy projects is key to supporting the commercialisation and deployment of this emerging technology. Existing heat mapping exercises show where heat distribution is sufficient at a reasonable depth for initial drilling campaigns (Figure 13). Future heat and feasibility mapping exercises focused on superhot rock geothermal potential can integrate where compatible oil and gas drilling technologies can be utilised.

Figure 13: Geothermal heat reservoirs in Europe at depth of 9,5 km[65]



In November 2022, CATF published the Superhot Rock Project Map,[66] a web-based interactive map that highlights superhot rock projects and shows the estimated depth to reach a temperature of 450°C across the world. The map also shows the level of maturity of existing superhot rock geothermal projects with links to detailed factsheets for select projects. Learnings from these projects can support countries with best planning practices and improve their chances of successfully deploying this technology.

Think about clean energy in place and context

Climate and clean energy should not be considered narrowly or in isolation. The energy transition will play out within the land use, economic, political, industrial, and social contexts of each Member State. To ensure achievement of decarbonisation goals in 2030 and beyond, policymakers must consider this full context in their NECPs. Incentives, finance, and deployment strategies for clean energy technologies can fit into and support the broader socioeconomic, cultural, political, and security goals of Member States and the EU as a whole. Legacy energy systems, workforce capabilities, key economic sectors, and resources differ from country to country, and the most efficient path to decarbonisation for each country may vary widely depending on those factors. Understanding infrastructure and technology landscapes today and into the future provides opportunities to build upon and improve what already exists to reduce land use and environmental impact.

To date, NECPs have not gone far enough to ensure alignment of clean energy and climate policy with other important EU and Member State priorities. As discussed earlier in this report, maximising the decarbonisation technology options available through NECPs can help different Member States select the best technology portfolio available for their contexts. Member States select the best technology portfolio available for their contexts. Member States should also look to develop climate solutions that enable their economic and industrial ambitions, update modelling tools to comprehensively reflect the complexity of energy systems, and map the infrastructure of today and tomorrow to understand land use impacts and synergies with the current built environment.

Design climate solutions to empower economic and industrial ambitions

Policymakers and stakeholders must act on climate while keeping other economic, industrial, environmental, security, and social goals in mind. Climate and clean energy technology should not be thought of as separate from the economy at large; rather, these technologies should be integrated at the systems level across the economy and be deployed in support of other priorities.

Member States should develop a more integrated and synergistic approach to decarbonisation in their NECPs that supports and enables their economic and industrial ambitions. Identifying carbon storage in-country and importing carbon from other countries could provide a new revenue source while facilitating continued industrial production, maintaining the industrial workforce, and developing an infrastructure workforce. States with strong offshore wind industry can support the development of transmission lines in their NECPs to transport clean electricity to demand centres across Europe. And strengthening the grid can promote reliability, energy security, and affordability while enabling end use electrification.

Understanding how and where changes in one sector can impact or compound impacts in other sectors is fundamental to a broader, systems-based approach to policymaking and technology or infrastructure deployment. To design decarbonisation policies that maximise benefits economywide, Member States can identify and quantify the benefits of synergies between clean energy and other key economic sectors. This process will support more integrated and sophisticated planning out to 2030 and to 2050.

The Porthos project incentivises Dutch industrial decarbonisation

The Netherlands aims to advance national decarbonisation technologies through a subsidy scheme. In 2020, the country expanded the scheme, called SDE++, to allow carbon capture utilisation and sequestration used for industrial processes, including hydrogen production, to qualify for the subsidy. In 2021, the Dutch government awarded €2.1bn to the Port of Rotterdam Transport Hub and Offshore Storage (Porthos) project developed by the Port of Rotterdam, EBN and Gasunie to take emissions captured from industrial processes of Air Liquide, Air Products, ExxonMobil and Shell in the Port and store these emissions in empty North Sea gas fields.[67] Porthos is linked to the Port's H-vision effort,[68] an industrial decarbonisation project exploring residual gas capture that can be used as raw materials for blue hydrogen production.

Use up-to-date modelling tools and forward-looking modelling approaches

Energy systems modelling, typically in the form of cost optimisation models paired with capacity expansion models, is the knowledge foundation of the EU's climate and energy policies. However, these models are only helpful for policy to the extent they provide a robust approach to representing the energy system.[69]
Key elements of such a robust approach include:

- **Exploring uncertainties around key input assumptions through sensitivity analysis and/or probabilistic simulation.** Today, most NECP modelling is based on deterministic (i.e., single value) estimates for each parameter. If these assumptions are wrong or change over time, the model results will be invalid. Therefore, it is critical to explore the impact of changing or mis-estimated parameters on modelling to ensure that associated policies can be robust against this uncertainty.
- **Fully developed scenarios representing a range of possible futures, not a single or limited subset of a desired or anticipated future.** While a risk-adverse approach to decarbonisation modelling may be compelling, more emphasis should be placed on worst-case or more challenging scenarios to provide a fuller understanding of the scale and scope of change that may be required to sufficiently reduce emissions. Today, Member State NECPs model decarbonisation trajectories to 2030 and beyond using two scenarios – a scenario "with existing measures" and a scenario "with additional measures." This simple binary does not represent a sufficient range of futures and is insufficient for robust decision-making on energy policy.
- **Consider a range of impacts and evaluate associated trade-offs.** Most NECP modelling is done to minimise total system costs, which does not account for other preferences and trade-offs such as land use, critical minerals requirements, and reliability, among other considerations.
- **Evaluate reliability.** As electrification of end uses continues, energy system reliability will become even more critical to public health and economic stability. Models should test reliability of a proposed energy system against different "weather-years" with varying wind, solar, and precipitation patterns and should evaluate the performance against extreme events that will become more frequent and intense as climate change advances.

Recent analyses of new European policies suggests that modelling incorporated into those scenarios may not be sufficiently robust. An ECA report[70] found that the scenario analyses underlying the Fit for 55 package impact assessment included several outdated assumptions and did not sufficiently consider known issues, such as energy dependency on Russia and projected decreases in the availability of critical raw materials fundamental to the development of the renewables and batteries modelled in the scenarios. The 2019 NECPs appear to overemphasise renewable resources, using assumptions that underestimate barriers to renewable development and overlook clean technologies beyond renewables that can support national energy security and decarbonisation goals.[71] And the availability of land, social acceptance of new infrastructure, cost and supply of critical minerals, mechanics of asset mobilisation, labour supply and distribution are all emerging as practical speed and capacity limits to new clean energy development, but these barriers have not yet been meaningfully or accurately incorporated into models.

As a first step to improve and vet modelling scenarios, Member States could publicise the assumptions, parameters, and methodologies used in scenarios today. The NECP revision process should then promote robust energy system modelling going forward with up-to-date and transparent technology assumptions that help Member States plan adequately for a future with a sufficiently broad suite of decarbonisation technologies. These updated technology assumptions should contain accurate data on cost and performance and be subject to sufficiently regular review and update processes. Additionally, any planning processes or modelling efforts should generate a set of scenarios that reflect a range of possible futures. Scenarios should reflect varying degrees of labour and materials supply availability, coordination across jurisdictions and industries, and import dependencies to ensure strategies are robust and account for many potential realities. The EU can support Member States in these efforts by recalibrating its own modelling methods and underlying assumptions as it assesses its 2040 climate targets.[72] Additionally, because each country's 2030 climate and energy trajectory cannot be understood in isolation, Member States should be encouraged to incorporate assumptions about neighbouring regions into their planning.[73]

Conduct spatial analysis

Europe is one of the most intensively used land masses on earth – around 80% of Europe's land surface has been shaped by human action and is covered with buildings, roads, and industrial infrastructure or used for agriculture and grazing land.[74] How the EU and its Member States decide to make use of this limited and invaluable resource has far-reaching consequences that affect not only the economy, food provision, environment, and climate, but also society and culture. To improve Europe's planning processes and inform infrastructure decisions, more efforts and tools should be allocated to understanding the complex implications of land use choices.

A key element to building a coherent, net-zero infrastructure network is developing and analysing spatial scenarios for existing and planned infrastructure. In their updated NECPs, Member States should plan for an extensive scenario exercise to better understand potential land use needs for infrastructure and interconnections. Analysing a range of options for what infrastructure to deploy, where, and how can help policymakers and developers proactively define lowest impact options, thereby reducing deployment risks. Scenario analysis can also uncover potential synergies with existing electricity transmission or pipeline efforts to minimise land and cost impacts of new projects.

Enhanced scenario analysis can help identify the land-smart approaches to clean energy technology deployment as well as impact mitigation needs over the coming decades. Countries can use scenario analysis to assess options for the placement of renewable resources, nuclear energy, carbon capture and storage infrastructure, and zero-carbon fuel infrastructure. Improved spatial analysis of land and of existing renewable and fossil fuel generation projects would also identify opportunities for repowering existing renewables fleets, repurposing already disturbed lands, or decommissioning fossil infrastructure for renewables and other clean energy deployment.

Mapping relevant to both the 2030 and the net-zero 2050 timeframe must not only have spatial components, but also temporal components. Incorporating models of land use trade-offs into mapping analyses can make detailed projections representing how Europe's landscape could change in the future, depending on specific economic, social, and environmental goals, conditions, policies, and a changing climate. This type of modelling can help decision-makers understand complexity, not by attempting to predict what will happen in the future, but rather by showing the potential costs, benefits, and interactions of different choices.

Enhancing digital mapping tools can also be beneficial in facilitating cross-sectoral deployment planning. Given the focus on net-zero industry via the NZIA, it is crucial for responsible national, regional, and local authorities to consider incorporating provisions for net-zero technology manufacturing projects into their relevant planning processes. Conflicts related to land use can impede the implementation of manufacturing projects that support net-zero technologies. To address this issue, the updated NECPs should incorporate spatial planning that can promote the harmonisation of public interests and goods while considering environmental impacts. This approach can help mitigate potential conflicts and expedite the sustainable deployment of net-zero technologies manufacturing projects within the Union.

Inspire investor confidence and direct funds where most needed

Significant capital investment is required to scale up, develop, and deploy energy technologies needed for the energy transition. To securely provide that capital, investors need certainty and efficient investment signals over decades. Each Member State should put forth a detailed vision in its NECP that inspires long-term investor confidence, clearly identifies investment gaps, aims to drive capital toward clean energy infrastructure and technology, and helps investors understand its capital requirements and priorities relative to those of other Member States. Robust, updated NECPs could guide and attract the needed investment to net-zero and identify additional public and private financing opportunities, thus becoming a mechanism for investment planning.

Anticipate costs and funding sources to 2030 and beyond

The credibility and effectiveness of NECPs rely heavily on how countries plan to finance existing and proposed policies to achieve 2030 targets – against this rubric, the 2019 NECPs generally fell short. The European Commission's NECP assessment noted that some plans lacked financial detail and did not facilitate comparisons between or a summation of energy and climate investment needs.[75] Similarly, the ECA special report found that most NECPs lacked a general assessment of necessary funding sources, did not analyse complementarity between funding sources, and did not make clear enough the modelling assumptions used to determine investment needs.[76] As a result, the ECA criticized the 2019 NECPs for being incomplete, inconsistent, and showing significant disparities in methodology, with each country using its own approach. This lack of comparability across Member State plans prevents investors from drawing consistent conclusions and provides little clarity on relative investment needs.

Meeting the EU's ambitious Green Deal agenda will require significant investment. According to the Commission's estimations, the private and public investment gap for the green transition is estimated at nearly €520 billion per year over the next ten years.[77] Furthermore, according to the Commission's data, reducing fossil fuel dependence from non-EU countries and accelerating the Union's energy transition away from fossil fuels will require an estimated €210 billion of additional investments by the end of 2027. To address these concerns, an EU-wide effort is needed to streamline sustainable investment indicators across Europe.[78]

In this next round of NECPs, Member States should take a proactive role in assessing and mapping – in a detailed manner – existing and forthcoming sources of finance, both public and private. Greater understanding of funding sources and more granular data will help Member States disperse existing funding more efficiently and allow comparability and clarity that can increase cooperation

Funding enabling and connecting infrastructure

Meeting the 2030 and 2050 targets will mean going beyond investing in specific technologies, and also investing in enabling and connecting infrastructure to overcome a "chicken-and-egg" problem in infrastructure deployment. As an example, it is difficult to invest in carbon capture equipment or facilities without established transport and storage infrastructure for CO_2, but investing in the latter is also difficult without the existence of the former. Developing shared enabling infrastructure, such as transmission or CO_2 pipelines, can be a key enabler for decarbonisation projects, enhancing investor confidence and lowering risks. Member States should clearly identify not only funding needs for technologies, but also specific funding needs for enabling and connecting infrastructure. By anticipating funding needs and creating the business case to invest in the full technology value chain (e.g., CO_2 capture, transport, and storage for CCS), Member States could simultaneously increase the likelihood that technology and infrastructure will be developed and deployed in parallel, and that projects reach a final investment decision.

and innovation between countries. This inventory of funding will also be the first step in understanding national funding gaps and shortcomings of Member State approaches to funding research, development, demonstration, and deployment of clean technologies and other enabling infrastructure – including interconnection, transmission, flexibility mechanisms – that could significantly broaden the decarbonisation option set.

A parallel effort will be needed to centralise information on national and EU funding sources, update that information, and increase accessibility of funding opportunities to a broad group of interested stakeholders. Ultimately, these exercises will allow Europe to better estimate the investment gap for its ambitious 2030 and 2050 targets.

Advance policy mechanisms to reduce financial risks and sustain investment in key technologies

Secure and stable investment conditions for renewable and low-carbon energy developers are key to bringing down risk and capital costs while hedging costs for consumers. This ambition lies at the centre of the recent EU's electricity market design proposal, which ultimately seeks to prevent a recurrence of the sudden surge in power prices that occurred in 2022 due to the spike in gas prices following Russia's invasion of Ukraine.

Employing policy and financial mechanisms that lower financial risk for new technologies can help generate scalable investments that enhance investor returns and certainty while supporting the commercialisation of low-carbon technologies critical to achieving net-zero.

These mechanisms will be key to fostering the stability and predictability of energy costs across the EU, which is crucial to enhance the competitiveness of EU industry and maintain affordability for consumers. Carbon Contracts for Difference (CCfD) and Power Purchase Agreements (PPA) are two such mechanisms that could help get new technologies off the ground. Beyond CCfD and PPA contracts, Member States need to evaluate how to support clean firm technologies with competitive market-based capacity renumeration mechanisms to ensure the reliable integration of weather-dependent renewables. As discussed earlier in this report, continued electrification of end uses will require more storage and firm capacity on the system to ensure supply and demand are reliably managed. To support the development of clean firm generation, there is a growing consensus that market-based competitive capacity renumeration mechanisms, such as firm capacity contracts auctioned through a market, in addition to accurate resource adequacy and technology de-ratings, are needed to ensure a clean and reliable power system.[79]

In the next round of NECPs, Member States should reflect on whether existing national electricity market incentives are sufficient to accelerate investments and should engage financial stakeholders to better understand their risks, needs, and opportunities to support decarbonisation in key economic and industrial sectors. To improve societal buy-in, Member States should also communicate how they intend to bring the benefits of lower cost renewables and low-carbon technologies to consumers.

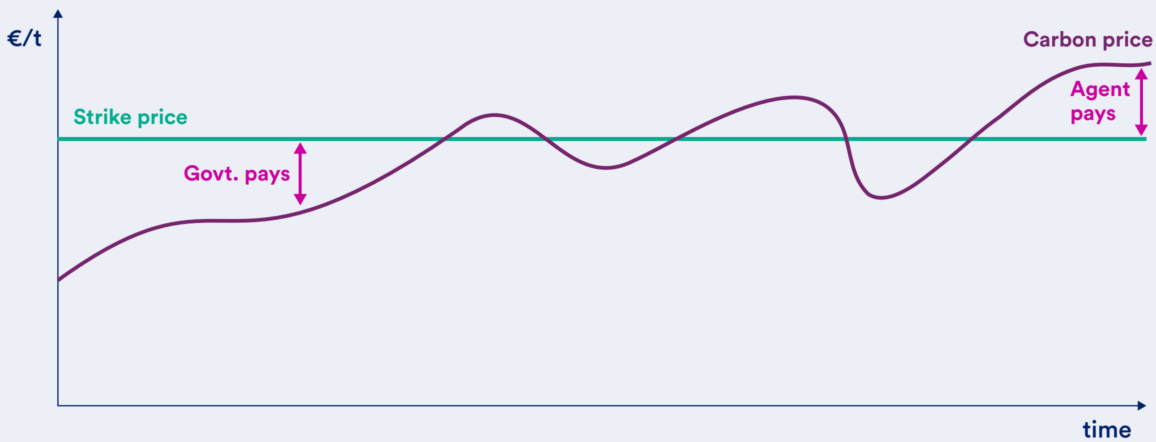
Carbon Contracts for Difference

The European cap-and-trade system, EU Emission Trading System (ETS), sets a cap on emissions in key sectors and allows participants to trade carbon allowances under that cap. Lower-emitting actors can sell their allowances to more-polluting actors who need the breathing room. This trading results in an effective "price on carbon" – a powerful and motivating investment indicator. Actors know they can make money by selling allowances into the market if the carbon price is greater than investments they make to decarbonise. And conversely, actors are hesitant to invest in technologies that will cost more than the carbon price because profits are uncertain or even unlikely.

In this environment, newer and capital-intensive technologies like renewable hydrogen, carbon capture and storage, and superhot rock geothermal energy incur upfront research and development, pilot program, and other expenses needed to scale and commercialise. Their propensity to cut into revenues from the sale of allowances in the carbon market is generally higher than fully commercialised technologies. To stimulate investment for these emerging technologies in the EU, instruments like Carbon Contracts for Difference (CCfD)[iii] stabilise revenue streams for market actors. In a CCfD, a market actor and the government agree on a price at which the market actor can sell carbon allowances into the market over a given time period (similar to a futures contract). If the price is higher than the carbon price, the government pays the market actor the difference between the two prices. If the carbon price is higher, the market actor pays the government the difference (Figure 14). This provides a kind of subsidy for actors, helping to promote innovative technologies when they are not sufficiently incentivised by the carbon market.

Figure 14: Carbon Contracts for Difference (CCfD)[80]

Graph based on "Carbon contracts for difference: an essential instrument for European industrial decarbonisation," Climate Policy Journal, 2020[81]



CCfDs have already gained traction at the EU level. The Innovation Fund, the EU's funding programme for the demonstration of innovative low-carbon technologies, is set to make use of CCfDs and other competitive bidding mechanisms in its next phase of operation.[82] At the national level, countries like the Netherlands and Denmark are already adopting CCfD approaches.[83] Other Member States can use the NECP revision process as an opportunity to consider implementing CCfDs to support national development and deployment of emerging low-carbon technologies.

[iii] For more information on Carbon Contracts for Difference, see the related CATF blog series.

Power Purchase Agreements

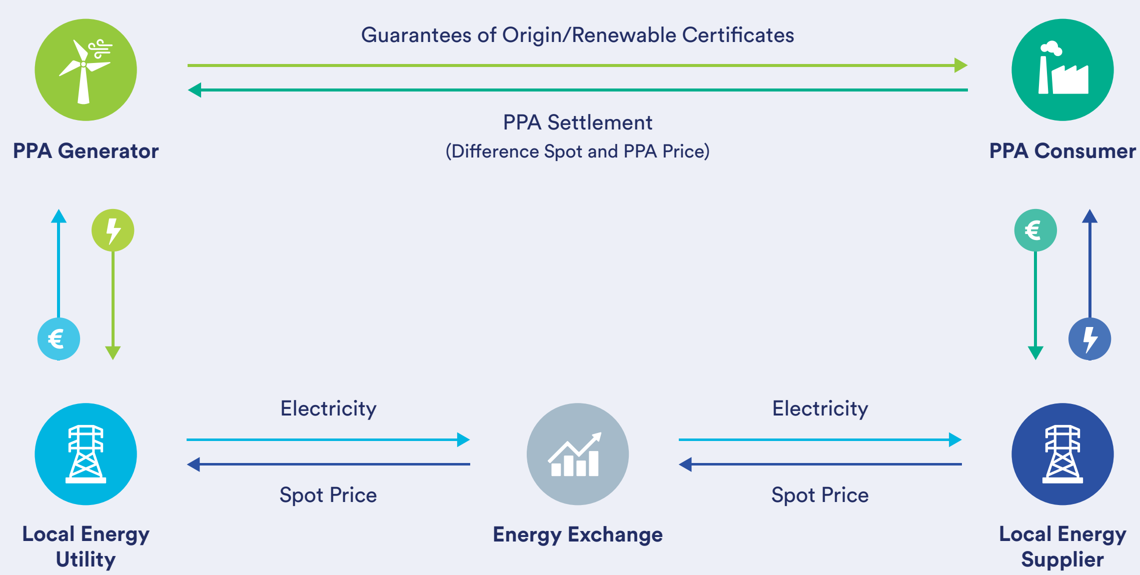
Power purchase agreements (PPAs) are long-term contracts where an entity agrees to purchase electricity directly from a power generator. These contracts reduce risk for project developers by guaranteeing off-takers for generated electricity and allow off-takers to negotiate and lock in a power price. PPAs are popular in North America and are increasingly used in Europe – in 2022, European developers signed 8.4 GW of PPA deals.[84]

The vast majority of PPAs in Europe – nearly 80% in 2022 – are corporate procurements.[85] Corporations operating in the EU are a key part of the region's decarbonisation efforts and can set internal renewable electricity sourcing or emissions reduction targets. Voluntary corporate coalitions, including RE100,[86] encourage 100% renewable electricity sourcing. Other initiatives, such as the United Nations 24/7 Carbon-Free Energy Compact, up the ante and promote sourcing of clean energy for a variety of end uses around the clock.

To meet increasingly ambitious clean electricity targets by these actors, increasingly sophisticated and flexible PPA mechanisms are emerging. For example, virtual PPAs (VPPA) are financial mechanisms that allow agreements between electricity procurers and electricity producers located in different areas not necessarily connected to the same electricity grid. Actors interested in sourcing more clean electricity can employ VPPAs to promote projects in other jurisdictions with greater renewable potential and greater available land area for project development (Figure 15).

Figure 15: Virtual Power Purchase Agreements[87]

The VPPA is a financial arrangement that allows an electricity consumer to support clean energy projects without necessarily owning or using any electrons generated by those projects. The consumer, in this case a corporate procurer, guarantees a fixed price for power to the clean energy project and receives in exchange guarantees of origin for the clean electricity the project produces. The clean energy project produces physical electrons and sells them to its local electricity grid at the variable, local market price. Then, the corporate procurer and the clean energy developer regularly settle the difference between the VPPA fixed price and the actual market price received by the project.



PPAs are commonly used to support independent power development – particularly renewables – but these agreements can also provide investor and developer certainty for non-renewable clean energy technologies. Advanced nuclear energy technology is one such resource to benefit from PPAs. European off-takers are increasingly interested in the capability of modular nuclear reactors to support decarbonisation of hard-to-abate industry, yet advanced nuclear technologies struggle to attract sufficient funding to commercialise and fulfil their potential as a decarbonisation tool.[88] In March 2023, a U.S.-based nuclear technology firm and project developer set up PPAs for 34 small modular reactor units with industrial partners in Poland and the United Kingdom to provide more commercial certainty for this nuclear technology.[89] While the specific terms are not yet public, the PPAs will likely guarantee revenue and off-takers for the nuclear energy project and a clean, baseload power supply at an agreed-upon cost for industrial actors.

In the next round of NECPs, countries are encouraged to foster and create dynamic PPA structures that incentivise power procurers to choose cleaner renewable or non-renewable options and help to hedge consumer energy price impacts. To facilitate 24/7 clean electricity procurement, Member States should consider "hybrid" PPAs – those that support a clean energy technology and storage – that guarantee hourly matching. PPA mechanisms also require careful tracking of new projects, off-takers, and the allocation of emissions reduction credits for carbon accounting purposes. To support tracking, Member States can also highlight the importance of a disclosure and verification framework for PPA structures in their NECPs.

Incorporate and encourage research, development, and demonstration funding for emerging technologies

Europe is typically a leader in research, but product and technology commercialisation often happens in other markets. However, the European Commission found insufficient support even for research supporting the delivery of climate and energy objectives in the 2019 Member State NECPs, and noted a limited approach to research and innovation (R&I) efforts overall.[90]

The Commission found an overall decrease in devoted R&I in clean energy technologies in national budgets, and a severe lack of national objectives and funding targets forging concrete and relevant pathways to 2030 and 2050. Additionally, most national plans focused on funding existing non-energy programs lasting fewer than five years, neglecting the necessary attention to research and development (R&D), which helps move technologies out of a fundamental research stage, for future clean energy technologies.

RD&D is particularly critical for emerging technologies

RD&D funding is especially critical for promising technologies supportive of a net-zero energy landscape that are building toward commercialisation post-2030. For example, superhot rock geothermal energy, which could bolster energy security and help phase out fossil fuels, has already benefitted from RD&D. Geothermal projects funded in Europe, including the Horizon 2020-funded DESCRAMBLE project that undertook a superhot geothermal system drilling project with participants from Germany, Norway, and Italy, demonstrate that focused funding in Europe has already contributed to understanding the potential of superhot geothermal energy on the continent. For emerging technologies with low technology readiness level like superhot rock geothermal, focused funding is a first critical step toward broader pilot projects, feasibility studies, and full-scale deployment in time to support 2050 goals.

While R&I and R&D funding is crucial in ensuring that Europe remains an innovation hub driving decarbonisation on a global level, Member States also need to provide funding to move the technologies all the way from the lab to demonstration, deployment, and later commercialisation stages. Therefore, dedicating finance for research, development, and deployment (RD&D) would bridge this gap and de-risk investments in emerging technologies, thus ensuring these technologies are able to contribute to decarbonisation and energy security on time. Focused, fit for purpose funding can improve performance and reduce cost in both proven technologies, like solar PV panels and wind turbines, and can advance newer technologies across all sectors and industries.

In the next round of updates, Member States should purposefully think beyond research and incorporate development and deployment when assessing its funding needs. Where possible, NECPs should include deployment timelines for emerging technologies to kickstart the long commercialisation process ahead of 2050. For that, policymakers should put more effort into clarifying the current technology deployment policy funding landscape across the EU and its Member States and implementing supportive accompanying policy instruments that are flexible and de-risk investments across the technology lifecycle. By identifying, distinguishing, and bridging the gaps between demonstration, deployment, and commercialisation in a longer timeframe, Member States will be able to create a business case to scale climate-beneficial technologies for 2030 and beyond. As part of an ongoing NECP updates, policymakers should also track efficient RD&D disbursement and its impact on technology uptake.

A truly coherent framework supporting technologies from the lab to the market will be necessary for Europe to become an innovation hub and could serve as a basis for energy RD&D planning and alignment in national NECPs. Such a framework can support countries in understanding whether their RD&D plans are truly suited to deliver successful technology deployment and how their plans could be improved and simplified. To develop this framework, Europe should map and assess the funding currently available by development stage and technologies across the EU and its Member States, compare it to scale-up targets, and develop the needed instruments in a coordinated manner to fill the gaps. A larger pot of EU funds dedicated to clean technology development would be beneficial to ensure that Member States with different fiscal capacities can evenly participate in clean tech development, to foster research partnerships, and to preserve the EU Single Market.

Uniting Member States through fusion research and cooperation

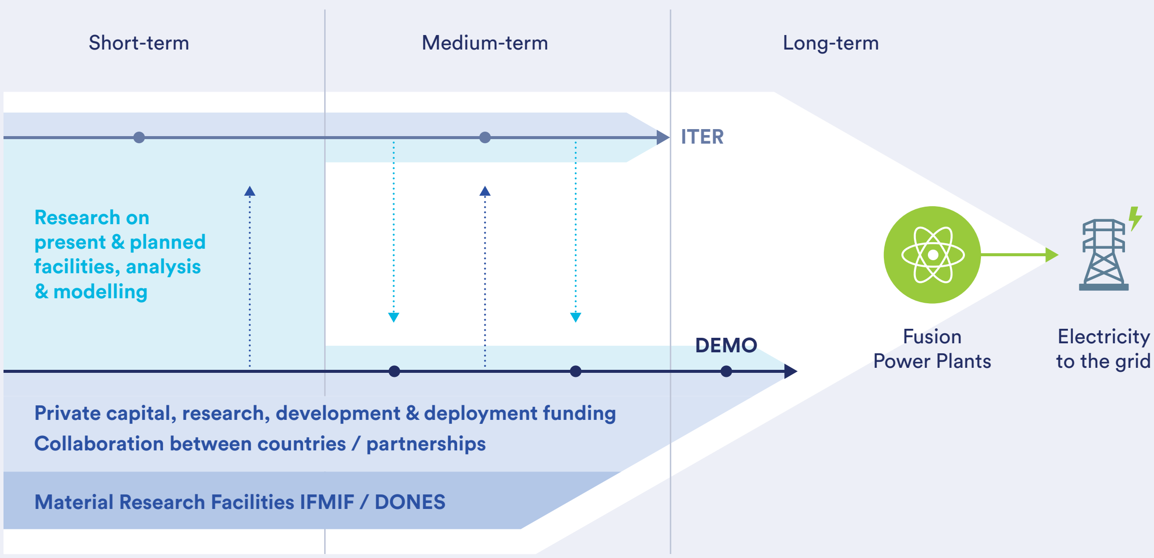
Europe has a long track record of collaboration in fusion research. EU laboratories and research groups joined forces to build the Joint European Torus in the United Kingdom, built to study fusion conditions that would be required in a power plant. Since then, several “tokamak” devices – machines designed to harness the energy of fusion for power – have been developed across the continent.[91,iv]

Today, 35 countries, including China, India, Japan, Korea, Russia and the United States, are working together in Southern France to build ITER, the world’s largest tokamak, to prove the scientific and technological feasibility of fusion as a future energy source.[92] Although ITER itself will not produce electricity and is an experiment, the next step will be a Demonstration Power Plant (DEMO) aiming to put power on the grid. This device would be much closer to a commercial fusion power plant and would provide the support to start the commercialisation process for fusion technologies, with the aim of connecting commercial fusion electricity to the grid by 2050.[93,94] In parallel, private capital in Europe’s fusion industry is promoting start-ups with more aggressive timelines that aim to put energy on the grid

[iv] Examples include Tore Supra in France, ASDEX in Germany, RFX in Italy, MAST in the UK, and TCV in Switzerland

in the 2030s. Another effort, called the International Fusion Materials Irradiation Facility – Demo Oriented Neutron Source (IFMIF-DONES), aims to build a large particle accelerator to produce neutrons[v] used to test materials to be used in more advanced fusion devices closer to commercialisation, like DEMO.[95] The IFMIF-DONES project also owes to an intra-European collaboration – it is the result of a joint declaration between Spain and Croatia in 2022 as first step for a broader collaboration within Europe. IFMIF-DONES would become the worldwide reference facility for providing key information about the performance of fusion material under fusion conditions, including the training of highly skilled personnel.

Figure 16: European Research Roadmap to the Realisation of Fusion Energy[96]



Fusion is garnering significant interest due to technology breakthroughs and the need for more clean and firm decarbonisation options. Once commercialised, fusion energy has the potential to become one of Europe's safe, abundant, zero-carbon sources of reliable electricity, can advance Europe's goal to get to net-zero emissions by 2050, and increase energy security. Member States should continue the legacy of cooperation in fusion research and proactively build a bold RD&D vision supporting fusion's commercialisation in the coming decades. More research and scientific collaborations as well as financial support at unprecedented scale will be needed across Member States and should be incorporated into the updated NECPs. More research funding and greater cooperation will allow more Member States the opportunity to gain access to experienced personnel, data and modelling software, and state-of-the-art facilities in development today.

[v] These neutrons mimic the energy spectrum of the neutrons produced in a Deuterium Tritium based fusion machine.

Look beyond borders

As unabated fossil fuel resources scale down, the dynamics of electricity transmission and distribution will shift from legacy hub-and-spoke models with a fossil plant in the centre to more distributed, resource-diverse systems. EU Member States diverse in geography, natural resources, and legacy energy system development, surrounded by equally diverse neighbouring countries and regions, can contribute to this new, interconnected energy system in specialised and specific ways. Member States with high wind, solar, and geothermal potential, for example, could produce clean electricity and renewable hydrogen affordably and can export energy to areas with lower technical potential or slower renewable deployment rates. Industrial hubs could capture unavoidable combustion and process emissions and ship them to countries with high carbon storage potential. And Member States developing advanced nuclear energy and superhot rock geothermal energy will be key contributors to the more than 100 GW of new clean firm power capacity needed across the continent by 2035 to meet increased demand.[97]

Historically, infrastructure planning and deployment in Europe has been developed and executed in isolation. Although the Governance Regulation was designed to stimulate cooperation between Member States at cross-border and regional levels, the European Commission found that Member States did not seize the full potential of regional cooperation during the preparation of the initial NECPs, and that few Member States took the opportunity to describe specific measures to improve cooperation with others.[98]

The NECP revision process is an opportunity to facilitate the shift from insular to more proactive and diverse cross-border planning approaches that are more likely to deliver a more efficient and less costly future energy system that plays to Member State and trading partner strengths. Greater communication, sharing of best practices, and collaboration between Member States, combined with regional and interregional proactive infrastructure planning approaches, can facilitate the most efficient energy systems and infrastructure needed to decarbonise. Member States should also make plans to import zero-carbon fuels from EU and non-EU countries to meet REPowerEU mandates and industrial needs and flesh out agreements to reduce upstream emissions from imported fuels. Europe is also geographically proximate to emerging energy economies in Africa, Asia, and the Middle East, and can better leverage its trade and geopolitical positions to advance climate objectives through fuel imports. For example, the EU has a European Neighbourhood Policy which covers 16 external countries, and it maintains a special relationship with Turkey and the Western Balkans. If Europe decides to lead on forward-looking climate policies, it could have ripple effects in dozens of other countries.

Think through import strategy for zero-carbon fuels

Europe's hydrogen demand is expected to increase from 280 TWh today to more than 2,000 TWh by 2050,[99] and REPowerEU puts near-term pressure on the bloc to generate and import hydrogen, committing the EU to produce up to 10 million tonnes per year and import the same amount by 2030.[100] Given these policy imperatives, Europe must think realistically about the logistics and cost-effectiveness of hydrogen production and imports at large scale.

CATF commissioned a study[101] to investigate the techno-economic pathways of importing hydrogen into Europe (via the Port of Rotterdam) from various global locations, including Norway, the Middle East and North Africa (MENA), and the U.S. The report concluded that under all scenarios, importing large quantities of hydrogen over long distances into Europe will be an expensive and relatively energy inefficient endeavour due to the inherent properties of hydrogen, particularly its low volumetric density. Of the options available, the results found that the most cost-effective method to transport hydrogen is by pipeline, ideally over the shortest distances possible, followed by maritime transport in the form of ammonia for direct use. However, if the ammonia is "cracked" to liberate pure hydrogen, this incurs significant energy penalties making the process even less efficient and costly. Hence, imported ammonia be prioritized for industry requirements for ammonia specifically, such as in the agriculture and as a zero-carbon fuel to decarbonise maritime shipping, as the fuel is much cheaper and more stable to transport via ship and truck than hydrogen. Additionally, the transport of the hydrogen and ammonia from its import site to demand centres will require significant infrastructure build out. To avoid cost ventures or stranded assets, Member States should carefully assess and select the most efficient pathways for importing hydrogen and ammonia and coordinate closely on international projects before any significant investments are made.

Despite these challenges, Europe will still be increasingly in need of imported energy, including zero-carbon fuels. Because it is difficult to import hydrogen efficiently, Member States may first look for ways to reduce demand for hydrogen imports, particularly in the near-term as domestic clean hydrogen production capacity builds, prioritising it use for its most critical, "no regrets" sectors for deployment. Additionally, in the wake of Russia's invasion of Ukraine and the energy and gas crises impacting Europe over the last 18 months, many Member States have been rapidly building out capacity for liquefied natural gas (LNG) import terminals and associated transport infrastructure. For the time being, the EU can utilise the some of the high supply of imported LNG for domestic low-carbon hydrogen production (with low carbon intensity, high carbon capture rates and strict methane emissions controls) by developing production infrastructure at or near the LNG terminals. Additionally, Member States may look to repurpose some of its existing natural gas pipeline infrastructure, where possible, to support hydrogen transport to its priority demand centres. These measures are likely to be more feasible and cost-effective than importing low-carbon hydrogen from distant suppliers, particularly in the short-medium term.

In Member States where hydrogen is specifically needed and is in short supply, countries should carefully assess where import terminals would be located and the most efficient transport methods to get hydrogen to where it is needed before making investments in hydrogen-specific infrastructure. In drafting updated NECPs, Member States should estimate their near- and long-term hydrogen and zero-carbon fuels demands, production capabilities, and import requirements, and understand current and future zero-carbon fuel infrastructure needs. These assessments should describe and incorporate pathways for oil-based transport fuel substitution through electrification and zero-carbon fuels and consider repurposing existing infrastructure (e.g., natural gas pipeline networks) for zero-carbon fuel transport where feasible. Where hydrogen is needed, Member States, particularly those with proximity to neighbouring states with clean hydrogen strategies or existing production facilities, could propose ideal import locations at their borders where importing is or could be feasible and should thoroughly vet the hydrogen production processes of these states to ensure the veracity of low- or zero-carbon claims. Public policies and resources should be leveraged to prioritise the most promising and cost-effective technologies first, recognizing that, while option value is important, we must avoid "white elephant" infrastructure projects—expensive investments that are inherently inefficient or unlikely to come to fruition.[vi]

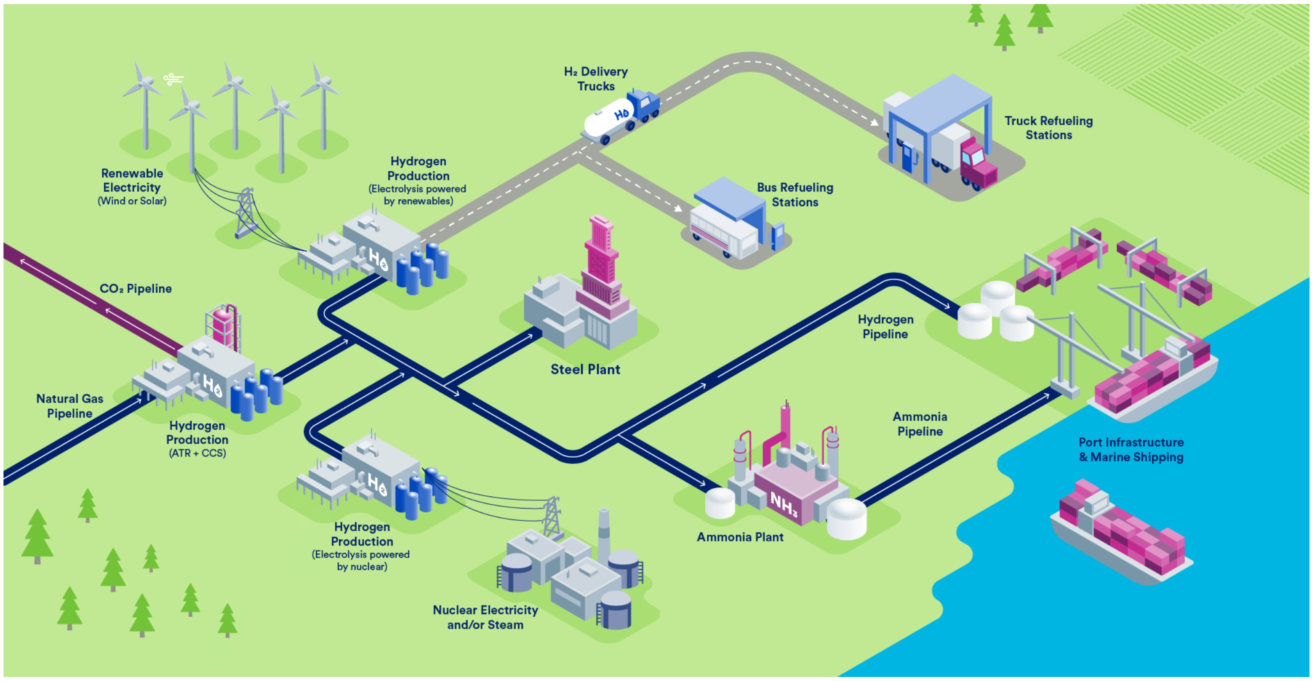
Member States should also call upon the EU to take a larger role in coordinating hydrogen and ammonia imports, setting a coherent strategy, and facilitating knowledge- and resource-sharing to bring these fuels and chemical feedstocks into the bloc where it is cheapest and most efficient, reduce infrastructure spend and land use impacts, and minimise contracts and related costs. One current effort by the EU to increase transparency and play a coordination role in facilitating hydrogen flows from outside the bloc is the EU Hydrogen Bank initiative.[102] Through this initiative, the Commission plans to gather and share information on hydrogen demand, supply, flows, and prices, and support infrastructure planning. It also intends to support Member States and companies in concluding Memoranda of Understanding with hydrogen producers abroad.

The EU Hydrogen Valleys partnership initiative[103] is also underway to enable the regional connectivity of clean hydrogen sources to end use demand sectors at scale. It encourages "matchmaking" and "co-investment," and already facilitates hydrogen relationships with parties outside of the EU, including with Norway and the UK. Recent EU focus on decarbonising industry will require more from these ongoing initiatives. For example, while Hydrogen Valleys contribute to the goals of REPowerEU, the NZIA intends to double these Valley projects. To support the rapid availability of hydrogen and zero-carbon fuels across the supply chain, a neutral, technology-optionality approach to hydrogen production could also be applied to current and future Hydrogen Valley projects. Of Hydrogen Valley projects announced so far, many focus solely on "green" hydrogen production via electrolysis from solar or wind energy sources. If developing Hydrogen Valley proposals in their draft NECPs, Member States should encourage project leads to include both electrolytic hydrogen production through electricity sources that include nuclear energy, geothermal, solar and wind energy, as well as other low-carbon hydrogen sources with strict methane emissions control and installed carbon capture and storage infrastructure.

vi For more information, see CATF's Zero-Carbon Fuels program webpage: https://www.catf.us/zero-carbon-fuels/program/

Figure 17: Hydrogen Valley as a "hub"

Hydrogen Valleys can serve as "hubs" that enable regional connectivity, develop the hydrogen supply chain in Europe, and promote economywide decarbonisation. A theoretical hub concept is shown here.



Plan cross-border infrastructure

Collaboration and coordination on regional and interregional infrastructure between Member States exists today. For example, the revised TEN-E regulation identifies guidelines for the development and operation of "priority corridors" and areas of trans-European infrastructure, as well as criteria for Projects of Common Interest (PCI),[104] or cross-border energy infrastructure projects needed to pursue European climate goals. Current PCIs include electricity transmission and storage projects, CO_2 network projects, and smart grid projects.[105] Despite existing efforts, however, cross-border infrastructure planning is not sufficiently incorporated into Member State planning documents. The European Commission noted that few Member States In their 2019 NECPs described specific measures to optimise access to and use of regional facilities, or how to plan better renewable energy deployment and energy efficiency measures in cooperation with other countries.[106]

Comprehensive regional and interregional infrastructure planning can help meet the scale of the clean energy deployment challenge cost-effectively and efficiently. Revised NECPs should rectify identified shortcomings and note specific opportunities for Member States to collaborate with others on infrastructure. On the zero-carbon fuels front, Member States that plan to import hydrogen and other clean fuels should assess national and cross-border infrastructure needs to allow the scaling up of the "no-regrets" infrastructure to receive the most efficient, cost-effective, and least energy intensive imported gas (e.g., gas and/or hydrogen by pipeline, gas via shipping to be converted to hydrogen in Europe). On top of this, it will be key for countries to base infrastructure decisions on connectivity with end users (e.g., from ports to hard-to-abate sectors) and future links into Hydrogen Valleys.

Unlocking the collaboration potential of the CEE region to increase security and lower power prices

Seeking firm, low carbon power, Central and Eastern European (CEE) countries[vii] are starting to embrace technological optionality and clean tech innovation into their climate and policy agendas. CCS technology is gaining momentum in countries like Poland[107] and Bulgaria,[108] where CCS projects are supported through the Innovation Fund.

Interest in SMR deployment is also on the rise across the region to complement renewables with clean firm power. Many of the CEE countries already have nuclear energy, as well as the infrastructure and regulations to support new nuclear energy programs. Opportunities exist to collaborate across CEE countries with current nuclear capabilities and those with nuclear energy aspirations to plan and deliver multiple deployments. The EU has many examples of successful multi-country procurement models, encompassing RD&D, manufacturing, and deployment, which could form a model for SMR and other advanced reactor fleet programs. Such a model could provide shared supply chain investments across many CEE countries and bring cost savings benefits to all deployments.

Member States should also incorporate ideas for hub integration and related carbon storage sites into NECPs. As not all Member States have carbon storage opportunities or the ability to develop them, developing cross-border CO_2 networks will be critical to ensure European industries can decarbonise their production processes with low additional cost to consumers. For this, more trans-European cooperation will be needed for the planning and development of the CO_2 storage network. Countries should take the opportunity of revising NECPs to exchange best practices and describe how they plan to develop CO_2 transport networks – including a combination of pipelines, shipping, rail, and road transport. As a first step, Member States can make available in their NECPs information on CCS potential, possible storage locations, and cross-border transportation costs. An efficient CCS market will only materialise if transport and storage is planned and developed in parallel, or the EU will risk having stranded storage availability with no network to deliver the CO_2 from industries.

To alleviate interconnection queues and ensure affordable, clean, and efficient power for demand centres, further collaboration on interstate electricity transmission capacity is needed. Member States can elaborate on specific contributions to PCIs and priority corridors running across their borders and detail how they will meet mandatory sustainability criteria for these projects. Member States can also coordinate on accelerating permitting processes for PCIs and other critical cross-border projects (discussed further in the **Enable Implementation** section). Offshore wind, a technology critical to Europe's decarbonisation strategy, also benefits from coordinated and proactive offshore transmission planning between Member States.[viii] Countries can use the NECPs as an opportunity to share joint plans for energy islands, meshed offshore grids, and other offshore technologies that will enable faster and easier deployment of offshore wind resources and interconnection to multiple country-level grids.

[vii] CEE countries include Estonia, Latvia, Lithuania, Poland, the Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Romania, and Bulgaria.

[viii] Though tailored to the U.S. context, CATF work highlights the environmental and cost benefits of planned offshore wind transmission. See: https://www.catf.us/2023/01/report-urgent-collaborative-offshore-wind-transmission-planning-needed-to-achieve-federal-and-state-clean-energy-goals/

The Hydrogen Backbone is an outcome of regional collaboration

The Hydrogen Backbone, an initiative launched between European energy infrastructure operators to accelerate the development of hydrogen infrastructure across Europe, has submitted around 150 infrastructure projects for "Projects of Common Interest" (PCI) selection. Those submitted are mainly for repurposing and retrofitting existing gas infrastructure, with new, dedicated hydrogen infrastructure assets only featuring as minor role. This type of regional coordination and promotion of projects for PCI consideration not only sends strong signals to investors, but also helps reduce land impacts and additional costs incurred from new infrastructure development.

Turn international ambition on greenhouse gases, including methane, into policy action

The European Union has domestic *and* international climate commitments and obligations. The NECPs provide an opportunity for Member States to demonstrate how domestic energy and climate planning will achieve their international climate pledges. The updated NECPs should reflect the requirements of the Paris Agreement, including in relation to NDCs, and the process set out by the Glasgow Climate Pact for raising mitigation ambition. The Glasgow Pact contains several decisions on energy and climate planning, including the phasing down of coal power, the phasing out of fossil fuel subsidies, and the consideration of further actions to reduce non-CO_2 emissions, including methane, by 2030.[109]

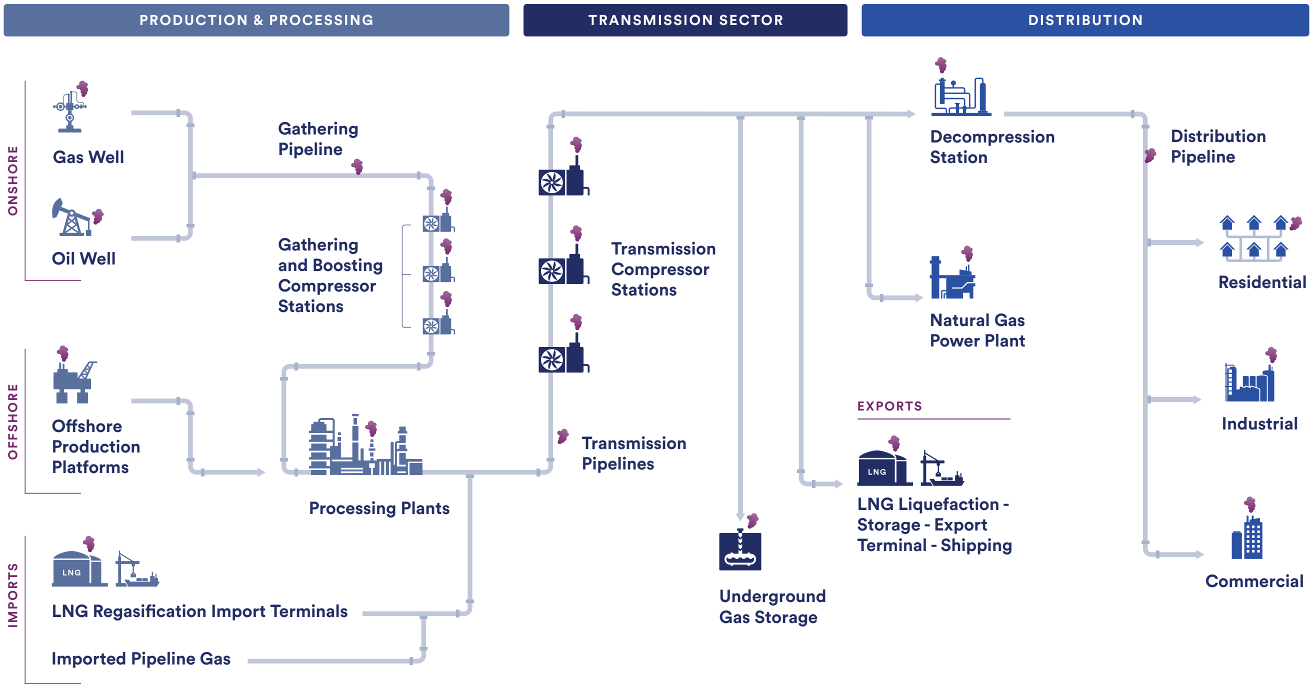
The Global Methane Pledge is another such agreement, which tackles the second largest contributor to climate change after carbon dioxide.[110] Initiated by the EU and the U.S., the Pledge was launched in November 2022 at the 26th Conference of the Parties (COP26) with more than 100 signatories committed to reducing their methane emissions globally by 30% by 2030 compared to 2020 levels. In the EU, around 53% of anthropogenic methane emissions comes from agriculture, 26% from waste, and 19% from energy, which includes oil, gas, and coal.[111] Of these sources, tackling methane emissions in the oil and gas industry is the lowest hanging fruit. And according to the IEA, 78% of these methane emissions can be abated with existing technology, with nearly 40% at marginal or negative costs to companies.[112]

As it is transported from production areas to consumers, methane can be emitted from many points along the supply chain. While some emissions are accidental leaks, others, like venting, which is done to release pressure or for maintenance activities, are intentional. Methane may be leaked or vented from pipelines, production and transmission equipment, and combustion sources throughout the value chain (Figure 18). Extensive research has shown that methane emissions from the oil and gas industry are highly underestimated.[113] Most scientific research on methane emissions in oil and gas has focused on the United States, given the large share of its contribution to global oil and gas production. While there has been some research on fossil gas emissions in Europe, more research is currently underway.

Because the EU Member States rely on imports for more than 80% of gas supply, they should first consider ways to minimise emissions from imported fossil fuels. In NECPs, Member States could support strengthened multilateral commitments on methane, like those between gas importers and exporters, which would help spur deeper emissions reductions. Member States could express intent that any new bilateral or multilateral gas purchasing agreements with exporter countries require the inclusion of methane mitigation actions in contract considerations, and that both partner countries and domestic companies with stakes in non-operated joint ventures abroad should negotiate concrete action to achieve near-zero methane leakage across the oil and gas supply chain. Intent of such agreements would publicise Member States demand for such low-emission fuels while allowing Member States to minimise the impact of hard-to-abate sectors where fossil fuels are still needed.

Member States could also push for the establishment of an **EU import standard**, which would collect fees from imported oil and gas that do not meet strict emissions intensity standards to create an EU methane fund managed by the European Commission. This EU methane fund could be put toward methane emission mitigation

Figure 18: Common points of methane leakage along the oil and gas value chain



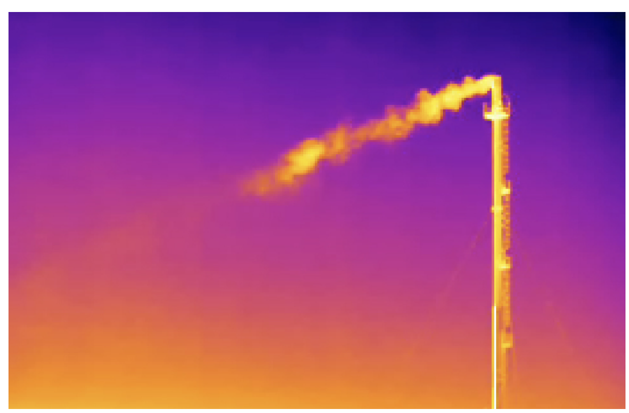
in oil and gas operations abroad, capacity building investment, measurement, reporting, and verification program implementation, and other methane abatement activities. Applying these funds to oil and gas projects in developing countries could provide financial support to overcome barriers to private investment in methane mitigation activities in those countries.

In the next round of NECPs, Member States can also prioritise quick and cost-efficient mitigation strategies to reduce methane emissions, including:

- Improving the measurement, reporting and verification programs for methane emissions in the energy sector.
- Mitigating emissions through mandatory monthly leak detection and repair (LDAR) requirements. Member States can use cost-effective solutions available today, including optical gas imaging cameras and other detection technology, as LDAR programs scale up to understand where oil and gas infrastructure is leaking toxic chemicals and methane.
- Banning routine venting and flaring.
- Developing an inventory of national abandoned wells and plan to seal and dismantle them.

Figure 19: Methane emissions from an emergency vent at an underground gas storage facility in Minerbio, Italy

Taken by CATF with using an optical gas imaging camera on April 17, 2021.



Methane mitigation plans for abandoned wells

The oil and gas industry in Europe dates back to the 1850s.[114] Since then, many wells have been abandoned for a wide range of reasons, including production declines and business migration to more productive oil fields. The issue of abandoned wells[ix] is complicated by the difficulty in identifying which companies own them or are responsible for them. In some cases, due to the way these wells were decommissioned, no owner can be identified and held accountable for the emissions and the measures needed to address them. The total number of abandoned wells in Europe is unknown. With their long history of oil and gas commercial operations, most European countries lack complete inventories of all wells drilled in their territories. And many of these abandoned wells are unplugged or improperly plugged, permitting harmful chemicals and gases to escape the well.[x] Unplugged wells present safety and environmental hazards today, and if unaddressed, will continue to pose issues as new wells are drilled and former drilling lands are repurposed.

Mapping these wells could be the first step to engage in plugging and sealing programs and would be crucial to provide good basis to gather accurate estimates of methane emissions, and to mobilise proper funding and resources for abandoned wells management programs at national and European level. Italy completed a project to comprehensively map old oil and gas wells, finishing the project in 2017. In the next round of NECPs, Member States could establish a separate program on methane mitigation for abandoned wells to ensure all these wells are identified, sealed, and monitored. The mapping should accompany the development of national databases of all wells in each country. These databases can aggregate information from a variety of sources, including:

- National public and company archives;
- Bottom-up reporting of wells by landowners and other members of the public; and
- Scientific surveys, notably those using magnetic surveys to detect wells in dense vegetation and buried wells beneath the surface.

Such a program could lead to substantial reductions in methane emissions from abandoned wells as well as create new employment opportunities. In parallel, Member States should understand the legal status of wells and put in place protocols and adequate funding to properly plug and monitor them.

One effort currently underway is the Visibility of Petroleum Exploration Data in Italy (ViDEPI) project,[115] which aims to make documentation around discontinued oil exploration sites in Italy more accessible. The project is aggregating mining licenses from different offices of national and regional mining authorities, mapping them, and putting their findings online.

Figure 20: Mapped ViDEPI project sites[116]

ix A well is considered abandoned when it reaches the end of its useful life, is no longer producing fuel, or is not producing enough fuel to make money. Abandoned wells are considered orphaned if the operating company went bankrupt, ceased activity, or otherwise cannot be located.

x Abandoned wells often release methane, a greenhouse gas containing about 86 times the climate-warming power of CO_2. Some also leak chemicals such as benzene into fields and groundwater.

Enable implementation

Previous recommendations support aligning long- and short-term climate goals, supporting emerging clean energy technologies, conducting robust analysis and mapping exercises, and planning for collaboration with other Member States and with other countries and regions. But planning cannot consist of goals and analysis alone – to be complete and effective, NECPs must also incorporate how these plans will be implemented in the short time available to limit global warming and succeed in the delivery of 2030 and 2050 targets.

Some of the biggest barriers yet to clean energy technologies and infrastructure are found in the details of implementation. Community opposition, limited land availability, delayed permitting timelines, and workforce shortages slow or halt projects today. And progress tracking and accountability mechanisms meant to promote timely implementation have not been put in place or evenly adopted in Member States. Every implementation delay will put Europe in jeopardy of failing to achieve its climate and energy security goals.

Member States must plan thoroughly to address and overcome these implementation barriers. At the same time, the decades ahead will inevitably bring about economic, geopolitical, and social change. Policymakers and other decision-makers should not anticipate that each and every component of plans made today will remain static over time. Rather, opportunities for revisions and re-evaluation should be actively baked into plans like NECPs.

Build robust implementation frameworks

Each clean energy project or plan supports regional, country-level, and local goals and can require approvals, permits, stakeholder buy-in, and assessments at one, some, or all those levels. Frameworks should be in place at each level to ensure sufficient regulatory, administrative, and community support and increase the probability of successful implementation. In their NECPs, Member States have an opportunity to develop and propose regulatory reforms that streamline and simplify implementation. At the national level, Member States should fully operationalise the EU emergency renewable permitting timelines and consider how to incorporate rapid permitting timelines more permanently to more clean energy technologies. To support these aims, Member States should ensure that agencies responsible for permitting are sufficiently staffed to handle the administrative burden of processing applications. These permitting systems should be modernised and digitised.

Member States could also adapt the NZIA's proposed "one-stop shop" concept, where a single agency is responsible for all facets of the net-zero industrial facility permitting process, to clean energy technology and infrastructure. Denmark, for example, has already established a one-stop shop for offshore wind permitting.[117] The Danish Energy Agency coordinates and grants all offshore wind development and construction licenses and centralises the coordination of other involved agencies.[118] Through centralisation of this responsibility, the Energy Agency has streamlined the permitting process – only three permits are required.

Speedy implementation can also be facilitated locally. France's Renewable Energy Acceleration Bill gives local municipalities the power to identify "renewable acceleration zones" where the permitting process will be limited to between one and three months, giving communities a say in the location of clean energy resources.[119] It also aims to free up less environmentally sensitive land (e.g., parking lots, land bordering major roads) for solar installation.

Policy and regulatory implementation frameworks can be supported and held accountable by an active civil society. Local NGOs and advocacy and activist groups with legal capacity can mobilise and engage Member States to apply pressure to uphold key regulations (e.g., methane regulations). These groups and other think tanks or organisations with subject matter expertise should be encouraged to provide technical and policy expertise as Member States think through policy implementation.

Set deadlines and track progress

Climate and energy plans put forth in NECPs will be implemented according to each Member State's political, regulatory, and policy environment. These plans may be complex, with each step requiring action from multiple stakeholders, and may also span several political administrations as well as EU-wide and Member State-specific policy reform. And these plans must remain consistent with other, longer-term planning mechanisms like the LTSs per the Governance of the Energy Union.

Ensuring consistency between and progress toward the NECPs and the Long-Term Strategies

Stable long-term plans that interim plans and goals can tie to are critical to the economic and industrial transformation Europe needs to achieve its net-zero vision. The Governance of the Energy Union underscores this, requiring countries to ensure consistency between their NECPs and their Long-Term Strategies (LTS). However, while the development of LTSs has positively influenced national policymaking in some Member States, the overall lack of clarity and information in the LTSs means that LTSs cannot adequately guide short-term policymaking (through 2030) and are limited in their usefulness as a planning tool to achieve interim targets (e.g., 2030, 2040). For example, external assessments find that several LTSs provide insufficient information on long-term goals, and some have already become obsolete.[120] And a few countries, such as Romania, Poland, and Ireland, have not submitted their LTSs, hampering the review process from the European Commission and the potential of this long-term planning mechanism.

Aligning the NECPs with longer-term plans like LTSs – in terms of both timing and content – is done every 10 years and is critical to maximise the effectiveness of both mechanisms as planning tools. To reflect dynamically evolving circumstances and ensure consistency, a stronger linkage between these plans will be needed, including more regular and frequent updates to both NECPs and LTSs.

To ensure that planning through 2030 is sufficiently well thought out, NECPs should outline the timing of major policy decisions required to implement climate and energy goals. This approach will require Member States to think through the necessary logistical, political, financial, and regulatory alignment far in advance of critical deadlines, promoting more resilient planning. This will also result in more comprehensive and strategic enforcement of EU law.

While the 2030 timeline is a must, there must be a stronger connection between today, 2030, 2040, and 2050 to ensure the EU is advancing at a pace matching its climate ambitions. Member States must plan beyond 2030 especially for earlier stage technologies and consider providing a trajectory for key milestone dates to guarantee that policymaking, RD&D, financing, public awareness campaigns, and construction of the technologies needed for climate neutrality are planned and are executed on time. This policy signal will be helpful to ensure that the deployment of the technology is planned according to the industrial decarbonisation needs, going beyond the 2030 timeframe.

Once key policy decisions and actions are outlined, progress against those milestones must be tracked and publicly reported over time. Reporting and monitoring are two key elements of the Governance Regulation.[121] These elements ensure that Member States meet agreed-upon energy and climate targets for 2030, track the EU's collective progress towards achieving policy objectives across the five dimensions of the Energy Union, and report out to the UNFCCC and Paris Agreement secretariat.

The NECP process already bakes in progress tracking – it required each country to submit a national energy and climate progress report (NECPR) covering the Energy Union dimensions by 15 March 2023 and mandates updated reports every two years thereafter.[122] These progress reports should contribute to an evidence-based assessment of progress in NECP implementation while identifying gaps and areas for improvement. However, despite such efforts to track progress, many Member States have not complied well. By 15 March 2023, only Finland and the Netherlands had submitted a progress report.[123] NECPRs submitted thus far are complex to interpret, effectively limiting public access to the information they provide. But the EU progress tracking system as it stands today does not lend itself to revealing detailed real-world developments that inform policy action. Without a reliable way to gather sufficient data over manageable time periods, tracking and monitoring progress can be difficult for Member States.

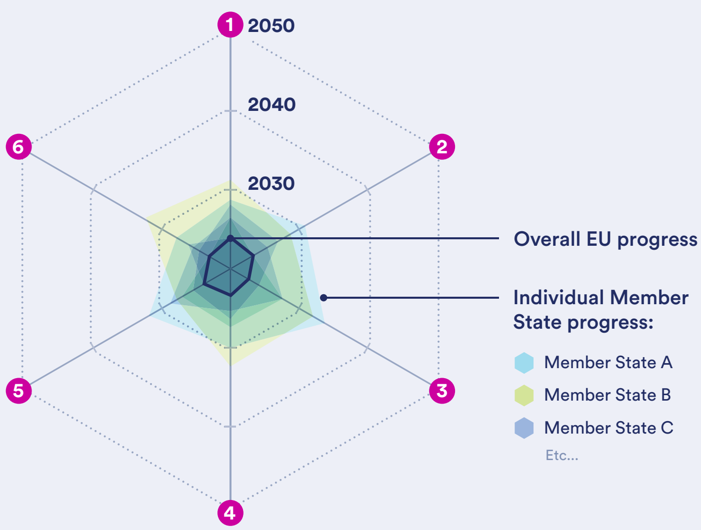
To facilitate improved and more reliable tracking toward climate goals, the European Commission must provide an official and easy-to-use tracking tool that limits the administrative burden on Member States and allows a more accessible overview of national progress. To succeed, the tracking tool should be updated regularly, based on recent modelling of reliable pathways to 2030, 2040 and 2050, and integrated with existing and complementary EU planning and monitoring systems (e.g., Climate Law, European Semester). Without more efficient and sophisticated tracking and reporting tools, countries and the European Union will be unable to effectively track progress against 2030 and 2050 decarbonisation goals.

Develop a net-zero implementation tracker (NZIT)

During the next Governance Regulation revision, the European Commission should consider developing a net-zero policy tracker (NZIT) that better aligns the NECP and LTS energy and climate planning mechanisms and takes stock of the current state of climate and energy target achievement. The NZIT should support tracking progress in the extended dimensions of the Energy Union, develop an in-depth, indicator-based understanding of the path towards climate neutrality and project those indicators against target dashboards and sectoral pathways. Such an advanced tool could draw key learnings from projected emission savings from different scenarios, provide key intel to countries decision-making and enable the EU to hold parties accountable for the achievement of interim goals that add up to success by 2050.

Figure 21: Progress tracking towards net zero

This highly simplified tracker example could serve as a beginning blueprint for an NZIT. Progress must be tracked across each Member State, and the totality of Member State efforts contributes to EU-wide progress toward net-zero goals.



DIMENSIONS OF THE ENERGY UNION

1. Energy security, solidarity and trust
2. A fully-integrated energy market
3. Energy efficiency first
4. Decarbonising the economy
5. Social dimension
6. Research, innovation and development, and competitiveness

Learn from the process and include opportunities to recalibrate

NECPs should not merely be considered a short-term planning tool. Rather, these plans should enable an ongoing process that is continually evaluated as it proceeds – from planning to implementation. By taking the learning opportunities of the NECP exercise more seriously, the EU will be able to optimise the transition process for climate, economic, and societal needs between now and 2050. With improved methods to track progress and more regular check-ins and evaluations fostered by the European Commission, Member States will be able to gauge the effectiveness of their actions and identify areas for improvement in the overall NECP process, allowing them the opportunity to adjust plans, technology learnings and deployment realities to new market and geopolitical circumstances if they arise. Understanding where countries face challenges in implementation will also help Europe to develop appropriate consequences for Member States for their lack of progress or engagement. An iterative process of assessment and adjustment would ensure that Europe remains adaptable and responsive to evolving geopolitical circumstances and learns from this process. Europe could establish dedicated NECP knowledge platforms that serve as repositories for lessons learned, capture valuable insights from ongoing initiatives, and share best practices. By fostering a culture of learning and knowledge exchange, Europe can collectively enhance its understanding of the road towards net-zero and accelerate progress not only nationally but also globally.

Strengthen public consultation and aim for community buy-in

Member States have the legal obligation to involve the public in policymaking per the Aarhus Convention and the Governance Regulation. NECPs are no exception – the Aarhus Convention requires early and effective consultation on the draft and final NECPs, and the Governance Regulation asks Member States to establish a Multilevel Climate and Energy Dialogue to discuss energy and climate policies, including NECPs. However, during the 2019 NECP drafting process, the European Commission found that stakeholder input was not always taken into consideration, and that EU recommendations between draft and final NECPs were only partially implemented.[124] Observers to the current round of NECP revision point to a similar situation – 35 NGOs sent a

Capturing best practices and sharing learning opportunities through the NECP process

Capturing best practices and sharing learning opportunities through the NECP process. There are clear benefits from having more regular exchanges between Member States and openly discussing different Member States experiences with the NECP process and decarbonisation more generally. Among others, the sharing of lessons learned would ultimately provide:

- Improved understanding of which technologies work best for which end users.
- Clarity on the best planning, coordination, and stakeholder engagement methods for developing infrastructure fit for net-zero.
- Innovation and improvements, and the dismantling of old and long-standing inefficient practices.
- More resilience to fluctuating global and in-country dynamics.
- Identification of a set of policies and instruments that have been most effective in de-risking technology and infrastructure projects and bringing cost-effective financial capital to the transition process.
- RD&D and innovation policies that foster create innovative environments (i.e., clusters) that lead to faster commercialisation of emerging technologies.

letter to the European Commission on 20 April 2023 expressing concern about the lack of opportunities for public participation in NECP drafting processes,[125] and a Climate Action Network (CAN) Europe and World Wildlife Federation report found that, as of April, 14 of 23 EU countries had yet to start any form of public consultation in advance of the NECP June draft submission deadline.[126]

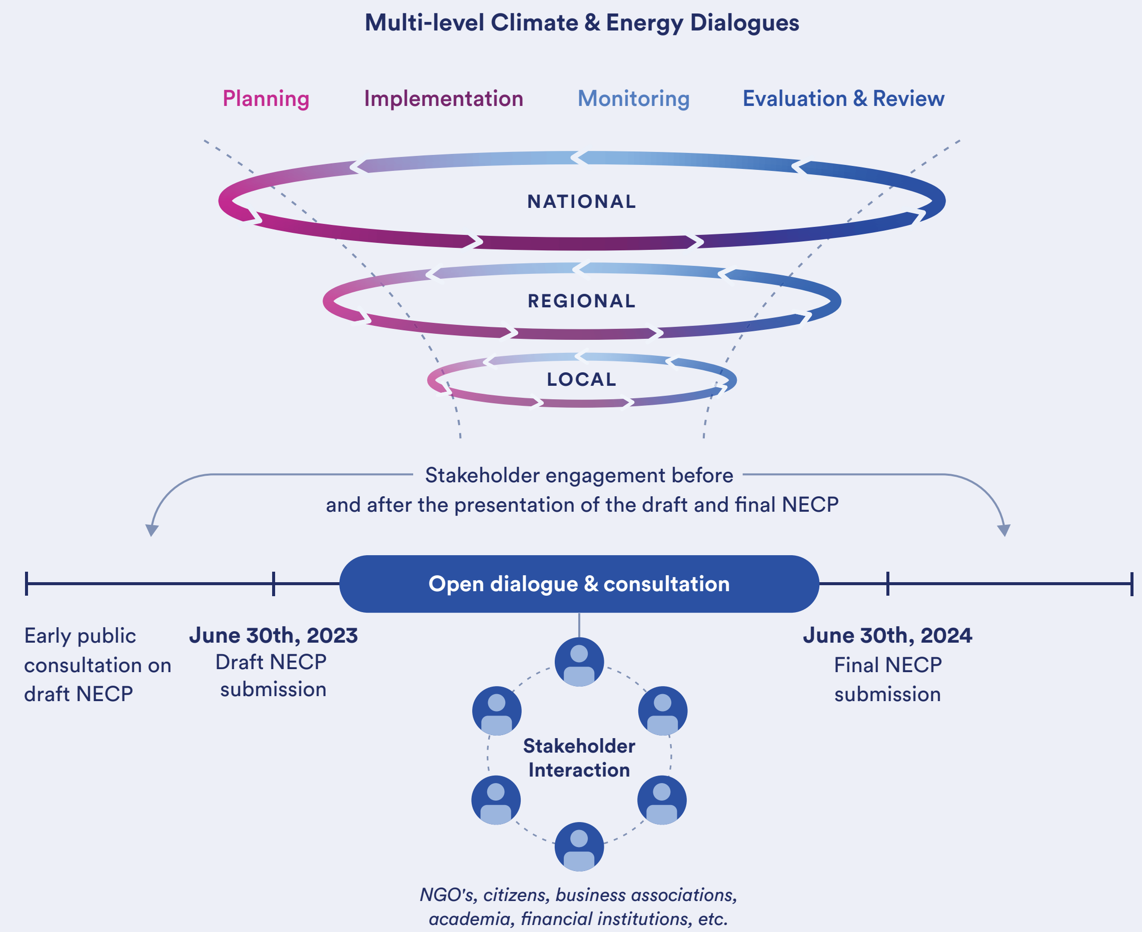
Facilitating effective public consultation and implementing the output of such consultation is a challenge not only in the NECP process, but in policymaking and clean energy project development more broadly. There are a wide range of stakeholders impacted by any policy or project approach from varied perspectives and with different needs and priorities. Policymakers and project developers can face administrative burden in processing public inputs, making it difficult to logistically account for all perspectives. To break this cycle and foster proactive engagement, the revised NECPs should actively incorporate opportunities for public consultation and strengthen multi-level climate dialogues. Consultation allows for public education and promotes awareness of key clean energy technologies that are not widely understood today, such as CCS, superhot rock geothermal energy, advanced nuclear energy, and the range of zero-carbon fuels. It can also increase the likelihood of successfully siting renewables projects, which are facing increasing community pushback. To avoid disruptions in siting and constructing new energy facilities, countries should plan innovative actions and strategies that could boost public awareness, trust in, and acceptance of these technologies. For example, countries could encourage communities proactively seek to be "renewable acceleration zones" or other sites for new clean energy technologies to grow their local economies and engage with the clean energy transition on their own terms.

Community engagement and broad societal buy-in across industrial players for clean energy is increasingly important to achieve the scale of deployment needed on a limited amount of land. And knowledge sharing between communities and Member States can facilitate adoption of best practices.

Strengthening multilevel governance platforms in national energy and climate policies

Effective climate and energy policies need broad private and public sector consultation, collaboration, and ultimately ownership across different governance levels. When preparing updated and final NECPs, Member States should set up climate and energy dialogues to collaboratively manage the design, planning, implementation, and monitoring of climate and energy policies. Such dialogue platforms can foster vertical and horizontal integration of energy and climate policies and bring together representatives from national and sub-national authorities, academia, industry, financial institutions, NGOs, and the broader civil society. These platforms can provide opportunities to align on the needs and capacities of each stakeholder group and to realistically discuss the challenges and opportunities of the energy transition in different sectors. Member States can take advantage of such platforms to identify and specify, together with industrial stakeholders, critical end-use sectors in their NECPs and jointly develop plans to decarbonise. This sector-driven approach will allow industries to research and present solutions that can realistically be deployed and scaled within a Member State, and/or replicated in other Member States. As such, platforms can promote best practices and solutions, and help governments identify and reflect on possible gaps to implementation. Overall, such a structure could promote stakeholder ownership and investment in the implementation of the integrated national plans and bring about new business and collaboration opportunities.

Figure 22: Climate and Energy Dialogue Platform



Understand workforce gaps and support skills development for quality jobs of the net-zero age

Skills shortages and mismatches could threaten the growth of European net-zero technology industries. Workforce development is needed throughout the bloc to install, operate, and maintain the necessary onshore solar and wind, offshore wind, battery storage, CO_2 storage, and pipeline infrastructure required for country-level and regional climate goals. A wide variety of skills and increasing numbers of workers with those skills over time will be needed to bring 2030 and 2050 decarbonisation goals to life.

For example, as superhot rock geothermal energy scales, skills ranging from computer modelling to physical drilling of ultra-deep wells will increasingly be needed. The solar sector anticipates that 80% of jobs in 2030 will be in installation, a function that companies find difficult to staff today.[127] An added challenge is that clean energy sectors often compete for GIS, systems and data analysis, O&M and field maintenance, and engineering professionals, among others.[128]

EU countries interested in deploying advanced nuclear energy will also need nuclear expertise and a well-qualified workforce for present and future nuclear applications, including for SMRs. While the European nuclear sector expects to create 300,000 additional, new direct, indirect jobs by 2050,[129] half of the EU's workforce involved in the lifecycle of nuclear energy (e.g., mining, design, regulation, construction, operation, decommissioning and waste management of nuclear facilities) is nearing retirement age.[130] This means that the nuclear energy sector would need to recruit more than 450,000 employees in the EU over the next 30 years, including more than 200,000 highly skilled people. It is therefore in the EU's strategic interest that skills are transferred to the next generation of scientists, engineers, and technicians.

Greater resource and workforce cooperation among industries will be needed if Europe is to realise its climate ambition. For instance, lack of sufficient CO_2 injection capacity infrastructure is the single largest bottleneck for CO_2 capture and storage for hard-to-abate industries through 2030. Oil and gas producers possess the assets, resources, and skills that could enable this capacity. Working together, these industries could find cost-effective projects and share capabilities to provide the necessary injection capacity ahead of demand.

To ensure that workforce capacity and skilling is sufficient to bring about a net-zero economy, countries need sound and realistic workforce transition plans that phase in skills from existing fossil and legacy energy industries. Existing skills from coal, oil, and gas industries could be repurposed into skills used in the clean energy transition. For example, superhot rock geothermal energy could harness the knowledge and technology expertise of the oil and gas drilling industry to produce clean energy jobs.

Skilled workers are not only needed to build and install clean technologies, but also to manage the administrative and regulatory burden that will result from massive clean energy deployment. Great numbers of permits must be processed, regulatory, technical, and environmental approvals provided, consultants engaged, intra- and inter-state infrastructure collaborations managed, and public-private partnerships developed. Member States should plan to train and staff up administrative and specialist staff to manage this logistical burden at the local and national levels. EU offices with oversight over cross-border projects and facilitation should also be sufficiently staffed.

To assess preparedness for a net-zero future, Member States should conduct workforce skill gap analyses for the 2030 and 2050 timeframes, understand potential skills transfers and overlaps from fossil jobs, and incorporate into their NECPs plans to upskill workers and promote workforce development based on these findings. Ideally, these plans would also reflect the EU's ambitions to build a net-zero industrial economy, as proposed in the NZIA.

SECTION 4

Conclusion

The climate, energy, and industrial policies proposed and enacted over the past several years will not alone guarantee a fully decarbonised, energy secure, energy independent, and economically prosperous Europe in 2050. Reaching net-zero in 2050 will require strategic, dedicated, interim planning efforts that provide robust roadmaps for the deployment of a broad suite of decarbonising technologies and infrastructure, funding for emerging technologies, workforce development, regional and international collaboration, and progress tracking and accountability. Comprehensive, forward-looking, and actionable NECPs can fill this planning gap, connecting the dots between the Europe of today and the Europe of 2030, 2040, and 2050.

NECPs should incorporate an options-based climate strategy, promoting investment in emerging clean firm technologies and identifying high value end uses for clean fuels. They should provide certainty to investors and direct funds to innovation, research, development, and deployment for infrastructure and energy technologies where most needed. NECPs should promote more robust analysis and mapping to understand land and environmental impacts of the energy transition and identify and implement win-win strategies to both decarbonise and implement important national and regional agendas. These plans should facilitate regional and international solutions for needed cross-border infrastructure and clean fuels imports. Most critically, NECPs must include implementation frameworks and set up the enabling conditions – community engagement, skilled workforce, accountability at the Member State and EU levels – for success.

The 2023-2024 NECP revision window is a can't miss opportunity to tailor Member State climate and energy strategies, align plans and actions with updated European industrial and economic policies and energy security goals, and ensure these plans are fit for purpose.

Beyond this revision, a more robust, accountable and coordinated governance approach is urgently needed to achieve the EU's climate and energy commitments. The Energy Union's governance relies heavily on voluntary cooperation between Member States, which is a major limit to the effectiveness of its policies. The upcoming review of the Governance Regulation, expected in 2024, is an opportunity to reinforce the rules that govern NECPs – an opportunity that, given the urgency of the climate challenge, must be fully exploited.

Fit for purpose NECPs presented in 2024 will be Europe's ultimate instrument to bring the planning, implementation and coordination pieces of climate and energy policies together and build the carbon-free present and future it desperately needs.

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