ACCELERATING THE FOSSIL GAS TRANSITION TO NET ZERO

Climate Bonds Initiative

Prepared by Climate Bonds Initiative.

Summary

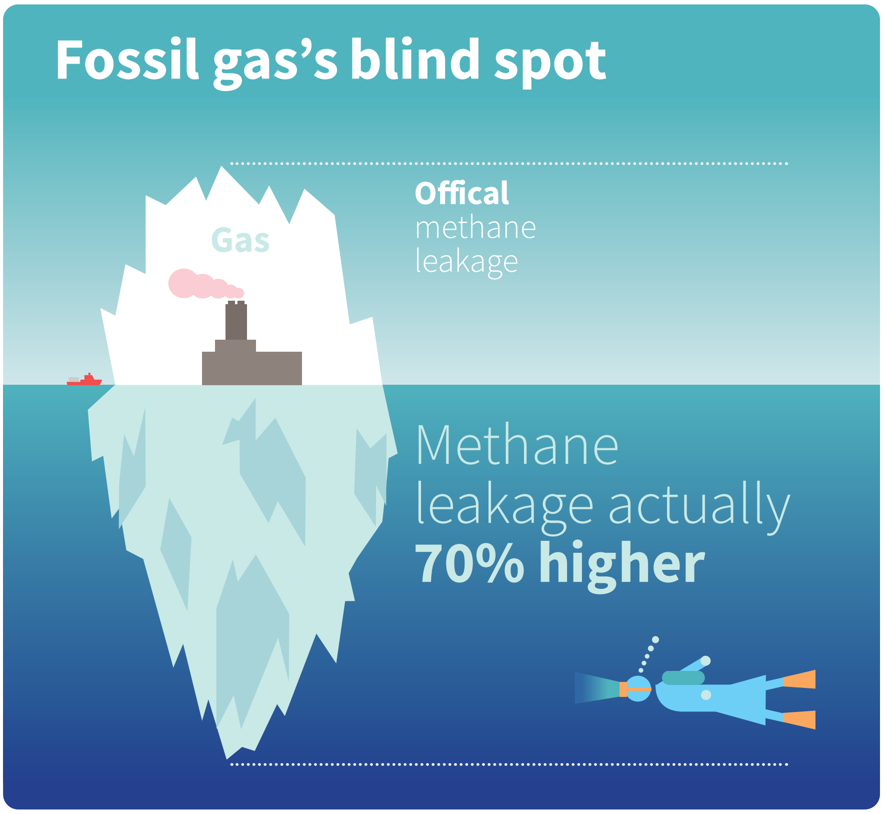
The IPCC has made it clear that if we are to avoid catastrophic climate change and limit global warming to 1.5°C, global carbon emissions must be cut 50% by 2030.

Investment in fossil gas is a threat to achieving the goals of the Paris Agreement. The scientific consensus from the Intergovernmental Panel on Climate Change (IPCC) and International Energy Agency (IEA) is that the global carbon budget to 1.5°C has **no room for new unabated fossil gas infrastructure or assets.** Existing fossil fuel infrastructure will emit more greenhouse gases (GHGs) than this budget without early retirement or reductions in utilisation.[1]

Fossil gas currently accounts for 22% of the EU energy mix, 90% of which is imported, and 50% from Russia.[2]

Fossil gas is mostly methane, a potent greenhouse gas with a global warming potential over 80 times that of carbon dioxide (CO_2) on a 20-year time scale.[3] Just 3% of methane leakage can **increase the carbon intensity of fossil gas-fired power to reach that of a coal-fired power plant**.[4]

Gas has in the past been thought of as a transition fuel. The IPCC and IEA reports and the leakage factors make it clear that it cannot be defined as such. Energy security issues arising from Russia's invasion of Ukraine make the transition away from fossil gas more important than ever.

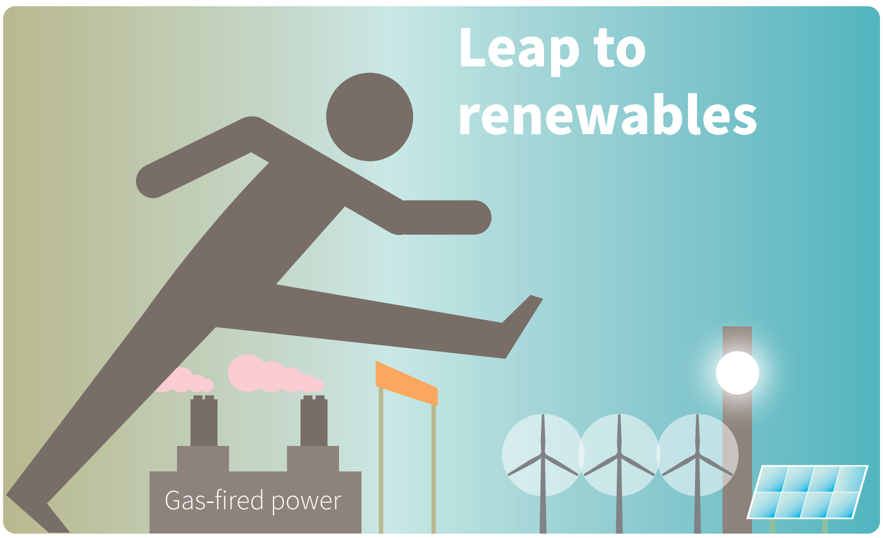


Fossil gas will never be a transition fuel: gas-fired power needs to be removed from the list of transition activities.

Methane emissions from the energy sector are 70% higher than official figures[5] – all fossil gas operations urgently require leakage mitigation. The extent to which this underestimation threatens the energy transition and climate goals calls for a precautionary approach – that **fossil gas operations cannot occur without certainty on leakage**. Full value chain leak detection and reduction technology, alongside full lifecycle assessments of carbon intensity, are critical.

Incremental change will not prevent catastrophic climate change.

The world needs to leapfrog from fossil fuels to renewable energy. The energy transition will be met not with incremental change but with the rapid expansion of renewable energy (RE), energy efficiency gains, and low-carbon hydrogen. This report outlines the opportunity for transformational change in fossil gas power distribution and generation.



Policy tools need to **accelerate** urgent action on methane leakage, alongside efforts to reduce overall demand. Policy will need to guide transition pathways, addressing key risks such as gas blending. These policies can also incorporate social development considerations to help ensure a Just Transition.

Incremental change is not aligned with the need for rapid decarbonisation by 2030. The transition is threatened by the inefficient and regressive strategy of gas blending, from which **a 5% by volume hydrogen blend only displaces 1.6% of fossil gas**. Blending has limited emissions reduction potential, and creates stranded asset risk and cost with the incremental retrofits/ technology replacements required for increasing blending volumes. This can be addressed by policies incentivising transformational rather than incremental change.

Retrofitting gas infrastructure is a **false transition pathway**. As blending is not a viable decarbonisation strategy, the only valid retrofit pathway is repurposing infrastructure for 100% hydrogen distribution. Given the smaller role of hydrogen in the future than fossil gas today and the differing distribution needs retrofit potential is extremely limited.

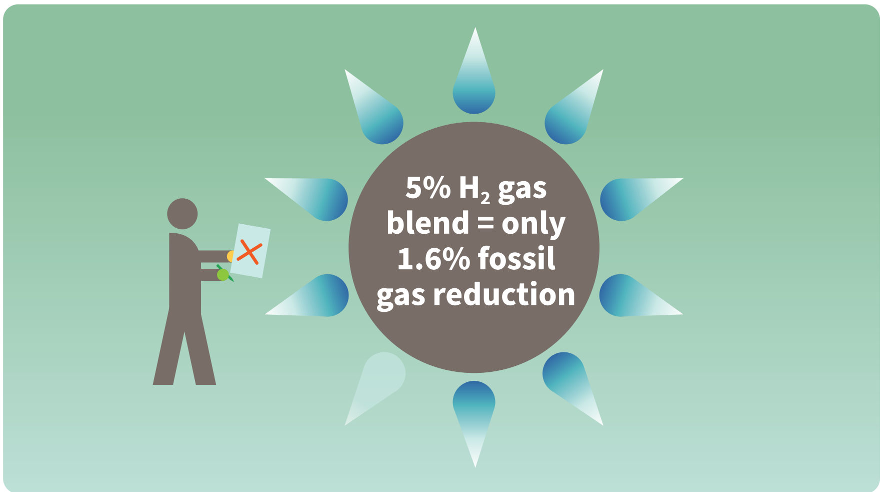
Low-carbon hydrogen provides a transition away from fossil gas in many hard-to-abate sectors.

Even conservative estimates expect hydrogen to grow from 2% to 13-14% of the EU energy mix. This will need rapid scaling of low-carbon hydrogen. Global hydrogen investment 2020-50 could total USD15tn.[6]

The scale of hydrogen project announcements and these projects' predictions of USD1-2/tH_2 prices in 2022 show hydrogen poses a greater opportunity than expected. Policy assistance to hydrogen clusters can further accelerate the growth of the low-carbon hydrogen economy.

Immediate emissions benefits of hydrogen vary significantly from sector to sector. To ensure rapid emissions reductions by 2030, hydrogen use will need to be **prioritised for sectors with the highest emissions reduction potential**. For example, the use of hydrogen in steel production results in 98% emissions reductions,[7] whereas in cement production, hydrogen could only address 1/3 of emissions.[8]

Given the expected scarcity of the resource, hydrogen deployment should be **prioritised** according to both impact and availability of other decarbonisation technologies.



Large-scale installation of grid-connected electrolysers will need to be linked to new renewable energy generation; otherwise they will increase fossil-powered electricity demand, hindering grid decarbonisation – planned electrolysers in the EU RED II would consume 50% of RED II planned renewable electricity supply growth and so **hinder grid decarbonisation**, unless accompanied by new dedicated renewables installations.

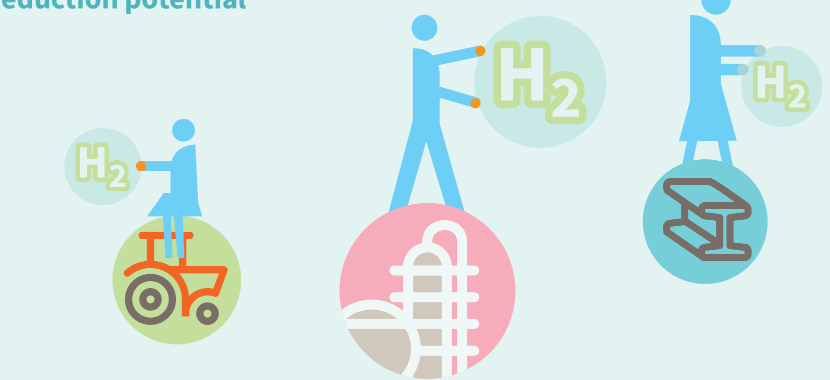
The energy sector needs increased investment and large-scale realignment.

The EU energy transition is estimated to increase investment needs by EUR390bn per year over the next ten years.[9] While the transition investment needs are high so are fossil fuel investment flows, accounting for 45% of global energy investment.

Policymaking can guide the transition, **defining credible technologies** with taxonomies and standards and setting out **pathways** with strategic energy and infrastructure policy. The European Commission's Fit for 55 policy package provides an overview framework for this. This report outlines how to deliver this, accelerate the transition and avoid locking in investments in further fossil gas infrastructure.

Gas-fired power, thanks to dangerous leakage across the system, is no longer a transition fuel and is also an energy security risk for Europe. REPowerEU is a critically important opportunity for the EU to transition away from all fossil fuels.

Hydrogen use will need to be prioritised for sectors with the highest emissions reduction potential



Contents

List of acronyms

bcm billion cubic metres
CBAM Carbon border adjustment mechanism
CCFD Carbon contract for difference
CCGT combined cycle gas turbine
CCS carbon capture and storage
CDA Complementary Delegated Act
CNG compressed natural gas
CO_2 carbon dioxide
CSRD Corporate Sustainability Reporting Directive
DA Delegated Act
DAC direct air capture
DNSH Do no Significant Harm
EBA European Banking Authority
ECB European Central Bank
ESAs European Supervisory Authorities
ESG environmental, social and governance
ESMA European Securities and Markets Authority
ETF exchange-traded fund
ETS emissions trading scheme
ETR environmental tax reform
GFC global financial crisis
GHG greenhouse gas
GPP green public procurement
GVA gross value added
HGV heavy goods vehicle
IEA International Energy Agency
IIGCC Institutional Investors Group on Climate Change
IPCC Intergovernmental Panel on Climate Change
ISSB International Sustainability Standards Board
LCOE levelized cost of energy
LDAR leak detection and reduction
LNG liquified natural gas
LRMC long run marginal cost
MS EU Member State
PCI Projects of Common Interest
PPAs power purchase agreements
PSF Platform on Sustainable Finance
QE quantitative easing
RE renewable energy
RFNBOs Renewable Fuels of Non-Biological Origin
SFDR Sustainable Finance Disclosure Regulation
SMR steam methane reforming
TEN-E Regulation 347/2013 on Trans-European Energy Networks
UNFCCC United Nations Framework Convention on Climate Change
VRE variable renewable energy

1. Introduction

There is growing evidence of the need to aim to limit the rise in global temperatures to 1.5°C to avoid the most catastrophic impacts of climate change. To achieve this limit, all sectors of the economy have to decarbonise rapidly, reducing emissions to net zero by 2050 and achieving significant reductions before 2030, particularly in developed markets. Carbon emissions from now until 2050 need to stay within the global carbon budget. This is the cumulative amount of CO_2 that can be emitted up to 2050 that will keep warming to within 1.5°C and is estimated to run out in just nine years.[10] This is why the 2030 55% emissions reduction is crucial.

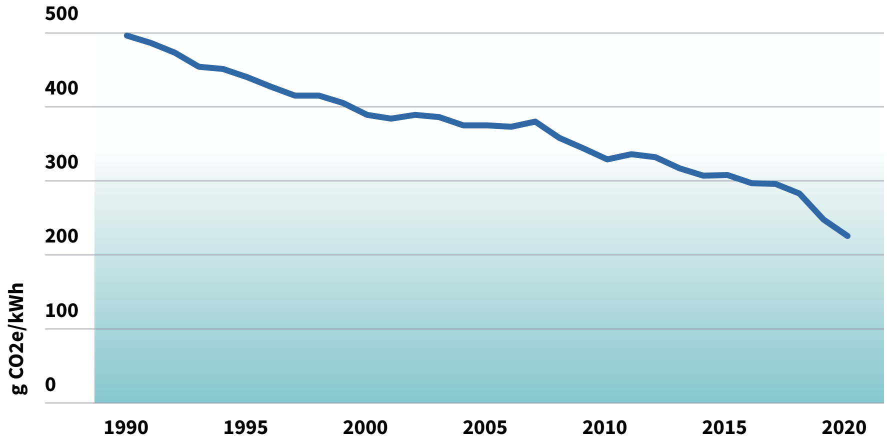
Only a few economic activities operate at or near zero emissions today; most sectors require significant financing, clear guidance, and a framework of supportive policies to facilitate their transition to net zero, particularly "hard to abate" sectors, such as agriculture, chemicals, fossil gas, cement and steel production. Greater attention is now being paid to these hard to abate sectors and detailed decarbonisation plans and pathways are being published, showing that feasible low- / zero-emissions solutions are possible within a reasonable timeframe. The challenge is not only in developing the technology but also in overcoming financial and political barriers.

To date, the European Union has led the way in the race to net zero with the ambitious Green Deal strategy and associated Fit for 55 policy package, yet challenges remain. Ensuring the suite of policies and legislation emerging in the EU to support net-zero transition are coherent and mutually reinforcing. Making finance available to transition all sectors of the economy. Ensuring transition is rapid enough to meet climate targets.

This policy package aims to support the EU in defining the necessary policy framework for financing the fossil gas transition. While primarily focused on the EU context, many policy tools are applicable globally. The decarbonisation pathways used in this package follow the EU's climate targets (2050 net zero and 2030 55% reduction target), the guidance of the Intergovernmental Panel on Climate Change (IPCC), and the 2021 International Energy Agency (IEA) Net Zero Roadmap.

Investing in the transition of the hard to abate sectors is a unique opportunity for the European economy to develop innovative technologies and become a front-runner in the renewable energy economy, paving the way for continued global leadership in industry and technology. Failure to grasp this opportunity and a continuation of business as usual in the energy sector will risk missing the EU's vital climate targets and increase the risk of physical climate-related damage. It will also risk the locking in of billions of Euros of stranded assets and a disorderly and chaotic transition, exposing both the real and financial economy to large transition risks and possible financial crisis.

Figure 1. Carbon intensity of EU electricity production



Energy supply (including fossil gas) accounts for 27% of emissions in the EU.[11] Decarbonising this sector is a key determinant of the success of the whole economic transition. The IPCC and IEA have also made it clear that the global carbon budget to limit warming to 1.5°C has no room for new fossil gas infrastructure and exploration.

While the growth of renewable energy has seen large success in recent years and carbon intensity of electricity generation has halved from 1990 to reach 230.7g C02e/kWh in 2020[12], challenges remain in transitioning the entire sector to net zero, particularly in areas where fossil energy supply cannot be easily substituted with electricity. This policy package focuses on the transition of the fossil gas and hydrogen sectors. These are combined due to interlinkages between the hydrogen and fossil gas transition pathways and associated policies. Many fossil gas applications can be replaced by renewables and electrification, such as power generation and heating and cooling. Certain uses will likely be better decarbonised with low-carbon hydrogen, such as industrial high-grade heat and chemical feedstocks.

Climate Bonds Initiative has embarked on an ambitious Transition Programme designed to provide the industrial pathways, sustainable finance standards, policies and investment guidance needed to deliver credible transition in the hard to abate sectors. Now that the technical pathways and standards are emerging to provide clear guidance for the actions industry needs to take, the next step is to facilitate the flow of finance to deliver these actions and decarbonise the sector. This **fossil gas and hydrogen sector transition policy paper** is part of a series focused on the policies and regulations needed in the European Union to facilitate the flow of finance necessary for the transition.

These policies will be complemented by the Climate Bonds sustainable finance criteria for the hydrogen sector and fossil gas sector, which will be released in 2022 and 2023.

This paper aims to address the following key question:

How can the EU policy and sustainable finance frameworks accelerate the fossil gas value chain transition to net zero, in the most economically efficient way and without compromising the transition pathways of other sectors?

Section 2 summarises the current European fossil gas and hydrogen sectors in terms of size, emissions contribution, technologies and investment flows. It also assesses the investment needs of the EU fossil gas transition.

Section 3 examines how policymakers can help ensure the credibility of this transition, drawing on existing EU policy and strategies and suggesting specific recommendations on how these might best deliver a credible transition. Section 4 establishes how policymakers can accelerate emissions reduction in the fossil gas sector. The growth of the low-carbon hydrogen economy is considered in Section 5, with measures suggested to maximise its potential in the net-zero transition.

The policies outlined in sections 2-5 will require capital availability. Section 6 suggests a range of ways that investment flows may be channelled to the transition by government, central bank, or regulator action.

Sections 3-6 are followed by summary policy recommendations.

1.1 Methodology

This policy package is based on analysis of existing EU policies and a review of literature relating to energy transition policy. It is accompanied by an assessment of the European fossil gas and hydrogen sectors, including a summary of the technologies. Sector and technology information is based on the Hydrogen Council's 2021 'Hydrogen Insights: A perspective on hydrogen investment, market development and cost competitiveness',[13] the IEA 'World Energy Investment 2021'[14] and Eurostat data.

EU policies relevant to the sectoral transition were identified and analysed against the Climate Bonds Credible Transition Principles, see Figure 2, and the decarbonisation pathway set out by the IEA, to assess their sufficiency in facilitating the sector's transition. Particular attention was paid to the Fit for 55 policy package which aims to deliver rapid decarbonisation in the next decade, the Taxonomy Regulation and associated Delegated Acts, and the plans proposed in REPowerEU.

The policy suggestions are also informed by literature review. Key literature on the need to decarbonise the sector are the IPCC's Assessment Reports and the IEA's World Energy Outlook, Methane Report, etc. EU policy analysis is supported by analysis from Bellona, Agora Energiewende, WWF and the EU Platform on Sustainable Finance.[15] Key literature informing policy recommendations include the Energy Transition Commission's 2021 'Making the Hydrogen Economy Possible: Accelerating clean hydrogen in an electrified economy',[16] the Hydrogen Council 2020 'Path to hydrogen competitiveness: a cost perspective'[17], E3G's Hydrogen Factsheets,[18] IIGCC's Net Zero Standard for Oil and Gas companies.[19]

The paper is supported by extensive stakeholder analysis. This analysis identifies vested interests, assessing key stakeholders' views and commitments on the energy transition. The results of this analysis are summarised in Appendix III.

Figure 2. Climate Bonds Principles for a Credible Transition

1. In line with 1.5 degree trajectory. All goals and pathways need to align with zero carbon by 2050 and nearly halving emissions by 2030.

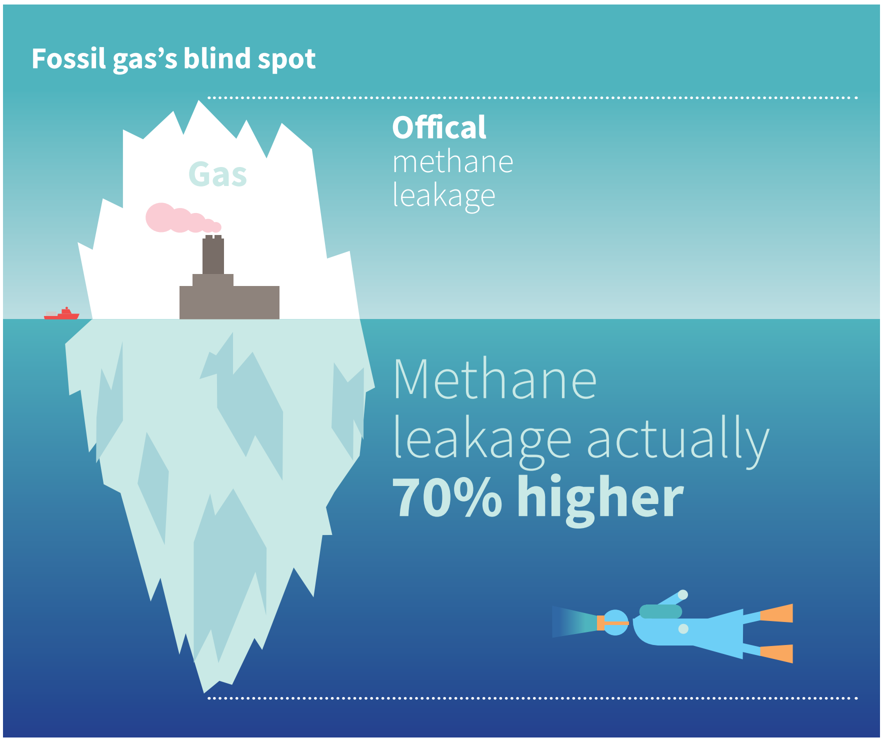
2. Established by science. All goals and pathways must be led by scientific experts and be harmonised across countries.

3. Offsets don't count. Credible transition goals and pathways don't count offsets, but should count upstream Scope 3 emissions.

4. Technological viability trumps economic competitiveness. Pathways must include an assessment of current and expected technologies. Where a viable technology exists, even if relatively expensive, it should be used to determine the decarbonisation pathway for that economic activity.

5. Action not pledges. A credible transition is backed by operating metrics rather than a commitment/pledge to follow a transition pathway at some point in the future. In other words, this is NOT a transition to a transition.

2. Fossil gas dominance in the energy mix



Fossil gas accounts for a large proportion of the EU energy and electricity mix. Fossil gas power plants are the European Union's largest single source of CO_2 emissions from energy, at 231 Mt CO_2/year.[20] In addition, methane emissions from the fossil gas value chain due to EU imports are estimated to be 308-691 Mt CO_2e/year.[21] Including these fugitive methane emissions significantly increases fossil gas carbon intensity, further precluding its expansion as a transition fuel. Leakage estimates are massively underreported; methane emissions from the energy sector are 70% higher than official figures.[22]

The EU fossil gas industry is highly dependent on imports and so is vulnerable to supply and price shocks. Decarbonisation targets mean EU fossil gas consumption should decrease 32–37% by 2030.[23] This puts new fossil gas infrastructure at risk of stranding. One option for reducing fossil gas emissions is using a different energy vector, hydrogen. However, 'hydrogen-ready' infrastructure will also hold investment risk given the expected differences in distribution requirements of the two end uses.

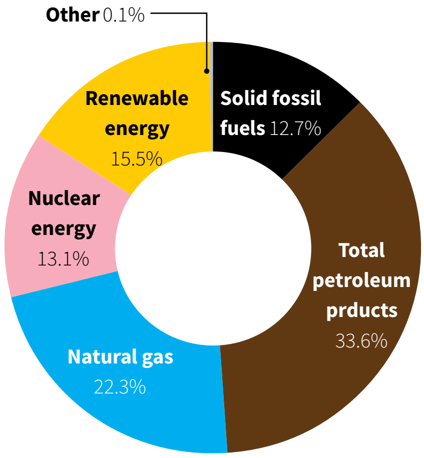
Hydrogen production is currently mostly fossil-based, providing industrial feedstocks. Low-carbon hydrogen production is a fast-growing industry, with many commercial-scale projects being initiated globally. Low-carbon hydrogen investment needs rapid scaling to enable the decarbonisation of many energy-intensive industries. Green hydrogen is expected to rapidly reach cost parity with fossil hydrogen production, however, current CAPEX costs reduce the attractiveness of investment – policymakers can help to channel private finance flows into this nascent sector. Investment flows are needed not only to finance green projects but also to help manage down emissions intensities of fossil fuel companies.

2.1 Scale of the fossil gas and hydrogen sectors

The EU energy mix[24] in 2019 was 36% petroleum products, 22% fossil gas, 15% renewable energy, 13% nuclear and 13% solid fossil fuels.[25] The electricity mix, in comparison, has higher renewables penetration; 2020 saw renewables overtake fossil fuels as the EU's largest power source for the first time – generating 38% of electricity, compared to 37% fossil fuels.[26]

Total consumption of **fossil gas** was 379.9 billion cubic meters (bcm) in 2020,[27] of which nearly 90% (2019) is imported, 50% from Russia,[28] followed by Norway at 24% and Algeria at 10%.[29] Fossil gas is used in electricity generation (20%[30]), heating (primary energy source in buildings), industry (chemical feedstocks and heat) and transport (compressed (CNG) or liquified (LNG)). Germany

Figure 3. EU energy mix 2019[71]



is the largest fossil gas consumer, followed by Italy and France.[31]

The value added from fossil gas extraction is EUR6.5bn/year, from manufacture and distribution EUR21.8bn/year, while hydrogen manufacture's value added is EUR3.8bn/year.[32]

EU **hydrogen** production totalled 14 bcm in 2020,[33] 64% of which is captive hydrogen, produced on site of use. Production is mostly small-scale, fossil-based specialist production with very high greenhouse gas (GHG) emissions per tonne of production (9.3 tonnes of CO_2 per tonne of hydrogen, or 280 gCO_2/KWh direct emissions from production).[34] Usage is mainly industrial, in fertiliser production, oil refining, and chemical feedstocks (75% crude oil refining and ammonia and methanol synthesis).

Hydrogen is expected to fulfil a much larger role in the future EU energy mix, growing from 2 to 13-14% of the mix in 2050, bridging the gap where renewable electricity is unable to replace fossil fuels. Europe currently uses 339 TWh of hydrogen a year, with use expected to increase to 667-4000 TWh in 2050.[35] New potential applications for hydrogen include renewable energy storage, mobility, and industrial high-grade heat.

2.2 New evidence reveals true emissions of fossil gas

EU fossil gas power plants produced 231 Mt of **direct** CO_2 emissions in 2020, overtaking lignite coal plants to become the EU's largest single source of emissions from energy.[36] The direct GHG emissions intensity of gas-fired power plants varies widely, from over 600 gCO_2e/kWh to 365 gCO_2e/kWh in the most efficient combined cycle gas turbine (CCGT) plants.[37] However, these numbers do not incorporate life cycle emissions of fossil gas production supply chains. Increasing

Increasing evidence shows that the level of greenhouse gas emissions from fossil gas-fired power generation are close to those of coal power emissions due to methane leakage along the extraction and distribution supply chain.

evidence shows that greenhouse gas emissions from fossil gas-fired power generation are much closer to coal power emissions due to methane emissions in extraction and distribution. The leakages of methane along the supply chain, despite being small percentages (1-5%), still have a significant climate impact due to methane being a much more potent greenhouse gas than CO_2. Methane is shorter-lived in the atmosphere than CO_2 but has a global warming potential (GWP) 82.5 times greater over a 20-year time horizon, and a GWP of 29.8 on a 100-year scale.[38]

Ice core analysis has demonstrated that anthropogenic methane emissions have been underestimated by 25-40%.[39] Underreporting of methane leakage has led to an underestimation of fossil gas's climate impact. **Methane emissions from the energy sector are 70% higher than official figures**.[40] Methane leakage is a growing concern, with atmospheric concentrations rising by record amounts over the last two years.[41]

While upstream companies do have an incentive to address leakage, posed by loss of revenue, this is estimated to be only 1/10th of the environmental cost of the leak.[42] The majority of emissions also come from a very small number of leaks, with 5% of leaks contributing 50% emissions globally.[43] Increasing evidence from satellite imagery and infrared imaging shows unreported methane leakages from pipelines in Europe. Therefore, improvements in management are required to provide continuous supply chain leak detection and reduction (LDAR) are required.

With 90% fossil gas imported from outside the EU, estimates suggest less than a fifth of fossil gas consumption methane emissions occur within its borders. **Fossil gas methane emissions within EU borders are estimated to be 76 Mt CO_2e, and emissions outside the borders are estimated to be 232-615 Mt CO_2e**, with the lower estimate calculated from national inventories, and the higher from the research of value chain emissions factors.[44]

One literature review estimates upstream (including transport) fossil gas GHG emissions in the EU to be between 9.72 and 118.08g CO_2 e/kWh.[45] With average direct emissions from EU electricity plants at 270g CO_2/kWh, upstream emissions are a significant element of the sector's climate forcing.

Pipeline emissions may be bringing carbon intensity of fossil gas generation higher than coal generation. However, challenges with monitoring pipeline leakage, particularly in Russia – Europe's major gas exporter, mean there is considerable uncertainty over leakage levels.

2.3The fossil gas value chain presents challenges for transition

The fossil gas industry incorporates various actors and technologies across extraction, transmission, distribution and consumption (see Figure 4). This increases the complexity of its transition, as all these elements must be accounted for in transition policymaking. Nealy 90% of EU fossil gas consumption is met by imports, delivered via pipelines, or shipped under compression (CNG) or liquified (LNG).

Fossil gas infrastructure includes extractive infrastructure, processing and compression plants, pipelines for transmission and distribution, combustion plants and other end-use infrastructure.

Currently emissions reduction measures in this sector focus mainly on reducing fugitive emissions in the pipeline by improving LDAR, reducing venting and flaring, and development of carbon capture and storage (CCS) technologies at power plants. These technologies are yet to reach net-zero alignment, but fugitive emissions reduction efforts will require significant growth to deliver rapid emissions reductions in existing infrastructure.

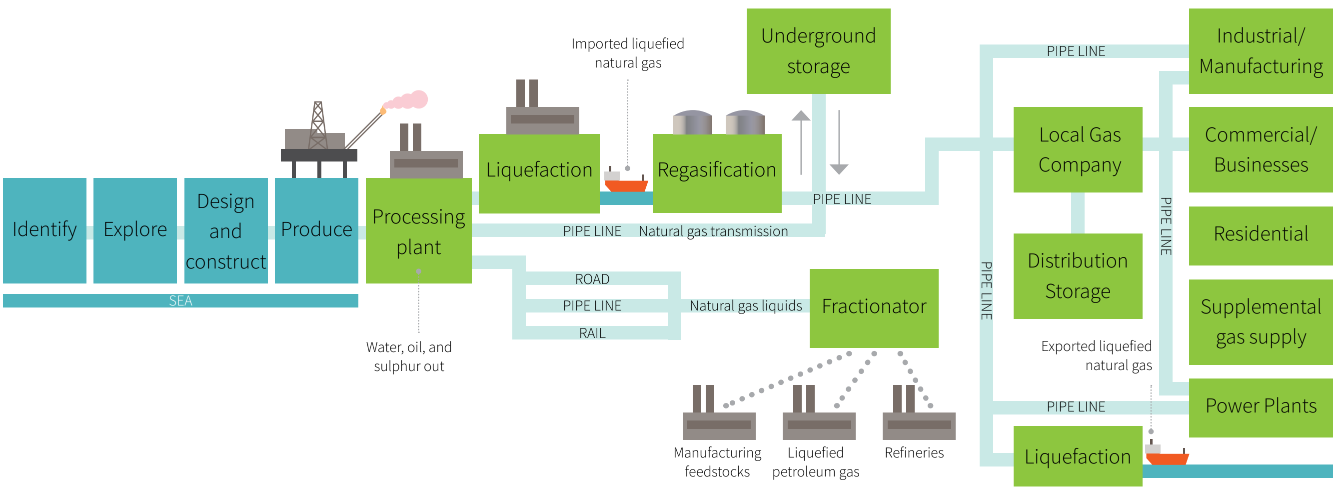
This infrastructure is exposed to asset stranding risk as EU fossil gas consumption is wound down. Given current EU fossil gas overcapacity, new fossil gas infrastructure presents a high investment risk.[46]

The declining role of fossil gas in the EU energy mix has led to growth of plans for 'hydrogen-ready' or retrofit of fossil gas infrastructure. However, even 'hydrogen-ready' infrastructure poses investment risks as hydrogen and fossil gas differ significantly in the geographical location of demand and supply, and estimates of future demand and supply patterns vary. 'Hydrogen-ready' infrastructure will also often still require retrofit to carry hydrogen. While many elements of the fossil gas value chain can be retrofitted for the hydrogen economy, the volume of gas being produced, distributed and stored will be much smaller in a net-zero economy. Early retirement may well prove the most cost-effective decarbonisation strategy for much of the fossil gas infrastructure.

2.4 Net zero-aligned low-carbon hydrogen production

Hydrogen (H_2) production is currently dominated by fossil-based production, accounting for 95% production, this leads to nine to 12 tonnes of CO_2 emitted for every tonne of H_2 produced.[47] Electrolysis accounts for 5% of production. The current hydrogen economy is also very small and so requires both decarbonisation and scaling to meet the expected 2030 demand for low-carbon hydrogen. The EU Hydrogen Strategy aims to grow EU green hydrogen electrolyser capacity from below 1 GW to 40 GW in 2030. The transition requires huge investments in electrolysers, renewable electricity production and distribution, and extremely robust source of origin certification to prevent high-carbon hydrogen from entering the supply chain.

Figure 4: Conceptual diagram of the fossil gas value chain



Box 1: The rainbow of hydrogen production technologies

Grey hydrogen, referred to as fossil-based hydrogen in the Commission's hydrogen strategy, is produced via steam methane reforming (SMR) or oil/coal gasification. Carbon intensity of steam methane reforming is 222-325 gCO_2e/kWh.[72]

Hydrogen from coal gasification can also be referred to as brown (from lignite) or black (from black coal).

Blue hydrogen: grey production with carbon capture and storage (CCS). Retrofitting SMR plants with CCS can rapidly reduce emissions from current production and meet demand while green hydrogen production and storage capacity ramp up.

There are also emissions associated with the fossil gas supply – upstream leakage rates must also be included in emissions intensity. Leakage rates are difficult to estimate, given a lack of monitoring, but are estimated to be 0.5-4.1% of supply. Given methane's far higher greenhouse potency than CO2, this increases the carbon intensity of grey and blue hydrogen production; at a 1.5% leakage estimate, this equates to 3t CO_2e/tH_2.[73]

For blue hydrogen to meet carbon intensity thresholds, it requires high levels of CCS and effective methane leak detection and mitigation. CCS efficiency is expected to reach 85-95% efficiency but is currently much lower. Blue hydrogen's average emissions intensity is 143-218g CO_2e/kWh.[74]

Green or renewable hydrogen is produced from renewable electricity-fuelled electrolysis of water. Electricity is used to split water molecules into hydrogen and oxygen. The conversion process entails a 30% loss of energy.[75]

Green hydrogen production from electrolysis does not directly emit any GHGs as long as the electricity inputted is renewable, although electrolyser production will entail a level of lifecycle GHG emissions. Electrolysers are often directly connected to a dedicated wind or solar installation. Electrolysers run directly off the grid would produce relatively high emissions-intensive hydrogen: electricity emissions intensity need to be lower than 190g CO_2e/kWh for the hydrogen to have lower overall CO_2 emissions than grey.[76] However, as decarbonisation of the grid progresses, grid-based electrolysers are expected to become increasingly common, playing a potential balancing role to manage demand in the face of variable renewable supply. Electrolytic hydrogen technology costs are assessed in Appendix II.

Pink hydrogen is also electrolytic hydrogen, but the electrolysers are powered by nuclear energy. Due to the low carbon intensity of nuclear energy, pink hydrogen is also very low carbon. Nuclear's ability to run electrolysers continuously means this could help rapidly scale the hydrogen economy.

This report uses the EU Taxonomy criteria as the threshold for '**low-carbon hydrogen**'. The criteria require life-cycle GHG emissions lower than 3t CO_2e/tH_2 from blue or green production (see Box 1 for an explanation of definitions). Electrolysis would require electricity with carbon intensity of 45g CO_2e/kWh to meet this. For blue hydrogen production to achieve this, it will require >90% CCS and <0.5% upstream leakage.[48]

Green hydrogen is most competitive in areas of abundant renewable energy; this competitive advantage of certain geographical locations can be considered alongside demand locations and transportation methods and costs when scaling the hydrogen economy. Elevated fossil gas prices may already have pushed grey hydrogen prices higher than green.[49] Green hydrogen is currently undergoing rapid price decline, as RE costs continue to fall and the cost of electrolysers decreases with scaling of production. The EU Hydrogen Strategy uses a 2030 green hydrogen price of USD1.1-2.4 and USD2-2.5 for blue hydrogen.[50] However, these predictions are likely highly conservative. Europe's largest green hydrogen project, HyDeal, is finalizing commercial offtake agreements with ArcelorMittal and fertilizer company Fertiberia of USD1.75-2/kg.[51] Adani Group stated that they plan to start producing green hydrogen in 2022 at about USD1.50/kg, reaching **USD0.97/kgH_2** as production scales over 3-5 years.[52]

Low-carbon hydrogen will likely still not be competitive with fossil fuels without high carbon pricing in many applications. Even with green hydrogen costing USD1/kg, green ammonia for ships would cost 55% more than heavy fuel oil and synthetic fuel would cost 65% more than conventional jet fuel.[53]

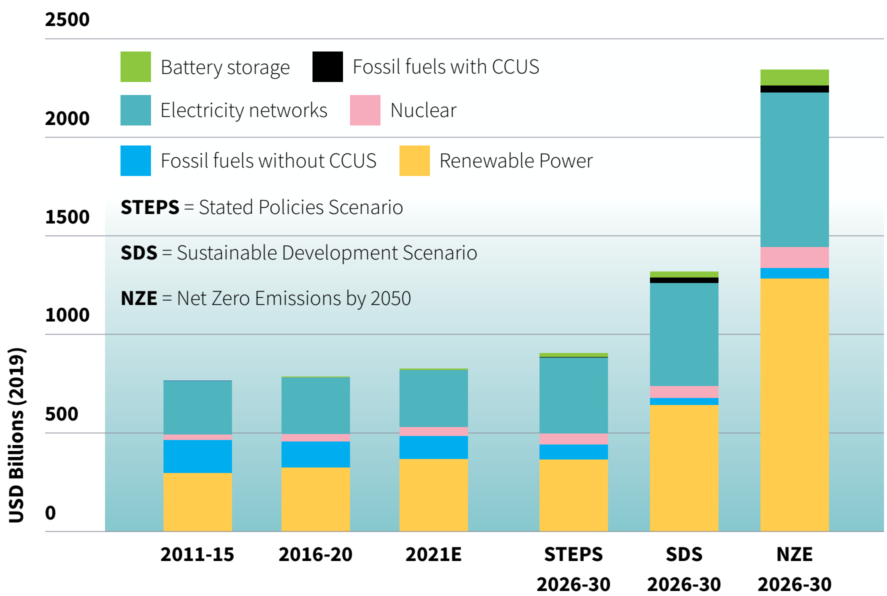
Carbon pricing will be required to close the cost gap. In some industries, this may already be possible. For example, recent project announcements suggest competitive green steel production this decade.[54] Additionally, the use of green hydrogen translates to a negligible impact on final product prices, resulting in a trivial 'green consumer premium' except in aviation.[55]

Currently, at least 2,100 hours of electrolyser operation are needed for competitive hydrogen production cost (for feedstock production), but the high cost of some end products, such as transportation fuel, makes electrolysis a viable option for such end uses.[56]

2.5 Investment flows required for the transition

The EU energy transition will increase energy investment needs by EUR390bn per year over the next ten years compared to the average annual investment of the last decade.[57] In Europe, investment in the electricity sector is expected to increase, but the rate of this increase needs to accelerate to meet the requirements of transition. There is a large need for increased investment in renewable generation, transmission and storage for direct

Figure 5. Global investment in the electricity sector compared with annual average investment needs, 2026-30, by scenario[77]



electrification of appropriate infrastructure and in electrolysers). Existing infrastructure also requires modification; grey hydrogen production facilities need transformation to low-carbon hydrogen production. Investment can also be used to transform the fossil gas sector – rather than stranding this entire EUR28.3bn/year industry,[58] transformation of infrastructure, workforce, expertise and other assets can minimise financial losses whilst substantially contributing to the economic transition.

The gross value added (GVA)[59] of the EU clean energy sector has seen average annual growth of 5% since 2010 and reached EUR133bn in 2018.[60] However, this growth needs to accelerate and be accompanied by a decline in fossil fuel production and use. Phase-out of fossil fuel-fired power generation, and increasing electrification will require a large increase in investment in the electricity sector. Figure 5 shows the scale of this requirement.

Fossil fuels currently account for 45% of global energy supply investment,[61] capturing and redeploying these investment flows is crucial to enabling transition. Investment flows need to be redirected from fossil fuel processes to clean energy processes. These flows also need to be directed towards nascent and developing technologies, such as electrolysers, that are crucial to the green energy transition rather than being captured by the most profitable technologies. Investment needs are also complex as the fossil gas companies still require investment to make the transformational changes to become green energy companies. This provides opportunities for sustainability-linked bonds or other KPI-linked financing. Investors will need to identify whether such KPIs and transition strategies are robust and credible.[62]

The EU Hydrogen Strategy, adopted in 2020, plans investment in 80 GW of electrolysers (in the EU and EU Neighbourhood) by 2030 to grow the share of hydrogen in the energy mix from less than 2% to 13-14% by 2050. It projects **cumulative investment in green hydrogen of EUR180-470bn by 2050** and EUR3-18bn in blue, including retrofitting existing SMR plants with CCS.[63] The size of the 2050 hydrogen industry is estimated at USD2.5trn sales of hydrogen and equipment.[64] The Strategy estimates EUR24-42bn investments in electrolysers, EUR220-340bn to provide the necessary additional renewable electricity, and EUR65bn investment for hydrogen transport, distribution and storage, from now to 2030.[65]

Figure 6. EU wholesale gas prices, Dutch TTF, EUR/MWh[78]

Demand for green investment products currently outstrips supply, as demonstrated by the *greenium*[66] seen on many green bonds compared to their vanilla equivalents.[67] Investors are attracted to renewables not only for low carbon credentials and lower transition risk exposure but also their performance. Recent years low-yield environment linked to central banks' quantitative easing programmes and the post-covid stimulus packages are favourable to long-term investments. Renewable power companies show lower volatility and outperform both listed fossil fuel companies and public equity market indices (10-year global market return of 422.7%, compared to 59.0% for fossil fuels).[68]

Fossil gas investment is becoming increasingly unattractive

Fossil gas-powered electricity generation is becoming non-cost competitive with renewable energy. Median levelised cost of energy (LCOE) of fossil gas CCGT power was USD71/MWh in 2020, while onshore wind LCOE was USD50/MWh and solar PV USD56/MWh.[69] Recent EU gas price volatility has increased the gap with renewables, with wholesale prices surging to EUR180/MWh in December 2021 and EUR227/MWh in March 2022. In a year, the price of fossil gas has surged from EUR19/MWh to EUR115/MWh on 1 April 2022, see Figure 6.

Over 20% of fossil gas plants in Europe are now lossmaking and, in the US, new onshore wind and solar investment options already cheaper than the continued operation of existing gas plants. Carbon Tracker projects the costs for both renewable technologies will fall to levels less than half the long run marginal cost (LRMC) for gas by 2030.[70]

3. Ensuring a credible transition

Alongside measures to disincentivise high-emitting and incentivise low-emitting activities, the transition of the fossil gas sector requires significant guidance to ensure transition investments are aligned with the 1.5°C trajectory and are economically feasible. This is vital to ensure the success of the transition and to generate investor confidence.

Presented in December 2019, the **European Green Deal** sets out a roadmap for the EU to achieve climate neutrality by 2050, decouple economic growth from resource use and achieve a just transition.[79] In the framework of the Green Deal, the European Commission has also announced a **renewed sustainable finance strategy**, to lay out the policies needed to finance the transition of EU economic activities towards climate neutrality while ensuring recovery from the COVID-19 crisis. This strategy aims to create the regulatory framework to channel both public and private sectors' investments into sustainable activities.[80] One-third of the EUR1.8tn investments from the Next Generation EU Recovery Plan and the EU's seven-year budget will finance the European Green Deal.

The **'Fit for 55' policy proposal** is an interconnected set of policies to deliver the Green Deal, aimed at transformational change of economy, society and industry. The package strengthens eight existing pieces of legislation and presents five new initiatives across a range of policy areas and sectors: climate, energy and fuels, transport, buildings, land use and forestry.[81]

The ambition of the Fit for 55 proposals are expected to be strengthened by the REPowerEU plans; as the Commission seeks to accelerate energy sector decarbonisation as part of efforts to curtail reliance on Russian fossil gas.[82]

The EU sustainable finance framework consists of the EU taxonomy, disclosure regime and investment tools. Disclosure requirements include the impact of a company's activities on the environment and society and the business and financial risks faced by a company due to its sustainability exposures (the 'double materiality' concept). These are complemented by a set of investment tools to enable financial market participants to align their investment strategies with the EU's climate and environmental goals and provide greater transparency to market participants. These include the EU Climate Transition Benchmarks and the EU Paris-aligned Benchmarks,[83] and the legislative proposal for a European green bond standard, intended to create a high-quality voluntary standard to help issuers attract sustainable investments.[84]

Table 1: Components of the 'Fit for 55' proposal

Pricing	Targets	Rules
ETS with aviation	Effort Sharing Regulation	Stricter CO2 for vehicles
ETS extension to include maritime, road transport and buildings	LULUCF Regulation	Alternative Fuels Infrastructure
Energy Taxation Directive	Renewable Energy Directive	ReFuelEU
Carbon Border Adjustment Mechanism	Energy Efficiency Directive	FuelEU
Support measures		
Social Climate Fund		

Table 2: EU Sustainability Disclosure Regime for financial and non-financial companies[134]

Instrument	Corporate Sustainability Reporting Directive (CSRD) proposal	Sustainable Finance Disclosure Regulation (EU) 2019/2088	Taxonomy Regulation (EU) 2020/852
Scope	All EU large companies and all listed companies (except listed micro enterprises)	Financial market participants offering investment products, and financial advisers	Financial market participants; all companies subject to CSRD
Disclosure	Report on the basis of formal reporting standards, subject to external audit	Entity and product level, on sustainability risks and principal adverse impacts	Turnover, capex, and opex from products or activities associated with Taxonomy
Status	Under negotiation, expected to apply from 2023	Applies from 10 March 2021	Applies from January 2022

Policies to guide green investment

Institutional investors are increasingly voicing their support for action to address climate change.[85] However, there are still too few tools to help ensure that their investments are making a significant impact, particularly for debt-based investments. The market needs transparent and robust science-driven guidance on which assets and activities are consistent with a rapid transition to a low-carbon economy. Taxonomies have been designed to address this need and easily identify the assets, activities and projects needed to deliver a low carbon economy in line with the goals of the Paris Agreement.

The EU sustainable finance strategy is underpinned by the sustainability reporting regime of the Non-financial Reporting Directive (NFRD) (soon to be replaced by the Corporate Sustainability Reporting Directive (CSRD)), the Sustainable Finance Disclosure Regulation (SFRD) and the Taxonomy Regulation and Delegated Acts. Mandatory disclosure of climate risks is an important prudential tool and can facilitate information sharing between the real and financial economy; CSRD reporting is designed to inform SFDR reporting. Central banks and supervisors are seeing increasing demand for mandatory disclosure regimes, especially from investors who are highly aware of the risks posed by lack of visibility of portfolios' climate exposure and impact.[86]

Taxonomies provide clear guidance to investors on what constitutes a green activity for investment and to bond issuers on the eligible use of proceeds for green bond issuance. Taxonomies can also underly climate credit risk assessment: an organisation's exposure to climate risk depends on the carbon-dependency, location and physical resilience of their assets. The **Climate Bonds Taxonomy** can be used by

Figure 7. Taxonomy development around the world

any entity to identify which assets, activities and associated financial instruments are compatible with trajectory to net zero by 2050.[87]

National taxonomy developers increasingly recognise the value of alignment and interoperability in enabling international investment flows. EU Climate Diplomacy can encourage this and hold other countries to a high standard to safeguard the global transition, possibly leveraging the IPSF **Common Ground Taxonomy**.[88]

Taxonomies can also be used to assess what constitutes a credible transition investment or activity. Climate Bonds Criteria are being developed for the transition of hard-to-abate sectors. The work of the EU Platform on Sustainable Finance (PSF) on extending the Taxonomy to cover negative and low impact activities[89] is expected to inform assessments of companies' or activities' position on the transition pathway.

Ensuring a science-based EU Taxonomy

In 2016, the European Commission accepted a recommendation by the EU High-level Expert Group on Sustainable Finance to develop an **EU Sustainable Finance Taxonomy**. Its development has been supported by the work of the Technical Expert Group (TEG), and its successor, the Platform on Sustainable Finance (PSF). The Taxonomy Regulation entered into force in July 2020, with the first Delegated Act, covering climate change mitigation and adaptation activities, entering into force on 1 January 2022. The EU Taxonomy has been developed as part of the wider EU Sustainable Finance Strategy and its primary use is to support mandatory disclosure of sustainable investments and assets by investors, banks, and corporates in the EU.

The Taxonomy will eventually provide criteria for activities' contribution to six environmental objectives, covering sustainable water use, circular economy, pollution prevention and biodiversity in addition to climate mitigation and adaptation. The Commission is also considering extending the scope of the Taxonomy to cover significantly harmful and low impact activities and to cover social issues. This will be informed by the work of the PSF.[90]

Agreeing on standardised criteria for high-emitting activities is a fundamental step in guiding investors to invest in credible transition activity, asset owners' engagement and policymakers to incentivise the transition. Criteria can be utilised by governments in setting regulations or recommendations for decarbonising the sector. The EU Taxonomy is particularly relevant because it will ensure that investments falling under its criteria will be eligible for green bonds under the EU Green Bond Standard. As the EU Taxonomy lays out long-term standards, it also serves the purpose of encouraging investment in innovative technologies and transition-friendly investments: a critical issue for "hard-to-abate" sectors such as the steel industry.[91]

The Complementary Delegated Act on fossil gas and nuclear energy threatens the Taxonomy's credibility

The EU Taxonomy's criteria for electricity and hydrogen generation and infrastructure are scientifically credible. However, on 9 March 2022, the Commission adopted a Complementary Delegated Act (CDA) proposing criteria for fossil gas and nuclear power as green transition. The criteria for fossil gas-fired electricity introduce weaker thresholds than those established by the first DA on sustainable activities for climate change adaptation and mitigation objectives.

While limiting production and use, it covers plants permitted up to the end of 2030 – this could lead to stranded assets and increased loss and damage from climate change.

The CDA describes the need to recognise that fossil gas and nuclear energy can contribute to EU decarbonisation, stating that the use of fossil gas in electricity generation, CHP and district heating/cooling "should be qualified as transitional … given that renewable energies that comply with the appropriate threshold are not yet commercially available at a sufficient scale". However, wind and solar technologies are now mature and scalable – this justification does not stand for electricity generation.

The CDA introduces two different sets of criteria for fossil gas activities. While the first (1)(a) is in line with the 1st DA's significant contribution criteria on climate mitigation, the second (1)(b) introduce weaker criteria for facilities permitted by 31 December 2030. Criteria (1)(b) establish thresholds of direct GHG emissions lower than 270g CO_2e/kWh of the output energy or annual GHG emissions of the activity below an average of 550kg CO_2e/kW of the output energy of the facility's capacity over 20 years.

The 270g threshold matches the *Do no Significant Harm* (DNSH) requirements of the Taxonomy Regulation and reflects the average emissions intensity of EU power generation. However, as this covers direct emissions, not full lifecycle, fugitive methane emissions that would be unaccounted for in these plants would bring the emissions intensity far higher than 270g CO_2e/kWh, consequently doing significant harm to the principle (2) of Climate change mitigation.

The use of the 2030 end date for permitting would expose investors to a high level of stranded asset risk, given the 25-30 year lifetimes of EU plants would mean they were in operation beyond the 2050 carbon neutrality target. Similarly, caveats requiring plans for the plant to switch to renewable or low-carbon gases by 2035 could also lead to asset stranding, given the uncertainties around the role of hydrogen in electricity generation.

The criteria introduced in the CDA threaten the usability and credibility of the Taxonomy and pose a threat to the EU energy transition. Approving the CDA would risk locking the EU into a high carbon trajectory incompatible with its climate targets. If MEPs reject the CDA, this gives the Commission an opportunity to redraft Paris-aligned transition criteria for the sector.

Transparency obligations encouraging green

The **SFDR**[92] lays out sustainability disclosure obligations for financial market participants. It was introduced to prevent fragmented development of disclosure measures and reduce information asymmetries across financial products and regions, possible market inefficiencies and competition distortion. The Regulation updates fiduciary duty requirements; growing evidence of climate risk materiality to investment portfolios means due diligence to clients now includes sustainability risks alongside traditional financial risks. The SFDR importantly considers double materiality – the impact of investments on sustainability factors and the impact of sustainability factors on investments.

Level 1, entity-level requirements became effective as of 01/03/2021. These require disclosure of sustainability risk exposure, integration and management policies and explanation when they deem sustainability risks not to be relevant. Application of level 2, product-level requirements has been delayed to 01/01/2023.[93]

The SFDR classifies funds into three strategies for product-level disclosures; Article 6 funds do not incorporate any sustainability considerations into the investment process, Article 8 funds promote certain environmental or social characteristics (light green), and Article 9 funds target sustainable investments (dark green). Article 8 and 9 funds each require additional disclosures, for Article 8 funds to demonstrate how promoted characteristics are met, and for Article 9 funds to show alignment with their environmental or social objectives. In July 2021, Article 8 and 9 funds respectively covered 30.3% and 3.7%, respectively, of fund assets.[94] Article 8 and 9 classifications are increasing steadily, and concerns over credibility are growing.[95]

To reduce the burden of disclosures, the SFDR has been designed in alignment with the CSRD. When approved, the CSRD will increase the scope of companies required to make non-financial disclosures. With both directives requiring disclosure against the EU Taxonomy, portfolio managers will be able to use company-level disclosures to feed directly into portfolio disclosures.

Financial companies covered by SFDR and companies covered by the NFRD will also **disclose information on how and to what extent their activities meet the Taxonomy criteria**. These requirements are set out in Article 8 of the Taxonomy regulation. The CSRD will widen the scope of companies covered by Article 8. The Taxonomy, therefore, has the power to further specify the regulations set out in SFDR and CSRD/NFRD. From 2024, European banks will also report their green asset ratio, using the Taxonomy criteria, to demonstrate the extent to which their activities are associated with Taxonomy-aligned economic activities.

Lack of regulatory alignment and data availability, standardisation, and verification will pose a challenge in the application of the EU Taxonomy to non-EU assets on banks' balance sheets. While EU-based companies are subject to the CSRD, non-EU based companies do not have a legal incentive or obligation to generate relevant data.[96] A European bank lending mostly to European corporates covered by CSRD could find reporting much simpler than a one with high international exposure and a much higher proportion of assets that are out of scope of the CSRD.[97] Global alignment of taxonomies or international comparability mechanisms are crucial, hence the importance of the International Sustainability Standards Board (ISSB). Meanwhile, guidance from European Supervisory Authorities on applying the EU Taxonomy to non-EU based assets would be valuable to asset managers.

Coherent standards providing market certainty

Standards facilitate green and transition bond issuance by providing issuers clear guidance on aligning debt issuance and business models with the Paris Agreement. Green standards and criteria are closely linked to taxonomies, and they provide the technical criteria underpinning credible taxonomies and providing confidence for the market. Scientific criteria provide investors with the assurance that investments are Paris aligned, allaying greenwashing concerns and reducing due diligence requirements. International cooperation on standards will also facilitate green international trade and the cross-border infrastructure required for the energy transition. The Climate Bonds Standards for hydrogen and fossil gas are in development and will be released in 2022 and 2023.

Standards are required for the **decarbonisation of the fossil gas sector** on the carbon intensity of end uses such as electricity generation, heat, and industrial materials. The use of declining thresholds for carbon emissions, as seen in the EU Taxonomy, provides the sector with long term guidance on how to align with the net-zero trajectory.

Standards can inform gas companies' transition pathways, ensuring emissions reductions are steep enough to reach net zero. This can prevent situations of under-ambition; some fossil gas producers' emissions reduction plans solely tackle fugitive emissions which, while important, do not make up the entirety of their emissions. Similarly, those which plan gas blending as a decarbonisation strategy are limited by infrastructure's ability to cope with high proportions of hydrogen and so are unlikely to reduce emissions by more than 3%, see page 18.

Standards are crucial for **hydrogen**, given the range in carbon intensities of hydrogen production. They can overcome the confusion created by the many varying descriptions of hydrogen. For example, 'clean' hydrogen can describe solely green hydrogen or include blue hydrogen at varying levels of CCS. Given the multiple production methods resulting in a chemically uniform gas, it is important that criteria be technology-neutral, establishing a clear net zero-aligned carbon intensity threshold. The EU Taxonomy's criteria for hydrogen production requires lifecycle GHG emissions lower than 3t CO_2e/tH_2 from blue or green production. This would require >90% CCS and <0.5% upstream leakage for blue hydrogen.[98]

The EU's CertifHy project, in comparison, defines low-carbon hydrogen as below a maximum threshold of 4.4t CO_2e/tH_2 on a full lifecycle basis. This is around 60% below grey hydrogen levels – reflecting capture rates currently easily achievable in SMR+CCS. Not only is this threshold too weak, but it also provides a very confusing signal to project developers over what is considered a "green" hydrogen investment in the EU, and has the potential to weaken ambition.

The use of an emissions threshold also prevents electrolysis being run off potentially high-carbon grid electricity; Only Norway, Sweden, France, and Lithuania have grid CO_2 intensities below the level of 45g CO_2e/kWh for EU Taxonomy-compliant electrolytic hydrogen, while several countries' grids would result in carbon intensity higher than grey hydrogen.[99]

Robust standards take **full value chain and life cycle emissions** into account, enabling investors to make informed investment decisions without fears of greenwashing or underreporting of emissions. These lifecycle assessments also ensure consistency and compatibility with GHG certification schemes for other commodities like electricity or fossil gas.

Guarantees of origin for hydrogen are needed, given the emissions intensity can only be established from production analysis, not the final product. These can build on lessons from biofuel certification schemes. As grey, blue and green hydrogen are chemically identical, such a scheme will be vital once hydrogen trade picks up.

The Commission's December 2021 proposed framework of legislative proposals to decarbonise the gas markets (hereinafter *gas package*)[100] contradicts the EU Taxonomy in not making reference to lifecycle emissions for the assessment of renewable gases, defining all hydrogen as "low-carbon" if it meets a direct GHG reduction potential of 70% compared to fossil gas. This can to lead to stranded asset creation if such infrastructure does not qualify as net zero-aligned.

Standards can also inform regulation. Particularly in transition, where wide-ranging regulation is likely to impact these industries, basing all regulations on the same robust standards and definitions will provide clarity and certainty to the market. Aligning all legislation with the Taxonomy definition of renewable hydrogen will best deliver the Green Deal and carbon neutrality.

Aligning standards internationally

The EU Hydrogen Strategy envisages significant hydrogen imports, targeting equivalent electrolyser capacity in the EU Neighbourhood as within the EU. Defining common standards at the international level is crucial to enabling the trade of any energy sources, including low-carbon hydrogen and reducing GHG emissions in all regions.

International collaboration will be vital to hydrogen standards and guarantees of origin. International recognition and consensus on low-carbon hydrogen standards will enable international trade, helping to establish the global market. For example, the Hydrogen Production Analysis Task Force from the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) aims to develop a harmonised methodology and terminology to define and standardise clean hydrogen across different countries. As hydrogen is likely to become a globally traded commodity, international guarantees of origin certifications will be needed assessing the CO2 emissions of all types of hydrogen available on the market so that low-carbon hydrogen would not have to face unfair competitiveness of fossil-based hydrogen.[101]

The IFRS Foundation has announced the establishment of the International Sustainability Standards Board (ISSB) at COP26.[102] The ISSB's objective is to develop such global standards with a clear focus on sustainability and environmental, social and governance (ESG) issues. Common standards help countries plan cross-border projects, especially the needed infrastructure, leading to lower costs, faster implementation and security of supply. In particular, agreeing on standards and targets is crucial to gas composition, especially for hydrogen, and it would improve international trade and infrastructure development for low-carbon hydrogen. Such standards need to be focused on sustainability, operation and pipeline requirements.[103]

The limited role of carbon pricing

Carbon pricing is implemented to fix market distortions and capture the external costs of GHG emissions by charging emitters, either with a tax on emissions or a "cap and trade" system whereby sectors are allocated a certain level of emissions allowances. By placing a cost on emissions, carbon pricing can improve the business case for green technologies and incentivise efficiency gains. To do so, prices need to be high enough to have a material impact and not be weakened by free emissions allowances. Part of carbon pricing's value is its technology neutrality, enabling the market to find the most cost-effective solutions to carbon-intensive activities.

Carbon pricing increases the competitiveness of green technologies with traditional, carbon-intensive technologies. A carbon price will help close the gap between low-carbon hydrogen and conventional fuels. For example, even at USD1/kg hydrogen, green ammonia for ships would cost 55% more than heavy fuel oil and synthetic fuel 65% more than conventional jet fuel. There is also a premium at an intermediate product level, near zero green steel will be 40% more expensive,[104] which the carbon price can help reduce.

However, carbon pricing alone is unlikely to make hydrogen cost competitive with fossil-based energy and products. While, a carbon price of EUR79-103/tCO_2 in 2030 is estimated to be required to make green hydrogen competitive with grey, it is calculated that fossil gas will remain a cheaper option when the carbon price is below EUR200/tCO_2. Renewable hydrogen would need prices of EUR300/tCO_2 to reach break-even and then have to contend with carbon leakage issues.[105]

The EU carbon price, established via the **Emissions Trading System** (ETS) doubled over 2021, from EUR33.69/tCO_2 on 4 January to EUR80.65 on 31 December.[106] The ETS works through a "cap and trade" system: within this cap, companies buy or receive carbon allowances that they can trade with each other. It covers energy-intensive industry, fossil fuel power generation and commercial aviation,[107] and an extension to buildings and transport fuel and the maritime sector is proposed amongst the 'Fit for 55' policies, as is an increased rate of emission reduction, to 61% reduction on 2005 levels by 2030 for ETS sectors by lowering the annual emissions cap in line with the 2030 pathway.[108] The ETS is being extended to building and transport fuel producers, from 2026. The scheme focuses on upstream fuel suppliers.

The **Carbon Border Adjustment Mechanism** (CBAM) proposed in Fit for 55 is designed to prevent carbon leakage and ensure EU emissions reductions contribute to global decline whilst protecting EU industrial competitiveness.[109] It covers aluminium, cement, electricity, fertilisers, iron and steel imports from the rest of the world. Itis expected to affect Russia, China, UK and India the most.[110] The CBAM is intended to substitute the free allowances of the ETS. The EU Commission has proposed a reduction of free allowances currently allocated to energy-intensive sectors with the elimination of allowances covered by the CBAM from 2026 and completely phased out by 2035. Under the CBAM, ETS-sector importers would purchase certificates equivalent to the ETS carbon price, minus any carbon price paid in the country of production. The CBAM would be applied from 2023 and EU importers subjected to payments from 2026.[111]

The CBAM will prevent carbon leakage and the relocation of high-emitting activities outside the EU. Broadening its scope and including indirect emissions will further protect EU companies from international competition. Stakeholders need to be reassured on the future evolution of carbon prices to make informed investment decisions. Clear signals on free emissions allowance phase-out and faster application of the CBAM will provide this certainty and ensure allowances do not water down the whole carbon pricing mechanism.

The ETS is designed to limit emissions, letting the market set a price and enable the most cost-efficient methods of cutting carbon emissions. However, this creates price uncertainty, particularly given uncertainty over reductions of allowances.[112] A **carbon price floor** would provide a price stability mechanism to reduce volatility of price and ensure resilience of the financial system to carbon pricing. Germany already plans to introduce a minimum domestic carbon price of EUR60/tCO_2 if an EU-wide floor price cannot be implemented.[113] The EU can also consider supporting the IMF staff proposal for an international carbon price floor.[114] This suggests a differentiated price floor of USD25, USD50 and USD75 depending on development levels.

Carbon pricing has in the past been suggested as an all-encompassing solution to competitiveness of green technologies. However, while it can improve the economic case for green investments, other policies are required to further disincentivise fossil fuels and overcome issues of inertia, uncertainty and demand. Carbon pricing needs to be introduced alongside other measures to ensure speed of transition, as markets are not solely driven by price – carbon pricing acts as a supportive mechanism for other regulations.

Accelerating renewable energy investment

The Renewable Energy Directive (RED II) was adopted on 11 December 2018 as part of the Clean Energy Package for All Europeans. It included guidance for the Commission to publish a Delegated Act on Renewable Fuels of Non-Biological Origin (RFNBOs), expected in 2022. The revision of the Renewable Energy Directive is one of the regulatory pieces presented in the 'Fit for 55' package proposal. This sees a strengthening of RE targets from 32% to **40% by 2030**, bringing the directive in line with the 2030 emissions target,[115]

The 40% target represents almost a doubling of the current RE share of energy consumption.[116] This revision strengthens targets in sectors where progress in integrating renewables has been slower to date (such as transport, buildings and industry) and includes measures to accelerate RE deployment. These include new provisions to facilitate collective renewable energy power purchase agreements (PPAs), simplifying administrative procedures, labelling methodology for industrial products produced using renewable energy and a cross-border pilot project to foster regional cooperation. The revision also targets a significant increase in renewable hydrogen usage.

Calculations by Bellona suggest that the targets for RFNBOs in industry and transport would require 500 TWh of renewable electricity – half the total RE generation in 2019.[117] Therefore, it is crucial that the additionality of new renewable generation to meet the needs of new electrolysis hydrogen production is included in RED II, to prevent the potential cannibalization of half the renewable energy installations targeted.[118] Given the energy losses of the electrolysis process, direct electrification is a more efficient decarbonisation method. Industrial targets could be adjusted to encourage direct electrification wherever possible

Notwithstanding the work to be done on the RNFBO DA, the principle of additionality can be embedded in several articles of the proposed RED II revision. In Article 2 (Definitions), the definition of 'renewable fuels of non-biological origin' and the definitions of 'renewable fuels' and 'renewable liquid and gaseous transport fuels of non-biological origin' could state that the renewable energy source for these fuels is additional. Articles 22a and 25 can also include an additionality requirement for RNFBOs to count towards targets.

Requiring prioritisation of direct electrification and including GHG intensity targets in Article 22a would incentivise energy efficiency alongside renewable energy usage.[119] Article 22a targets a 50% replacement of grey hydrogen usage with green hydrogen in industry – this is a strong target as it directs the use of green hydrogen where it is most needed. However, the ambition of industry targets can be raised from a 1.1% annual increase in RE use in industry to 2.2%. 1.1% is not a stretch target for industry as it would be achieved anyway with the Directive's increase in grid renewables and grey-to-green hydrogen targets.

Given the relative scarcity of hydrogen production, targets can be accompanied by guidance on priorities for end uses, for example, prioritising HGVs, shipping and aviation in the transport sector. Bringing RNFBO targets in transport in line with ReFuelEU and FuelEU would help ensure targeted use of hydrogen in aviation and shipping, respectively. The inefficiencies and financial impacts on consumers of gas blending, see page 18 could be reduced by caveating against the renewable energy targets in Article 24 (District heating and cooling) being achieved with gas blending.

Without additionality and production correlation requirements, there is a potential for RED II to effectively subsidise fossil fuel-based RNFBO production, creating market distortion as grid-powered hydrogen production would always outcompete off-grid RE powered hydrogen due to longer running times.[120] This presents an investment risk to those investing in hydrogen clusters and off-grid installations, contradicting the priorities of the EU Hydrogen Strategy.[121] Without strict controls on the carbon-intensity of this grid-based hydrogen, this could incentivise high-carbon hydrogen over low-carbon hydrogen, undermining green capital flows.

It is important that hydrogen producers hold responsibility for the renewable electricity inputs they require; this will ensure a level playing field between hydrogen investments and could encourage RE producers to invest in green hydrogen as a grid balancing tool, installing electrolysers to offtake surplus energy which would otherwise be curtailed and therefore increasing the running hours of RE installations.

Grid flexibility can be further promoted in the RED II revision – particularly in Article 3, which sets the overall target for MS. Article 3 could also promote direct electrification and require the additionality of RE generation to safeguard grid decarbonisation.

The criteria for renewable fuels of non-biological origin and recycled carbon fuels require GHG emissions savings of at least 70% for these fuels to be counted towards RED II targets (Article 29a). Aligning with the EU Taxonomy definition of full lifecycle emissions reductions of 73.4% and $3tCO_2/tH_2$[122] will ensure coherency of legislation

Targets for RE uptake could also be paired with investment targets. Specific targets are set for certain industries, recognizing the differing

Additionality refers to the matching of new hydrogen electricity demand with extra renewable generation. Additionality requires electrolysers to be associated with dedicated new REinstallation or powered by surplus renewable energy. If additionality is omitted from hydrogen definitions, electrolytic hydrogen will otherwise endanger the wider economic transition.

speeds of transition; for example, a new target is set for 49% of energy use in EU buildings to come from RES and a target for renewable fuels from non-biological origin (i.e., mainly hydrogen) in transport of 2.6 %. Investment targets would guide member states (MS) to enable green investment in areas which currently show less favourable conditions than wind farms etc.

Ensuring green hydrogen delivers deep emissions reduction

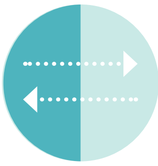
The delegated act of the RED II on Renewable Fuels of Non-Biological Origin (RFNBOs) will determine the quality of green hydrogen under RED II by dictating what electricity can be used to produce it. The DA was due at the end of 2021 and has yet to be published. Since the 2018 RED II, hydrogen has risen significantly up the decarbonisation agenda, and the EU has set targets for largescale electrolyser deployment and hydrogen use by 2030 and 2050. This has put pressure on the commission to weaken the DA's additionality and production correlation requirements to ease deployment of electrolysers.

The guidance in RED II (2018) on the DA suggested three requirements; temporal and geographical correlation of hydrogen and RE production and an additionality element.[123] However, this guidance is not binding, and latest drafts of the DA show a weakening of these requirements. The DA is likely to not include additionality in practice, with hydrogen suppliers guaranteed a certain level of electrolyser running time (4000-5000 hours/year) regardless of grid carbon intensity and removing suppliers' responsibility for adding renewable energy to the grid. Without additionality, the electricity requirements of the hydrogen use targeted in the revision have the potential to absorb half the planned RE expansion.

Standard guarantees of origin will not be sufficient to guarantee geographical and temporal correlation, instead dedicated PPAs will help ensure low carbon hydrogen production. Additionality rules will ensure decarbonisation of the energy system stays on track.[124] Grid-connected electrolyser installations will need to be accompanied by new RE installations or run only when there is a surplus of RE which would otherwise be curtailed or dissipated.

A strong DA will include the requirements set out in the 2018 RED II: temporal and geographical correlation of hydrogen and RE production and additionality of supply. See also page 22.

Strategic infrastructure development

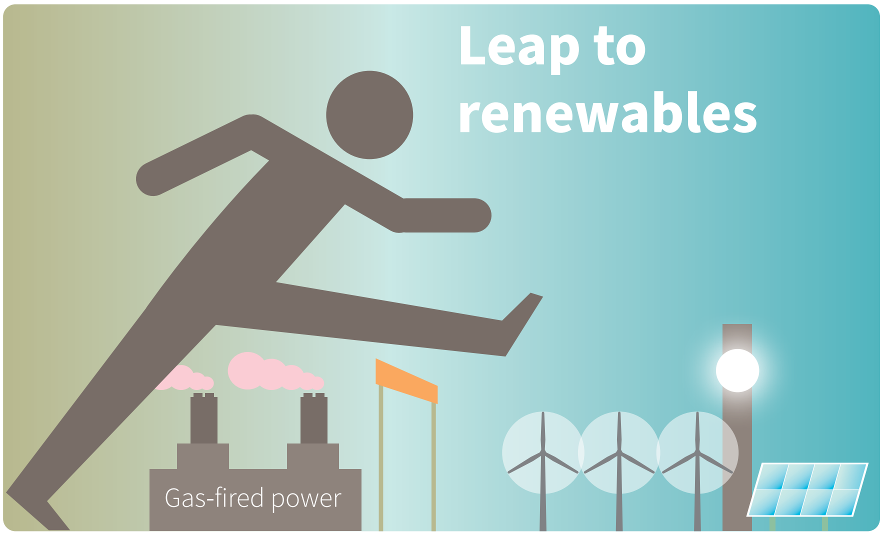


Cross-border energy networks, on average, have a life expectancy of 80-years for gas pipes and between 40- and 80-years for electricity infrastructures or equipment. Consequently, current investments determine the structure of the EU energy system for the coming decades. Directing these investments toward the infrastructure necessary for the clean energy economy is an important element of energy transition policymaking.

Regulation 347/2013 on Trans-European Energy Networks (TEN-E) provides a framework to foster the "timely development and interoperability of trans-European energy infrastructure". It accelerates infrastructure projects that support EU energy policy goals; functioning and integrating the internal energy market, security of supply, promotion of energy efficiency and integration of renewable energy sources. It addresses the identification and implementation of Projects of Common Interest (PCIs), projects' regulatory treatment, and eligibility criteria for financial assistance under the Connecting Europe Facility budget for Energy (CEF-E).

The Council and Parliament have reached a provisional agreement on a new TEN-E revision, aiming to align TEN-E with the EU Green Deal.[125] The revision attempts to anticipate the EU's future energy infrastructure needs and promotes the use of innovative energy carriers such as hydrogen. The revision ends support for new dedicated fossil gas and oil infrastructure, established mandatory sustainability criteria for projects and focuses on smart grids, electrification and hydrogen.

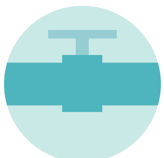
New gas infrastructure is allowed to carry a blended mix of hydrogen and fossil gas/biomethane until the end of the decade. Strengthening these requirements, for example, requiring project evaluation according to their contribution to the hydrogen economy after 2030, can remove any short-term incentive to design these pipelines to meet current gas needs, as will specifying a high minimum blend of hydrogen. Fossil gas end-use appliances and infrastructures tend to require retrofit to receive over a 10% blend of hydrogen, so a minimum blend over 10% would mean the gas would only be able to be used by hydrogen-ready appliances and industrial units, while a lower blend would have negligible impact on emissions.



Improving interoperability of European energy networks can provide resilience to variable renewable energy (VRE) supplies and improve energy security. EU initiatives on wholesale electricity market integration such as market coupling help to improve cross-border grid connectivity within the EU,[126] but similar initiatives could be introduced to enable electricity trade with the EU Neighbourhood, see page 27.

PCI allocation now includes sustainability criteria, prioritising those projects that have the greater impact in transition to net-zero, particularly in building up renewable capabilities in those countries currently most dependent on fossil fuels will ensure an efficient use of resources to achieve largescale emissions reductions.

Tackling fossil gas energy security issues



Energy security is threatened by issues of energy supply variability and by overreliance on imports, particularly fossil gas. Energy security concerns around fossil gas have been brought to the fore by the war in Ukraine. Almost half of EU fossil gas is supplied by Russia. The war in Ukraine has prompted action to rapidly reduce EU reliance on Russian gas.

Variable renewable energy supply driven by daily and seasonal variation in wind and solar intensity is seen as a threat to continuous energy supply, with the 2021 winter energy price surge blamed on renewable energy penetration by some. However, this was driven by fossil gas shortages, as global demand spiked following the economic restart out of lockdown. Fossil gas has been presented as a source of long-term energy security in an electricity system with high renewable penetration. However, **import reliance has been revealed as a major source of vulnerability**, first by the 2021/22 winter supply issues and then by the efforts to reduce imports from Russia.[127]

The European Commission published its REPowerEU communication on 8 March 2022 to make Europe independent of Russian fossil fuels "well before 2030", by reducing fossil gas consumption by 155 bcm (amount imported from Russia in 2021). 100 bcm of this reduction are targeted by the end of 2022.[128] Concrete proposals are expected in May. REPowerEU consists of two pillars: diversifying gas supplies and reducing dependence on fossil fuels through increasing energy efficiency and RE penetration. The communication suggests co-legislators boost the Fit for 55 proposals with higher/earlier renewable energy and energy efficiency targets.[129] A plan will be proposed based on identification of suitable projects and reforms at national, regional and EU levels. Pillar 1, gas supply diversification, is planned through increasing LNG imports and pipeline imports from other countries.[130]

Current supply disruption risks are currently perceived as far higher than future transition risks. Mid-stream infrastructure for intra-state fossil gas transmission may be needed, particularly for those nations predominantly served by Russian pipelines such as Germany. However, fossil gas supply diversification investments will require careful evaluation of their ability to meet current needs and comparison with lower-carbon alternatives, particularly in terms of time scales for project delivery. Energy efficiency gains and other demand-side responses should also be incorporated into assessment of investment needs.[131]

The EU may require new fossil gas import capacity for immediate supply diversification but it is still on track for continued excessive net import capacity, and new LNG terminals may not be built in time to address immediate gas needs.[132] New LNG infrastructure introduces a large stranded asset risk.

The Global Gas Infrastructure Tracker estimates that proposed EU expansion of net gas import capacity to be 160.2 bcm/year costing

EUR26.4bn. This does not include the over 70 bcm/year announcements made following the invasion of Ukraine. Given the 100 bcm reduction in gas consumption forecast in Fit for 55, this represents a significant investment risk.[133]

Building new fossil gas infrastructure needs to be avoided as much as possible to avoid lock-in to asset stranding and jeopardising emissions targets. Switching import reliance to another country will also still leave energy security vulnerabilities. Lock-in risks are also posed by long term offtake contracts; EU negotiators are likely to carefully negotiate contracts to ensure they also avoid lock-in risks. However, lock-ins of price premiums for these contracts will be very likely.

The communication also covers a 'hydrogen accelerator', increasing the ambition of the Hydrogen Strategy with an additional 15 mt/year (five EU produced, ten imported) of renewable hydrogen. This will require significant RE capacity – the current 10 mt target in Fit for 55 will already require 477 TWh RE. Therefore, it is vital that additional RE is linked to this new accelerator.

Reduced demand will be key to these rapid reductions in consumption. The REPowerEU communication states the importance of the energy efficiency first principle and suggests strengthening of Fit for 55 policies on energy efficiency, particularly in homes. Pillar 2 also plans renewable energy acceleration with simplification of permitting. This is a key bottleneck to overcome and could also improve the investibility of renewable energy. Increasing renewables penetration is suggested to be possibly achieved with carbon contracts for difference, see page 25.

Recommendations on ensuring a credible transition

- The EU Taxonomy establishes a scientific 100g CO_2e/kWh declining threshold for green electricity generation. The Complementary Delegated Act to the Regulation on fossil gas and nuclear power uses weaker criteria. Approving the CDA would risk locking the EU into a high carbon trajectory incompatible with its climate targets. If MEPs reject the CDA, this allows the Commission to redraft Paris-aligned transition criteria for the sector.
- **Inconsistency of standards** could hinder transition investments and create market imbalances. Application of consistent scientific definitions, using the Taxonomy full lifecycle emissions threshold of 3tCO_2e/tH_2, across all legislation will ensure consistency of policymaking and streamline transition investments.
- Carbon pricing has been proposed as a fix-all solution to enable the transition, but action is not solely driven by price. Accompanying carbon pricing with other regulations, subsidies and R&D support, as seen in the Fit for 55 package, will prevent over-reliance on pricing signals to enable the transition.
- Electrolyser installations could appropriate large swathes of electricity grids' new renewable installation, hindering grid decarbonisation. Including additionality requirements in RED II and its Delegated Act, ensuring electrolysers are accompanied by dedicated renewable installations, will prevent this.
- There is a risk that the TEN-E requirements on gas pipelines could allow subsidise fossil gas infrastructure. Specifying a high minimum blend of hydrogen will ensure the infrastructure is not used to simply meet existing fossil gas requirements.
- European energy security is threatened by **reliance on fossil gas imports**. Gas switching is not the path forward. Diversifying gas supplies may meet short term energy needs but long-term energy security will be provided by rapid transition to an energy mix met almost entirely by domestic renewable energy production. Energy security investments should therefore avoid locking in new fossil gas infrastructure, prioritising renewable infrastructure installations whenever possible.

4. Facilitating transition away from fossil gas

The existing fossil gas sector will need to undergo transformational change to align with net zero. The required policy scenario to limit warming to 1.5°C modelled by the Inevitable Policy Response (IPR RPS) sees global fossil gas demand dropping 60% by 2050, and 75% in the power sector.[135] Energy modelling also makes it clear that developed markets such as the EU will need the highest ambitions on emissions reductions.[136] The policies outlined above will help to encourage companies to transition their businesses. However, policymakers can provide further guidance on these transitions, to minimise asset stranding risks and ensure efficiency of the whole economy transition. These policies can also ensure economically efficient transition priorities, avoiding damaging efforts such as gas blending which ultimately hinder transition and increase stranded asset risks.

Fossil gas infrastructure leaks methane, a greenhouse gas, 82.5x stronger than CO_2 on a 20-year timescale. Methane emissions from the energy sector are 70% higher than official figures; recognising the true carbon intensity of fossil gas will help guide the energy transition to truly low-carbon investments. Reducing methane leakage is a significant challenge, given that 4/5 of the methane leakage associated with EU fossil gas consumption is beyond EU borders. The severity of this issue will require precautionary regulation, that any gas infrastructure operation must provide evidence of low enough leakage rates, using LDAR, to avoid the need for corrective action. **The difficulties of this will be far higher than simply not using fossil gas.**

For a successful transition of the fossil gas sector, it is important to consider the vested interests of nations with large gas reserves, and gas sector actors with high sunk costs in fossil gas infrastructure. Hydrogen cannot be used to enable continued expansion of fossil gas infrastructure and instead be prioritised for hardest to abate sectors such as steel and freight where it has the greatest decarbonisation potential. A limited portion of fossil gas infrastructure may be repurposed for low-carbon hydrogen processes, but this will not provide a transition strategy for the whole fossil gas distribution and transportation sector.

Shareholders and investors can also play an important role in prompting transition of companies, calling for climate action, requesting greater ambition, and engaging with companies on the benefits of the transition. Fossil gas companies need to grasp the opportunity posed by the transition, recognising first-mover advantages and the favourable investment landscape for green investments.

Urgently reducing methane leakage from fossil gas

Fossil gas infrastructure leaks methane along the entire value chain. Methane has a GWP 82.5 times that of CO_2 on a 20-year time scale and 29.8 on a 100-year scale.[137] So even small leakage rates have a significant climate impact. The European Commission's proposal for a regulation on methane emissions reduction in the energy sector seeks to address emissions from upstream oil and gas activities, coal mines and fossil gas transmission, distribution and storage.[138]

Methane emissions are consistently underestimated, as demonstrated by ice core analysis.[139] The IEA has found that global energy sector methane leakage is 70% higher than officially reported.[140] Underreporting of methane leakage has led to an underestimation of fossil gas climate impact. This will likely have also led to an overestimation of its potential role in the future energy mix if energy system models have used too low carbon intensities for fossil gas.

The uncertainty around methane leakage data means the risk of underestimating the impact of fossil gas emissions needs countering with robust regulation. The majority of emissions also comes from a very small number of leaks, with 5% of leaks contributing 50% of emissions globally.[141] This means that for leak detection and reduction (LDAR) to be effective, it must cover the entire supply chain.

While upstream companies do have an incentive to address leakage, posed by loss of revenue, this is estimated to be only 1/10th of the environmental cost of the leak.[142] Increasing evidence from satellite imagery and infrared imaging shows unreported methane leakages from pipelines in Europe. Therefore, regulation is required to enforce improvements in management and continuous supply chain LDAR.

The proposed Methane Regulation would establish requirements for companies to measure and quantify their asset-level methane emissions at source and carry out comprehensive surveys to detect and repair methane leaks in their operations and bans venting and flaring practices. However, the severity of methane leakage's underestimation and climate impact calls for a strong precautionary approach in the regulation. Reinforcing supply chain LDAR in the regulation and specifying regularity of pipeline inspection will ensure whole value chain coverage.

The regulation will not apply to fossil fuel imports until the 2025 regulation review. With 90% fossil gas imported from outside the EU, estimates suggest less than a fifth of methane emissions from fossil gas consumption occur within its borders, 76 Mt CO_2e compared to 232-615 Mt CO_2e.[143] Extending the framework to imports would tackle far more of the EU's fossil gas methane emissions.

Fugitive emissions can increase a fossil gas-fired power plant's emissions intensity by 30% and bring its carbon intensity in line with coal-fired power due to methane's very high global warming potential.[144] Use of lifecycle emissions thresholds means methane leakage is included in assessments of fossil gas end uses such as electricity generation. This enables accurate assessment of fossil gas-fired power's carbon intensity and comparison with other technologies.

Avoiding gas blending

Gas blending entails mixing a certain proportion of hydrogen, or other low carbon gas, into the fossil gas supply. At hydrogen volumes up to 10%, this does not require retrofit of distribution or end-use infrastructure. However, given the lower energy density of hydrogen, a 5% blend by volume would only displace 1.6% of fossil gas supply[145] and so blending levels cannot be equated with emissions reduction. Impact is further reduced if blue hydrogen is used.

Gas blending also reduces the decarbonisation potential of hydrogen. Combustion of hydrogen for domestic heating or electricity generation results in energy losses of around 30% during the conversion process from electricity to hydrogen.[146] Hydrogen is better suited to uses where direct electrification is not possible, such as industrial processes.

Gas blending is not aligned with the Climate Bonds Principles for a Credible Transition, see Figure 2. Blending does not align with zero carbon by 2050 and there are other viable technologies which provide deeper decarbonisation of fossil gas end uses. Incremental change is not aligned with the need for rapid decarbonisation to 2030. Prioritising dedicated hydrogen infrastructure will avoid cost inefficiencies and lock-in risks.

For those elements of the grid which will be needed for hydrogen distribution, blending does not enable a smoother transition to a 100% hydrogen grid, as it would still need retrofits once blending limits (around 10% volume) are reached – this could incentivize inefficient, incremental retrofit efforts, further slowing transition.

Blending also poses a risk to the just transition, see page 20. Blending would mean costs of hydrogen development would fall to current fossil gas consumers, further driving up energy bills, despite their not necessarily being the primary beneficiaries. A just transition requires the cost of the hydrogen transition to be borne by its primary beneficiaries and demand centres. Equally, unnecessary replacement of boilers and other end use infrastructure would also cause significant cost to the consumer.

Various stakeholders advocate for gas blending as a way to boost demand in the near term and so drive down costs of hydrogen production. However, gas blending could hinder transition of other activities for which hydrogen is currently the only viable decarbonisation technology by absorbing much of the EU's hydrogen production. These sectors are far better suited to boost demand without creating asset stranding and other investment risks.

Accelerating buildings decarbonisation

Domestic consumption accounts for 41% of final EU fossil gas consumption.[147] The heating and cooling sector is a Commission priority for achieving decarbonisation targets, also targeted in the REPowerEU communication. The IPR RPS sees global building sector gas demand fall to almost zero in 2050.[148] Gas is used for space heating, cooking and hot water in commercial and domestic properties. This variety of uses and the large number of independent stakeholders requires a variety of policy levers to enable decarbonisation.

Building decarbonisation will entail largescale reduction in fuel demand through insulation and passive technologies. Residual heating requirements can be met by various solutions: heat pumps, decarbonised district heating and hydrogen boilers, alongside energy efficiency improvements. Given the range of building types and energy efficiency and insulation levels, case-by-case analysis is required to determine the most cost-effective solution for each context. REPowerEU mentions accelerated deployment of rooftop solar and heat pumps. UK scenario analysis found a top-down "blanket" solution such as all-electric or all-hydrogen is projected to cost 2 or 3.5 times as much respectively compared to a bottom-up approach that chooses the best low carbon heating solutions on a place-by-place basis.[149]

In most cases, low-carbon hydrogen is not likely to outcompete direct electrification in decarbonising decentralised heating as it is more expensive than electric heat pumps and requires appliance retrofit. Blanket incentives for hydrogen-based decentralised heating would undermine strategic deployment elsewhere in the economy and create inefficiencies.[150] However, it could be a midterm decarbonisation option for district heating – in instances where waste heat, geothermal, and heat pumps can't be used.

Incentive schemes for individual interventions are already present across the EU, for example Italy's 2019 Ecobonus and 2021 Superbonus tax relief scheme.[151] This triggered a 500% increase in home renovations 2020-2021.[152] However it is only available for privately-owned houses, with public administrations having to access the Conto Termico instead and neither scheme available for commercial property. It is also available for any energy efficiency measure, regardless of efficiency gains made, whereas the EU Taxonomy requires building retrofits to make a significant contribution to energy savings to qualify as green.

New buildings provide an opportunity for greater ambition. The recast of the Energy Performance of Buildings Directive (EPBD) requires new residential buildings to be net-zero in operation from 2030 and new public buildings by 2027.[153] This can be strengthened to prohibit the supply of fossil fuels to new buildings. The longer phase-in time could be used for full lifecycle emissions, given the difficulties in decarbonising building materials.

Preferential capital requirements on green mortgages provide a fiscally efficient incentive for building decarbonisation. Green mortgage schemes offer more favourable lending conditions against houses with a certain level of energy efficiency or for green energy interventions. These can be supported by the central bank, following the model of Hungary's Magyar Nemzeti Bank (MNB) which discounts capital requirements against lenders' balance sheet exposure to green mortgages, reflecting their reduced risk of default.[154]

Limits of repurposing fossil gas infrastructure

Retrofit of fossil gas infrastructure for hydrogen or synthetic fuels is promoted widely as a transition pathway for the fossil gas sector. However, the cost of such retrofit and the differing natures of the two economies mean this will likely be the case for a very small proportion of existing infrastructure. For the same reason, new 'hydrogen-ready' fossil gas infrastructure cannot be assumed to be needed for hydrogen distribution. Labelling 'hydrogen-ready' fossil gas infrastructure as green poses an investment risk in both asset stranding and greenwashing accusations, see page 11.

Public authorities and financial actors will need to keep in mind that the retrofit potential of gas infrastructure is limited and not overestimate the importance of gases in the net-zero economy. Objective metrics can be used to assess future retrofitting against other decarbonisation strategies and in the context of national energy infrastructure requirements.

Several fossil gas distributors already target a hydrogen transition. As part of Snam's aims to transport 100% hydrogen and biomethane by 2050, it is working to develop hydrogen refuelling infrastructure for Italian railways and on projects piloting hydrogen in several other industries.[155] Those companies which are already remodelling as integrated energy players or even transitioning to become pureplay low-carbon energy providers are already reaping the benefits; for example, Ørsted's transition away from fossil fuel reliance to become the largest offshore wind energy producer in the world.[156]

The IPR RPS sees gas + CCS accounting for all remaining EU fossil fuel generation after 2035,[157] and CCS retrofit could provide significant emissions reductions from existing plants. However, this would require very strong action on fugitive emissions to meet even DNSH requirements of the EU Taxonomy and is unlikely to reach low enough emissions intensity to qualify as a green investment.

The different geographies of fossil gas and hydrogen supply and demand, in terms of volume and location, **limit pipeline retrofit potential for hydrogen transport**. Distributors cannot expect this to be an adequate transition of their business model.

Policymakers can play a crucial role in this process by assessing national distribution requirements and carrying out a comprehensive cost-benefit analysis. Transparency in this process and the planning and timelines for networks also helps investment and identification of potential routes.

Governments and fossil gas distributors will also need to accept that much of the gas transmission and distribution network will become stranded assets (this will vary across countries and regions) as future demand of low carbon gases are never expected to reach that of current fossil gas demand, and transport requirements will vary widely. Building new gas infrastructure according to expected future hydrogen distribution requirements will help prevent asset stranding.

While there are opportunities in repurposing existing infrastructure, which is highlighted in the European Commission's hydrogen strategy, policymakers will need to also take the depreciation of repurposed infrastructure into account.

An example of pipeline repurposing is provided by Dutch state-owned network operator, Gasunie, which will develop a Dutch national hydrogen network at the initiative of the Dutch government. Given hydrogen's current lack of profitability, full deployment would not be possible without this public sector initiative. This grid is necessary for the deployment of the hydrogen value chain to enable industry and other sectors to transition into hydrogen, so this initiative prevents a possible future bottleneck. 85% of existing pipelines will be repurposed to save costs. The project amounts to EUR1.5bn and is due for completion by 2027.[158] Gasunie expects the costs to be 4 times lower than if entirely new pipelines were laid. The capacity of the network is 10 GW, equal to 25% of the total energy consumption of Dutch industry; although in time this can be expanded further.[159] Dutch industry currently amounts to 25% of total CO2 emissions in the Netherlands.[160]

Repurposing plants to run on hydrogen or other low carbon gases has been promoted as a way to rapidly scale demand for low-carbon hydrogen and/or to decarbonise fossil gas-fired power. However, with RE providing a much cheaper and cost-effective way to decarbonise the electricity sector, this is **not a viable strategy for all gas power plants**. There is an opportunity to repurpose fossil gas plants' electricity grid connections for hydrogen production sites. Such creative reworkings will ensure maximum capture of transition opportunities by the sector.

The only exception to this is posed by the possible role of hydrogen in grid balancing. Once the electricity grid sees a high proportion of renewables, issues of supply variability pose a challenge on daily and seasonal scales. Balancing (smoothing supply/demand peaks) could be achieved through green hydrogen production, storage, and combustion in repurposed fossil gas-fired plants, alongside other measures such as smart usage technologies and batteries.

Given the inefficiencies in hydrogen combustion (energy losses at each stage of electricity-hydrogen-electricity conversion) and constraints on hydrogen supply, power plant repurposing will need careful regulation to ensure that it is only used for grid balancing. Specifying hydrogen power plants as balancing service providers[161] would also allow hydrogen power stations to be paid appropriately for their role, allowing for a price premium reflective of the value of grid balancing while protecting consumers from the cost of hydrogen power being run as baseload.

A holistic approach to Just Transition

The energy transition poses risks to social development. Restructuring of the global energy system has the potential to increase inequalities and hinder development if mismanaged. However, it also holds potential to facilitate development, tackling important inequalities such as environmental quality and fuel poverty. Just Transition measures often have a narrow focus on protecting jobs in developed market fossil fuel industries. Widening these measures to include other measures of social development and a global perspective can ensure greater impact.[162]

Just transition efforts can minimise the impact on those employed in the fossil gas sector. Reskilling this workforce will reduce job losses and associated opposition to transition. This can also create efficiencies for companies looking to transform their business models from fossil-based energy generation to renewable energy generation. Opportunities to leverage the existing workforce skillset include project planning, manufacturing of support structures, installation and grid connection, and operations and maintenance.[163] According to the International Energy Agency, approximately 40% of the total lifetime costs of an offshore wind project has significant synergies with the offshore oil and gas sector.[164]

Box 2: HyDeal Ambition, an example of largescale repurposing of fossil gas infrastructure

A consortium of 30 solar developers, electrolysis manufacturers and contractors, gas transmission systems operators, energy groups, infrastructure funds and consultants initiated by DH2 energy has launched HyDeal Ambition. They aim to install 95GW of solar and 67GW of electrolysis capacity in Iberia by 2030 to deliver 3.6 million tonnes of green hydrogen annually across Spain, France and Germany using the existing gas transmission and storage network.

The collaborative approach is designed to achieve fossil fuel parity (targeting EUR1.5/kg including transmission and storage) with a rapid scale-up of production and an integrated value chain approach.[179] This largescale project is presented as an alternative to the local, MW-scale projects. HyDeal uses co-location of electrolysers and renewables (up to 1 GW per site), connected to a pipeline network built along existing gas pipelines, with high-capacity underground storage to serve industrial off takers.[180]

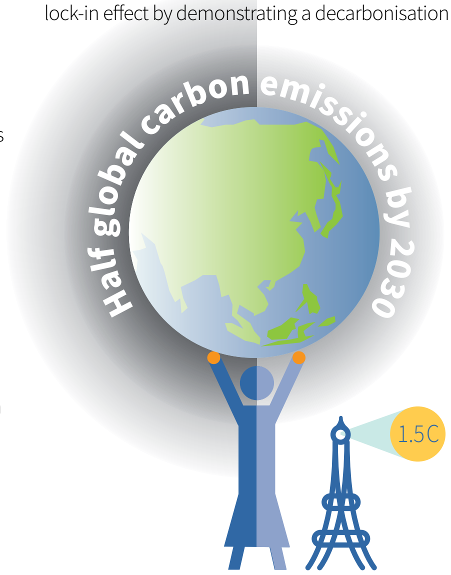
Cost-benefit analysis found laying new pipes alongside fossil gas pipes to be the most efficient method, utilising existing planning permission and excavation. This demonstrates how assets beyond physical infrastructure can be considered for repurposing.

Carbon pricing policies on road transport and buildings can produce regressive distributional effects, affecting proportionally more low- and middle-income households than high-income[165] because low-income households spend a higher share of income on energy. The new proposed ETS scheme for buildings and mobility will likely result in more inequalities and in an increase in energy poverty since the additional costs would likely be passed on to the consumers. With energy prices increasing due to Ukraine war-related disruptions,[166] these impacts will need careful consideration.

The European Commission presented a Just Transition Mechanism in January 2020 and a proposal for a Social Climate Fund in July 2021. The size of the Social Climate Fund will correspond to a dedicated share of the revenues from the auctioning of emission allowances under the building and road transport ETS. The Social Climate Fund would be financed by 25% of the expected emissions trading revenues for building and road transport fuels. It will provide EUR72.2bn of funding to MS, for the period 2025 – 2032. With a proposal to draw on matching MS funding, the Fund would mobilise EUR144bn. However, the European Commission has estimated that until 2030 around EUR350bn (of this, EUR130bn in the transport sector and EUR110bn in the buildings sector) will be needed in additional energy system investment annually to meet the 'Fit for 55' targets. Greater involvement of public funds will be needed to address this, given the limited inflows of private capital to such projects.

There is also a question on whether the proposal is ambitious enough to sufficiently compensate poorer European households so that the costs of transition are shared fairly. The proposed design of the Fund may also not be effective since it plans to compensate households using revenues arising from carbon pricing on transport and buildings, which will be mainly paid by households themselves.[167] Dependency on revenue from the building/transport fuel ETS, which will be implemented from 2027, means the Fund's implementation will be severely delayed, with consumers only able to access support once they are already impacted by the ETS.

New state aid guidelines seek to align state aid rules with the Green Deal. These provide support for RE expansion and coal phase-out but include a special clause to allow the lowest GDP MS to transition from coal to gas. Criteria for fossil gas projects to win EU state aid approval include being 'future-proof' and hydrogen/biogas-ready and prevent lock-in effect by demonstrating a decarbonisation



pathway.[168] However, being hydrogen/bio-gas ready is not a valid decarbonisation strategy given the differing geography of future hydrogen demand to fossil gas demand – this extra support would be better placed enabling electrification and RE expansion. Elevated fossil gas prices mean that coal to gas transition is also likely to create a large financial burden, hindering the just transition.

Allocation of the Social Climate Fund and state aid can be strengthened by incorporating a wider understanding of the social impacts of the transition, beyond job losses and fuel prices and including metrics such as health, environmental quality and natural capital stocks.[169]

Investor engagement for transition

Transition-related investments are profitable. Renewable power is already demonstrating a superior risk and return profile compared to fossil fuels. The IEA and the Centre for Climate Finance & Investment found that the market correlation of a reference renewable power portfolio fell during a market downturn, indicating a potential diversification benefit of renewables investments. Renewable power was also more resilient than fossil fuels during the pandemic period of severe stress and volatility.[170] This shows asset managers are able to channel finance towards green investments whilst meeting customer expectations on risk and return. Also, annualised volatility is lower for renewable power than fossil fuels in global and advanced economies portfolios. However, for more nascent and high-risk technologies, private capital which requires lock-in investments of several years may require further incentives from risk-sharing mechanisms, guarantees etc.

Asset owners are often pressured to divest from fossil fuel investments to green their portfolios, however, there is growing understanding that divestment does not materially reduce carbon emissions and should instead be used as a last resort sanction in engagement strategies. Divestment is resulting in fossil fuel assets being increasingly held by private investors, reducing the visibility of these investment flows; however, private investors will eventually come under EU disclosure obligations.

Engagement is increasingly recognised as a powerful tool to accelerate companies' actions. Investors in fossil gas firms can use shareholder rights such as AGM votes to influence the company's strategy (Investor Activism), for example, shareholder resolutions on emissions reduction targets at ConocoPhillips (fossil gas) and Phillips 66 (oil and gas) achieved majority shareholder approval, despite ConocoPhillips recommending a 'no' vote. These actions were supported by Climate Action 100+, an investor-led coalition engaging with the world's largest GHG emitters to ensure they take action on climate change.[171]

Investors can engage with companies to request they implement transition strategies, examine the ambition level of these strategies and request an increase in ambition. To do so, they can use the Climate Bonds Principles for a credible transition and sector criteria, see Figure 2.[172] This is especially important in a sector where many transition plans are characterised by energy efficiency gains and/or reliance on unproven technologies such as direct air capture (DAC) or on offsets.

Even in passive investing, transition can be considered, and investors increasingly select climate-related passive funds based on asset managers' track records and stewardship capability expectations.

Asset managers can find it difficult to engage with transition sectors such as natural gas given green portfolio's carbon intensity requirements or find that creation of low-carbon indices result in domination by sectors such as technology or web services.

With much investor action on climate currently voluntary, there is room for regulation to harmonise and enforce such action. The EU's SFDR regulation, see page 11, will help do so but incorporating climate considerations into fiduciary duty could do so too.

Removing fossil fuel subsidies for clarity of policy signals

Fossil fuel subsidy phaseout is key to ensuring policy coherency, freeing up spending for green subsidies and strengthening the carbon price signal. The EU committed to phasing out inefficient fossil fuel subsidies at COP26 and agreed the 8th EU Environment Action Programme (EAP) in December 2021, but without concrete deadlines for subsidy phase-out. EU fossil fuel subsidies amounted to EUR52bn in 2020, compared to EUR78bn for RE in 2019.[173] Setting a deadline would provide a clear signal to investors of the need to move away from fossil fuels.

The proposed Revised Energy Taxation Directive in 'Fit for 55' includes aligning minimum tax rates for heating and transport with climate objectives. It will also remove exemptions and reduced rates, such as for maritime and aviation fuel, that encourage fossil fuel use.[174] This should reduce the harmful effects of energy tax competition while providing revenue for member states and ensuring coherency of economic policy, preventing dilution of carbon price signals – see page 14.

The use of environmental tax reform (ETR) can ensure consumers are not disadvantaged by subsidy removal, channelling the savings into just transition measures such as grants for refitting home heating systems. As stated in the 2021 State of the Energy Union Report: "Fossil fuel subsidies should come to an end. With lower expenditures for fossil fuel subsidies and pollution related disease, national budgets will have a greater margin for investments in innovative technologies, in green skills, and in mitigating potential distributional effects of the transition."[175]

The revision of the Energy Taxation Directive also sets minimum taxation levels for renewable and low-carbon gases used as heating or motor fuel of EUR 0.15/GJ (compared to EUR 0.6/GJ for fossil gas). These minimum taxation levels can be used to guide the application of low-carbon hydrogen in areas where it is most needed for decarbonisation.[176]

Several MS coal phaseouts see fossil gas as a bridging technology from coal to renewables, despite the low cost of renewable technologies.[177] Elevated fossil gas prices and the cost of building up fossil gas infrastructure to achieve the low level of emissions savings from fossil gas-switching means this makes little economic sense,[178] even before the likelihood of fossil gas infrastructure stranding in 2050 is considered. Fiscally efficient coal phaseout guidance would instead encourage a direct switch to renewables.

Recommendations on facilitating transition away from fossil gas

- Incremental change is not aligned with the need for rapid decarbonisation by 2030. The transition is threatened by the inefficient and regressive strategy of gas blending, from which **a 5% by volume hydrogen blend only displaces 1.6% of fossil gas**. Blending has limited emissions reduction potential and creates stranded asset risk and cost with the incremental retrofits/technology replacements required for increasing blending volumes. This can be addressed by policies incentivising transformational rather than incremental change.

- **Methane** leakage brings gas-fired power carbon intensity in line with that of coal power. This means gas is not a transition fuel. Leakage is 70% higher than reported – all fossil gas operations urgently require leakage mitigation. The extent to which this underestimation threatens the energy transition and climate goals calls for a precautionary approach – that **fossil gas operations cannot occur without certainty on leakage**. Full value chain leak detection and reduction technology, alongside full lifecycle assessments of carbon intensity are critical.

- There is growing evidence that fossil fuel divestment does not result in real economy GHG emissions reductions. Investor engagement can directly influence fossil gas companies to decarbonise their operations.

- The EU has committed to phasing out inefficient fossil fuel subsidies. Setting a deadline would provide a clear signal to investors of the need to move away from fossil fuels

5. Facilitating transition to hydrogen

A net-zero economy will require large quantities of renewable hydrogen. Estimates vary on exact quantities as end uses have various decarbonisation pathways, but the EU Hydrogen Strategy estimates hydrogen to grow from 2% to 13-14% of the energy mix by 2050.

With EU hydrogen production currently dominated by small scale grey hydrogen production, it will need to undergo expansion and transition simultaneously. This will require strong private-public sector collaboration to grow nascent technologies, strategic deployment to prevent supply chain bottlenecks, and robust regulation to ensure hydrogen's contribution to the energy transition.

95% of current hydrogen production is fossil-based; this presents an immediate emissions reduction opportunity. These plants could be retrofitted with CCS to allow continued use of existing assets whilst lowering emissions intensity.[181] However, blue hydrogen's emissions intensity (from both residual CO_2 emissions not captured by CCS technology and methane emissions in the fossil gas supply) mean there is a need for robust lifecycle emissions standards to ensure Paris-alignment and prevent incremental emissions reductions.

Increasing the ambition of the EU Hydrogen Strategy

The EU Hydrogen Strategy[182] plans investments of 80 GW electrolysers by 2030 (57% of which in EU), so as to meet the strategic vision for climate neutrality, with the share of hydrogen in the energy mix predicted to grow from less than 2% to 13-14% by 2050. These targets are likely to be increased by the REPowerEU plans, page 16. Roadmaps and strategies provide a market signal, increasing investor confidence while also shaping the growth trajectory of an industry, ensuring policy and infrastructure frameworks are in place to support the new industry.

Whilst the Strategy prioritises renewable (green) hydrogen, it suggests that other forms of low-carbon hydrogen are needed in the short/medium term to reduce emissions from current production and support future uptake of renewable hydrogen. The decarbonisation of current SMR production with CCS presents an immediate emissions reduction opportunity. Given varying capture rates of CCS, using the EU Taxonomy criteria for hydrogen will simplify understanding of viable hydrogen technologies. This can ensure the construction of SMR+CCS plants which are net zero-aligned and avoid stranded asset risks. It can also enable investment, facilitating green bond issuance in hydrogen and ensuring investor confidence in a project's Paris and Taxonomy alignment.

The Hydrogen Strategy's Roadmap sets out three phases for the hydrogen industry, initially prioritising scale-up of electrolyser manufacture, with hydrogen valleys and EU-wide infrastructure development beginning in the 2nd, 2025-2030 phase. The roadmap sees green hydrogen technologies reaching maturity in the 3rd phase towards 2050 and being deployed at scale across hard-to-abate technologies.[183] Accelerating the Roadmap, prioritising immediate cluster development and large scale deployment from 2025 would encourage greater earlier investment and send a signal to industry to invest in hydrogen inputs at the next investment cycle,[184] not after 2030.

The **Hydrogen Strategy import targets** are also seen as potentially overambitious, given the limited RE installations in the EU Neighbourhood and the need for these countries to also meet their own net zero strategies. This raises Just Transition concerns if emerging markets with high RE potential are producing and exporting hydrogen to Europe and not getting any of the RE benefits. Policies will need to ensure against increasing the low-income countries' resource curse; see page 26 for how trade policies might tackle this.

EU-wide and national strategies can help ensure policy coherency, ensure that demand and supply are aligned, and prevent contradictory policymaking that can potentially reduce investor confidence. It is also important that strategies are consistent over time. for example, some see the hydrogen development pathway to be a stepwise progression from grey to blue to green, neglecting the fact that each production method requires different infrastructure — while demand can seamlessly evolve in this fashion, supply cannot.

Almost all MS have set hydrogen targets. National electrolyser targets are at 38GW by 2030, near the EU's 40GW capacity target. However, national Hydrogen Strategies vary; while Germany's hydrogen strategy[185] sees only green hydrogen to be sustainable in the long term, others also include blue hydrogen. Bringing national strategies in line with the EU Strategy and Taxonomy threshold will enable intra-EU trade and investment.

Accelerating growth through hydrogen clusters

Hydrogen clusters or valleys are areas where hydrogen production and consumption are developed together, ensuring demand and supply scale together, creating a local hydrogen economy or hydrogen ecosystem.

The EU Hydrogen Strategy places the development of "Hydrogen Valleys" in the second phase (2025-2030) of its roadmap.[186] However, cluster development in the first phase would enable uptake of hydrogen technologies whilst still higher cost, given the lower distribution costs of linked supply and demand, and reducing the supply chain complexity created by transport requirements. Bringing clusters forward in the roadmap would help scale the market.

Co-locating supply and demand overcomes the specific challenges of the hydrogen value chain. Simultaneous development of production, storage, transport and use can de-risk investment and drive self-reinforcing development. This demand certainty is very important to make the business case for investments in production. Hydrogen valleys can also be established with simplified planning permissions, overcoming authorisation issues.

Clusters can be supported with subsidies, such as on electricity tariffs. Economic support can also be provided by underwriting long term purchase agreements or providing blended financing to the early development of end-use applications. Clusters can be located in existing industrial areas where hydrogen is possibly already produced. For example, in industrial ports - encouraging refining and chemical plants that currently use grey hydrogen to shift to cleaner production. The hydrogen can also fuel ships and trucks, power nearby steel plants etc. Inland transport hubs also have high potential for cluster development, as do refining/fertiliser clusters and steel plants.[187] Hydrogen clusters can also utilise public-private partnerships, targeting key technologies and capabilities.

Hydrogen clusters also provide wider economic stimulus; as such they are well suited to Next

Box 3: HyBalance: hydrogen valley development in Denmark

The Danish HyBalance project, led by Air Liquide, was funded with EUR15m from the European Fuel Cell and Hydrogen 2 Joint Undertaking. With Danish electricity production dominated by wind power, hydrogen production can store energy that would otherwise be lost and so ensure grid stability.[207]

The project demonstrates the role of hydrogen in balancing the electricity grid, see page 24. Hydrogen is stored in compressed cylinders and is transported via pipelines and trucking to provide industrial feedstocks and transportation fuels.[208]

The project has also stimulated the growth of a local hydrogen economy, attracting companies such as a fuel cell manufacturer.[209]

Generation EU (NGEU) funding. The EUR800bn NGEU recovery package provides economic stimulus following the COVID-19 economic shutdown. EUR250bn is funded by green bond issuance. The green bond framework is aligned with the EU Taxonomy and explicitly excludes fossil gas infrastructure.[188]

The Recovery and Resiliency Facility (RRF) provides EUR672.5 billion of loans and grants to Member States. Countries must allocate at least 37% and 20% of investments to the green and digital transitions. The RRF represents a unique opportunity for the EU to significantly advance its transition to a climate-neutral economy in line with the Paris Agreement objectives. 100% of investment must meet the EU Taxonomy's DNSH principles, while green projects are evaluated against the EU Taxonomy. Only green hydrogen is eligible to receive funds from this stimulus package.

An example of the use of EU funds for transition is the development of the Hydrogen Valley in Tarragona, which is currently a petrochemical industry hub. Spain has committed to allocate EUR1.55bn over the next three years to green hydrogen projects and expects this public support to mobilise up to EUR8.9bn by 2030.[189]

Safeguarding grid decarbonisation

For green hydrogen to be a viable decarbonisation option, RE capacity needs dramatic scale up. The 40GW planned EU electrolyser capacity will require 80-120GW additional RE capacity, on top of the 50 GW already required per year to reach climate neutrality. Anticipating supply chain needs will be crucial to prevent bottlenecks – green hydrogen could generate extra 300,000 TWh demand on the 800,000 TWh demand of direct electrification.[190]

Given the carbon intensity of European electricity grids, policymakers are clear on the need to link green hydrogen (physically or contractually) to RE installations. For instance, electrolysis hydrogen produced in Germany directly from the grid would be as carbon-intensive as grey hydrogen – emitting 3.5 times more CO_2 than the EU Taxonomy threshold of 3 tCO_2/tH_2.[191]

However, requirements safeguarding carbon intensity of electrolytic hydrogen will also need to ensure hydrogen production does not cannibalise RE production. There is a danger of large swathes of RE intended for grid decarbonisation being dedicated to electrolysers and therefore not contributing to the decarbonisation of electricity supply. Enabling legislation such as RED II (3.4), TEN-E (3.5) and the REPowerEU plans (3.6) will need to ensure and catalyse additional deployment of renewables to meet the needs of hydrogen production.

Additionality requires either off-grid production, on-grid associated with dedicated new RE installation or on-grid and powered by surplus renewable energy. Electrolysis hydrogen production will otherwise endanger the wider economic transition if additionality is omitted.

These additionality requirements will require careful drafting to allow room for green hydrogen's possible role in **grid balancing**. The EU Hydrogen Strategy sees hydrogen playing a balancing role, providing a medium-term supply buffer from the mid-2020s. Electrolysis presents one way for a 100% VRE grid to mitigate surging or blackouts by operating electrolysers at times of low demand, storing the hydrogen for combustion in power plants at times of high demand, and/or feeding the hydrogen into distribution for hard-to-abate sectors. Hydrogen has potential for daily and seasonal grid balancing and may be more cost-competitive than batteries. With increasing penetration of VRE, periods of surplus will be longer, with zero or negative market prices for electricity enabling the use of high CAPEX solutions such as hydrogen production. However, the losses of the conversion process mean shorter-term balancing needs may be best met by batteries or pumped hydropower. Hydrogen from surplus electricity may be best suited to seasonal grid balancing – given the greater suitability for long-term storage – or for sector coupling and transportation fuel production.

Incentives and market rules could encourage electrolyser operators to use RE that would otherwise be curtailed. One strategy would be locating them in areas with recurring grid congestion.[192] However, green hydrogen is not the only option for grid balancing and is an inherently inefficient process.

Maximising emissions reduction by prioritising hydrogen application

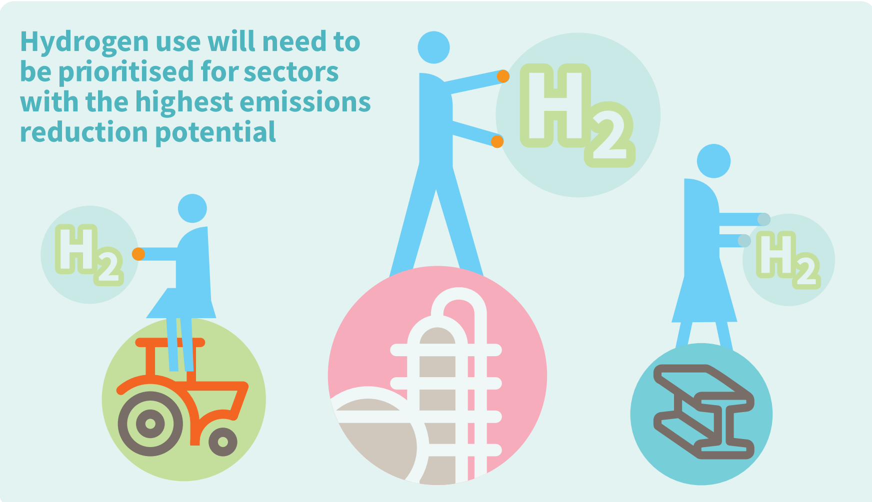
Green hydrogen will likely be the most competitive low carbon option across 22 applications by 2030, comprising 15% of global energy consumption[193]. There are certain sectors where hydrogen is expected to be a major method of decarbonisation (i.e., the 'no regret moves'[194]) such as steel, (long haul) aviation, shipping, industrial feedstock and high-grade heat. Policy can accelerate technological development and early adoption in these areas with high potential demand. The IEA identified refining, chemicals, iron and steel, freight and long-distance transport, buildings, and power generation and storage as the most promising sectors.[195].

Stimulating demand for low-carbon hydrogen is required to incentivise production. Policies are needed to create demand and investor confidence. Creating new lead markets goes hand in hand with scaling production. Long term offtake agreements can reduce market uncertainty; however, few sectors are market ready to provide large-scale hydrogen demand.

An immediate priority for the hydrogen economy is to replace the current use of grey hydrogen with green and stimulate its development in sectors with guaranteed long-term demand. Current grey hydrogen consumers such as fertiliser and chemicals producers present '**captive demand**' and can be prioritised. Fossil gas price surges are also likely to accelerate the transition of fertiliser production. Mandates could be set on the use of low-carbon hydrogen for feedstocks and eventually extended to outright bans on high-carbon hydrogen use.[196]

Hard-to-abate sectors such as steel, heavy-duty transport and chemicals require prioritisation for hydrogen usage over those such as heating which are currently possible and cheaper to electrify. Public sector funding for pilot programmes, such as the EU's InnovFin facility, can prioritise these sectors, particularly as many hydrogen technologies are currently still only at pilot stages and require scaling.

Mobility will also provide a large market for hydrogen. Liquid hydrogen, ammonia and synthetic aviation fuel for heavy-duty vehicles, shipping and aviation can provide large scale



demand. These are not as likely to be electrified, given the size and weight of the batteries required for their power. While synthetic aviation fuels will see a considerable cost premium, hydrogen fuel electric vehicles (FCEVs) would break even with diesel in HGVs if hydrogen were available at USD4.5/kg – commercial-scale pilot projects are already in the pipeline with significantly lower planned hydrogen prices. Mandates could help drive uptake in shipping and aviation, setting strong targets to stimulate synthetic fuel development; this could also prevent emissions targets from being met with damaging biofuels practices, as seen with corn ethanol in the US.

In sectors where other decarbonisation technologies exist, transition incentives can remain technology-agnostic to ensure cost effective application. While public transport will mostly be electrified, certain applications, such as long-distance, remote and high-altitude railways will find hydrogen more cost effective. Public transportation fleets provide a significant opportunity for long term offtake agreements to stimulate production, see page 26.

Demand creation is vital for the scaling up of decarbonised or low carbon energy sources. Market signals such as phase-out dates will help stimulate this and increase acceptance of the green premium.[197] These can also be supported by manufacturing targets for electrolysers and investment support for large scale manufacture and installation.[198] While it is often best for policy to be technology-neutral, allowing the most cost-effective and efficient technologies to come to the fore, there is a role for policy which accelerates economies of scale and the experience curve for a specific technology. Competitive electrolysis requires 70GW capacity, and green currently has a funding gap of USD20bn with grey hydrogen.[199]

Preventing bottlenecks

Support for hydrogen distribution infrastructure is a medium-term priority under the EU Hydrogen Strategy (page 22) because initial supply and demand are expected to be co-located. As hydrogen production costs fall and hydrogen use becomes more widespread, costs related to its distribution will play an important role.

While attention has mainly been focused on decreasing costs and boosting supply/demand, investors' concerns around distribution infrastructure need to be addressed, and distribution infrastructure undergo cost decline. This requires a strong push from public sector to ensure midstream distribution not neglected – cannot solely focus on supply and demand. There is a risk of hydrogen project failure as a result of a lack of distribution infrastructure between supply and demand locations: "project on project risk".[200]

The EU single market provides a strong advantage for developing a largescale infrastructure network and a sophisticated hydrogen economy. The recommendations of the Strategic Forum for Important Projects of Common European Interest (IPCEI) are to take joint action across several MS to support a hydrogen supply chain. The IPCEI instrument enables State aid to address market failures for cross-border integrated hydrogen projects.

Policies related to low-carbon hydrogen distribution need to support different methods of transporting hydrogen. Support measures for hydrogen distribution will be challenging to implement due to the complex cost differentials of pipelines, shipping and trucking. Hydrogen pipelines represent the cheapest option for distribution for short- and medium-term distances.[201] Pipelines can transport ten times the amount of energy carried by electricity lines and have nearly the same CAPEX as fossil gas pipelines. In particular, pipelines are the most cost-efficient means of distribution in the long term when more than 10t/day of hydrogen are transported.[202] However, in the short- to medium-term, colocation is most competitive and will often outcompete transport. The TEN-E PCI mechanism is well suited to provide support to hydrogen distribution as projects are evaluated on a case-by-case basis.

Hydrogen long-distance distribution is also highly dependent on partnerships between countries and developing common standards, tackling issues such as safety risks, operation and liability and international guarantees of origin and CO_2 emissions.

Spurring innovation

Establishing research and development (R&D) programmes is one of the first steps for governments to support nascent transitional technologies. R&D programmes can be target particular technical challenges, harnessing academic and industrial expertise. The IEA estimates European spending on energy R&D at USD8.5bn in 2020 and USD8.9bn 2019,[203] however, the EU's rate of public investment in clean energy technologies needed for decarbonisation is the lowest of the major economies (0.027 % of GDP in 2019).[204]

Cooperation and collaboration are crucial to the success of R&D programmes. Collaboration with industry allows identification of R&D priorities, strengthening knowledge flows. Such industrial collaboration is also seen in the development of hydrogen clusters. International cooperation will also enhance innovation. This will also help facilitate potential future hydrogen trade deals, enabling the EU Hydrogen Strategy's trade ambitions.

An example of R&D support that can boost hydrogen investment is the EIB's InnovFin Energy Demo Projects initiative. This provides loans, loan guarantees or equity-type financing of EUR7.5-75m to innovative demonstration projects in energy transformation.[205]

Private investment can also drive R&D, private equity (PE) and venture capital (VC) investments to support early-stage projects. Green PE and VC hold growth potential – the European Investment Fund's (EIF) SME, PE and VC support[206] could integrate climate impact, providing more favourable guarantees and equity on green projects. See page 25 for more on guarantees and subsidies.

Recommendations to facilitate transition to hydrogen

- The Hydrogen Strategy's roadmap envisages large-scale deployment to begin after 2030. Increasing this ambition will encourage investment and encourage hard-to-abate sectors to invest in hydrogen in the next investment cycle.
- Uncertainty over demand, distribution, or supply can reduce investibility of hydrogen projects. Clusters, co-locating supply and demand can overcome this and represent a powerful strategy to rapidly grow the hydrogen economy. Targeting cluster development now rather than in the second phase of the roadmap would help overcome transport costs.
- Large-scale installation of grid-connected electrolysers will increase electricity demand – planned electrolysers in RED II would consume 50% of RED II planned renewable electricity supply growth and so **hinder grid decarbonisation**, unless accompanied by new dedicated renewables installations.
- Sector transitions need to keep the whole economy transition in mind; the emissions reduction potential of hydrogen significantly varies from sector to sector. To ensure rapid emissions reductions by 2030, hydrogen use will need to be **prioritised for sectors with the highest emissions reduction potential**.

6. Mobilising investment to meet 1.5°C

Investment in the energy transition needs rapid scaling, involving reorientating of flows from high to low carbon, and the growth of overall energy investment. This can be facilitated by government action to enable pilot projects and de-risk investments, central banks incorporating climate factors into monetary policy and prudential regulation, and regulators increasing climate risk considerations.

Nascent, relatively unknown projects require public resources to de-risk investment – as seen in early stages of wind and solar development.[210] Alongside direct public funding, governments can establish credible long-term fiscal and regulatory frameworks, e.g., contracts for difference, to lower the associated risks borne by investors. Public-private partnerships (PPPs) can encourage private capital flows into higher risk areas. **Blended finance** uses various instruments to crowd in private capital including guarantees, insurance, currency hedging, technical assistance grants, first loss capital, and loan syndication.

However, such mechanisms may not be required across all applications of these technologies as hydrogen production is beginning to be proven at scale by private actors. PPPs may hold most value in challenging projects such as largescale hydrogen transmission networks. Feed in tariffs can help overcome price differentials between conventional high-carbon and green production and offer long-term security to renewable energy producers. Feed in tariffs were instrumental to wind and solar scaling, however, they are increasingly replaced by instruments which also enable competitive pricing – such as contracts for difference or auctioning.[211]

A key EU tool to finance towards innovative technologies is the Innovation fund, implementation of which is set to be brought forward under REPowerEU to accelerate the industrial transition away from fossil gas.

De-risking investment

Guarantees are important enablers of nascent technologies such as green hydrogen production. They address the investment risk of first-movers and encourage private sector investment.[212] Guarantees can be fiscally efficient as they mobilise additional investment, therefore, having a far greater impact than direct investment and result in lower balance sheet liability than direct subsidies. Green guarantees and subsidies will all need alignment with the EU Taxonomy to ensure they are supporting robust green investments.

Guarantees can mobilise massive investments, provide convening support to platforms orchestrating value-chain collaborations and de-risk demonstration funding, for example, the InvestEU Fund, 30% of which must support climate investments which aims to mobilise over EUR372bn of public and private investment through an EU budget guarantee of EUR26.2bn.[213] 75% of the guarantee will be implemented by the EIB, which has already committed to becoming the EU's Climate Bank and to raise climate financing from 25% to 50%.[214] This has raised concerns over the value of providing guarantees to the EIB, and whether these will create additionality, given the experience of the Juncker Plan, i.e. whether the EIB would have funded the guaranteed projects anyway.[215] Further specifying minimum allocations of the Fund to innovative climate investments will ensure greater additionality.

Subsidies also mobilise private investment. In 2019, renewables received EUR78bn in subsidies. It is important that subsidies target those sectors for which there is the greatest need to improve investibility, such as hydrogen. Many different EU subsidy schemes are available to hydrogen projects, however, EU-level subsidy schemes will often require MS supporting schemes to ensure their accessibility.[216] Establishing clear phase-out dates for subsidies also ensures that schemes do not stifle competitiveness and innovation – private investment has been proven to step in once subsidies are phased out.[217]

Improving renewable energy competitiveness

Carbon contracts for difference (CCfDs) provide low carbon electricity generators with revenue certainty, with the producer paid a subsidy to cover the cost difference with conventional electricity production. This improves the cost competitiveness of renewable energy production.

Unlike feed in tariffs, CCfDs are auctioned to ensure competitive pricing. However, depending on their scope, their contribution to scaling innovative technologies may be limited if they are technology agnostic. In this case, auctions may be dominated by mature technologies, limiting the support available to novel technologies such as hydrogen.[218] For this reason, the UK Government is consulting on a separate CCfD scheme for hydrogen.[219]

The REPowerEU communication declared the Commission's intention to bring forward the implementation of the Innovation Fund to support industrial switch to electrification and hydrogen, including through an EU-wide scheme for CCfDs.[220] CCfDs also come under the new EU state aid guidelines. The guidelines will allow governments to support clean technology with CCfDs.

The UK CCfD scheme for low carbon electricity generation provides an example to the EU for development of a hydrogen CCfD scheme. The scheme establishes a 15-year period of payments based on the difference between the production cost of low-carbon energy and average market energy prices. This provides direct protection to developers from volatile wholesale prices, a critical issue when considering projects with high upfront costs and long lifetimes. Additionally, they protect consumers from paying a premium to suppliers when electricity prices are high, and so can contribute to the Just Transition. The competitive nature of the programme means the strike price (i.e., the agreed price on the contract for difference) decrease over time; reflecting and incentivising decreasing technology costs. The scheme is funded by a levy on electricity suppliers (the Supplier Obligation), and so provides an additional transition incentive.[221]

Technology agnostic CCfDs may not contribute to scaling innovative technologies. Sector-specific hydrogen CCfD programmes could help rapidly grow the industry in those sectors for which hydrogen is the most viable decarbonisation method, without providing blanket support which could create inefficiencies. An EU-wide low-carbon hydrogen CCfD programme could promote the transition of existing hydrogen production, and support green ammonia and synthetic fuel deployment.[222] Alignment with EU hydrogen standards and regulations such as the Taxonomy and RED II can ease deployment. Additionality requirements can protect renewable electricity expansion. Sector-specific CCfDs can also help target hydrogen deployment to those areas where it will be most needed for decarbonisation. Germany is already planning pilot CCfDs to promote green hydrogen in the hard-to-abate sectors of steel and chemicals.[223]

Facilitating financial innovation

Financial innovation is intrinsic to any financial system but suffered an important setback in the aftermath of the 2007 global financial crisis. The subprime mortgage market in the US and emergence of complex financial products were a catalyst for deep market disruptions and the bankruptcy of major financial institutions.[224]

However, financial innovations such as the CCfDs outlined above have helped overcome financing challenges of the energy transition, namely long-term investment horizons and associated uncertainty. Supportive frameworks for the creation of new financial mechanisms could complement the existing set of financial mechanisms currently used to finance transition activities.

Regulatory compliance requirements can

prevent financial players, especially smaller ones, from innovation. Therefore, many regulators are establishing so-called regulatory sandboxes that allow financial products to be tested in a controlled environment, exempt from compliance with regulatory requirements. Complying with such regulatory framework is the biggest barrier to entry for financial services providers. Once these are tested, and if successful, they shall be launched on to the market and required to comply with the regulatory framework in place. Many European countries have established their Sandboxes,[225] but the UK's Financial Conduct Authority is a pioneer in promoting innovation in finance to support the transition to net zero through its *Green Fintech Challenge*[226] and *Digital Sandbox.*[227]

Securitisation was also seen as contributing to the GFC. The EU securitisation market has not recovered since despite the issues lying with the US, not the EU, market. The European Banking Authority has issued recommendations to promote sustainability in the EU securitisation market to foster transparency and credibility and support its sound development.[228] Institutional investor demand for securitized solar assets (asset-backed securities) is growing,[229] and therefore, a sound framework for the securitization of hydrogen-related assets could help securing additional financing to the sector.

Other financial innovations can be applied to the financing of the transition of the gas sector, such as sector-specific exchange-traded funds (ETFs). LGIM issued its USD500m L&G Hydrogen Economy UCITS ETF in 2021 to allow investors to gain exposure to this sector.[230] ESG ETFs are growing in popularity.[231] ESG funds have recently been targeted by climate activists to exclude gas-related stocks due to the war in Ukraine and following the proposed Taxonomy Delegated Act including nuclear and gas.[232]

The European Investment Bank's InnovFin Advisory service guides Research and Innovation projects to improve their access to financing. The InnovFin Advisory has advisory agreements with major industry representatives such as Hydrogen Europe, the Hydrogen Council and France Hydrogène, to promote innovative financial schemes to fund large-scale hydrogen projects.[233] The InnovFin Advisory helped H2 Mobility Deutschland, a consortium and supported by the German Transport Ministry, to design a financing model to maintain and expand a network of 100 hydrogen refuelling stations in Germany. The Advisory Hub identified several public-private partnership options that could be used to finance the project, ensuring public funds are invested efficiently in the project.[234]

The EIB also provides via its NER 300 Advisory programme[235] advice to early-stage innovative low-carbon projects which are prepared for commercial roll-out. This will increase chances of receiving financing from EIB and other EU programmes, namely the European Commission's Innovation Fund[236], which articulates the European Commission's financing strategy for climate action. This Fund is financed by EU ETS income. Its first Large Projects call amounted a total of EUR1bn awarded to a total of 7 projects. The second, totalling EUR1.5bn,[237] and received 138 applications amounting to EUR12.1bn, mainly from Spain, France and Germany, 25 of which were related to hydrogen.[238] This oversubscription will require careful prioritisation by impact. It also suggests the Commission significantly increases the available funding in future calls since clean technology investment is a key lever for the EU to achieve its climate objectives. An additional call of EUR100m for small-scale projects with capital costs under EUR7.5m will be launched in 2022. As the Innovation Fund is funded by ETS revenues, a faster phase out of free permits would permit raising the total financing available to develop much-needed technological innovation.[239]

Encouraging green public procurement

Government procurement can play a significant role in energy sector transition. Not only does it account for a significant portion of emissions but long-term offtake agreements generate demand security. This can ensure investor confidence on returns and price stability.

While public procurement provides greater opportunities in the steel and concrete transitions, given the large share of demand from public buildings and infrastructure, there are still opportunities to transition energy demand.[240] Given current uncertainty over demand for hydrogen, and a need to stimulate both supply and demand to grow the sector and procurement could help stimulate the hydrogen economy. Public bus and train fleets could provide captive recurring demand, when electrification is not possible. Hydrogen-powered trains are planned in Germany[241] and Italy[242] to replace diesel trains on long train lines where electrification would entail higher costs. These can also boost local industry and establish hydrogen clusters, such as in the Italian case.

The EU has published voluntary GPP criteria so as to facilitate the inclusion of green requirements in public tenders.[243] These voluntary criteria could be gradually replaced with mandatory criteria, embedding preferential spending across ministerial budgets, ensuring climate policies are realised in all sectors of the economy. Ministries could be obliged to incorporate climate considerations into cost assessments or to allocate a certain portion of budgets to low carbon solutions. Given the large purchasing power of governments, such policies can not only send a market signal but also make a significant contribution to sustainability targets. These criteria can also be aligned with the EU Taxonomy criteria, ensuring consistency of green investment.

Targeting of such spending to less mature green technologies can also act as a "demand-pull" driver, driving down their cost, as seen with solar and wind installations.[244] Green procurement policies (GPPs) can be used to stimulate local economies. GPPs can also improve economic stability, insulating government spending from external shocks such as volatility in oil prices.

GPPs could also enable decarbonisation of heating. District heating, whereby many individual houses are centrally heated by one source, is one solution to replacing gas boilers. A GPP for the heat supply agreement could establish an offtake agreement with a renewable electricity supplier. This could also help stimulate the local economy as the district heating system would require installation and operation of heat generation and transmission infrastructure. Such a scheme would also align housing policies with the proposed extension of the EU ETS to domestic fuel providers from 2026 and revision of the Energy Taxation Directive to align heating fuel tax rates with climate policies.[245]

Initiating global hydrogen trade

Estimates predict that the global hydrogen market will reach USD 2.5 trillion by mid-century.[246] The EU's hydrogen strategy anticipates substantial imports of green hydrogen with 40 GW of the 82 GW planned electrolysers located in the EU Neighbourhood,[247] REPowerEU is set to increase this. North Africa's high renewables potential means it could provide cost competitive green hydrogen to Europe. Similarly, eastern and southern Europe may also be able to build hydrogen export markets. The Hydrogen Strategy suggests the EU actively promote new opportunities for cooperation on clean hydrogen such as agreements with European Neighbourhood. There is a danger posed by overreliance on expected imports. For example, the 40 GW of electrolysers envisaged in the EU Neighbourhood would require 77 GW RE capacity but the 2021 capacity in Ukraine and North Africa was 22 GW.[248]

REPowerEU plans pilot projects on renewable hydrogen production and transport in the EU neighbourhood, starting with a Mediterranean Green Hydrogen Partnership. Hydrogen imports from the EU Neighbourhood also pose a risk that exports cannibalise much of these countries' RE expansion, limiting their own transitions, particularly given some countries' current low RE penetration and largely untapped renewable potentials. Green hydrogen production for the European market would likely provide companies with the highest economic returns on their electricity. This would substantially slow the transition of the local electricity grid away from fossil-based generation. High demand for hydrogen from the developed world has the potential to exacerbate low-income countries' resource curse. Trade agreements for hydrogen, or indeed renewable electricity will need caveats beyond the RE additionality requirements suggested for the EU that ensure contribution to local transition.

Carbon pricing and the CBAM have been seen as limiting international trade. A green window offers an opportunity to compensate for CBAM trade curtailments. A green window would entail reducing tariffs on environmentally friendly goods and services and products that are produced using green processes, such as low-carbon hydrogen: "zero tariffs on zero-carbon". Green hydrogen has been suggested as a potential transatlantic trade flow from the US.[249] There is potential for the launching of international shipping routes – utilising lessons from the growth of the global LNG market.[250]

Reorienting investment flows

The European Central Bank (ECB) presented an Action Plan to include climate change elements in its monetary policy strategy as part of the monetary policy general review[251] and is committed to develop new experimental indicators covering green financial products and the carbon footprint of financial institutions. The ECB will follow-up in 2022 with step-by-step enhancements of such indicators.[252]

ECB has analysed the integration of climate risk in the European banking sector, covering 112 directly supervised banks with combined assets of EUR24tn, and concluded that none were close to meeting its expectations on climate and environmental risks[253] and called on them to address their shortcomings. In some cases, banks will receive a qualitative requirement as part of the Supervisory Review and Evaluation Process (SREP). The ECB will gradually integrate climate and environmental risk into its SREP methodology. This will eventually influence Pillar 2 capital requirements. The ECB will need to continue pushing for the integration of climate risk in European banks' balance sheets.

Prudential regulation can ensure financial resilience to transition risks. Inefficient investment decisions in the gas sector have important implications in the financial system: Central banks need to address the risk of stranded assets posed by investments in fossil gas infrastructure from financial institutions which could potentially jeopardise the whole financial system's stability.[254]

In this sense, prudential adjustments can be made so as to preference green lending or discourage lending to assets liable to climate risk. **Risk weighting of assets** can be made more sensitive to climate risk, for example, People's Bank of China (PBOC) gives banks a higher macroprudential assessment score if they hold a high number of green assets.[255] Whilst there are concerns over the impact of adjusting risk weighting on bank stability, green supporting factors can overcome the higher risk weights often on green assets given their longer payback periods but require greater risk sensitivity provided by taxonomy and disclosure requirements.[256]

Basel III's Countercyclical Capital Buffer (CCyB) is a powerful macroprudential tool which aims to protect the banking sector from periods of excess aggregate credit growth that have often been associated with the build-up of system-wide risk.[257] A **countercyclical carbon capital buffer** could be implemented, acting similarly to the CCyB to give climate-sensitive resilience to banks or setting exposure restrictions for certain assets or sectors.[258]

Central banks can vary **capital requirements** according to an FI's climate risk exposure. Capital buffers would be set higher for those with greater exposure to unsustainable activities because these FIs would be at greater risk of default. Finance Watch has proposed a "one-for-one" capital requirement rule for the financing of new fossil fuels: that for each euro/dollar that finances new fossil fuels projects, banks and insurers have a euro/dollar of their own funds held liable for potential losses. Conversely, capital requirements could be discounted according to an FI's green lending. In 2019 the Hungarian central bank, Magyar Nemzeti Bank (MNB), did so, announcing a preferential capital requirement against balance sheet exposure to energy-efficient housing loans.[259] The discount reflected the reduced risk of default on green mortgages.[260] Similarly, Lebanon's CB, Banque du Liban, differentiates reserve requirement ratios according to the amount of bank lending flowing to renewable energy and energy efficiency projects.[261]

The ECB has carried out a 30-year **economy-wide stress test**, the results of which showed concentration of climate-related risks in certain regions, sectors and companies.[262] This informs CB and wider EU policy. Communication of the stress test results can also aid the real economy – for example, in all sectors, a lack of transition increased the risk of default. MS CBs could carry out stress testing to identify national vulnerabilities. These could be focused on the energy transition in CBs with lower capacity for stress testing. Energy transition stress tests could follow the example of De Nederschlande Bank (DNB), whose 2018 stress test showed that a disruptive energy transition would have a greater impact on financial institutions, with losses mitigated by early transition policies.[263]

Monetary Policy can be adjusted to include assets' climate risk. The ECB's quantitative easing (QE) programme has benefitted all corporate bond issuers, especially larger corporates, and generally contributed to lower yields. Currently, the ECB's bond purchases are driven by the 'market neutrality' principle: the composition of corporate sector purchase programme (CSPP) holdings is generally intended to reflect the existing eligible bond market structure. The ECB applies this approach by ensuring its purchases mirror the eligible CSPP bond universe by country, sector, and rating group.

However, this principle disproportionately favours carbon intensive sectors, particularly the fossil fuel sector, as it relies on backwards-looking metrics.[264] According to Reclaim Finance, the ECB has likely bought about EUR15.3bn of fossil fuel bonds and EUr80bn bonds from carbon-intensive activities with its COVID-19 QE expansion.

ECB increased the number of Shell, Total Energies, Repsol, Eni and OMV bonds by 16.2% from April 2020 to September 2020. Some Total and Shell bonds held by the ECB will not be repaid before 2040 and 2039 respectively, while Repsol, OMV and Eni bonds mature in 2033, 2034 and 2031. This discredits the ECB's July 2021 climate roadmap.[265] These companies are all diverging from transition pathways. None has ceased exploration or new production approvals or announced credible production reduction plans. Notably, Shell, Total, Repsol and Eni are aggressively betting on LNG with 20 new LNG terminal projects, despite the IEA stressing that such projects are risky and unnecessary.[266] Carbon Tracker found that planned fossil fuel capex exceeds the IEA's STEPS scenario that drives global warming to 2.7°C by an average 65.6%[267]

Green QE is currently being considered by central bankers across the globe. **Negative screening** is one of the most common sustainable portfolio management tools used by central banks and is used chiefly in CB's equity holdings.[268] For example, in 2019 Sweden's Riksbank applied climate risk-weightings to a portion of its SEK500bn foreign exchange reserves. This resulted in it excluding bonds issued by the highly fossil fuel-exposed provinces of Alberta, Canada and Queensland and Western Australia.[269] Riksbank also applied exclusion criteria to its corporate bond purchase programme, requiring bond issuers comply with sustainability standards to be eligible for the QE programme.[270] The Bank of England published how it will green its Corporate Bond Purchase Scheme (CBPS) to account for the climate impact of the issuers of the bonds held, targeting a 25% reduction in the weighted average carbon intensity of the CBPS portfolio by 2025, and full net zero alignment by 2050.[271] Exclusion of assets with high climate-risks from asset purchases can also help to reduce the risk to the central bank's balance sheet.[272]

Negative effects on credit flow to corporations in hard to abate sectors suggest that central banks could look at incorporating transition-labelled bonds in their corporate bond purchase programmes. Central bank intervention could also push for financing of transition specifically and not just “green” activities.

The energy transition poses a financial risk due to the impact of energy prices on inflation. Following the 2021/22 winter energy price shocks, the ECB has raised the possibility of the energy transition causing prolonged inflation of energy prices. The possibility of the energy transition causing energy prices to impact consumer price inflation was one factor in its decision to reduce the pace of asset purchases.[273] The ECB can consider, in order to provide a further boost to the green bond market, running a permanent QE programme holding exclusively green and other labelled bonds alone, even once current expansive monetary policies are halted.[274]

Recommendations to mobilise investment to meet 1.5°C

- Guarantees and subsidies can de-risk clean energy investments but if not targeted can be absorbed by more mature technologies. Requiring a certain level of allocation to nascent technologies can ensure they facilitate those projects which are most in need of investment. Carbon contracts for difference represent a powerful tool to grow renewables and hydrogen production.
- Financial innovation is limited by the regulatory environment. The EU could consider establishing regulatory sandboxes to facilitate financial innovation.
- The EU has green public procurement criteria, but these are currently voluntary. Establishing a timeline for introduction of mandatory criteria in line with the EU Green Deal would enable the embedding of preferential spending in ministerial budgets. Aligning green public procurement standards with the EU Taxonomy criteria will ensure consistency of green public investment.
- To compensate for CBAM trade curtailments, trade negotiations can be used to establish green windows; preferential trade agreements on green goods such as low-carbon hydrogen and ammonia.
- The ECB has recognised that traditional asset purchase along market neutrality principles overly favours fossil fuel assets. Prioritising green assets in the corporate bond purchase programme will address this imbalance.
- Given the importance of bank lending in this sector, the ECB could increase reserve requirements according to carbon intensity of lending, encouraging origination of green debt.

7. Conclusions

The fossil gas value chain stretches across much of the economy; used domestically and industrially. The fossil gas and wider energy transition will result in a reshaping of the global economy. The transition will be met by many different activities, from demand reduction to electrification to hydrogen use. Therefore, transition policies will need to be equally wide-ranging, while also providing direction and certainty for investment.

The transition is also complicated by the wide range of actors in the sector, with strong vested interests, often backed by powerful lobbying capabilities. The success of the fossil gas transition relies on strong policy support. Policymakers not only set out the conditions required for a net-zero energy sector but also play a major role in determining which pathways are taken. The Climate Bonds Standards for fossil gas and hydrogen (still in development) and this policy package provide science-based guidance on what constitutes a truly 1.5°C-aligned fossil gas sector transition.

The most important role of policy in this process is to provide investment **clarity, certainty and direction**. Policies must be coherent and aligned, to encourage rapid reduction of fossil gas demand, facilitate investment in the transformation of fossil gas companies and assets, and enable scaling of nascent technologies.

Transition of the fossil gas sector requires business model transformation, renewable electricity expansion, energy efficiency gains, and development of a low-carbon hydrogen economy. Policymaking will need to allow flexibility over the means by which targets are implemented so as to allow for implementation of the most cost-effective technology for each context. However, there is also a need for **strategic** policy to prevent bottlenecks and enable the reshaping of supply and demand that the net-zero energy system requires. Policies will need to scale production and create demand, whilst ensuring strategic application of what will be a limited resource and including careful additionality requirements to prevent electrolysis from cannibalising large swathes of renewable electricity capacity

The policy toolbox for this transition is therefore wide-ranging; including economy-wide standards and regulation, sector-specific support such as contracts for difference and strategic legislation such as TEN-E. Policies can also safeguard against decarbonisation strategies which may hinder rapid decarbonisation or threaten the Just Transition. For example, switching to marginally more efficient combustion technologies may lock in years of future emissions, while gas blending may land consumers with the cost of developing hydrogen networks despite not being the beneficiaries of them.

Large capital flows are required for this transition, including an increase in overall energy spending. Policymakers can prevent this from discouraging action; while costs of transition are high, these are dwarfed by the cost of inaction.[275] There is large investor appetite for Paris-aligned investments, but existing energy sector investment is dominated by fossil fuels. The challenge is largely in **redirecting capital flows**, and in ensuring strategic investments to create a reliable and comprehensive renewable energy system to replace the fossil-dominated energy system.

While gas will continue to play a role in the energy mix up to 2050, that does not imply that it should qualify as a "transitional activity".[276] Attempts to define unabated fossil gas power as green/transitional will create confusion, possibly endangering investment in other green projects.[277] The transition of the fossil gas sector must also not hinder the transition of other sectors. A holistic approach to transition, as set out in this policy package, will ensure whole-economy emissions reductions.

Appendices

Appendix I: Financing trends

- There is high demand for green bonds
- The fossil gas sector needs investment to transition its operations to align with Fit for 55 and Climate goals
- Clear finance criteria setting out investment standards to transition fossil gas are needed to guide issuers and investors

USD34.79bn bonds were issued in the fossil gas sector in 2020, of which USD5.44bn were green bonds (less than 2% of total green bond issuance). With green bond appetite still outpacing supply, this market and the nascent transition/sustainability-linked bond market holds high potential to fund the sector's green transition if clear Paris-aligned criteria are maintained.

Global energy investment is set to rise to USD1.9tn in 2021, a 10% rise on 2020, bringing investment back to pre-pandemic levels. However, investment trends are changing, with investment composition shifting away from traditional fuel production and towards power and end usage, see Figure 9: Global Energy Investment. Upstream oil and gas supply has seen a significant drop on 2019 investment, whilst renewable power has seen a steady increase, see figure 5. The IEA attributes the 2021 upswing to both a cyclical response to recovery and a structural shift in capital flows towards cleaner technologies.[278]

Investment in renewables account for 70% new power generation investment, with investment thriving in markets with well-established supply chains and regulatory frameworks that provide cash flow visibility.[279] Whilst this change in investment patterns signals the energy transition is indeed underway, this transition requires acceleration. Policy is required to both ensure a smooth and just transition, but also ensure the transition follows the steep emissions decline required to meet the 1.5-degree target.

Figure 8. Annual global fossil gas sector bond issuance[303]

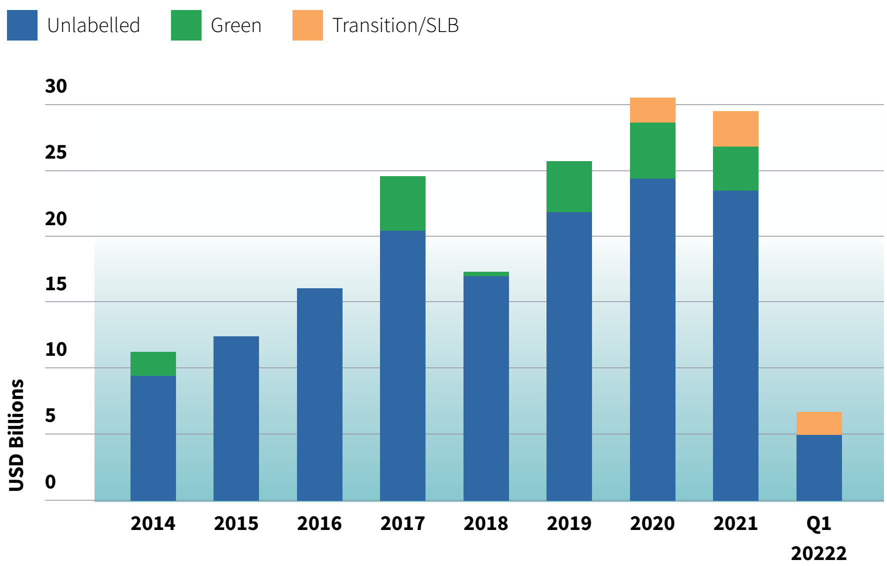


Figure 9. Global Energy Investment[304]

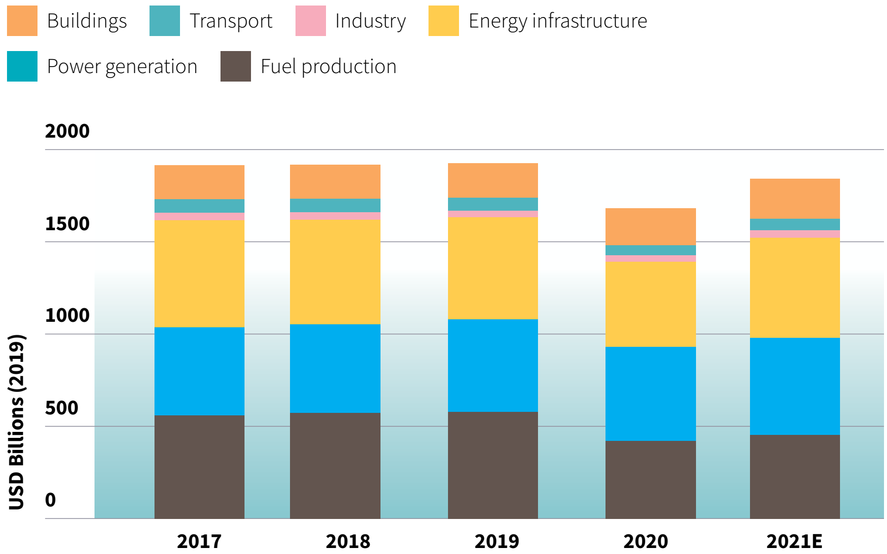
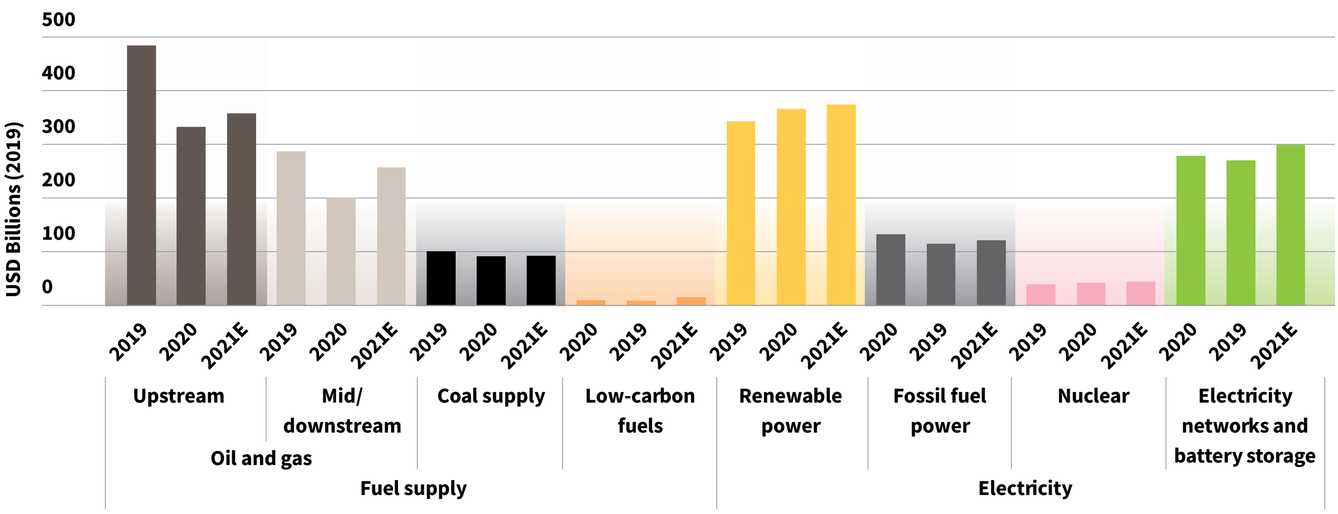


Figure 10. Global energy supply investment by sector[305]



Appendix II: Cost of green hydrogen technologies

While the cost of electrolysers has fallen 60% since 2010,[280] it is currently USD800/kW. As the technology matures and scaling introduces cost efficiencies, the cost is expected to decline significantly and could be USD200/kW in 2030 and USD100/kW in 2050.[281] Higher capacity factors will also reduce cost, as the CAPEX is distributed over more operating hours.[282] Given high electrolyser costs, low-cost electricity is needed (USD20/MWh) to bring green hydrogen comparable with grey.[283]

- Levelized cost of storage (LCOS) of hydrogen in salt caverns is estimated to be between EUR6 / $MWhH_2$ (monthly cycling) and EUR26 /$MWhH_2$ (biannual cycling), in rock caverns EUR19 / $MWhH_2$ (monthly cycling) and EUR104 /$MWhH_2$ (biannual cycling), and depleted gas fields EUR51-76 /$MWhH_2$
- Levelized cost of transmission (LCOT) of hydrogen from retrofitting fossil gas infrastructure is estimated at EUR3.7m/ MWh_{H2}/600km, LCOT of new infrastructure estimates vary from EUR4.6-45m/ MWh_{H2}/600km
- Levelized cost of distribution: in new infrastructure EUR0.05-1.61 /$MWhH_2$/km, refurbished EUR0.11 /$MWhH_2$/km, and by truck EUR0.54-2.46 /$MWhH_2$/km[284]

Scale-up will be the biggest driver of cost reduction. 90% of cost reduction for non-transport applications are from scaling up supply chain, 70% cost reduction for transport applications are from scale-up of end-use equipment. Scaling can target critical tipping points, e.g., 70 GW electrolyser capacity.[285]

Electrolyser manufacturer Nel is targeting green hydrogen production costs of USD1.5/ kg (competitive with grey) by 2025. The German industrial conglomerate Siemens also targets USD1.5/kg green hydrogen production by 2025 based on large-scale commercial projects in operation. Adani in India is targeting USD1/kg in 2022.[286]

Appendix III: EU Stakeholders

- At EU level, the European Commission is responsible for drawing up proposals for EU legislation and for implementing the decisions of European Parliament and Council. The European Commission's Directorate Generals of Industry, Environment, Energy, Climate and Financial Services produce legislation that directly impacts the gas industry and market.
- Fossil gas industry players and associations are powerful stakeholders, with strong vested interest in the continued expansion of the fossil gas sector and so have put a lot of resources into labelling it as transitional. However, these players also hold valuable resources for the gas transition, with some already significantly diversifying their business into renewables and green hydrogen to capture the opportunities of the transition.
- Hydrogen associations are working to promote the role of green hydrogen in the transition, with support from the European Commission, as are research bodies and non-governmental organisations.
- Environmental NGOs, active both at national and EU level, are pushing for a quick transition to net zero societies and the removal of fossil gas from the energy mix of EU Member States.

Industry stakeholders represent a powerful lobby in favour of the status quo calling for continued or even expanded use of fossil gas, rebranded as "sustainable, natural or decarbonised gas". These tactics are bearing fruit in Europe with increasing confusion over the sustainability of gas and the risks of asset stranding, runaway climate change, continued energy insecurity and energy poverty all successfully obfuscated by fossil fuel lobbyists.

Fossil gas industry stakeholders

Eurogas represents European fossil gas wholesale, retail and distribution sectors. It promotes fossil, renewable and decarbonised or low-emissions gas[287] as part of the transition.[288] **Gas Infrastructure Europe** is the gas infrastructure operators' industry association, envisaging new gas infrastructure development as the backbone of the 2050 energy system.[289]

Both are part of GasNaturally, a partnership of eight associations representing the European fossil gas value chain. GasNaturally promotes the use of fossil gas as part of the energy transition, claiming its role in transitioning away from coal and balancing the energy grid.[290] It also strongly promotes CCS and blue hydrogen production for transition.

Europe's biggest gas transmission system operators (TSOs) are Enagás (Spain), Fluxys (Belgium), GRTgaz (France) and Snam (Italy), together owning more than half the EU's LNG terminals and over 100,000km of pipeline[291] TSOs see gas sector transition as a case of replacing fossil gas with hydrogen and/or biogas, so as to minimise changes to their business models. For example, Snam aims to be net zero carbon by 2040 (scope 1 and 2 emissions),[292] transport entirely decarbonised gas (blue/green hydrogen and biomethane) and is testing hydrogen blending in fossil gas supplies.[293]

Major gas companies in Europe including Shell, Exxon and Total promote fossil gas as a transition fuel, whereas others are already focussing on transition to other fuel sources. Orsted is an example of an oil and gas major transitioning to producing solely renewable energy, targeting carbon neutrality by 2025. It reached a 90% green energy share in 2020, using green bonds and loans to fund the green transformation and build-out of green energy. It is also planning renewable hydrogen projects centred on industrial centres such as the Dutch-Flemish North Sea Port cluster, partnering with industry to create regional hydrogen economies.[294]

Enel plans to increase its green hydrogen capacity to over 2 GW by 2030, developing a series of projects for the production of green hydrogen by installing electrolysers powered by renewable energy and located near consumption sites. Enel sees green hydrogen as the only sustainable hydrogen and promotes its use for hard to abate sectors rather than grid decarbonisation.[295]

Hydrogen economy stakeholders

The **Renewable Hydrogen Coalition** aim to position Europe as the global leader in green hydrogen, providing proposals for the scaling up and market uptake of green hydrogen. They promote green hydrogen over other forms to avoid carbon lock-in and GHG emissions of blue, as well as to balance the European energy system and use excess renewable electricity.[296] Pureplay hydrogen companies are often small-scale chemical feedstock specialists, but larger companies include Air products in France, targeting hydrogen mobility[297] and DH2 Energy which aims to scale hydrogen production to reach competitivity with fossil fuels in industry, power generation, heat etc.[298]

The **European Clean Hydrogen Alliance** is one of the key initiatives of the EU Hydrogen Strategy for a climate neutral Europe, launched in July 2020 to support its hydrogen production and deployment ambitions. It is building up a pipeline of investment projects along the green and blue hydrogen value chain.[299] Over 1500 stakeholders have joined since the Alliance's launch and over 1000 projects submitted. The project pipeline was unveiled in November 2021. It includes over 750 projects from all parts of the value chain.

Institutional stakeholders

The **European Commission** holds energy policies as a core competency, with several Directorate-Generals and Commissioners involved with them. The new executive structure defined by President Ursula von der Leyen is based on a hierarchy of nationally elected Commissioners grouped in areas under control of one of the five Executive Vice-Presidents.

The **European Parliament** is responsible for passing law initiated by the European Commission. The work of the Parliament is prepared in parliamentary committees. The committees impacting on the gas industry and market are: ENVI - Environment, Public Health and Food Safety[300], the ITRE - Industry, Research and Energy[301], the IMCO _ - Internal Market and Consumer Protection and ECON - Economic and Monetary Affairs[302].

The **European Council** defines the EU's overall political direction and priorities, headed by the 27 Heads of EU Member States. The Council of Ministers is negotiating EU legislations with the EU Parliament. The Permanent Representations of each Member State accompany Ministers at the negotiation meetings. Communicating with the 27 Permanent Representations

Table 3: Political Structure of the European Commission's DGs and Executive Vice-Presidencies involved in energy policies

Commission Vice President Frans Timmermans responsible for delivering the European Green Deal			
Reporting to Timmermans	F. Timmermans	Climate	DG CLIMA
	S. Kyriakides	Health & Food	DG SANTE
	A. Valean	Transport	DG MOVE
	K. Simson	Energy	DG ENER
	V. Sinkevicius	Environment	DG ENVI
	J. Wojciechowski	Agriculture	DG AGRI
	E. Ferreira	Cohesion &Reforms	DG REGIO
Vice President Valdis Dombrovskis responsible for delivering an Economy that Works for People			
Reporting to Dombrovskis	V. Dombrovskis	Trade	DG TRADE
	N. Schmit	Jobs	DG EMPL
	P. Gentiloni	Economy	DG TAXUD
	E. Ferreira	Cohesion &Reforms	DG REGIO
	M. McGuinness	Financial Services	DG FISMA

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Author: Lily Burge

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