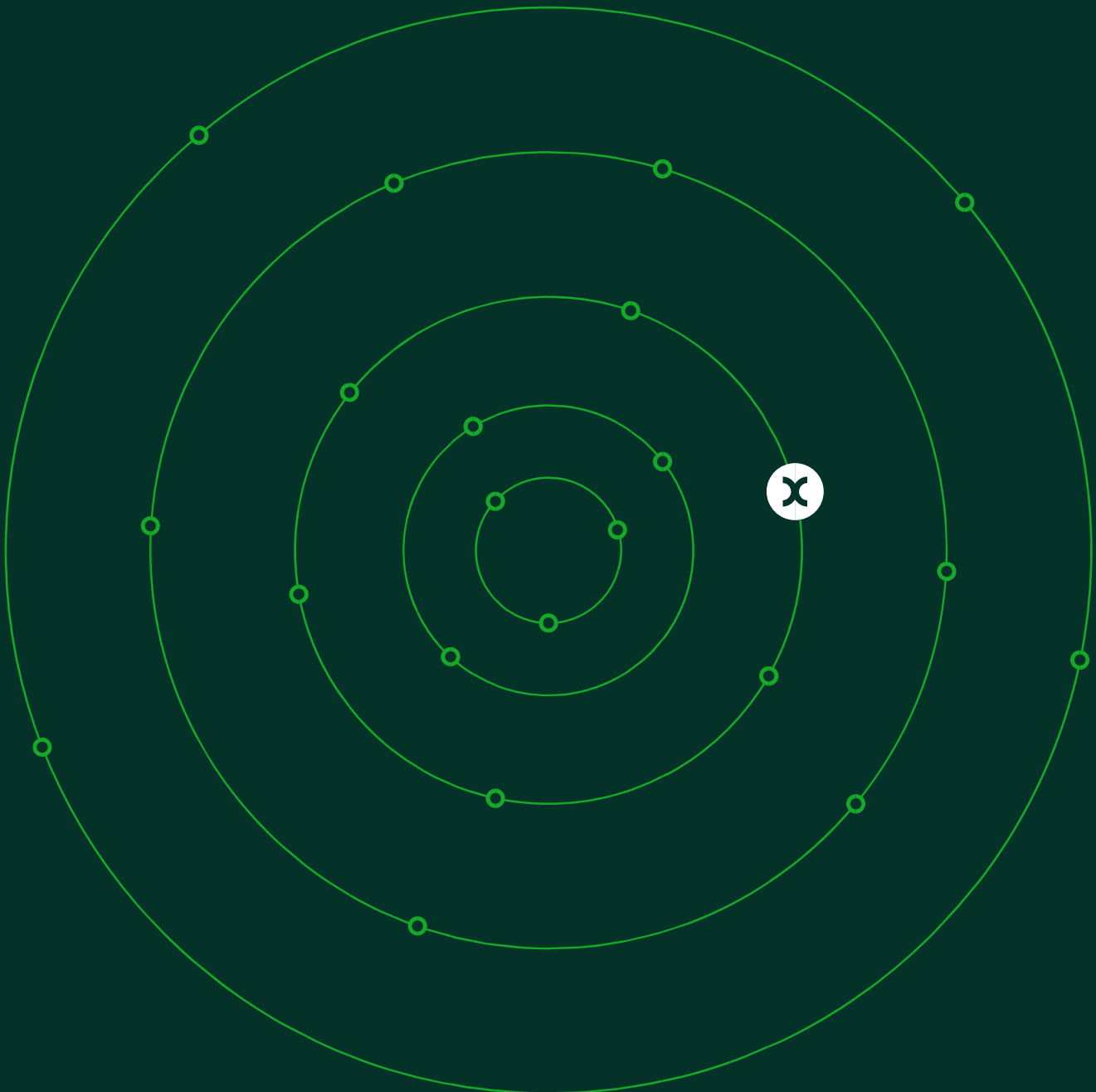


Combining government and markets

1 November 2024



## Contents

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## Executive summary

In line with many other countries, under the Paris Agreement, Australia has made commitments to achieve net zero emissions by 2050 and to reduce greenhouse gas emissions by 43% below 2005 levels by 2030. Achieving those commitments requires a significant transition away from embedded fossil-fuel-dependent technologies to a decarbonised or low-carbon economy, and for many countries, net zero targets will not be met without an increase in decarbonisation activity. Policy interventions need to drive major changes in behaviour and elicit large infrastructure investment to deliver this transition; Australia has set out a range of commitments, policies and programmes to deliver the change.

can net zero policy be designed in an efficient and effective manner?

<sup>1</sup> How

In this report, we focus on two high-level types of policies that are being implemented around the world to support decarbonisation aims: regulations and subsidies. We set out a taxonomy of broader policies (including performance standards and carbon pricing) that have been, or could be, used to support net zero targets in the electricity value chain, highlighting where competitive market mechanisms can be (and have been) used. We present three case studies from the EU, the UK and the USA, giving practical illustrations of how different policy designs affect outcomes. We examine policies designed to: encourage renewable generation; support development of the hydrogen value chain; and promote electric vehicle penetration. In these

examples, we set out how policies have been adjusted, reflecting market specificities and responses.

We find that a holistic approach that considers all levels of any value chain is needed to ensure that policy interventions can deliver decarbonisation goals. As renewable generation sources have successfully grown to be cost-competitive with fossil-fuel sources, crucial to achieving progress towards net zero targets is overcoming coordination problems and first-mover disadvantages throughout each value chain. Additionally, in the face of substantial subsidies in other regions and ongoing market failures, competitive forces may have a more limited role.

Governments have a key role to play in overcoming the many market failures, but that intervention needs to be planned at the system level, be flexible in the face of market developments, and be designed to encourage and support private sector involvement. Government funding is central, as is ensuring the development of timely regulatory arrangements to support the right infrastructure. Allocation mechanisms for funding should include competitive principles to ensure that the most efficient technologies and providers are funded and that markets are facilitated where possible, recognising some of the challenges of competing where others are heavily subsidising certain activities.

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<sup>1</sup> Australian Government (2022), 'Australian Government Climate Change commitments, policies and programs', November.

# 1 Introduction and key findings



Net zero targets across the world will not be met without a significant uptick in decarbonisation activity. Additional government subsidy and investment programmes and regulations will be required. The EU has set out an ambitious plan in its Green Deal (and its Fit for 55 and the Recovery and Resilience Facility post-Covid) to support European decarbonisation, while the USA's Inflation Reduction Act is described as 'one of the largest investments in the American economy, energy security, and climate that Congress has made in the nation's history.' But these are difficult problems, with governments faced with the trilemma of achieving decarbonisation, while keeping energy affordable and continuing to achieve excellent levels of security of supply. In a world of scarce resources (especially public sector), how can net zero policy be designed in an efficient and effective manner?

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Net zero targets across the world will not be met without a significant uptick in decarbonisation activity.

Given that this transition requires system-wide changes, significant investment at all levels of the energy value chain is needed, and for a variety of asset categories:

- ❓ production assets, which are destined to provide for the energy demand;
- ❓ network assets, which are necessary to properly dimension networks and adapt them to new usage;
- ❓ flexibility assets, which are needed to ensure that networks remain in balance despite the significant changes in the energy mix that are expected to occur in the coming years.

Policy needs to be designed to elicit and support efficient public and private investment. In addition to supporting new upstream technologies, in many cases anticipatory investment in complementary elements is required, as well as designing ways to encourage consumers to adopt the necessary consumption/investment choices.

Policy needs to be designed to elicit and support efficient public and private investment.

Each of these asset categories is confronted with specific market failures. As a result, the appropriate financing constraints and the instruments needed to alleviate these are not necessarily identical. At the same time, significant uncertainties remain around what the future energy system will look like. For instance, the role that will be played in the decarbonised energy system of 2050 by technologies that are still in

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<sup>2</sup> U.S. Department of the Treasury website, '[Inflation Reduction Act](#)' (accessed 31 October 2024).

their infancy today remains unclear due to uncertainties related to technical performance, safety, public acceptance, and costs. Meanwhile, there may be a natural bias among policymakers and market participants towards the adoption of today's mature technologies, such that these could attract most of the financing available. The risk of asset stranding and affordability concerns around the cost of the energy transition could hamper the success of today's unproven technologies.

The risk of asset stranding and affordability concerns around the cost of the energy transition could hamper the success of today's unproven technologies.

In all likelihood, the reality is that because of these uncertainties, the formation of the future energy system is going to involve trial and error and a degree of fragmentation of national approaches towards the ultimate goal of carbon neutrality. As lessons are learned about which approaches are most efficient for achieving the multiple objectives of the energy transition, some investments will become partially or entirely stranded in the future if they prove inefficient in helping the energy transition effort.

Subsidies for renewable energy technologies are also closely tied to the objective of reducing their costs resulting from greater deployment, 'learning effects', and technical innovation, and in ensuring some control over crucial supply chains as part of industrial policies. The EU has become a leader in certain renewable energy markets, indicating that investment in this sector has also been part of a deliberate industrial strategy. <sup>3</sup> The USA Inflation Reduction Act is explicitly designed to support US industry while achieving a systemic transformation of the US economy towards a low-carbon future. <sup>4</sup>

There are strong benefits to flexible net zero policies linked to market mechanisms.

Balancing the risks and uncertainties of placing the wrong technological bet versus missing out on a first-mover advantage means that there are strong benefits to flexible net zero policies linked to market mechanisms. With such large investments planned, the challenge of implementing these efficiently remains. The Australian national interest framework 'Future Made in Australia' further underlines how government must take care not to 'pick winners' that do not in fact have a long-term comparative advantage in sectors of importance to the Australian government. Nor should there be a spur to the development of industries that are unsustainable without long-term government support. <sup>5</sup>

'Future Made in Australia' underlines how government must take care not to 'pick winners' that do not have a long-term comparative advantage.

<sup>3</sup> European Commission (2021), 'EU's global leadership in renewables', July.

<sup>4</sup> The White House (2023), 'Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action', January, p. 5.

<sup>5</sup> Australian Treasury (2024), 'Future Made in Australia – National Interest Framework'.

## 1.1 Outline of report

This report is aimed at providing food for thought on the following three elements of net zero policies:

- ❑ subsidy design for supporting renewable electricity generation technologies;
- ❑ the challenges in developing a sustainable hydrogen value chain to decarbonise hard-to-abate sectors;
- ❑ electric vehicle (EV) policies.

The report draws on Oxera's experience in advising on carbon policies in the UK, the EU, and further afield. We also present a short summary of some recent research conducted by Oxera and Cambridge Econometrics that looks at the beneficial growth outcomes in the EU and the UK that could follow from policy interventions designed to achieve net zero commitments by 2050. This is not directly applicable to the Australian situation, but is a reminder that well-designed policies, even with hefty price tags, do have broader beneficial spillover effects.

The remainder of this report is structured as follows.

- ❑ In section 2, we first set out a brief background to the current net zero context in Australia.
- ❑ In section 3, we provide a taxonomy of policies that have been used in promoting the transition to a net zero economy through the electricity value chain.
- ❑ In sections 4 to 6, we present three case studies that focus on some of the discussed policies. First, we analyse the use of subsidies in the Spanish solar photovoltaic sector in the early 2000s to show how lessons were learned from poorly designed mechanisms. Second, we review the considerations relevant now in designing policy around hydrogen investments, illustrated with examples from both the USA and the EU. The third case study relates to the support needed to encourage the uptake of EVs: both in terms of purchase decisions and the necessary charging infrastructure.

## 1.2 Key conclusions and policy recommendations

Achieving net zero aims will require significant coordinated change. A holistic approach that considers all levels of each relevant value chain is needed to ensure that policy interventions can deliver decarbonisation goals. Overcoming coordination problems and first-mover disadvantages is crucial to developing a mature decarbonisation solution.

In the upstream generation layer, different policies are more appropriate at different stages of technological development in order to elicit significant investment. Careful design of renewable subsidy programmes has been very effective at incentivising the sector and has delivered learning by doing and scale economies, so that the levelised cost of energy (LCOE) of solar and wind now compete against fossil fuels without need of subsidy. Government subsidy programmes need to be flexible to adapt to changes in the LCOE and increases in capacity. This means more emphasis now on interventions to remunerate dispatchable plant or storage where required to ensure security of supply to address intermittency challenges. There is a subtle balance to be struck between providing investor certainty and regulatory flexibility in designing these programmes.

Government subsidy programmes need to be flexible to adapt to changes in the LCOE and increases in capacity.

For the grid, regulatory design is more relevant than market support to drive the necessary anticipatory investment. This investment in the grid is needed to support RES investment to manage dramatically different generation patterns.

Hydrogen is a nascent industry surrounded by uncertainty regarding the viability of future production, transportation, and end uses. The economics of hydrogen usage will require significant subsidies on the current ambitious 2030 and 2050 target timelines. It will also require significant complementary investment to ensure take-up, as the transport and storage of hydrogen remain expensive hurdles to bringing the supply chains to maturity, which is a precondition for hydrogen deployment at scale. The different sections of the value chain cannot be addressed in isolation or sequentially; rather, a holistic plan is needed. The EU has implemented an unbundled approach to this challenge; however vertical integration may be needed to overcome the coordination challenges, although it brings more risks around future competitive outcomes. Taking no action risks abandoning one of the most promising solutions to hard-to-abate emissions in crucial sectors and one where Australia has identified a comparative advantage.

The economics of hydrogen usage will require significant subsidies on the current ambitious 2030 and 2050 target timelines.

In many countries, the purchase of EVs is stimulated by governments through financial incentives (although for the EU and the USA, this is potentially offset by trade policy now seeking to increase the price of Chinese imports on the basis of unfair state subsidies). The second important factor for the EV penetration rate is ensuring that there is an EV charging infrastructure with good geographic coverage, ideally with competitive market outcomes at the point of use.

To encourage the EV penetration rate, it is important to ensure that there is an EV charging infrastructure with good geographic coverage.

Supporting infrastructure for EV charging may become a better use of funds than upfront subsidies, as EV prices fall. Competition authorities

need to consider the competitive dynamics in this sector to ensure widespread service outside cities. This has proven challenging in many regions, and a range of arrangements have been used to incentivise broader provision. These have involved exclusivity, long-term concession arrangements or the freedom to price high, but concerns have arisen about the anti- or un-competitive nature of some of these practices. Careful design of public sector or regulatory support for grid development and installation can complement competitive forces in the charging market.

There is a key role for the private sector to play in achieving net zero.

Finally, there is a key role for the private sector to play in achieving net zero, and policy needs to consider this interaction. Governments are well aware of the risks of state-led solutions, in terms of potential asset stranding and crowding-out of private sector investments. We flag two further considerations when appraising policy options.

The state aid regime in Europe may be a useful framework to consider to ensure that subsidies are building sustainable industries that will not require continuous support.

First, the state aid regime in Europe requires consideration of the distortive effect of any subsidies within Europe and may be a useful framework to consider to ensure that subsidies are building sustainable industries that will not require continuous support. Second, there may be the need for private sector firms and even competitors to coordinate on their sustainability efforts, given the coordination challenges that abound. While mandatory regulations can obviate this concern (through bans or enforcing standards), in principle, there may be scope for more flexible coordination. This could fall foul of competition law; however, the Australian legal framework already has the option to consider the public interest and balance that against any potential restriction of competition. Good practice would require identifying the additionality of any coordination and then valuing those benefits. Unlike the EU, the Australian approach does allow a broader range of interest to be included in such benefits' valuation.

Private sector firms, and even competitors, may need to coordinate on their sustainability efforts.

A holistic approach that considers all levels of any value chain is needed to ensure that policy interventions can deliver decarbonisation goals.





We start by summarising the Australian net zero context in terms of the commitments made, the current levels of emissions and energy mix, and the Future Made in Australia policy, which sets out the government's aims with respect to supporting the transition to net zero,<sup>6</sup> while also responding to the changing international competitive landscape where state aid has become the norm.<sup>7</sup>

### 2.1 Australia's climate commitments

Aiming for a 43% reduction in emissions from 2005 levels by 2030 and complete net zero emissions by 2050, Australia's commitment to climate goals are ambitious. These figures are an increase on its Paris Agreement commitment of a 26–28% reduction from 2005 levels by 2030.<sup>8</sup> These goals are particularly ambitious due to the country's current reliance on fossil fuels such as coal and natural gas. As at 2023, fossil fuels account for approximately 65% of total electricity generation in Australia, with coal contributing about half of the total electricity generation. Yet the government recently announced plans to remove reliance on coal by 2038, with 90% of the 21 GW of coal capacity retiring by 2034–35.

In supporting the phase-out of coal, Australian commitments envision a substantial increase in the penetration of renewable energy generation. Leveraging both the private sector and public support, Australia aims to generate 82% of its electricity from renewable sources by 2030. Such a build-up of renewable capacity is vital if the fossil-fuel exit is to occur on the accelerated schedule proposed.

### 2.2 Australia's current emissions and energy mix

The sector accounting for the highest volume of Australian emissions is that of the energy sector, accounting for 161.4289 Mt (CO<sub>2</sub>-e) in 2022, as shown in the figure below.<sup>9</sup> These emissions are lower than the 2009

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<sup>6</sup> For greater detail regarding the Future Made in Australia Bill, see the 2024 National Interest Framework and related publications by the Australian Treasury <https://treasury.gov.au/publication/p2024-526942>.

<sup>7</sup> For more information on the programme's response to policy developments internationally, see Prime Minister Albanese's speech 'A future made in Australia' from 11 April 2024, held in Brisbane at the Queensland Media Club (accessed 31 October 2024).

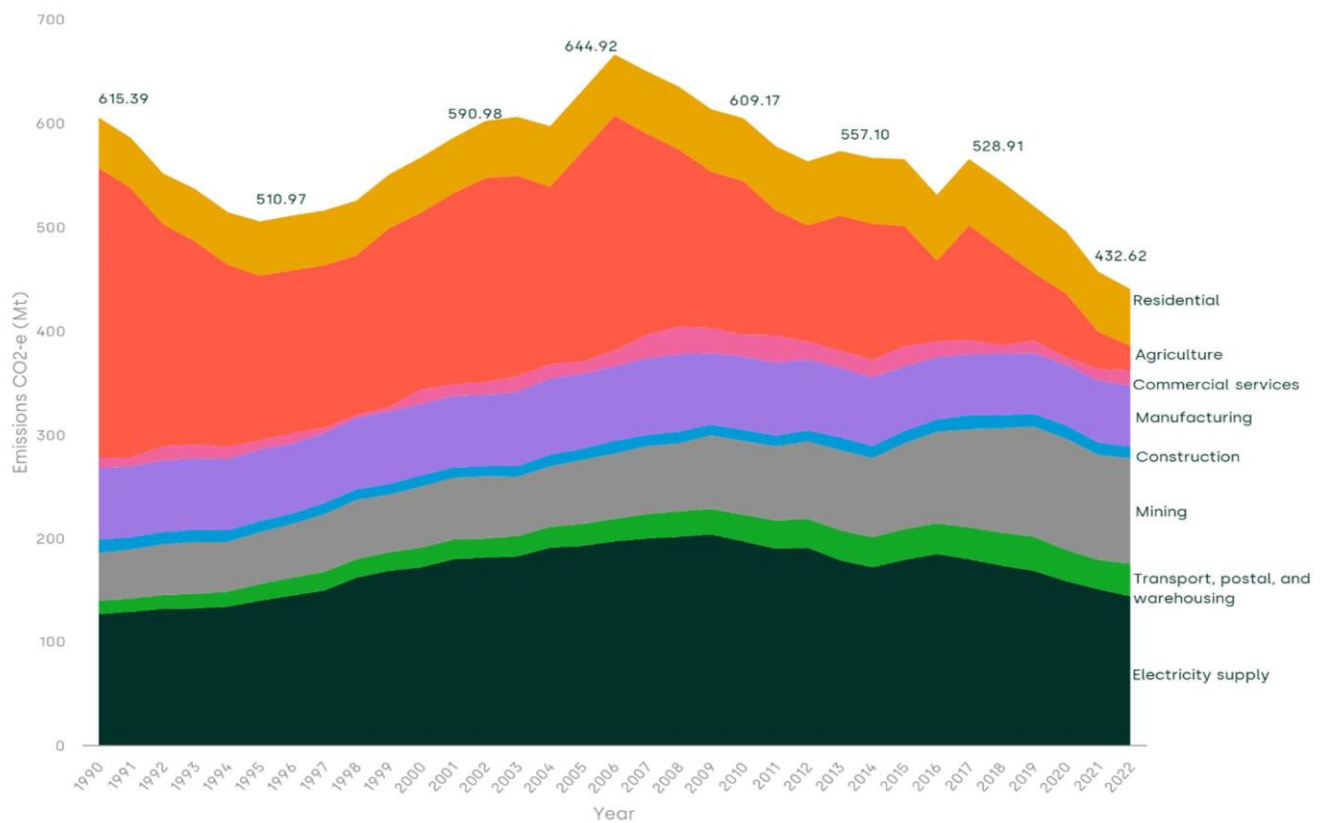
<sup>8</sup> Australian Energy Market Operator (2024), 'Integrated System Plan for the National Electricity Market: A roadmap for the energy transition' (accessed 31 October 2024).

<sup>9</sup> Total and sectoral emissions data is sourced from the Australian Department of Climate Change, Energy, the Environment and Water's (DCCEEW) annual national emissions inventory. These emissions are displayed according to the global warming potential of gases from the

peak of 223.2960 Mt, reflecting decreasing emissions despite population and GDP growth. The shrinking in the share of coal in Australia's energy mix coupled with an increase in renewable electricity generation is the primary cause for this decrease, see further discussion below.

Mining has developed into a large source of Australia's emissions, representing 101.2799 MT of emissions in 2022. Emissions result through the powering of mining sites and equipment, as well as fugitive emissions. The sector is critical to both Australia's (export) economy and its net zero ambitions, with many green technologies drawing on resources such as lithium and cobalt.

**Figure 2.1** Australian emissions by sector (CO<sub>2</sub>-e)

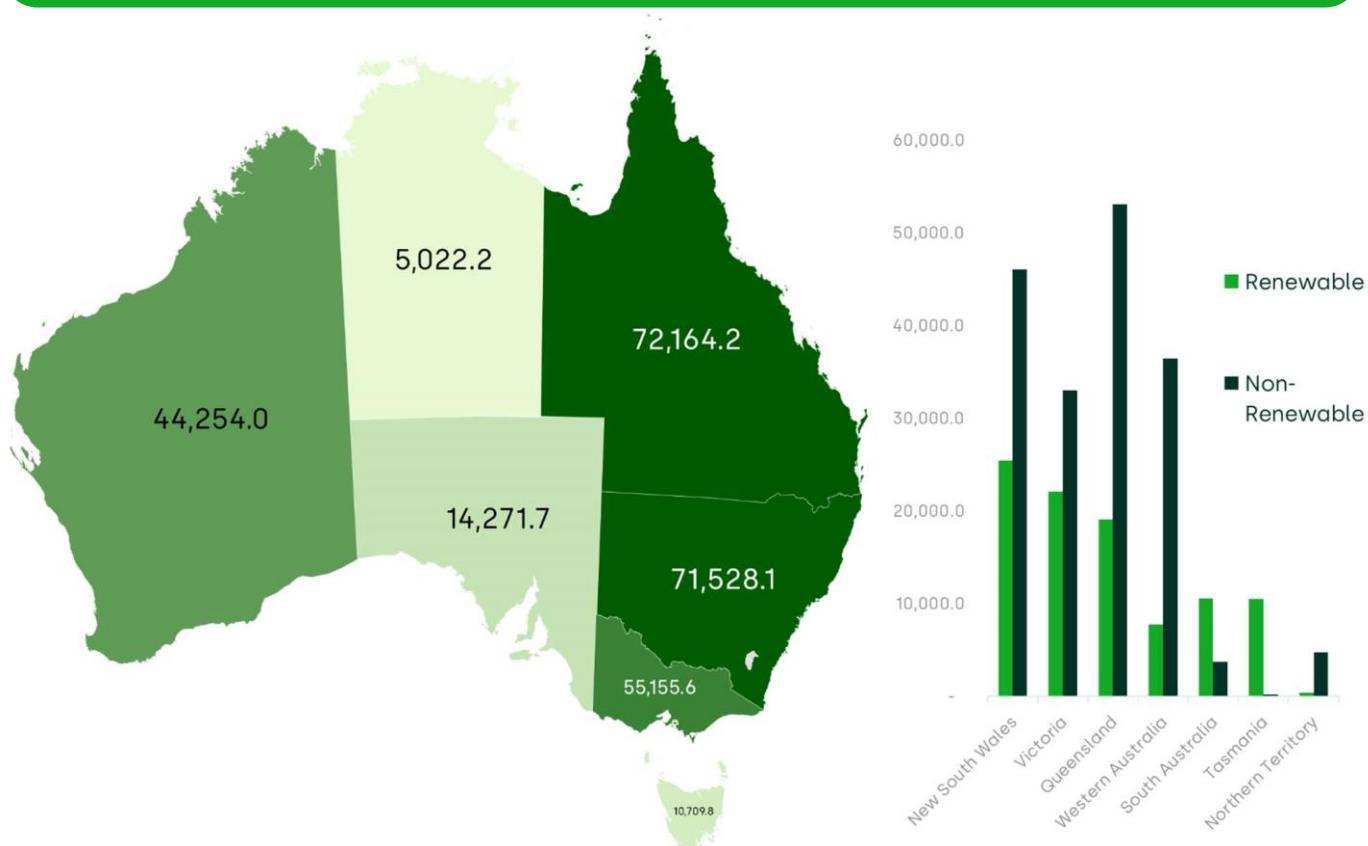


Note: Carbon Dioxide Equivalent gases (CO<sub>2</sub>-e) using the global warming potentials (GWP) of gases from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5). Not all (sub-)sectors are shown.

Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5) and expressed in terms of carbon dioxide equivalent emissions (CO<sub>2</sub>-e). The DCCEEW publishes an interactive interface on emission inventories by sector, available [here](#) (accessed 31 October 2024).

As in the figure above, the energy sector is the largest source of emissions in Australia, as it is worldwide. In 2023, Australia generated a total of 273,105.5 GWh of electricity, of which 95,963.03 GWh, roughly 35%, was generated using renewable sources, as illustrated below.

Figure 2.2 Australian electricity generation in 2023 (GWh)



Source: Department of Climate Change, Energy, the Environment and Water (2024), 'Australian Energy Statistics', March, Table O1.2.

The majority of electricity generation in 2023 occurred in the eastern-most states of Queensland, Victoria and New South Wales, home to over half of Australia's population and the nation's three most populous

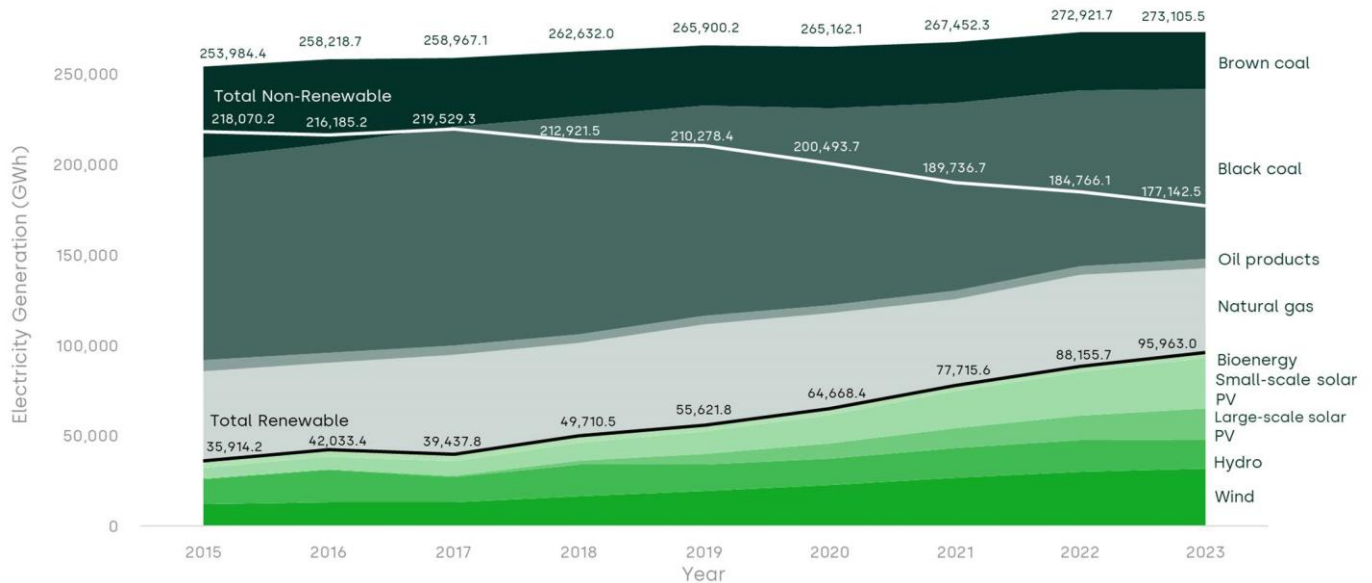
cities. The sparsely populated Northern Territory accounted for 5,022.2 GWh, or just 1.8% of the total electricity generated.

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Australia's energy mix still consists mostly of non-renewables, with coal being the main source of electricity (see the figure below). However, the amount of electricity produced from non-renewables has decreased steadily from 2017, while the amount produced from renewable sources has doubled, to deliver the growing overall demand for electricity generation.

Solar photovoltaic electricity generation has witnessed the most dramatic growth, particularly among small-scale generation, which includes rooftop solar applications.

Figure 2.3 Australian electricity generation by fuel type



Note: Black coal also known as hard coal; brown coal also known as lignite.

Source: Department of Climate Change, Energy, the Environment and Water (2024), 'Australian Energy Statistics', March, Table O1.2.

Variations exist regarding the share of renewable energy sources in the mix across the country. Regional and demographic factors influence the choice of inputs among the non-renewable and green sources, with

<sup>10</sup> Department of Climate Change, Energy, the Environment and Water (2024), 'Australian Energy Statistics', March, Table O1.2

different states exploiting their local environment and resources in their electricity generation processes.

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Tasmania's generation is almost entirely powered from renewable sources, with South Australia similarly sourcing most of its electricity from renewables. However, all other Australian states see the majority of their electricity stem from non-renewables. The Northern Territory, Western Australia and Queensland are particularly reliant on non-renewables for their electricity.

The Northern Territory and Western Australia leverage their proximity to large gas basins off the north-western coast of Australia, and as such see most of their electricity stem from natural gas, with shares of 82.8% and 60% in their respective energy mixes. Among the renewable sources used, small-scale solar is present in both states, with wind power also prominent in Western Australia.

The populous states of Queensland, New South Wales and Victoria source most of their electricity from coal, with the latter using brown coal while Queensland and New South Wales rely on black coal. This is in line with the physical location of lignite and bituminous coal deposits on the east and south coasts of Australia.

In terms of renewable energy implementation, Victoria outpaces New South Wales and Queensland, sourcing 40.1% of its electricity from renewable inputs, compared to New South Wales' 35.6% and Queensland's 26.5%.

Wind energy is also far more present in Victoria, whereas the main renewable source in Queensland and New South Wales remains solar photovoltaic energy. The higher elevations and increased rainfall of New South Wales and Victoria allow the use of hydroelectric power in these states as well.

South Australia and Tasmania have extensive developments of renewables (73.3% and 98% shares respectively). South Australia's wind generation accounts for 43.8% of the state's total generation, with solar (of all generation scales) adding another 29.6%. Tasmania is unique in

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<sup>11</sup> The statistics for state-level energy inputs refer to calendar-years and are sourced from the Australian Department of Climate Change, Energy, the Environment and Water, specifically, ['Australian Energy Statistics, Table O Electricity generation by fuel type 2022-23 and 2023', Tables O2.2 to O9.2](#) (accessed 31 October 2024).

the significant role that hydropower plays, as it sources 78.1% of its electricity from it, with another 17.8% coming from wind power.

### 2.2.1 Future Made in Australia programme

In April 2024, Prime Minister Albanese announced the Future Made in Australia Act, supporting the transition to net zero while also responding to the changing international competitive landscape where state aid has become the norm.

The programme sets aside \$22bn for investment in clean industries, with investment into key industries such as green hydrogen (\$8bn) and critical minerals (\$7bn), as well as the production of green technologies including solar, and manufacturing and battery production (\$1bn and \$500m of planned investment respectively). The Act aims to accelerate the transition to net zero emissions while safeguarding Australia's economic security in a net zero world, through two streams.

The Net Zero Transformation stream has as its goal the support of industries in which Australia may 'hold a sustained competitive advantage in a net zero global economy' and that need significant public investment.<sup>12</sup> The current 2024–25 budget includes five industries that are aligned with this National Interest Framework: renewable hydrogen; critical minerals processing; green metals; low-carbon liquid fuels; and clean energy technology manufacturing.

The complementary second stream of the programme identifies vital sectors that are defined as necessary to Australia's security, with global supply chains that are concentrated and vulnerable to disruption. In providing government support to these sectors, the Framework sets out that this stream should not 'pick winners' that do not have a long-term comparative advantage. Nor should the programme be used to spur the development of industries that are unsustainable without long-term government support.

Australia also needs to develop and maintain strong trading partnerships with countries producing vital technologies at scale. Australia cannot match the committed levels of public investment in

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<sup>12</sup> Preliminary identifying characteristics of industries falling within this stream include those drawing on inputs that Australia is expected to have abundant access to in the future, as well as those with existing capabilities honed through research & development. Australia's highly skilled workforce will also be key in bringing to bear its vast green potential.

<sup>13</sup> An example of this is the heavy investing by the EU, the USA and Canada in their photovoltaic sectors in a bid to reduce their dependence on Chinese manufacturing, which currently fills most of global demand.

other regions and lacks the large domestic market it needs to establish such economies of scale, but it can seek to benefit from these spillovers through trade agreements, thereby potentially freeing up funds for investment elsewhere.

### 3 Taxonomy of policies to encourage the transition to net zero

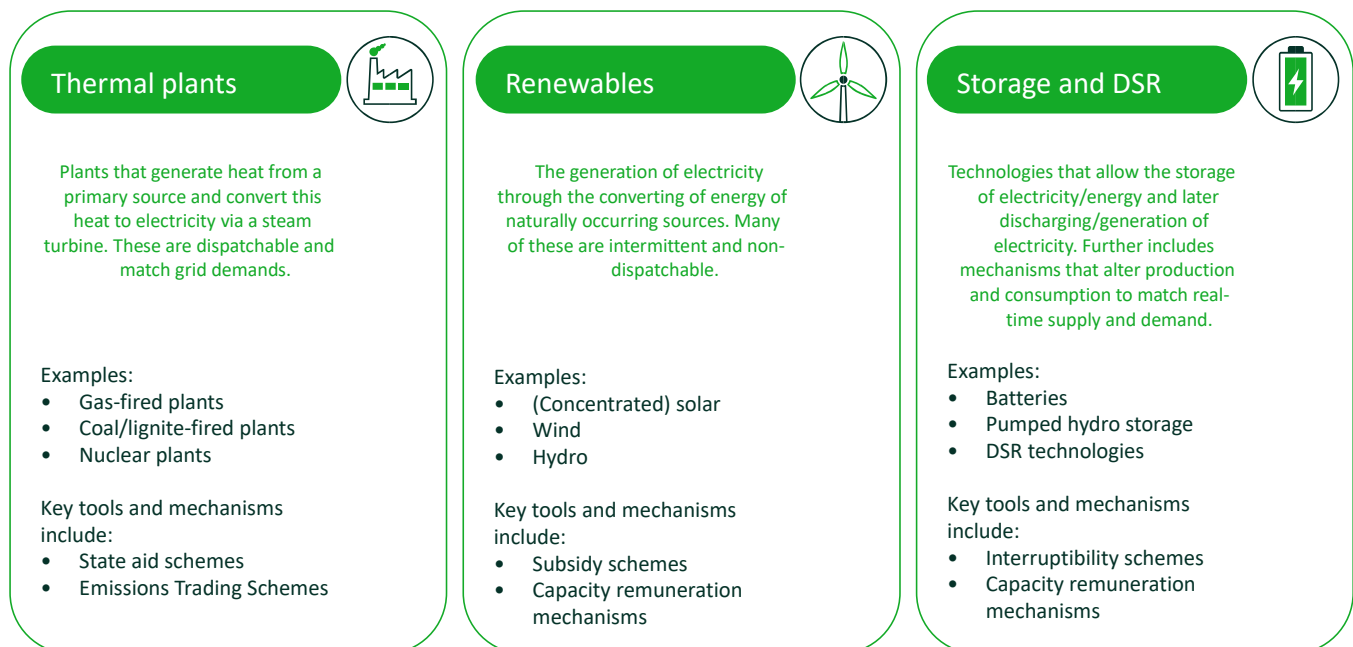


In order to facilitate the transition to net zero, policy across the globe has been designed to incentivise the production and consumption of sustainable products and services.

The electricity sector inhabits a prominent role globally in the net zero transition, because of both its significant contribution to current emissions in most countries and the role electrification plays in decarbonising other activities (e.g. transport). To support achieving net zero targets, policy must consider all parts of this value chain: generation, transmission, and distribution to end-users. In this chain, subsidies are used extensively to support the various actors, complemented where appropriate by regulation.

#### 3.1 Role of policy in electricity generation

Generation of electricity is a focal point for transitioning the electricity sector, and the economy at large, to net zero. In generalised terms (see the figure below), electricity is generated through one of three main types: thermal plants, renewables, and storage/demand-side response (DSR). As a competitive sector with many generation methods, there are a plethora of policies that can support decarbonisation.



Source: Oxera.

Carbon pricing and regulations designed to reduce the utilisation of thermal sources are common, and may result in shortening their economic life. This is then complemented by investment subsidies and research & development funding that incentivise renewables and also develop DSR technology to complement the roll-out of the latter.

Renewable energy technologies have seen rapid development, with newer iterations eclipsing the efficiency and generation capacity of their predecessors. Subsidy and other support programmes have been an important part of allowing these industries to become more investible, building on learning-by-doing scale effects.

As renewable sources become more cost-effective, the need and focus for regulation and support programmes changes but does not disappear. As an example, there is a well-established ‘missing money’ challenge for ensuring ongoing generation investment and to ensure security of supply. Subsidy programmes for renewable energy technologies have mitigated high up-front investment costs and supported generation capacity, but once operational, the low variable costs on account of the non-existent fuel costs (for solar and wind), can make it difficult for the next generation of plant to be built commercially. Capacity mechanisms and other such interventions then follow.

Similarly, on the demand side, sustainable options for consumers may not prove as attractive as conventional options (e.g. EVs) or may require replacing existing equipment (e.g. boilers/heating systems). This softness in demand, often caused by high prices, as well as limited supporting infrastructure, disincentives the production and development of net zero products and services.

This section will provide a taxonomy of different policy instruments used to facilitate the green transition, discussing their benefits and drawbacks, as well as their effectiveness in industries to which these policies have been applied. In this way we will address the role of these policies along the energy value chain.

### 3.1.1 Phase-out of thermal power plants

The phase-out of thermal power plants, which have traditionally constituted the bulk of electricity generation, often requires incentives for firms. An example of a mechanism that is widely employed to reduce utilisation of thermal plant is that of emissions trading systems (ETSs). These are a form of carbon pricing which consists of setting a maximum emission allowance for firms. These firms, in turn, may buy or sell such emission credits on the carbon market with firms that do not reach or

exceed their allocated emissions volume. The allowances are designed to be ratcheted down each year, increasing the scarcity and thus the cost of such emissions. The policy thus acts to create a market incentive to reduce greenhouse gas emissions. Through the cost of ETS credits, the most polluting sources of energy, such as coal and lignite, see their marginal costs increase relative to cleaner sources, and thus the closure of the most polluting plants is incentivised.

The EU implemented the first international emissions trading system, which was adopted in a Directive in 2003 before being launched in 2005 (the EU ETS). In the first phase of the scheme, the scope was limited to CO<sub>2</sub> emissions resulting from power generation and energy-intensive industries, with almost all allowances being allocated for free. In doing so, the system established a carbon price, as well as the trade of emission allowances. In phase 2, from 2008–12, the system expanded to include Iceland, Liechtenstein and Norway, as well as increasing the scope to include nitrous-oxide emissions from nitric acid production. Phase 3 introduced a unitary EU cap on emissions rather than the national caps used previously, while establishing auctions as the primary method of allocating allowances.<sup>14</sup> Further expansions in sectors and gases considered by the scheme also occurred. The current fourth phase of the EU ETS has seen increases in the system's ambition, with higher goals set, and includes maritime transport as well. A separate ETS for buildings, road transport, and additional sectors was further established.

Crucially, the EU ETS is complemented by the Carbon Border Adjustment Mechanism (CBAM), which calibrates imports by adjusting for emissions that occur in their production. The goal of such a mechanism is to avoid carbon leakages, which occur when firms relocate production to jurisdictions with less stringent climate policies, thereby raising global emissions.

Complementing these ETSs are government support measures (such as emissions performance standards) that further incentivise the closure of polluting thermal plants. In the Netherlands, for example, government compensation was offered to the operators of a coal plant that was forced into early closure by national law. Germany saw a similar compensation scheme for thermal plants fired by lignite, which are planned to be mothballed and eventually closed. To minimise the impact

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<sup>14</sup> These free allocations are mostly concentrated among chemical industries and heavy industry such as steel and cement manufacturing, but also include the aviation sector in the current phase of the EU ETS. See European Commission website, '[Free allocation](#)' (accessed 31 October 2024).

on property rights of plant owners during the mandated coal exit, Germany had further introduced a tender mechanism that would offer shutdown premiums for coal-fired plants. In the UK, emissions performance standards were instrumental in delivering its fast coal phase-out.

The phase-out of fossil-fuel-powered thermal plants reveals an interplay between government support and regulation. In addition to market-based instruments, regulation may serve as an effective tool to move the economy forward to net zero. Particularly for regulated networks and infrastructure, such oversight can be utilised to ensure that firms operate in a manner consistent with goals set for the green transition. In several jurisdictions, this mixture of regulation and market incentives has led to an acceleration of the transition, with coal plants being closed ahead of planned schedules and prior to the end of their economic life. <sup>15</sup>

### 3.1.2 Encouraging renewable generation

Green energy subsidies are a key part of decarbonisation policies, generally tied to renewable energy targets expressed as a percentage of energy consumption. In the EU, targets are agreed at the EU level and are then binding on individual member states. Similarly, the USA has earmarked significant support to green technologies through tax credits in its Inflation Reduction Act.

These policies aim to add new renewable energy sources (RES) capacity, as well as repower existing plants with newer and more efficient technology. In addition to ensuring uptake, subsidies for renewable energy technologies are also closely tied to the objective of reducing their costs through greater deployment, ‘learning effects’, and technical innovation. Indeed, the EU has become a leader in renewable energy markets globally, with the state aid investment in this sector part of a deliberate industrial strategy. <sup>16</sup>

In the last 20 years, EU member states (including the UK) have gained significant experience of deploying a variety of subsidy mechanisms for renewable and low-carbon energy producers and generators. Among

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<sup>15</sup> The Second Compensation Auction in Germany to close coal-fired plants was oversubscribed, with 1.5 GW of total capacity being bid to be closed. As a result of this Auction, the plants of Wilhelmshaven, Merhum and Deuben were set to cease operations. See European Commission (2021), ‘Quarterly Report on European Electricity Markets: with focus on the impact of high carbon prices in the electricity sector’, Market Observatory for Energy, DG Energy, 14:1, p. 26.

<sup>16</sup> European Commission (2021), ‘EU’s global leadership in renewables’, July, p. 8.

subsidy schemes, distinctions are made between mature and innovative technologies, with the size of installations further being considered. We set out here the main instruments that have been used, illustrating how the design has adapted as the technologies have matured. While at the earliest stage of technical development, subsidies reward deployment, over time the subsidy programmes are adjusted to respond to market signals.

Governments may also give guarantees that encourage investment into the research & development of promising projects. Power Purchasing Agreements (PPAs) decrease the risk of undertaking a project, which aims to increase their financing through investment and easing credit conditions. In their applications, PPAs have often existed as stand-alone contracts rather than constituting a part of a larger scheme. This allows such contracts to be highly customisable and tailored to specific projects (e.g. pricing, grid access, availability). Yet, the elevated administrative burden of negotiating these instruments has resulted in their application being limited to larger projects, as well as markets that are not fully liberalised or see limited competition.

Where there is an existing grid into which RES will feed, early subsidy programmes were designed as feed-in-tariffs (FiTs). These tariffs consist of setting a designated per-unit price on electricity provided to the grid. This price is set above the market price and, given the long-term nature of FiT agreements generally, provides operators with revenue certainty. These policy instruments were widespread in the bringing to market of solar and wind energy, as these, alongside falling technology costs, spurred investment into the sectors.

A strength of this approach was deemed to be its selectivity, as only operators delivering electricity to the grid were remunerated. However, a downside is that this instrument shields electricity generators from market signals. By receiving a guaranteed payment for electricity, operators are incentivised to adopt the ‘produce-and-forget’ approach, maximising output even when supply eclipsed demand to such an extent that prices turn negative. Furthermore, these tariffs proved to be quite costly for the governments that implemented them and required frequent adjustment to reflect shifts in technology costs.

An evolution from FiTs was found in the feed-in-premia (FiPs), which offer a fixed or variable premium on top of the price, rather than a fixed price. As such, they transmit market signals to operators, and ensure implicit subsidies do not increase as costs reduce. Despite the added volatility considerations for investors, FiPs were successfully used to further support the roll-out of renewable electricity generation.

In the EU, support schemes first took the shape of FiTs. Yet, alongside technology costs falling and increased RES penetration, subsidy costs rose significantly, leading FiPs to become the preferred policy. These FiPs were set out to gradually replace FiTs in the European Commission's 2014 revision of State aid guidelines for energy and environmental protection, with a 2022 revision on State aid guidelines for climate, environmental protection, and energy (the CEEAG by the Commission) re-affirming this policy standpoint.

These same guidelines recommend that competitive bidding processes should be used increasingly to award support to eligible generators. This latter point is especially true for larger installations and those utilising more mature technologies, while smaller plants and 'innovative' technologies are often selected through administrative procedures, as well as benefiting from FiTs. In general, however, the technology-neutrality principle states that European aid should be accessible to all types of technology.

However, the scope of subsidy-eligible technologies has expanded in Europe. Aside from RES generation, any technology that contributes to reductions in greenhouse gas emissions may be supported through schemes, as long as appropriate reasoning for their support is provided. This revision is closer to the traditional approach in the USA, where technologies that have not been developed at scale and are not mature are funded alongside established technologies.

Further refinements of FiPs led to the popular Contracts-for-Difference (CfDs), which are two-way support schemes. These operate by obligating generators to pay (receive) any positive (negative) differences of the market price to a reference price. This reference price is commonly a 'day-ahead' market price expressed per MWh. As part of their design, CfDs shield operators and their investors from low electricity prices while further allowing governments to control the costs of support schemes and avoiding the over-remuneration of operators. Well-designed CfDs included the use of auctions at regular intervals, and at quantities and with reserve prices (the administrative strike price) that the government controlled.

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<sup>17</sup> An Italian renewable energy support scheme in 2019 targeted electricity generation using on-shore wind power, solar, hydropower, and sewage gases. These were chosen due to their status as relatively mature technologies with stable costs. Subsidies were defined as two-way CfDs and awarded through descending auctions.

Additional adjustments to support schemes include provisions that limit the applicability of subsidies. Eligible operating hours might be capped per year, with considerations of rewarding the most efficient producers. In solar electricity generation, such considerations might come in the form of segmenting operators based on their location in solar radiation zones and the tracking technology they use, if any. <sup>18</sup> Subsidies may also be designed to circumvent the ‘produce-and-forget approach’ by, for example, halting support payments if electricity prices fall below (a threshold near) zero for a specified amount of time.

The differing experiences of countries that have implemented such refinements is visible to a greater extent in Europe. While countries with older support schemes, like Italy, witnessed significant subsidy cost increases in the recent energy cost crisis, France was able to collect revenues from its CfD scheme. Experiences such as these led the Commission to recommend CfDs to become the primary policy tool for RES generation support. There has also been an embedding of mechanisms into CfDs which better transmit market signals, such as breaks in support payments when prices reach or fall below zero for a specified period, as is the case in Germany (2017) and Italy (2019).

Innovative technologies may further receive support in the form of direct grants. These transfers of funds from public entities to private companies might become necessary when the high upfront costs of projects or their associated risks prove prohibitive.

In a similar vein, subsidised loans are used to encourage project development and cover high upfront costs. These loans may be priced at far more attractive terms than other leverage options. Another form of credit subsidy is that of loan guarantees, which offer loans where projects may not qualify for other financing due to elevated technology risks. Loan forgiveness programmes are also used to hinder firms involved in the green transition from facing bankruptcy. Extending credit for specific purposes may prove to be more attractive than grants due to the lesser impact on public budgets and the associated lower degree of political scrutiny.

Another form in which support can be granted is through production tax credits, which offer tax incentives to producers in return for RES

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<sup>18</sup> For example, solar tracking technology could be preferred, since it boosts daily productivity and smooths the electricity output of panels across daylight hours. In particular, dual-axis tracking technology, which tracks the sun throughout the day and year, maximises the efficiency of solar panels by continuously adjusting their optimum position.

electricity generation. <sup>19</sup> Furthermore, accelerated depreciation schedules for renewable installations offer tax advantages that raise the relative attractiveness of developing renewable electricity capacity.

These policies have been especially popular in the USA, with the Inflation Reduction Act making significant use of tax credits and loans. The Act includes high credit facilities for clean electricity generation and the creation of green technology. In addition to such federal initiatives, several states have implemented their own funding options to develop renewable generation and leverage their state's specific advantages.

The LCOE of many renewables has decreased significantly over time, and in some cases, now rivals the costs of electricity generated through fossil fuels, which in Australia stand at 0.0909 2023 USD/kWh for combined-cycle gas turbines (CCGT), 0.1523 2023 USD/kWh for coal, and 0.2163 2023 USD/kWh for open-cycle gas turbines (OCGT).

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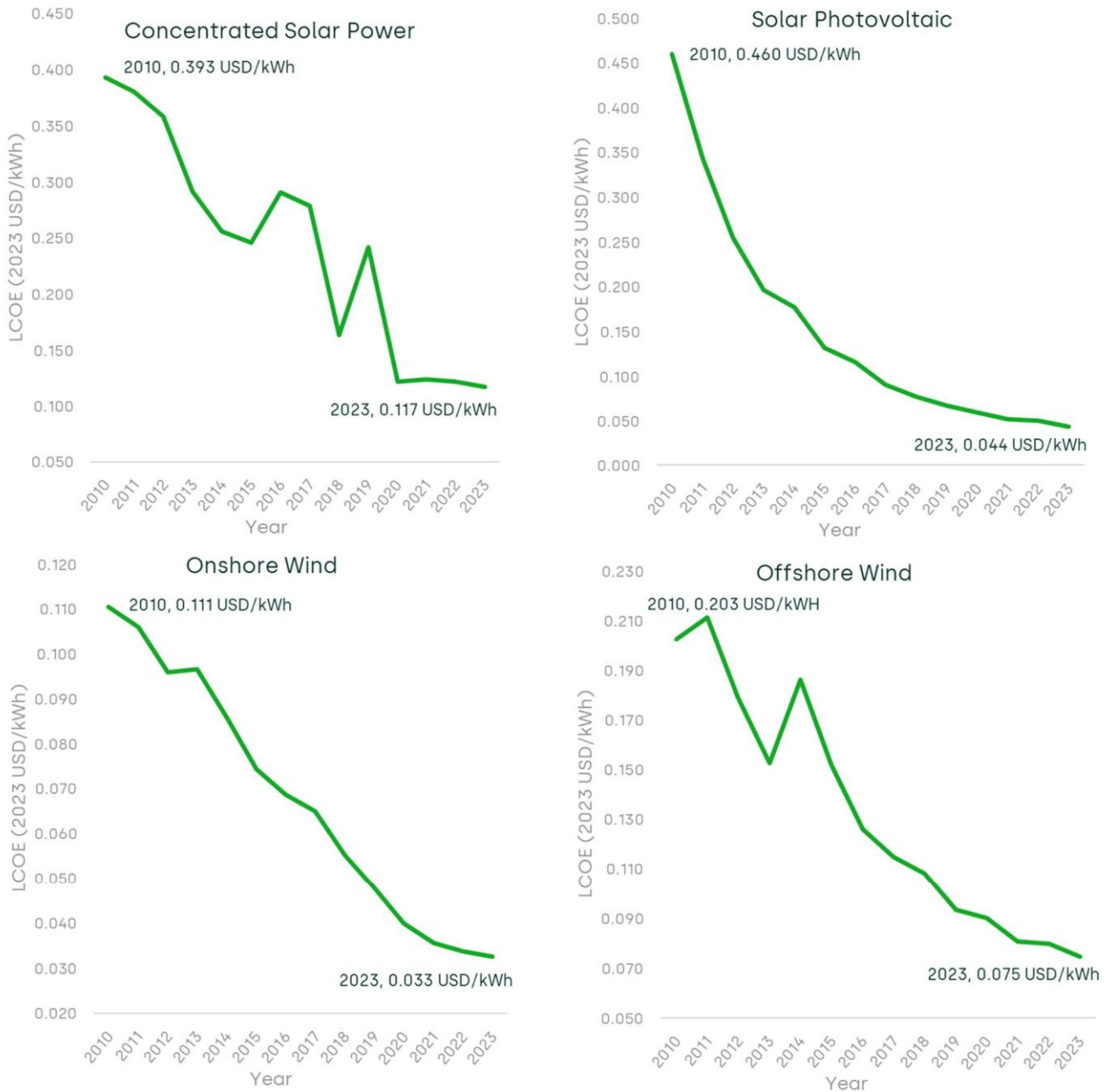
Learning-by-doing effects and the maturation of technology have driven this decrease, as well as subsidies. The latter have played a substantial role in crowding in private investment, allowing these technologies to reach scale and develop.

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<sup>19</sup> The 2022 US Inflation Reduction Act includes reworked tax credits for both the production of clean electricity (tax code 45) and the investment into clean energy (tax code 48). Both of these existing tax credits will be replaced by the reworked the 45Y tax credit programme, which includes a wider range of eligible energy projects to incentivise net zero energy production and investment.

<sup>20</sup> IRENA (2024), 'Renewable Power Generation Costs in 2023'.

Figure 3.1 Global LCOE curves for selected renewables



Source: IRENA (2024), 'Renewable Power Generation Costs in 2023'.

### 3.1.3 Storage, DSR and protecting from intermittency

While RES capacity has increasingly replaced thermal capacity in the last decade, dispatchable, flexible or storage capacity has not developed at the same pace. This poses a unique challenge in that some thermal capacity must be retained to ensure the grid can adequately meet demand, especially with dependence on intermittent renewable

sources. Yet, with an increase in RES penetration, electricity prices based on marginal fuel costs may not be high enough to prove profitable for thermal operators.

To combat this phenomenon, capacity remuneration mechanisms (CRMs) were introduced as a temporary tool that offers a fixed fee for operators to make available their capacity. In fact, they are now generally embedded for the long term, given the scale of RES capacities. While many technology types may meet eligibility criteria for CRMs, RES have relatively low participation rates as their reliability in times of system stress is considered in the application process. Storage and DSR had historically counted for only a limited proportion of selected capacity, although recent auctions in Italy have shown promising increases in this regard. In a CRM auction for delivery from 2024, 30% of the new-built capacity selected was accounted for by storage technologies for a total of 1.1 GW.<sup>21</sup> In Sardinia, all new capacity was composed of storage, effectively crowding out thermal plant capacity.

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To incentivise the development of DSR, interruptibility schemes are employed by governments. These schemes leverage the participation of consumers (mostly industrial consumers) who commit to reducing their electricity consumption in times of scarcity. In doing so, the electricity consumption curve is smoothed, and the demands of the grid are balanced more evenly.

### 3.2 Role of policy in electricity transmission and distribution

A vital part of the net zero transition is the transmission and distribution grids. As the pace of renewable deployment increases, these grids need to adapt to a new energy generation system that consists primarily of intermittent and decentralised electricity generation (rather than the centralised generation seen with thermal power stations). Attention to this infrastructure becomes more important to preserve network stability and safeguard against grid failures.<sup>23</sup> Increasingly, there is seen to be a need for independent system operators to plan these transitions independently of grid ownership.

Germany has invested in cross-border transmission links to manage intermittency risks.

<sup>21</sup> See European Commission (2019), 'State Aid SA.53821 (2019/N) – Italy Modification of the Italian capacity mechanism', C(2019) 4509 final of 14 June 2019, State aid SA.53821 (2019/N); Terna (2022), '[Mercato della capacità: Rendiconto degli esiti – Asta madre 2024](#)'.

<sup>22</sup> Terna (2022), '[Mercato della capacità: Rendiconto degli esiti – Asta madre 2024](#)'.

<sup>23</sup> A major blackout occurred in the UK in 2019. One million electricity customers were affected in a 40-minute blackout that hit key infrastructure such as Ipswich Hospital, London's rail system and Newcastle Airport. The causes were the unexpected shutdowns of the Hornsea offshore wind farm, as well as the failure of the Little Barford gas-fired power plant.

In the first quarter of 2021, Germany installed 1.3 GW of new solar capacity, with the government announcing plans for an extended solar power tender in 2022, which would push capacity up to 6 GW. Several projects also became operational in Q1 2021, boosting Germany's cross-border transmission capacity. Among these is a 1,400 MW undersea cable between Germany and Norway—the world's longest—aiming to link German wind energy with hydropower produced in the Nordics. However, internal bottlenecks have plagued the German grid, limiting the effective operation of the cable in the first few years. These grid limitations restricted the capacity of electricity transmission during this initial period. <sup>24</sup>

In contrast to electricity generation, the transportation of electricity is generally characterised by natural monopoly. This is the case for both the transmission and distribution of electricity, with the transmission system operator (TSO) and distribution system operator (DSO) acting as a regional natural or legal monopolist. The costs of duplicating infrastructure mean that it is efficient to have only one operator in a given area, leading to regulation to ensure that those efficiencies benefit customers.

Existing regulatory structures can be used to address the additional market failures arising in preparing energy infrastructure for the net zero transition. To promote the research & development of innovative solutions, innovation allowances are used, which have also been allocated through competitive processes in certain instances. For example, the GB energy regulator, Ofgem, has implemented the RIIO-2 Network Innovation Allowance to support innovation by TSOs in the sector. <sup>25</sup> To spur on innovation hindered by any first-mover disadvantage, coordination incentives are used to incentivise firms to undertake such projects together. The European Network of Transmission System Operators for Electricity (ENTSO-E) promotes such cooperation among TSOs and is complemented by the Inter-Transmission System Operator Compensation (ITC) mechanism. The latter compensates TSOs for cross-border electricity flows to

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<sup>24</sup> European Commission (2021), 'Quarterly Report on European Electricity Markets: with focus on the impact of high carbon prices in the electricity sector', Market Observatory for Energy, DG Energy, 14:1, p. 26.

<sup>25</sup> National Grid Group (2021), '[Electricity Transmission Innovation in RIIO-2](#)'.

encourage cooperation and the efficiency of the interconnected European grid. <sup>26</sup>

With reference to the significant investments that are needed in this transition, licence obligations have been used. These require certain investments to be made by operators, with penalties for non-compliance. Furthermore, rules on investment measures have been used that allow the costs of investments to be recovered more easily. In the EU, these arrangements reflect the (often varying) capital expenditures of operators and include returns in line with the operator's financing costs.

In dealing with the uncertainty involved in investing in energy infrastructure, calibration schemes have been introduced, which aim to increase rewards for investments with higher risks (such as asset stranding). Uncertainty mechanisms further address such risks, including the adjustment of allowances during price control periods, as well as adjustment of the period's lengths.

### 3.3 Role of policy in electricity retail markets

Energy markets in the West are largely liberalised, with Australia's energy markets being no exception. As such, there is a significant degree of competition in the retail segment of the electricity value chain. Government support in this segment is increasingly rare in liberalised markets, with national regulatory authorities retreating into the role of overseer.

Instead, policy related to the net zero transition has concentrated on encouraging the use of sustainable electricity by (mostly industrial) consumers. In the UK, the use of Renewable Energy Guarantees of Origin (REGOs), a type of Renewable Electricity Certificate (REC), allows consumers to be assured of the proportion of their purchased electricity that is sourced renewably. In turn, these can be used to satisfy business ESG commitments, and incentivise renewable electricity consumption, despite the risk of greenwashing occurring.

Regulation further supports the goal of increasing sustainable electricity consumption, with renewable portfolio standards (RPS) requiring utilities to source a specified proportion of their electricity sales from renewable sources. Twenty-nine states in the USA, in addition to the

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<sup>26</sup> European Union Agency for the Cooperation of Energy Regulators (2024), 'Inter-TSO Compensation monitoring'.

District of Columbia, have implemented RPS schemes, with 16 of these including targets of at least 50% of retail sales.

Programmes aimed at reducing and smoothing electricity consumption are increasingly utilised to ease strains on power grids. Such demand flexibility schemes reward consumers for reducing their consumption or flexibly redistributing it during peak hours of grid stress.

To reduce consumption, governments may also employ interventionist regulation such as bans. In the Netherlands, for example, fossil-fuel boilers will be banned from 2026, while Italy and Spain mandate a maximum heat of 19°C or below for commercial buildings. <sup>27</sup> EVs are another major example of a product that is widely subsidised as its polluting equivalent of internal combustion engines is set to be banned from new sales in many jurisdictions.

Further subsidy policy in the retail segment includes the targeted support for firms in sectors in which the risk of carbon leakages is especially prevalent. Costs of emissions may be passed on to businesses consuming this electricity, which may as a result face higher electricity costs in their own production. Subsidies to counter carbon leakages thus counteract the incentive to relocate production to areas in which less stringent climate action removes such indirect costs.

Finally, support for the adoption of small-scale renewable electricity generation technologies, particularly solar photovoltaic, has proven effective in promoting further penetration of RES generation. Similarly, subsidies for investment into efficient appliances, such as boilers and washing machines are a popular policy instrument. Such purchasing support as well as tax credits incentivise sustainable consumption investments and aim to make these technologies more affordable.

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<sup>27</sup> Von Bebenburg, C., Mikovic, P., Robins, N. and Vitelli, R. (2024), '[Incentivising Behavioural Change: Subsidies vs Regulation](#)', *Concurrences*, May. N° 2-2024, Art. N° 118172.



### Box 3.1 Growth Zero

Across the world, countries and governments are all facing the challenge of climate change. The race to reduce emissions and limit global warming demands rapid, economy-wide transformation and innovation, with governments and businesses playing a crucial role.

Based on the current trajectory for the EU, most forecasts indicate that this target will not be met by the 2050 deadline, despite the significant improvements that are already underway. Governments and businesses will need to increase their actions to close this gap. The potential policies can be divided into four themes: carbon pricing, regulation, private sector innovation, and fiscal policy.

Oxera has undertaken a thought experiment—Growth Zero—that explores the macro effects of these levers, each representing a possible economic pathway to achieving net zero by 2050. By amplifying key EU policy interventions and market mechanisms, the work shows we could achieve net zero faster and drive economic development. The findings suggest that net zero can unlock a growth opportunity across Europe worth between €4tn and €4.8tn.

Growth Zero highlights the necessity of a consistent microeconomics approach in order to facilitate a successful transition: building a net zero economy involves market and consumer incentives; new financial markets must be created to meet the need for investment in decarbonisation; and necessary collaboration between companies can be encouraged to achieve shared sustainability goals.

In the study we combine a discussion on the most effective ways of decarbonising with a focus on the growth opportunities that achieving net zero could bring. The underlying analysis has been run for Europe as a whole and the UK specifically. It can also provide insight for other jurisdictions that are considering how to implement policy measures.

In each lever, a specific set of policy assumptions are applied as ‘shocks’ to a macroeconomic model to ascertain the

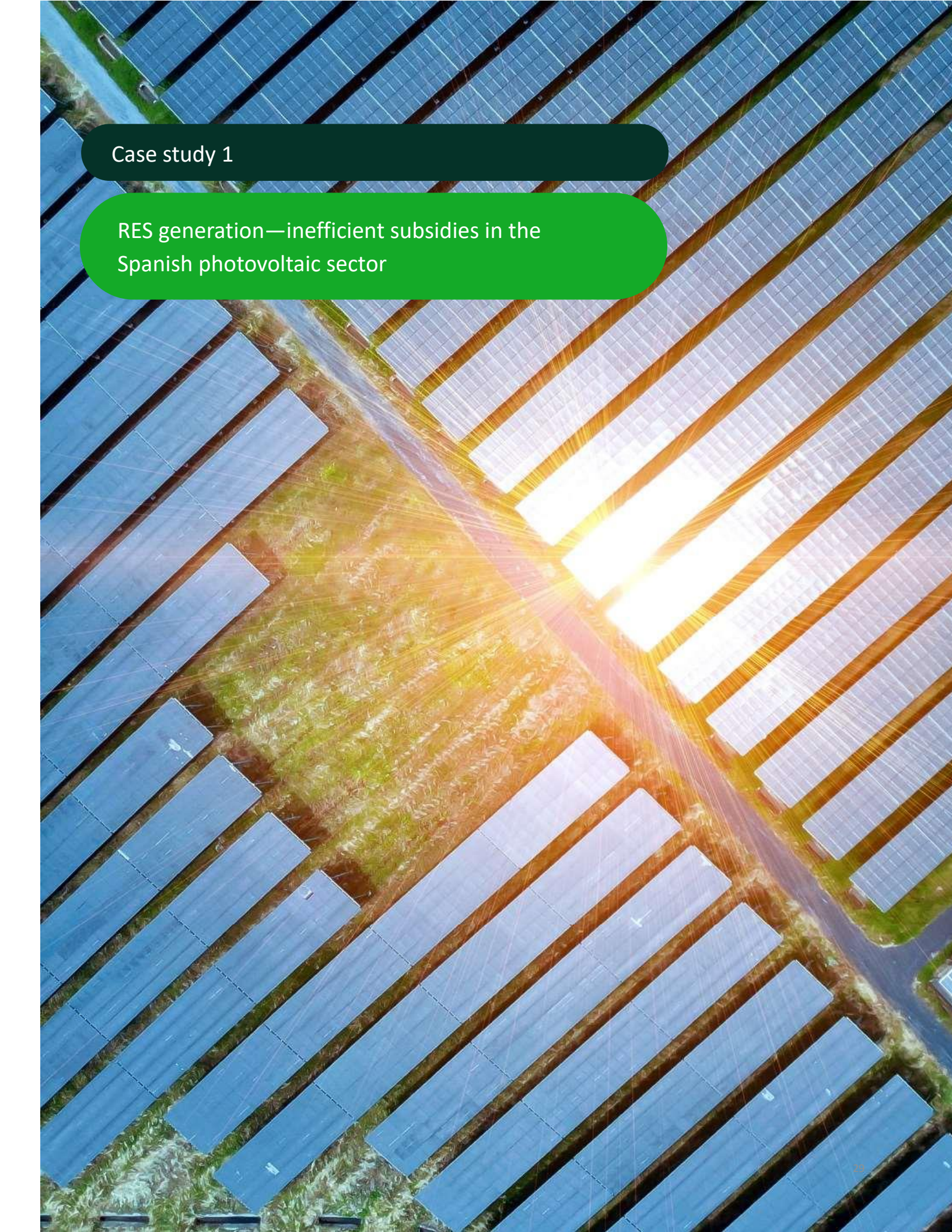
impact on the economy. The underlying mechanisms are based on policies or measures that are discussed in this report, and more specifically in each of the case studies since they are already in place—or are planned for implementation—in the UK and the EU. They are increased or brought forward in the relevant lever:

- ② Regulation: strict penalties are placed on high-emission sectors and phase-out dates of fossil-fuel-dependent technologies are brought forward.
- ② Private sector innovation: large-scale deployment of new, green-technology-based production capacities accelerates transition due to efficiencies of scale and learning-by-doing.
- ② Fiscal policy: subsidies for established low-carbon technologies are ramped up while taxes are increased on carbon-intensive industries.

There is no easy solution, and a blend of approaches driven by incentives, regulation, and taxation—both government-led and private-sector-led—will be critical in achieving this milestone. Growth Zero demonstrates that, from a macroeconomics perspective, there are many ways of closing the net zero gap, while also supporting prosperity and largely ensuring a stable or increasing disposable income for consumers. It also shows that economic growth and sustainability are not mutually exclusive.

Source: Oxera.

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An aerial photograph of a vast solar farm. The image shows numerous rows of solar panels stretching across a landscape. A bright sun is positioned in the upper right, creating a strong lens flare that illuminates the scene. The panels are arranged in a grid-like pattern, with some areas showing more densely packed rows than others. The overall color palette is dominated by the blue of the panels and the golden-yellow of the sunlight.

## Case study 1

### RES generation—inefficient subsidies in the Spanish photovoltaic sector

## 4 RES generation—inefficient subsidies in the Spanish photovoltaic sector

Subsidies may prove effective in accelerating investments into the net-zero transition but are vulnerable to poor design or poor estimation of post-implementation effects. In particular, they can be expensive and inefficient if they are not designed with an eye to interactions with future market mechanisms.

For FiTs and FiPs, their effectiveness in terms of attracting investments into renewables depends greatly on the technology-specific tariff/premium offered. This is similar to the role of the strike price for CfDs. Advancements in technology and cost reductions due to economies of scale must also be considered when designing policies as these may lead to ballooning costs. Miscalibration of such factors may come at a high cost, as was seen in the Spanish photovoltaic sector.

In the wake of cost crises such as the one experienced in Spain and due to the widespread adoption of competitive tenders to determine the awarding of subsidies, the efficiency and effectiveness of subsidies (CfDs in particular) has increased greatly.

The Spanish photovoltaic sector (also referred to as solar energy sector) in the early 2000s provides an example of when such policy decisions inadvertently led to a solar boom. Investments were spurred in this sector through a range of government policies, leading to a substantive growth of solar energy capacity. This bubble, when it burst, paralysed the sector for several years, leaving Spain behind on solar energy growth when other countries were adding large volumes of capacity.

### 4.1 Spain's special regime for renewable electricity

Spain introduced legislation to conform with the EU's target of 12% renewable energy generation by 2010. Eager to boost its production of solar energy to meet its climate commitments, Spain introduced a 'Special Regime'. This regime was established to incentivise investments into the sector through a series of decrees and laws aimed at supporting electricity producers utilising renewable sources.

The special regime was introduced through gradual measures, beginning in 1994,<sup>28</sup> when electricity distributors were obligated to purchase surplus electricity from RES generators with less than 100 MW of plant capacity.<sup>29</sup> Building on this, grid access for RES producers was established three years later through the Electricity Sector Law (Law 54/1997). Furthermore, this law granted government premiums to small RES electricity generators (< 10 MW) with the price of electricity received by operators ranging from 80 to 90 per cent of the average electricity price faced by end consumers, with adjustments made annually.<sup>30</sup>

This fixed price (FiT) regime was altered in 1998, increasing tariff rates while allowing generators to choose between receiving a fixed premium on the market price for electricity, or a fixed total price.<sup>31</sup> Royal Decree 436/2004 then revised this scheme again to stabilise the tariffs by setting these to be a percentage of the Average Electricity tariff (AET), with adjustments every four years.<sup>32</sup>

The choice of FiTs as the main instrument of the special regime was informed by its successful use in Germany and in other countries in the mid-1990s, while other policies, such as the UK's bidding scheme, were seen to be ineffective.<sup>33</sup> Furthermore, FiTs were deemed to be politically safe, with little anticipated resistance due to the policy's low administrative burden and that only those renewable providers actually generating electricity receive support.

Yet, the main weakness of FiTs (the lack of ability to adjust to market conditions) was not addressed effectively in the 2004 amendment to the regime. In fact, the move to tariff adjustments every four years rather than the annual adjustments in the decrees that preceded it increased this challenge.

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<sup>28</sup> Royal Decree 2366/1994

<sup>29</sup> International Energy Agency (2017) Policies. Royal Decree 2366/1994. <https://www.iea.org/policies/3856-royal-decree-23661994>

<sup>30</sup> International Energy Agency (2017) Policies. General Electricity Law 54/1997. <https://prod.iea.org/policies/3853-general-electricity-law-541997>

<sup>31</sup> This change came through Royal Decree 2818/1998. International Energy Agency (2017) Policies. Royal Decree 2818/1998: "Special Regime". <https://www.iea.org/policies/3849-royal-decree-28181998-special-regime>

<sup>32</sup> International Energy Agency (2017) Policies. Special Regime for the production of electricity from RES (Royal Decree 436/2004). <https://www.iea.org/policies/4198-special-regime-for-the-production-of-electricity-from-res-royal-decree-4362004>

<sup>33</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p.6

## 4.2 The investment rush into the solar PV sector

The weakness of Spain's policy design was laid bare as market conditions changed in the mid-2000s. Easy access credit fuelled investment into the sector, as did a low interest rate.<sup>34</sup> Furthermore a benign Euro-Dollar exchange rate made solar panels especially attractive investments, as these are traded internationally in US dollars.<sup>35</sup> The technology for solar panels had also become far cheaper as production expanded and reached scale. Lastly, investment into solar PVs with guaranteed revenues through the subsidy programmes became attractive as returns in housing and other sectors in Spain fell.<sup>36</sup>

In this context, Royal Decree 661/2007<sup>37</sup> was implemented. With the rising costs of the subsidy scheme, the government altered the nature of the tariffs to decouple these from the AET. As such, generators of renewable energy were no longer able to choose the price-premium option offered under the electricity sector law, instead having to opt for a fixed rate tariff.<sup>38</sup>

Yet, with solar PV deployment rates still trailing government goals, the decree did not aim to limit investment into the sector. Hence the actual tariff rates offered remained largely unchanged, apart from solar PV installations of capacities between 100 kW and 10 MW, which were raised by 82%.<sup>39</sup> Crucially, the Spanish government did not design FiTs that would allow the rates to adjust to decreasing technology and installation costs (now considered best practice). These manufacturing and installation costs, unlike tariff rates, had reduced significantly since the regime's last update in 2004. The new regime did not take such cost decreases into account, which rendered the largely unchanged tariffs

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<sup>34</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p.15

<sup>35</sup> Between 2006 and 2008, the U.S. dollar weakened considerably vis-à-vis the Euro, with the average exchange rate being \$1.47 per Euro from June 2007 to August 2008. With solar PV imports being paid in U.S. dollars, this amounted to an effective discount on PV cells. del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p.15

<sup>36</sup> The first slowdowns in the Spanish housing market had begun appearing in 2007, leading to a noticeable reallocation of investments to the relatively safe and profitable solar PV sector in Spain. del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p.15

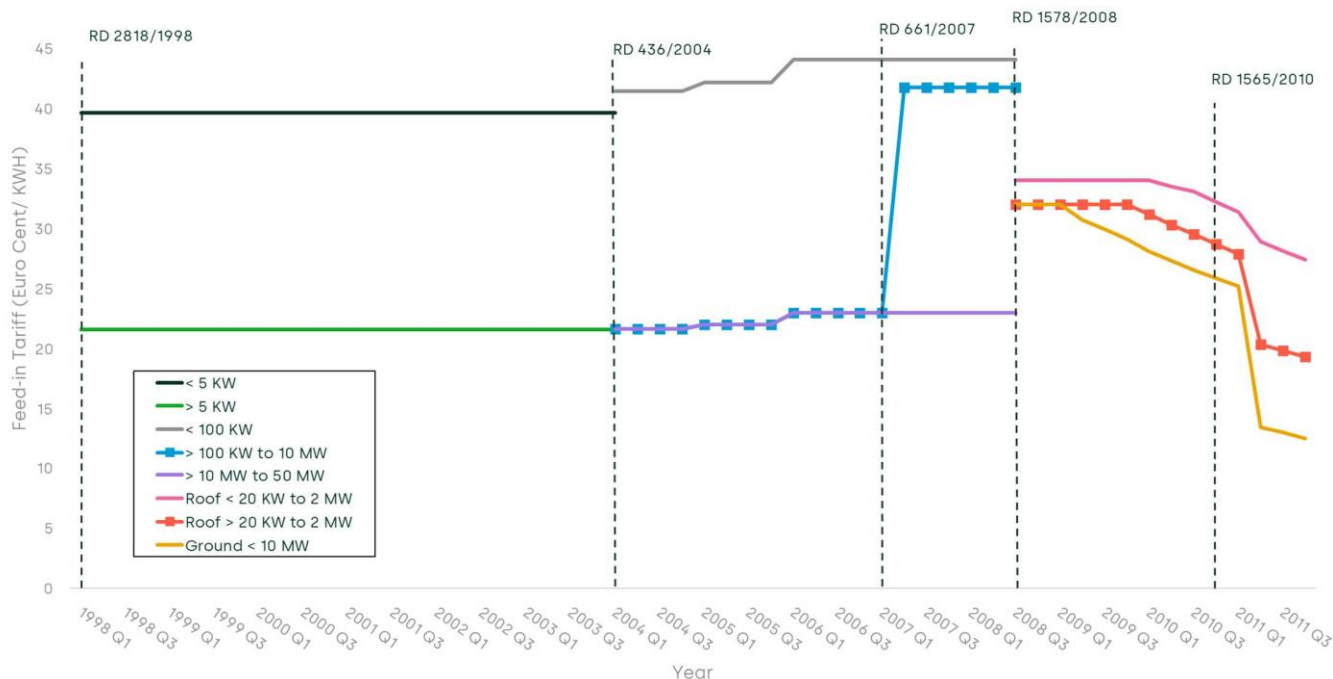
<sup>37</sup> This new regime promised a long-running tariff periods, with FiTs applied for a 25-year period with adjustments every 4 years. Following this 25-year period, operators would receive approximately 80% of the FiT for the remaining lifetime of the asset. The length of the tariffs contributed to investor confidence. Oxera (2019) Blinded by the Sun: the Future of Renewables Disputes. p.1

<sup>38</sup> International Energy Agency (2017) Policies. Feed-in tariffs for electricity from renewable energy sources (Special regime). <https://www.iea.org/policies/4555-feed-in-tariffs-for-electricity-from-renewable-energy-sources-special-regime>

<sup>39</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p. 7

excessively generous. The figure below sets out the evolution of Spanish FiTs over this period.

Figure 4.1 Evolution of Spanish solar PV tariff rates



Source: del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development.

The advancements in PV technology had vastly increased efficiency and decreased costs of manufacturing. As a result higher rates of electricity generation, and correspondingly increased revenues at high guaranteed tariffs, drew in a wave of investors in the Spanish PV sector, with rapid increases in capacity added in 2007. Decree 661/2007 also granted renewable electricity generators priority access to the grid. Such developments increased investor confidence, as lower volatility and risk contributed to the large-scale investment drive.

All these factors were also compounded by the fact that, rather than building one large installation, investors could cluster several smaller-sized ones close by and thus benefit from the elevated tariffs for these, while still exploiting the economies of scale through so called “solar orchards”. Clauses regarding the repowering of existing installations further drove increased investment. Older installations could be upgraded with newer (and consequently more efficient) PV panels to

benefit from the higher tariffs of decree 661/2007 so long as they maintained their nominal capacity.

<sup>40</sup>

Vital too to the rapid expansion was the market's expectation that such a benevolent tariff scheme would not remain for long. RD661/2007 set out that the tariff regime it defined would be revised in 2010 or when a capacity target of 371 MW of solar PV electricity was reached. Once 85% of this capacity was attained, the government would be required to implement a new FiT regime within one year. With this 85% threshold being reached by June 2007, a draft of the new FiT scheme was published in September 2007.

<sup>41</sup>

Although the markets expected a decrease in tariffs would follow once the capacity target of RD 661/2007 were met, the decrease exceeded the market's expectations significantly. This led to a rush of new project proposals seeking to certify under the more generous old FiT scheme under RD 661/2007. The lowering of administrative hurdles by regional authorities aided the rapid deployment of solar PV capacity in 2007-2008.

#### 4.3 Government response to the bubble

As PV deployment and electricity generation rose sharply, so did the cost of Spain's 2007 tariff scheme. Despite the policy response in reducing tariffs taking only a year, the speed of the administrative change was outpaced by the installation rate of solar PV, which at this point had become highly modular. The issues were compounded by Spain having very little interconnection capacity or storage and thus had an inability to manage any excess electricity production.

<sup>42</sup>

Faced with a large tariff deficit adding to the strained Spanish debt situation in 2007, the Spanish government made a series of significant legislative changes.

<sup>43</sup>

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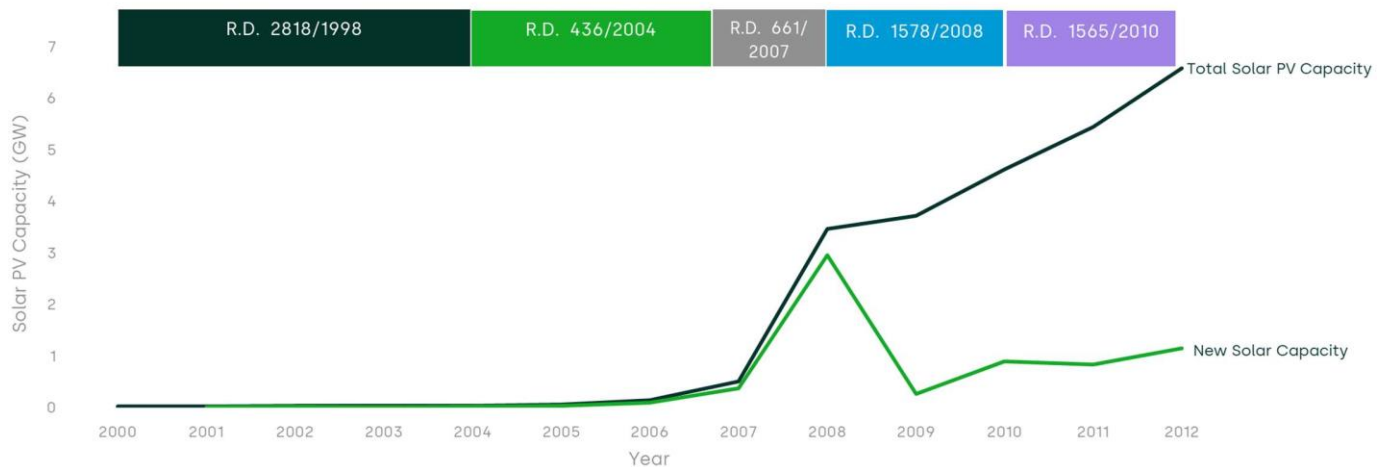
<sup>40</sup> The legal capacity was determined by the installation's inverter rather than the sum of peak capacities of all the panels, which led to operators to repower their installations to 15% to 20% over the inverter's name-plate capacity, and thus generate more electricity.

<sup>41</sup> This became Royal Decree 1578/2008.

<sup>42</sup> Spanish excess electricity generation capacity reached extreme levels in 2009, with installed capacity (including all generation technologies) being 93,000 MW while maximum peak demand reaches only 44,000 MW. del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p. 8

<sup>43</sup> RD 1578/2008 was the first of these legislative changes that weakened support to solar PV operators. del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. pp. 14-18

Figure 4.2 Spanish solar PV capacity 2000–12



Source: Ember Energy. Yearly Electricity Data. 2024

Apart from the reduced tariff levels for small- and medium-sized PV installations, the 2008 amendment further introduced quarterly capacity quotas. Importantly, the decree defined a time period for the FiTs for all new plant of 25 years, rather than the tariffs being available for the lifetime of an installations. <sup>44</sup>

In R.D. 1565/2010, tariffs were cut further, reflecting manufacturing cost decreases at the end of the global polysilicon shortages. Yet, the most controversial aspect of the change was that this decree retroactively applied the 25-year FiT limit to all existing installations, not just those connected to the grid post-September 2008. <sup>45</sup> The policy also limited the hours of operation eligible for the FiT for all plant. These were significant reductions to revenue expectations for the many investors that had been promised payments for their installation's lifetime and for all hours of operation. From 2012 a moratorium was placed on subsidies for new renewable energy projects. <sup>46</sup>

#### 4.4 The fallout

The Spanish PV sector reacted strongly to the significant reductions in the subsidy support and the moratorium on new projects, reflected in

<sup>44</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. pp. 14-18

<sup>45</sup> Oxera (2019) Blinded by the Sun: the Future of Renewables Disputes. p.1

<sup>46</sup> Oxera (2019) Blinded by the Sun: the Future of Renewables Disputes. p.2

limited growth in solar capacity. Newly added capacity fell to low levels between 2008 and 2012, and negligible PV capacity was added between 2014 and 2018.<sup>47</sup> This cutback was felt in sector employment too, with Spanish jobs in the solar PV sector falling from 41,700 in 2008 to 13,900 in 2009, and less than 10,000 in 2012.<sup>48</sup>

Aside from the excessive costs of this regime, the regulatory uncertainty damaged investor confidence in the Spanish renewable energy market. By implementing such big changes, and particularly by retroactively applying tariff regulations, significant risk had been introduced in the market. Various legal challenges have been brought against the Spanish government by investors and operators, seeking compensation for damages suffered as a result of the tariff regime changes.<sup>49</sup>

Since 2018, the Spanish solar PV sector is experiencing a renewed boom, with yearly capacity additions eclipsing those experienced in 2007.<sup>50</sup> Alongside continued decreases in the cost of solar PV technology, changes in Spain's regulatory environment once more have spurred investment into the sector. One of these reforms consisted of the removal of the "sun tax" which had levied charges on self-consumption of generated electricity.<sup>51</sup> Further boosting the sector are the recent post-COVID state aid measures, with Spain's recovery and resilience plan allocating 3.9 billion Euros towards renewable energy sources.<sup>52</sup>

#### 4.5 Comparison with other European experiences

Italy's solar PV sector had a similar boom-bust experience which largely mirrored the Spanish example. A primary reason for a spike in the addition in capacity was again the lag in adjusting regulations for market conditions and a failure to account for the speed of investments in this sector.

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<sup>47</sup> Ember Energy (2024) Yearly Electricity Data. <https://ember-energy.org/data/yearly-electricity-data/>

<sup>48</sup> Mir, P. (2012): Economía de la generación eléctrica solar. La regulación fotovoltaica y solar termoeléctrica en España, Civitas, Madrid. p.364  
del Rio & Mir-Artigues (2012) Support for solar PV deployment in Spain; Some policy lessons. Renewable and Sustainable Energy Reviews. Volume 16. Issue 8. <https://doi.org/10.1016/j.rser.2012.05.011>.

<sup>49</sup> Oxera (2019) Blinded by the Sun: the Future of Renewables Disputes p.2

<sup>50</sup> Ember Energy (2024) Yearly Electricity Data. <https://ember-energy.org/data/yearly-electricity-data/>

<sup>51</sup> Reuters (2018) Spain scraps 'sun tax' in measures to cool electricity prices. <https://www.reuters.com/article/business/environment/spain-scraps-sun-tax-in-measures-to-cool-electricity-prices-idUSKCN1MF1SZ/>

<sup>52</sup> European Commission (2021) Laying the Foundations for Recovery: Spain. [https://commission.europa.eu/document/download/2e4c8870-70da-4d37-9bec-1712eda9791b\\_en?filename=spain-recovery-resilience-factsheet\\_en.pdf](https://commission.europa.eu/document/download/2e4c8870-70da-4d37-9bec-1712eda9791b_en?filename=spain-recovery-resilience-factsheet_en.pdf)

Prior to the boom, Italian PV generation had been subject to the Second Energy Bill, which was in place since 2007. While these rules were originally meant to be replaced in 2010, the tariffs were extended to include all installations built prior to the end of 2010 and operating by the end of June 2011.<sup>53</sup> This triggered a rush into the sector, with many seeking to qualify for these more generous rules through having their installation operating by the end of June 2011. In 2010, 2.3 GW of solar capacity, a figure that rose to 9.3 GW in 2011, and fell to only 3.4 GW in 2012.<sup>54</sup>

Unlike Spain, there were regulated downward revisions of FiTs. The Second Energy Bill saw yearly decreases of only 2% in tariffs; however reductions were increased to 14% in the Third Energy Bill.<sup>55</sup> These still implied high levels of subsidies and the Italian government cut tariffs further only 5 months after the Third Energy Bill. However, with skyrocketing costs, further revisions were needed, particularly in the context of Italy's ballooning public deficit, ushering in further reductions in July 2012.<sup>56</sup>

Germany on the other hand, was able to avoid a cost crisis and the booms and busts of Italy and Spain. Despite using FiTs as well, the German market did not necessitate government intervention to suddenly cut subsidy costs and saw extensive additions in capacity in the early 2010s, whilst the Spanish market added negligible amounts of capacity in this same period.

The German tariff regime had been in place since 2000, with the Erneuerbare-Energien-Gesetz (EEG) guiding the rules for solar PV operators. Although amended through numerous revisions, the basic structure of the bill remained stable; offering tariffs based on installation type, size, and technology that were paid by consumers through higher electricity bills.<sup>57</sup>

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<sup>53</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p. 25

<sup>54</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p. 26

<sup>55</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain's solar PV investment bubble. International Institute for Sustainable Development. p. 25

<sup>56</sup> Gestore Servizi Energetici (GES). (2013). Fotovoltaico.  
<http://www.gse.it/it/Conto%20Energia/Fotovoltaico/Pages/default.aspx>

<sup>57</sup> del Rio & Mir-Artigues (2012) Support for solar PV deployment in Spain; Some policy lessons. Renewable and Sustainable Energy Reviews. Volume 16. Issue 8.  
p.5.<https://doi.org/10.1016/j.rser.2012.05.011>.

Crucially, the EEG had implemented degressions in tariffs since its inception, allowing tariffs to be reduced year-on-year to adjust support levels to the decreasing costs of installation. These degression rates were set at 5% annually in 2003, before being adjusted to 6.5% for ground-mounted PV installation in 2008.<sup>58</sup> In the same year, a major revision was made to the degression regime, establishing a “corridor system” for tariff degressions, in which the tariff reductions would be determined by the solar PV capacity added in the prior year. A range for these reductions was established as being between 5.5% and 7.5% every year.

However, given the falls in technology costs for Solar PV in 2009 with module prices falling as much as 40% in 2009, the German government undertook ad-hoc recalibration of tariffs. These took place mostly in 2010 and accelerated degression up to a maximum of 15%. Finally, in 2012, the revised EEG replaced the FiT regime with FiPs, rewarding solar PV operators with a premium above the market price.<sup>59</sup>

The German approach, which included both degression and flexibility to respond to rapidly evolving technology cost decreases, allowed the sector to avoid the cost crises which had occurred in Spain and Italy. Whilst both Spain and Italy saw marked slowdowns in their added PV capacity, Germany added swathes of solar capacity, with 7.4 GW, 7.5 GW, and 7.6 GW added in 2010, 2011, and 2012 respectively.<sup>60</sup>

#### 4.6 Lessons learned

The case studies from the early European experiences in the solar PV sector demonstrate how vital it is to have appropriately designed subsidy schemes and the adverse effects these can have on markets.

Subsidy schemes, particularly those including tariffs, must be properly calibrated and include technology-adjusting mechanisms that adjust for decreases in technology and installation costs. Cost-containment measures should also be incorporated into subsidy schemes to ensure that rapid adjustments to schemes are not required. In doing so, the

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<sup>58</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain’s solar PV investment bubble. International Institute for Sustainable Development. p. 28

<sup>59</sup> del Rio & Mir-Artigues (2012) Support for solar PV deployment in Spain; Some policy lessons. Renewable and Sustainable Energy Reviews. Volume 16. Issue 8. p.9.<https://doi.org/10.1016/j.rser.2012.05.011>.

<sup>60</sup> del Rio & Mir-Artigues, (2014) A Cautionary Tale: Spain’s solar PV investment bubble. International Institute for Sustainable Development. p. 27-30

design of subsidy schemes should disincentivise both speculation and inefficient production.

Yet, given the long periods over which a subsidy scheme may operate, the risk of crises should be considered in the design. As such, effective data collection and independent oversight is necessary to react to crises as they develop, and subsidy schemes should be rigorously stress tested.

Crucially, policy changes should not have excessively long transition periods, especially for rapidly deployable technology. This is to combat rapid inflows of investment prior to regime changes, as was seen in Italy and Spain. Furthermore, retroactive policy changes should be avoided as these are harmful for the future of the industry and create regulatory uncertainty.

Following the COVID-19 pandemic, major recovery fiscal plans emerged across Europe and the world. Many of these include significant support to renewables in a bid to further develop sectors essential to the net-zero transition whilst leading their respective economies out of crisis. A key objective of such funding is spurring job creation in the green sector, with this being emphasised to a greater extent in subsidy programmes following the pandemic with specific targets being implemented.

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The EU strongly prioritised investments in the green transition as part of its crisis recovery, with the European Commission inviting member states to ensure that their respective Recovery and Resilience Plans include at least 37% climate-related expenditures.<sup>62</sup> Furthermore, 28 billion Euros in green bonds were raised between June 2021 and July 2022 alone as part of the NextGenerationEU (NGEU) funding programme.<sup>63</sup>

Spain is a major beneficiary of this funding effort, as their national recovery and resilience plan is the second largest (in absolute terms)

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<sup>61</sup> The UK's Ten Point Plan for A Green Industrial Revolution, published following the COVID-19 pandemic, sought to support up to 250,000 jobs in green sectors by 2030 Green Jobs Taskforce (2021) Report to Government, Industry and the Skills Sector <https://assets.publishing.service.gov.uk/media/650466aadc5be000dc35f85/green-jobs-taskforce-report-2021.pdf>

<sup>62</sup> Global Renewables Congress (2021) Renewables in the post COVID-19 recovery package of the EU. p.1 [https://renewablescongress.org/wp-content/uploads/GRC\\_REcovery\\_EU\\_FINAL.pdf](https://renewablescongress.org/wp-content/uploads/GRC_REcovery_EU_FINAL.pdf)

<sup>63</sup> European Commission (2022) NextGenerationEU funding operations progress well according to new report. [https://commission.europa.eu/news/nextgenerationeu-funding-operations-progress-well-according-new-report-2022-07-08\\_en](https://commission.europa.eu/news/nextgenerationeu-funding-operations-progress-well-according-new-report-2022-07-08_en)

funded by the NGEU. 39.9% of the plan's 163 billion Euro value is devoted to the green transition, of which 3.2 billion will benefit the integration and implementation of renewable energies.<sup>64</sup> These large investments are reflective of Spain's renewed commitment to supporting and expanding its renewable sector to achieve its climate goals.

In recent years, there has been a further renewed focus on ensuring grid stability and the implementation of digital solutions. Partly informed by the risk exposure to shocks uncovered through the COVID-19 pandemic, several countries have begun initiatives to upscale and enforce their grids. A key example of this is the U.S. Department of Energy's Grid Modernization Initiative (GMI), which supports the development of innovative green solutions.<sup>65</sup>

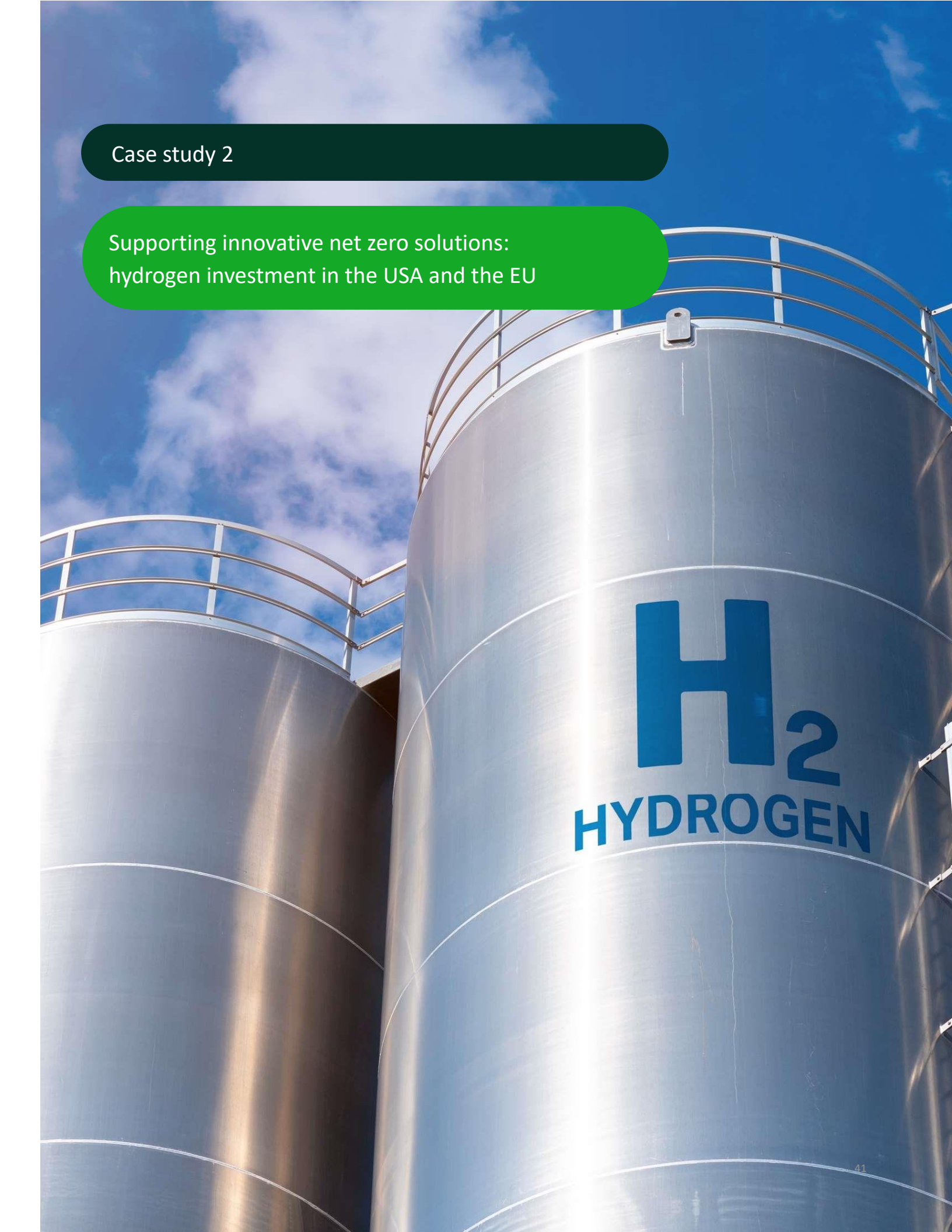
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<sup>64</sup> European Parliament (2024) Spain's National Recovery and Resilience Plan: Latest state of play. Briefing. [https://www.europarl.europa.eu/thinktank/en/document/EPRS\\_BRI\(2022\)698878](https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)698878)

<sup>65</sup> U.S. Department of Energy (2024) Grid Modernization Strategy 2024 [https://www.energy.gov/sites/default/files/2024-07/EXEC-2023-003965%20-%20Grid%20Modernization%20Strategy%202024%20-%20Signed%20by%20S4%20Richmond\\_FINAL%20FOR%20WEBSITE.pdf](https://www.energy.gov/sites/default/files/2024-07/EXEC-2023-003965%20-%20Grid%20Modernization%20Strategy%202024%20-%20Signed%20by%20S4%20Richmond_FINAL%20FOR%20WEBSITE.pdf)

## Case study 2

Supporting innovative net zero solutions:  
hydrogen investment in the USA and the EU



**H<sub>2</sub>**  
**HYDROGEN**

## 5 Supporting innovative net zero solutions: hydrogen investment in the USA and the EU

Hydrogen, when produced through green methods by using renewably sourced electricity ('green hydrogen'), promises to facilitate the energy transition in a plethora of ways. IRENA's 1.5°C global warming scenario by 2050 envisages that renewable- and low-carbon hydrogen could meet up to 12% of global final energy consumption. Hydrogen has applications as a clean-burning fuel, as well as an input in sectors plagued by major and hard to abate emissions. Considering the latter, hydrogen can act as a feedstock in steelmaking, chemical manufacturing, and as an energy carrier in transport applications, among others.<sup>66</sup> While its use cases are varied and promising, further development hinges on the effective and sustainable production of hydrogen, as well as its transport, storage and distribution. Balancing progress at each level is necessary to build a sustainable value chain in green hydrogen.

Due to the promising applications of this resource, it is increasingly a focus of net-zero policy. The USA, EU, and Australia have all set out their respective hydrogen strategies with ambitious deployment targets.

The EU's hydrogen and decarbonised gas market package envisages that the share of renewable and low-carbon gases in the EU will increase from just 5% today to 66% by 2050.<sup>67</sup> The EU hydrogen strategy under the Green New Deal sets targets of 40 GW of electrolyzers capacity to produce 10 million tonnes of renewable hydrogen by 2030.

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US targets for hydrogen adoption envisage scenarios in which domestic production reaches 10 million metric tonnes (MMT) annually in 2030, 20 MMT by 2040, and 30 MMT in 2050.<sup>69</sup> The national strategy set out by the U.S. aims to target certain high-impact uses in industrial applications, transportation, and the power sector. Furthermore, a cornerstone of the strategy is to reduce the costs associated with hydrogen, reducing

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<sup>66</sup> Burning H<sub>2</sub> is clean, but fugitive H<sub>2</sub> emissions through the supply chain do also have a global warming potential currently estimated at around 11x that of CO<sub>2</sub>.

<sup>67</sup> <https://www.consilium.europa.eu/en/infographics/fit-for-55-hydrogen-and-decarbonised-gas-market-package-explained/> Infographic (accessed 28 October 2024).

<sup>68</sup> European Hydrogen Observatory (2023) EU Hydrogen Strategy under the EU Green Deal. <https://observatory.clean-hydrogen.europa.eu/eu-policy/eu-hydrogen-strategy-under-eu-green-deal>

<sup>69</sup> U.S. Department of Energy (2023) U.S. National Clean Hydrogen Strategy and Roadmap. p.6 <https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap>

hydrogen production costs to 2 USD/kg by 2026 and 1 USD/kg by 2031, as well as setting out cost targets for onboard storage and delivery costs.<sup>70</sup>

Australia too has implemented ambitious targets for its hydrogen uptake, and hydrogen is prioritised significantly in the Future Made in Australia bill. In its national hydrogen strategy, Australia sets 5-year production milestones up to 2050. The aim of these is to produce 15 million tonnes of hydrogen annually with a stretch target of 30 million tonnes annually by 2050. Furthermore, exports of hydrogen are an important aspect of the country's hydrogen strategy, with a 2030 export target which aims to have a base of 0.2 million tonnes of exports per year, with a stretch target of 1.2 million tonnes annually.

In light of this extensive interest in hydrogen, we will address the challenges along the hydrogen value chain, illustrating the policy solutions implemented in various jurisdictions. In doing so, we will address how these will allow hydrogen to be effectively harnessed and brought to use in the many applications it is theorised to revolutionise in the modern economy.

### 5.1 Upstream Hydrogen Production

In the production of hydrogen, the distinction of the gases' 'colour' is made. These differentiate not only the inputs used in the production of hydrogen, but also the extraction process and the steps taken to mitigate additional pollution.

'Grey' hydrogen is the result of steam reforming, which takes natural gas ( $\text{CH}_4$ ) as an input, producing both Hydrogen ( $\text{H}_2$ ) and a by-product of Carbon Dioxide ( $\text{CO}_2$ ). These Carbon Dioxide emissions are not captured in the process of generating hydrogen, resulting in 'grey' hydrogen being the least sustainable method of producing hydrogen. Cost considerations and the availability of fossil fuels inform the continued persistence of 'grey' hydrogen in hydrogen mix.

In contrast to the above, 'blue' hydrogen captures and sequesters the carbon dioxide emissions resulting from the steam reforming process. Due to the added complexities of capturing, transporting, and

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<sup>70</sup> U.S. Department of Energy (2023) U.S. National Clean Hydrogen Strategy and Roadmap. p.8  
<https://www.hydrogen.energy.gov/library/roadmaps-vision/clean-hydrogen-strategy-roadmap>

sequestering emissions, ‘blue’ hydrogen proves more expensive than its ‘grey’ counterpart, yet results in 60-65% lower total emissions.

‘Green’ hydrogen is generated through electrolysis of water, sometimes also referred to as ‘electricity-based hydrogen’. This is currently the most expensive form of production, but it does not have any direct carbon emissions. The total carbon cost of producing green hydrogen depends on the underlying electricity mix used for the electrolysis. Green hydrogen production thus requires significant amounts of dedicated renewable and low-carbon generation. <sup>71</sup>

With support to upstream technologies, the cost of green hydrogen may fall significantly in the coming years driven by the reduced cost and increased availability of electrolyzers (and potentially further decreases in the cost of renewable energy production). This could potentially compete directly with grey hydrogen by 2030 (though the cost reductions likely to be achieved remain uncertain).

For example, the IEA expects that, compared to 2023, electrolyser costs could decrease by 60% by 2030, due to economies of scale and mass production—akin to the 80% reduction in solar photovoltaic (PV) costs between 2010 and 2020. <sup>72</sup> In regions with conditions conducive to solar generation, e.g. many parts of Africa, the Americas, the Middle East and Oceania, green hydrogen from solar PV could fall as low as 1.6 €/kg by 2030 (which would be in the lower range of current grey hydrogen production costs).

Current EU and US subsidy and tax credit programmes are targeting hydrogen production, aimed at driving down the cost curve. The commitment that public funds will be invested in the hydrogen sector decreases the perceived uncertainty of potential asset stranding for private lenders. This represents a way to ‘crowd in’ private capital by de-risking these investments. <sup>73</sup>

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<sup>71</sup> As an intermediary between the production of blue and green hydrogen, there exists ‘turquoise’ hydrogen. Such hydrogen is created through methane pyrolysis, yielding hydrogen and a solid carbon by-product. This method has yet to be proven at-scale but would require approximately half the amount of energy as steam reformation. There is also a rainbow of other hydrogen colours (of less importance), depending on the fuel inputs/hydrogen sources.

<sup>72</sup> IEA (2023), ‘Global Hydrogen Review’, June, pp. 74 and 80.

<sup>73</sup> For example, the Commission expects the €10.6 billion in IPCEI funding to unlock another €15.8 billion in private investments.

[https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/ipceis-hydrogen\\_en](https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/ipceis-hydrogen_en)  
European Commission, ‘IPCEIs on hydrogen’ (accessed 28 October 2024).

Among the main sources of subsidies at the EU level are the first two rounds of the Important Projects of Common European Interest (IPCEIs) <sup>74</sup> on hydrogen and the establishment of the European Hydrogen Bank. <sup>75</sup> The latter is an innovation fund that is not solely focused on production but aims to establish a full hydrogen value chain and supporting market whilst cooperating with partner countries. <sup>76</sup> In doing so, it provides a range of financial support, e.g. innovation grants and concessional loans, for renewable hydrogen production. The EU Renewable Energy Directive further requires that by 2030 42.5% of the hydrogen used by industry should come from renewable sources, with a goal of 60% by 2035. <sup>77</sup> These measures are complemented by state level initiatives and other state aid measures that can be adopted (following a notification process to the Commission). Across Europe, at least 16 member states have also adopted their own national hydrogen strategies. <sup>78</sup>

The United States supports hydrogen development through various federal and state initiatives. <sup>79</sup> Key federal incentives include the Inflation Reduction Act's Clean Hydrogen Production Tax Credit (45V), offering up to \$3 per kilogram of hydrogen produced depending on the carbon-intensity of the production process. Further included are the Advanced Energy Production Credit (48C), which extends a 30% investment tax credit to green hydrogen production infrastructure, among other green energy projects. In addition, investments are made using the Bipartisan Infrastructure Law's \$7 billion allocation for regional clean hydrogen hubs. The Department of Energy also provides grants and loans to

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<sup>74</sup> These were approved under the state aid discipline and allowed the financing of a number of projects aiming to, among others, use renewable hydrogen in industrial applications (see reference in footnote 27 above).

<sup>75</sup> European Commission (2023), 'COM(2023) 156 final. Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions on the European Hydrogen Bank', 16 March, pp. 5-6. A first round of auctions of the Hydrogen Bank, backed by €800 million from the Innovation Fund, are expected to take place towards the end of 2023.

<sup>76</sup> There are further technology-Neutral (i.e. not hydrogen-specific) innovation funds such as the EU-wide innovation fund grants. [https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/innovation-fund\\_en](https://single-market-economy.ec.europa.eu/industry/strategy/hydrogen/funding-guide/eu-programmes-funds/innovation-fund_en)

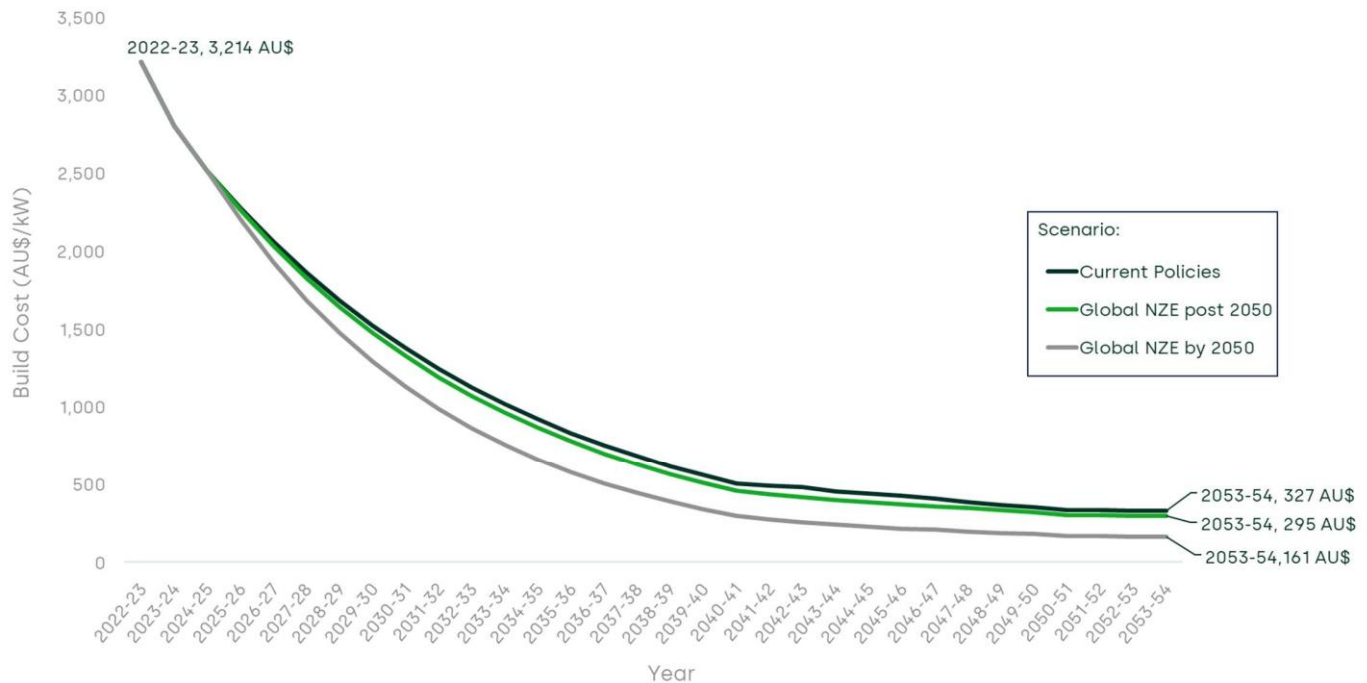
<sup>77</sup> European Commission (2022), 'REPowerEU Plan', 18 May and its adoption by the EU Council, as discussed here: <https://www.consilium.europa.eu/en/infographics/fit-for-55-how-the-eu-plans-to-boost-renewable-energy/> accessed 28 October 2024.

<sup>78</sup> European Commission (2023), 'COM(2023) 156 final. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions on the European Hydrogen Bank', 16 March, page 1.

<sup>79</sup> Office of Energy Efficiency & Renewable Energy (2024) Financial Incentives for Hydrogen and Fuel Cell Projects. <https://www.energy.gov/eere/fuelcells/financial-incentives-hydrogen-and-fuel-cell-projects>

advance hydrogen technologies. In addition to federal measures, several states have adopted their own hydrogen strategies and offer incentives such as grants, tax credits, and rebates for hydrogen projects.

Figure 5.1 Australian electrolyser—proton exchange membrane cost forecast



Note: Policy scenarios are adopted from the 2023 IASR workbook

Source: Australian Energy Market Operator. 2023 Inputs, Assumptions, and Scenarios (IASR) Workbook.

## 5.2 Midstream Hydrogen Transportation

A vital consideration in the hydrogen value chain is the transportation of hydrogen gas from its production sites to its demand centres. Green hydrogen requires large amounts of (excess) renewable electricity and water, limiting the locations in which it would be economically viable to produce it. Additionally, it may not prove feasible to co-locate (green) hydrogen production with industrial areas and urban centres that consume this hydrogen.

The transportation of hydrogen introduces its own hurdles. Particularly challenging is the difficulty in using existing gas transmission networks to transport hydrogen gas. Pipelines used in the liquified national gas network cannot be repurposed without significant upgrades, as hydrogen gas may embrittle steel pipelines, requiring fibre reinforced

polymer (FPR).<sup>80</sup> These however are cheaper to install than their steel counterparts as they are produced in segments longer than steel pipes, reducing welding costs.

The use of ships to transport hydrogen is complicated due to hydrogen's low liquification temperature of -253°C. The high energy usage in this conversion may further cause issues in this transportation method, as would the cost of ensuring ships and storage tanks are designed to meet insulation specifications that limit boil-off losses and ensure safety.

A solution to the port-to-port and road/rail transport of hydrogen exists in Liquid Organic Hydrogen Carriers (LOHC) such as Benzyltoluene. These chemical compounds can be bound with hydrogen, easily transported at atmospheric pressures, and then unbound at the destination, with the LOHC being reused for future transportation. However, the high energy costs and significant capital costs incurred as part of the conversion hamper this transportation method.

Ammonia transportation is another option. Ammonia can be transported easily and returned into its components of nitrogen and hydrogen through ammonia cracking. With well-established facilities that can be retrofitted and mature supply chains, this transportation method is promising. Yet, safety and environmental protection concerns impact the viability of this method of transporting hydrogen, particularly in consideration of transport to urban centres.

Hydrogen transport is a further key goal of the United States' investment into the hydrogen value chain, with the National Clean Hydrogen Strategy and Roadmap and the Bipartisan Infrastructure Bill drawing attention to the infrastructure build-up that is required. The department of Energy further supports the development of pipelines and hydrogen blending facilities.

Within the EU, Germany has ambitions to be at the forefront of the global hydrogen economy. Recognising the need to support the whole value chain to ensure success, it is planning to build a core hydrogen network to facilitate the distribution of hydrogen and hydrogen imports. This network will consist of 9,700km of pipelines (the bulk of which is

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<sup>80</sup> Roland Berger (2021) Hydrogen transportation: The key to unlocking the clean hydrogen economy. <https://www.rolandberger.com/en/Insights/Publications/Transporting-the-fuel-of-the-future.html>

transmission) and of which 60% will be repurposed gas pipelines. network's pipelines will be put into operation successively between 2025 and 2032.

<sup>81</sup> The

In order to allow transmission systems operators (TSOs) to recover their investment costs, the state will compensate network operators for costs not covered by tariffs. This negative delta between the costs and tariffs will be booked to an 'amortisation account' with the commitment made to balance this account by 2055. The draft law introducing this regime stipulates that this account will be balanced through a period of tariffs exceeding costs following an initial period with a negative delta.

Yet, the risk of asset stranding may hinder the development of the system. Low network utilisation might result from low hydrogen deployment, leaving network operators and investors without the tariff volume required to recuperate costs. In the case of such a market ramp-up failure, the state will bear some of the costs, with the remaining balance in the amortisation account in 2055 being split between the state (76%) and the network operators (24%). The Federal Ministry for Economic Affairs and Climate action, however, deems this to be an 'extremely low risk'.

This risk must however be considered in the context of the significant gap between Germany's climate ambitions and the current state of its hydrogen economy. First steps in the promotion of low-emission hydrogen adoption have been made, but these are currently insufficient to drive the costs of hydrogen down by scaling up production. Additionally, Germany will continue to rely on hydrogen imports, which in the face of the aforementioned lack of mature supply chains further limit hydrogen uptake. Compounding this is general uncertainty about the off-takers' future willingness or ability to pay for the additional costs of renewable hydrogen.

The coordination problem evident in the transport of hydrogen reveals the likely necessity of compensating market participants for the risks of moving first. <sup>82</sup> Such uncertainty may well be resolved over time with further network and market development, as well as the expansion of

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<sup>81</sup> 5400km of transmission pipelines are being re-purposed; this is 13.5% of the existing 40,000 gas transmission pipelines. In distribution: only 700km is committed yet (existing distribution gas pipelines are 555,000km). In principle, an alternative distribution network is planned in parallel to the core gas network.

<sup>82</sup> A real option premium was proposed by an Association of German Gas TSOs, but the regulator rejected this. Bundesnetzagentur (2024) Hydrogen Core Network. <https://www.bundesnetzagentur.de/EN/Areas/Energy/HydrogenCoreNetwork/start.html>

government hydrogen strategies concerning imports, port infrastructure, power plants, and carbon management. Furthermore, government-backed auctions<sup>83</sup> reveal willingness to pay and may further aid the building up confidence among investors and TSOs.

### 5.3 Downstream Hydrogen

There are several principal downstream use case classes for hydrogen that have been proposed or developed to various degrees. These remain far from proven and are discussed only briefly here.

It can substitute for gas (and other fossil fuels) as a heating source, and it can be used to produce synthetic fuels for heavy transport applications. Hydrogen is already, or is soon going to be, used as a direct industrial input into certain industrial processes like ammonia production, which in turn can be used to produce fertilisers, and Direct Reduced Iron production, which in turn can be used to produce 'green' steel.<sup>84</sup>

In the future, hydrogen may also be used to provide seasonal energy storage (similar to gas storage) to supplement renewable electricity plants during winter periods with high demand and limited wind or solar availability. It could be especially beneficial when co-located with other power applications to further aid in covering network shortfalls that may arise through elevated levels of intermittency as a greater amount of renewable capacity is added to the grid.

### 5.4 Policy Considerations in the Development of the Hydrogen Value Chain

Policy aimed at accelerating the roll-out of hydrogen must address the main market failures and barriers to the optimal development and scale of the green hydrogen economy. The hydrogen value chain exhibits coordination problems between demand and supply. For example, for

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<sup>83</sup> For example, the 900 million Euro H2Global auctions in late 2022, funded entirely by the German government was instrumental in establishing the willingness to pay. In this auction, the first trio of tenders was won by Fertiglobe – a joint venture between Abu Dhabi's state-owned oil company ADNOC and the OCI group.

<sup>84</sup> Steelmakers ArcelorMittal, Stahl-Holding-Saar, Salzgitter Flachstahl, and Thyssenkrupp received grants from the German government in 2024 for the transition to green steel production by replacing coal and coke intensive steelmaking with the use of Direct Reduction Plants and electric arc furnaces. The subsidies, amounting to 1.3 Billion for ArcelorMittal, 2.6 Billion in the case of Stahl-Holding-Saar, 1 Billion for Salzgitter Flachstahl, and 2.2 Billion for Thyssenkrupp originate out of a mix of federal and state-level funding. This follows previous French subsidies for ArcelorMittal in 2023 amounting to 850 million Euros. Clean Energy Wire (2024) Steelmaker ArcelorMittal to receive €1.3 bn in subsidies for green transformation of German sites. <https://www.cleanenergywire.org/news/steelmaker-arcelormittal-receive-eu13-bln-subsidies-green-transformation-german-sites>

potential producers to invest in a technology that is not yet cost competitive and is still unproven requires some degree of certainty over future off-takers, the infrastructure to reach end-users, and clarity around longer-term regulation and incentives.

Particularly relevant among these are the negative externalities of un-priced (or under-priced) carbon emissions, and how to best incorporate these across sectors. The hydrogen economy is still a nascent industry, and as such, is beset by financial frictions, insufficient 'learning by doing' and knowledge/technology transfers, as well as first mover disadvantages and lock in effects.

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The overarching policy and regulatory challenge is that the difficulties faced in the different parts of the value chain cannot be addressed in isolation, or sequentially. Indeed, establishing a green hydrogen market requires simultaneously coordinating among potential future suppliers, investors in the necessary infrastructure and storage facilities, and as yet unknown classes of consumers.

Vertical integration and vertical agreements may have a role to play in helping overcome these coordination challenges. Currently the EU is pursuing an unbundled approach, in line with the regulatory arrangements developed in the existing energy value chains. These existing infrastructures were originally developed during the vertically integrated national monopolies era. Unbundling and the necessary restructuring followed later. The EU is seeking to avoid that restructuring in the case of hydrogen; however, the coordination issues may lead to serious hold-up problems. While there are currently many plans, targets, and subsidy auctions, only a small minority of funded projects have reached Final Investment Decision.

Furthermore, many of these US and EU measures are relatively interventionist and assume that hydrogen will form a key part of that region's net zero energy mix. Put differently, compared to technology-neutral policy levers like carbon pricing or technology-neutral subsidy schemes, green hydrogen-specific state-aid/tax credits, grant funding or quotas are incentivising a specific energy source. Once cost competitive, hydrogen production is seen as a flexible, plentiful source

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<sup>85</sup> See for example the justification of support provided to developing the hydrogen economy in the USA: the White House (2023), 'The Economics of Demand-Side Support for the Department of Energy's Clean Hydrogen Hubs', 5 July. The policy brief relies on the underlying academic work by Armitage, S.C., Bakhtian, N. & Jaffe, A.B (2023), 'Innovation Market Failures and the Design of New Climate Policy Instruments', NBER Chapters in: Environmental and Energy Policy and the Economy, volume 5.

with the scope to lessen the types of geopolitical tensions around controlling energy sources as has been seen for fossil fuels.

This approach recognises that some hard-to-abate sectors effectively have no viable alternatives to hydrogen in the long run, and that achieving economies of scale in the production of hydrogen will help make key industrial sectors more competitive. As the Commission notes, it has developed ‘a fully-fledged legislative framework for the production, consumption, infrastructure development and market rules for a future hydrogen market, as well as binding quotas for renewable hydrogen consumption in industry and transport.’<sup>86</sup>

Policymakers and regulators also need to consider the ways in which the various mechanisms interact. For example, two of the main mechanisms at the EU level, the existing carbon pricing scheme (EU ETS) and the funding mechanism of the Hydrogen Bank (i.e. the Innovation Fund) are interlinked fiscally. The Innovation Fund is financed through the sale of EU ETS allowances, and the budget of future public grants available will thus depend on the carbon price.

Hydrogen-specific subsidies and consumption targets also create practical challenges. For example, they necessitate certification standards that define when hydrogen production (in the EU or abroad) is renewable (green), hence contributing to net zero targets. For example, the first two Delegated Acts on Renewable Hydrogen, accompanying Renewable Energy Directive, (i) sets out when hydrogen can be defined as fully renewable (thus categorised as RFNBOs), and (ii) provides a methodology for calculating life-cycle greenhouse gas emissions for RFNBOs, to determine whether they meet the Renewable Energy Directive’s minimum greenhouse gas emission saving threshold of 70% (compared to fossil fuels).<sup>87</sup>

There is also a risk of regulatory failure. It is important that the hydrogen market regulations and incentives are not considered in a vacuum, independent of other green alternatives and existing (fossil) commodity

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<sup>86</sup> European Commission (2023), ‘COM(2023) 156 final. Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions on the European Hydrogen Bank’, 16 March, page 1.

<sup>87</sup> See European Commission (2023), ‘Renewable hydrogen production: new rules formally adopted’, June

markets. And the coordination challenges mean the whole value chain needs to be considered.

The Australian National Hydrogen Strategy sets out ambitious steps for the country to take in both the production and export and use of hydrogen. The focus of the strategy lies in producing hydrogen from excess renewable energy rather than steam reformation, with expectations that green hydrogen costs will fall rapidly by 2030. With large-scale investment in electrolysis globally, the technology may plausibly achieve the expected reduction in costs in Australia.

The strategy's midstream goals of transporting and exporting hydrogen however is subject to several challenges. As discussed, the costs of transporting and storing hydrogen requires much capital investment and is generally cost-intensive throughout. Depending on the proximity of production sites to ports, Australia's export strategy may rely on the full transport value chain co-developing. In light of these cost considerations, Australia's export competitiveness may weaken vis-à-vis other major future producers of hydrogen (India, China, Africa and the Middle East). <sup>88</sup>

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<sup>88</sup> See the German-backed H2Global auctions where Fertiglobe — a joint venture between fertiliser group OCI and Abu Dhabi's state-owned oil company ADNOC, won all three tenders.

### Case study 3

Bringing low-/no-carbon solutions to  
market: electric vehicles



## 6 Bringing low/no-carbon solutions to market: electric vehicles

The residential and commercial transportation sector remains a key source of emissions, to be addressed in the transition to net-zero. With the introduction of battery-powered electric vehicles suitable for both private use and public transport, a significant amount of emissions can be avoided, particularly if the electricity used to power these vehicles is generated renewably. However, the process of replacing internal combustion engine vehicles with electric ones presents a number of specific challenges.

The phasing out of vehicles with internal combustion engines (ICE) has been proposed or signed into legislation in a number of countries. Signatories of the Glasgow Declaration are required to ban the sale of new emitting vehicles by 2040 at the latest, while a number of other states have committed to more ambitious timeframes. Approaches are varied and range from the (removal of) tax incentives to outright bans on new purchases of emitting vehicles.

Alongside the phase-out of ICE vehicles, governments worldwide are aiming to accelerate the deployment of electric vehicles (EVs) for consumers. Major hurdles to EV adoption are price and convenience. To incentivise the take-up of EVs, policies by various states support the purchase of EVs through grants and tax benefits, while also building up the critical infrastructure to support EV use. The incentives should go hand in hand to overcome the coordination problems that exists in this sector. EV take-up is in part driven by confidence that the infrastructure to support them will be there, but the infrastructure investment relies on expectations of significant future EV use.

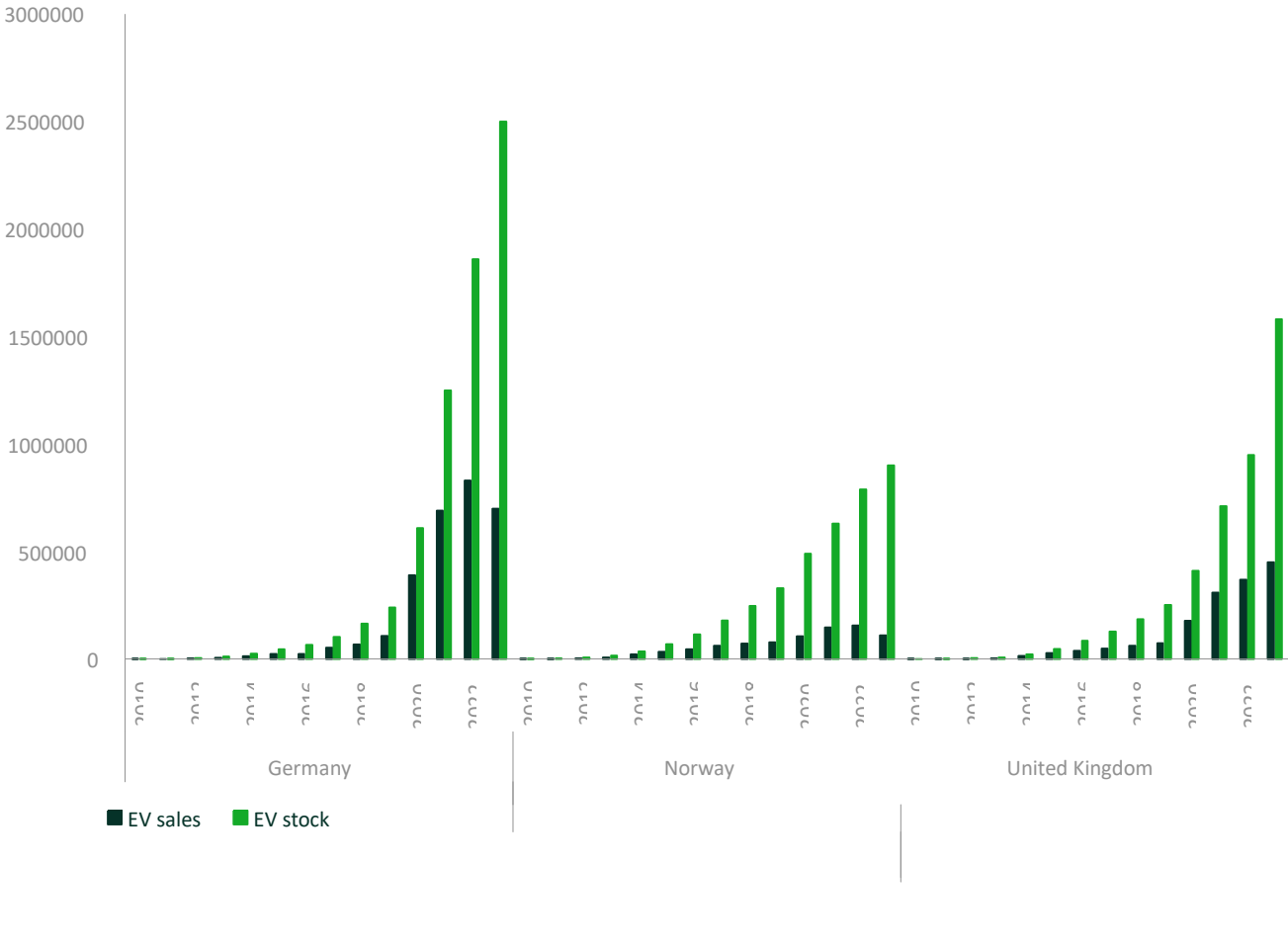
### 6.1 Electric vehicle purchase incentivisation

In supporting the purchase of EVs, many governments worldwide have implemented purchase support schemes. For example, buyers of EVs in France can receive a government grant of up to €6,000, with a further incentive in the form of a €2,500 premium for trade-ins of older and more polluting vehicles. In Germany and the United Kingdom, such purchasing subsidies amount to €9,000 and £2,500 respectively. The Norwegian approach further offered incentives such as exemptions from tolls from 1997 to 2017, free parking from 1999 to 2017, and allowed EVs to use bus lanes since 2003.

Tax policy is further used to drive EV adoption, with notable examples being that of Norway, Germany, and the UK. Norwegian vehicle registration taxes have not applied to EVs since 1990 and from value-added taxes since 2001. As these taxes are significantly high (up to half of the pre-tax vehicle purchase price), this proved to be a major incentive. Similarly, both Germany and the UK both offer exemptions from road taxes to boost take-up of EVs among consumers.

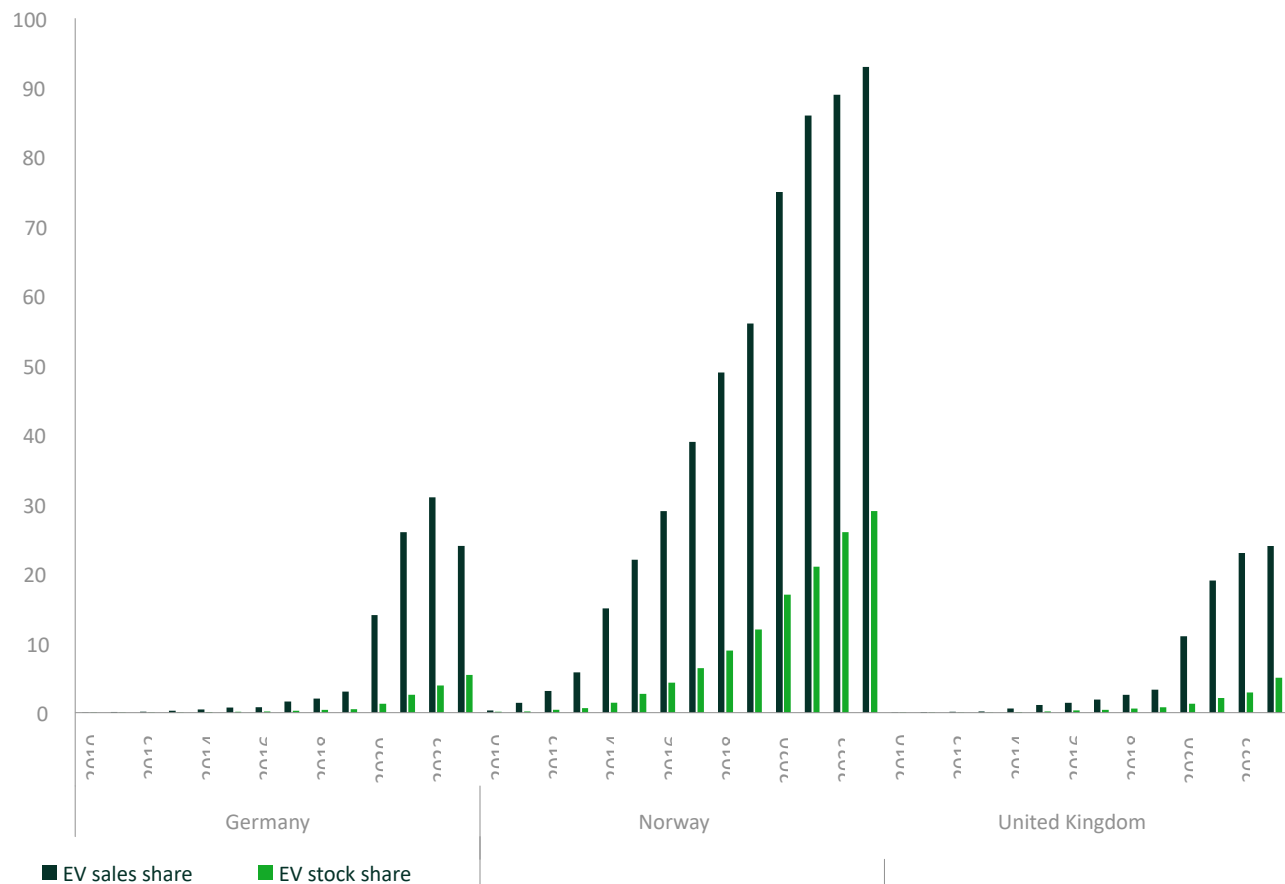
In 2022 and 2023, overall EV sales in Germany slowed down with the phase out of the subsidies to PHEV (while BEV sales continued to increase) as well as the EVs sales share. In the rest of Europe and in the UK EV have been constantly increasing, with the highest performances in the Nordic countries, Sweden (60%) and Norway (over 95% of EV sales share). <sup>89</sup>

Figure 6.1 EV sales and EV stock in Germany, Norway and the UK



<sup>89</sup> IEA (2024) – Global EV Outlook 2024 – Trends in Electric Cars. [link](#)

Figure 6.2 EV sales share and EV stock share in Germany, Norway and the UK



Note: mode: cars, powertrain: all EV categories  
 Source: IEA Global EVs data Explorer (April 2024) [link](#).

Finally, regulation is further used as a complement to the above policies. By banning the sale of ICE vehicles, as will be the case by 2040 for signatories to the Glasgow declaration, or by 2035 in the case of the UK, EU and a number of US states, including California. Less extensive regulation exists in the form of reduced emission zones which limit the practicality of older, more polluting vehicles by barring their use in certain areas. Such regulation has proven to be regressive in its effects,

mostly affecting consumers with an inability to upgrade to newer vehicles.<sup>90</sup>

While the aforementioned support schemes and tax incentives aim to encourage the adoption of EVs, they present a cost burden to the governments implementing these. While these incentives will likely be phased out as the cost of EV purchases drop, the immediate budgetary impact to governments remains significant.

Accompanying the greater expenditure are reduced tax revenues collected through fuel surcharges. As EVs do not consume gasoline or diesel, governments will face a substantial reduction in fuel tax revenues as the market shifts from ICE vehicles to electric alternatives. Much of road upkeep and maintenance has traditionally been funded through such surcharges, and in countries like Germany where the surcharge makes up roughly half of the fuel cost, represents a major source of income for the government.

The same is done in Australia, where income from fuel taxes and “road-related” taxes have been funding road expenses. In 2021-22 the net income from fuel taxes (fuel excises, levied at Government/Federal level), was \$10.4bn, and around \$13bn on average in the previous 15 years.<sup>91</sup>

Globally, it is estimated that the adoption of EVs led to the loss of almost \$12bn<sup>92</sup> in 2023 in fuel duties. At the same time, EVs paid around \$2bn in electricity tax, resulting in a net fiscal loss associated with the adoption of electric vehicles of around \$10bn for 2023.

To mitigate these losses, governments will need to implement alternative revenue mechanisms, such as road usage taxes, higher registration fees for EVs, or taxes on electricity used for charging. Each country will need to tailor its approach based on its unique fiscal needs and EV adoption rates, but the need for reform is clear if governments are to maintain the necessary funding for public infrastructure.

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<sup>90</sup> A number of councils in greater London unsuccessfully challenged the expansion of the ULEZ scheme in London on the basis of, inter alia, its regressive effects.

<sup>91</sup> Bureau of Infrastructure and transport research economics statistical report (2023), Australian Infrastructure and Transport Statistics – Yearbook 2023, p. 78  
<https://www.bitre.gov.au/sites/default/files/documents/bitre-yearbook-2023.pdf>

<sup>92</sup> IEA (2024), Global EV Outlook 2024, p. 152, <https://iea.blob.core.windows.net/assets/a9e3544b-0b12-4e15-b407-65f5c8ce1b5f/GlobalEVOutlook2024.pdf>

Countries across Europe have begun exploring policies and mechanisms to address the fiscal challenges posed by the decline in fuel tax revenue. These policies vary by country, but common strategies include introducing road usage fees, increasing registration fees for EVs, and taxing electricity used for vehicle charging, although these policies can be in conflict with those seeking to encourage EV adoption.

One of the proposed remedies exists in the shape of distance-based road pricing. Such taxes would charge drivers for every kilometre or mile they travel on public roads. The exact design of these fees depends on the technology involved and the goals of the government implementing them.

This remedy has been considered in Australia, focused on EVs. Victoria initially introduced a road-user charge for EVs in 2021 but this has been declared invalid.<sup>93</sup> New South Wales (NSW) has a similar intention to introduce a road user charge that will apply to eligible EVs from 1 July 2027 or when EVs make up 30 per cent of all new vehicle sales, whichever comes first. These policies are being reconsidered, given the High Court ruling.<sup>94</sup>

GPS pricing offers an accurate way to track the distance travelled by a vehicle, and further allows for differentiations to be made between distance travelled on different types of roads. As such, it can charge differentiated rates based on the type of road and the usual wear and tear experienced by these. Oregon in the United States currently is running such a vehicle-miles travelled pilot scheme, in which participants receive invoices based on their travelled distance. It further includes different rates for highways and city roads, allowing for an accurate tiered pricing structure. Yet, these systems are subject to significant privacy concerns as well as data privacy requirements.

A less invasive manner of implementing road pricing uses odometer readings to measure the distance travelled by a vehicle. With odometer readings already being a part of mandatory vehicles inspection in countries such as Germany, this system is simpler to implement and

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<sup>93</sup> <https://www.theguardian.com/law/2023/oct/18/why-the-high-court-struck-out-victorias-ev-tax-and-the-ripple-effects-of-the-decision> Decision in *Vanderstock v. The State of Victoria* (2023) determined that the Victorian Government's Zero and Low Emission Vehicle Distance-based Charge Act was invalid.

<sup>94</sup> <https://www.nsw.gov.au/driving-boating-and-transport/nsw-governments-electric-vehicle-strategy/road-user-charge#:~:text=The%20road%20user%20charge%20rate%20for%20the%202024%2D25%20financial,a%20plug%2Din%20hybrid%20EV>

addresses some of the privacy concerns of GPS tracking. However, this method does not allow for road-specific pricing and may further disproportionately affect those most reliant on cars for transport, such as rural populations and those not served by reliable public transport.

An alternative to road-pricing schemes may be increasing the taxes and fees for EVs, or where applicable, removing exemptions. In the UK for example, EVs will no longer be exempt from Vehicle Excise Duty (VED) starting in 2025. Similarly, Norway has ended many of the benefits available to owners of EVs, requiring (reduced) payments of tolls, and no longer exempting EVs from fees for parking and ferries. While these measures seek to limit the budgetary burden of EV support policies, such changes must be balanced with the overall goal of encouraging EV take-up.

A further proposal is the introduction of taxes on charging electricity, as an equivalent to fuel surcharges. Proposals to implement such a measure have emerged in several European countries, with calls to separate these electricity charging taxes from general electricity taxes. However, this approach needs to further balance the aim of recuperating revenues with further encouraging EV adoption.

## 6.2 Infrastructure development to encourage adoption

A second crucial aspect of the roll-out of EVs is the development of adequate infrastructure to support them. With ease of use being a major factor in the decision to purchase an EV, alongside the currently still limited range of EVs, ensuring that charging infrastructure is available and practical for consumers is a high priority for governments worldwide. One of the main constraints in the development of EV market is, in fact, the so called “range anxiety”, i.e. the fear of not being able to recharge the vehicle, particularly during an unfamiliar, or unusually long, journey.

The charging infrastructure in Australia is growing, following the uptake in EV sales. In 2023 the Australian EV fleet doubled and the number of public DC charging locations, increased from 464 to 812.<sup>95</sup> The total amount of charging locations of all types (regular AC, and DC fast and

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<sup>95</sup> Electric Vehicle Council (2023), Australian Electric Vehicle Industry Recap 2022 <https://electricvehiclecouncil.com.au/wp-content/uploads/2024/03/EVC-Australian-EV-Industry-Recap-2023.pdf>

ultrafast) in 2022 were around 2,400<sup>96</sup> across all the Australian States. The charging service is supplied across the country by more than 25 charging infrastructure providers, with a differentiated presence in the different States.<sup>97</sup> Australia started to fund infrastructure development ahead of the large-scale adoption of EVs, with a dedicated funding programme since 2020.<sup>98</sup>

From a policy perspective, to allow for the charging infrastructure to grow consistently with the desired growth of the EV market, the main tools identified in various countries, including in Europe are, on one hand the funding or incentive programs to develop the charging network and, on the other hand, the appropriate mechanisms to ensure fair competition among charging providers. The policy tools in place also need to ensure that the charging points of the appropriate type (slow, fast, ultrafast) are available over the whole territory, including urban areas, motorways and rural and remote regions.

In Europe, for instance, the European Commission defined the targets for the development of the charging network to be met by the Member States, in terms of minimum total power available and of distance between charging stations for light and heavy duty vehicles<sup>99</sup> and recently announced €1bn of fundings to be awarded to projects for new charging stations across the continent.<sup>100</sup>

At a Member State level funding and incentive schemes (such as tax exceptions and grants) are in place both for private and public charging stations.

As mentioned, a potential challenge is to ensure sufficient competition in the market for EV charging, whilst ensuring speedy expansion of this network, both in rural areas as well as within cities. Questions that are

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<sup>96</sup> Rachael Rosel, on Budget Direct, 2023, Electric Charging Station in Australia 2023

<https://www.budgetdirect.com.au/car-insurance/research/electric-vehicle-charging-points.html#ref1>

<sup>97</sup> Electric Vehicle Council, A-Z of EV Charging, <https://electricvehiclecouncil.com.au/a-z-charging/>

<sup>98</sup> IEA (2023) Global EV Outlook 2023 - Catching up with climate ambitions, OECD publishing, [https://www.oecd-ilibrary.org/energy/global-ev-outlook-2023\\_cbe724e8-en](https://www.oecd-ilibrary.org/energy/global-ev-outlook-2023_cbe724e8-en)

<sup>99</sup> Regulation (EU) 2023/1804 of the European Parliament and of the Council of 13 September 2023 on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1804>

<sup>100</sup> European Commission (2024), News article, 29 February 2024, Commission makes €1bn available for recharging and refuelling points under the Connecting Europe Facility (CEF) [https://transport.ec.europa.eu/news-events/news/commission-makes-eu1bn-available-recharging-and-refuelling-points-under-connecting-europe-facility-2024-02-29\\_en#:~:text=29%20February%202024-,Commission%20makes%20%E2%82%AC1bn%20available%20for%20recharging%20and%20refuelling%20points,Fuels%20Infrastructure%20Facility%20\(AFIF\).](https://transport.ec.europa.eu/news-events/news/commission-makes-eu1bn-available-recharging-and-refuelling-points-under-connecting-europe-facility-2024-02-29_en#:~:text=29%20February%202024-,Commission%20makes%20%E2%82%AC1bn%20available%20for%20recharging%20and%20refuelling%20points,Fuels%20Infrastructure%20Facility%20(AFIF).)

raised in this context are amongst others how to allocate slots for charging infrastructure and how to deal with constraints on electricity grid capacity and balancing any need for long-term exclusive contracts given upfront investment and risk with the concern that these may prevent entry by competitors. The insufficient level of competition in the EV charging market has emerged as a concern in many countries.

In 2021 the CMA published a market study into EV charging market in the UK.<sup>101</sup> The main findings of the report are:

- ❑ the very limited competition in en-route charging market, especially when looking at the motorway service area sites (MSA) with one company operating 80% of the market
- ❑ the risk that remote and rural areas remain unserved, because of the lack of attractiveness for the market;
- ❑ the risk of local monopolies to arise where the roll-out of charging points is very slow;
- ❑ the lack of transparency and the difficulties to access the charging service for drivers, with the risk of emerging practices, like subscriptions or bundling of services, to reduce consumers trust and competition in the market.

To address these issues the CMA provided recommendations to promote competition, unlock investments and strengthen consumers' trust, highlighting the role of the different actors involved (central and local public authorities, energy regulators, Distribution Network Operators (DNOs), charge-point operators).

The recommendations from the CMA reflect the need to tackle the roll-out of charging point in combination with regulatory tools<sup>102</sup> as well as ensuring competition<sup>103</sup> and the implementation of tools that ensure transparency and simplicity for consumers. This is against a government and regulatory backdrop that is providing a £950m Rapid Charging Fund to fund upgrades to the electricity network to help meet future demand for charge-points at motorway service areas and key A road locations where the costs of chargepoint installation are prohibitively expensive

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<sup>101</sup> CMA (2021), Building a comprehensive and competitive electric vehicle charging sector that works for all drivers – Final Report <https://www.gov.uk/government/publications/electric-vehicle-charging-market-study-final-report/final-report>

<sup>102</sup> For instance mechanism to support DNOs adapting the network capacity and resilience to overcome the network constraint for the development of charging points or the deployment of the Rapid Charging Fund.

<sup>103</sup> For instance requiring the role of competition authorities in monitoring the market and investigating commercial practices that can harm competition (long term agreements, bundling).

and uncommercial.<sup>104</sup> By providing this base network infrastructure in more remote areas through regulated means, competition for the charging services can develop on top of this.

Similarly, the Bundeskartellamt (BKartA), the German competition authority, in its recently published sector inquiry<sup>105</sup> found that competition is not working well in the EV charging market. This is despite the BKartA's and German government's intention to ensure the market for EV charging builds in competitive elements as it develops. Instead, the inquiry revealed that charging infrastructure installation contracts for public areas are not distributed in a non-discriminatory manner, with many (and in some cases, all) contracts being awarded to municipal utility companies or specific individual providers by local authorities. This has created high levels of market concentration which has yielded dominant market positions.

The BKartA furthermore raised the potential abuse of market power of local charging-point operators (CPOs) in setting higher prices where there is limited or no competition, squeezing the margins for competitors (via the price for charging energy to the mobility service providers (MSPs)), pushing competitors out of the market or creating an entry barrier for potential new entrants.

Market access to new entrant providers of charging infrastructure on motorways has improved due to the awarding of basic service areas (e.g. no additional services such as fuel, food services) through tenders. In contrast, for motorway service areas with other services (e.g. restaurant, petrol stations), the Federal government decided to award the service to the incumbent provider as an extension to current long-term concessions. This has led to a competition concern that this partial market access restriction (no ability for entrants to offer services for all rest areas) may affect entry incentives, especially as users may be more interested in having the option to use other services (e.g. café, restaurants) while charging their EV.

The BKartA has identified many situations in which its competition powers can be used to support the development of a competitive market for EV charging, through intervening in specific cases. These include: local authorities not using fair tendering processes; exclusivity

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<sup>104</sup> Para 2.38 CMA (2021), Building a comprehensive and competitive electric vehicle charging sector that works for all drivers – Final Report.

<sup>105</sup> Bundeskartellamt (2024), Sector enquiry for the provision and marketing of publicly accessible charging infrastructure for electric vehicles', October.

clauses in long-term contracts (or over-long periods); discriminatory or excessive prices for using the charging facilities.

It has also concluded that ‘Effective improvements that go beyond individual cases and lead to more competition can only be achieved by amending the regulatory framework.’<sup>106</sup> This highlights that the costs of installing and connecting charging infrastructure is costly, and if this must be recovered only from usage charges, then that would result in very high prices at less utilised, more remote sites. It recommends that any regulatory intervention should not include price regulation, or a requirement for private sector investors to provide third party access, as both these interventions will reduce the incentive to invest.

The recommendations instead include ensuring planning rules are adjusted to support this investment and that government subsidies to support the development of more remote sites are awarded via tender, through lots that are sufficiently small and potentially overlapping to encourage entry and competition once established.

As a last example, in Italy, concerns were raised about competition in the EVs charging market. In 2023 the Italian competition authority (AGCM) launched an investigation against some CPOs active in the Italian market.<sup>107</sup> The starting point for the investigation was the increasing wholesale energy prices applied to the mobility service providers (MSP) by the CPOs. Similarly to the issue highlighted in Germany, high energy prices applied to MSPs may imply the intention from vertically integrated operators (that provide both the charging service and the mobility service, i.e. the actual access to the charging point and also sell the energy to the customer) to squeeze the margin of the non-vertically integrated MSP. In this respect the tension between the national dimension of the market (energy prices are set at a national level) and the local nature of the service (drivers are likely to accept the charging price at the convenient stopping point, rather than search for cheaper charging) is relevant, as well as the potential partial overlap of the two services (and markets) provided by CPOs and MSPs. The investigation is still ongoing.

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<sup>106</sup> Andreas Mundt, 1 October 2024, Anti-competitive structures in the provision of EV charging electricity – Final report on sector inquiry into EV charging infrastructure. Press release.

<sup>107</sup> AGCM (2023) - A557 - Istruttoria nei confronti di Enel per possibile abuso di posizione dominante nel settore della mobilità elettrica. <https://www.agcm.it/dotcmsdoc/allegati-news/A557%20avvio%20istruttoria.pdf>

All three country examples here show that there is a role to play for competition authorities in the development of EV charging infrastructure. There are risks for competition in the initial phases of the development of the market. Here, the specific characteristics of the sector in terms of risk of cherry-picking sites, large grid investment needs and the structure of the industry (vertical integration, potential incumbent operators from the energy sector etc.) need to be taken into account when considering market design. Concessions, tendering and long-term contracting may be necessary to ensure private sector involvement in fast, widespread development of the infrastructure, but there may need to be attention paid to the rules around pricing and exclusivity periods to ensure the benefits of competition are delivered to users as soon as possible. Competition tools may be insufficient, but competition authorities can influence the way regulations develop to support this crucial roll-out.



## Contact

Dr Helen Jenkins

Partner

+44 (0) 1865 253016

[helen.jenkins@oxera.com](mailto:helen.jenkins@oxera.com)

[oxera.com](https://oxera.com)

