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Success factors for a low-carbon future in the power sector

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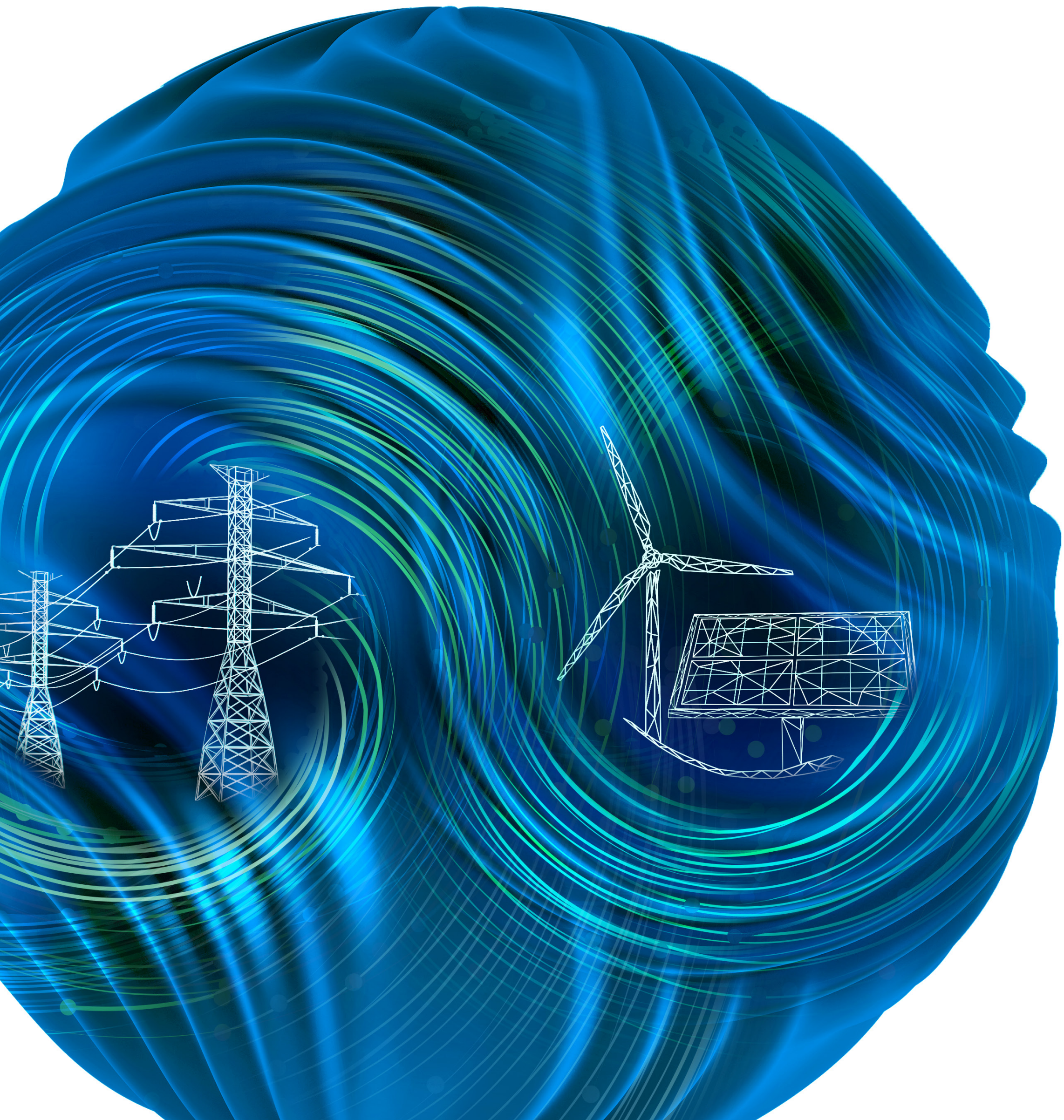
Contents

Introduction

Renewables are set to account for 95% of the net increase in global power capacity between now and 2025.[1] That growth is due to rising investor interest, the technology competitiveness of renewable technologies vis-à-vis conventional sources, creative financing models, and active policymaking at both the global and local level. Demand-side pressure also encourages change from governments and companies towards a low-carbon future. As consumers grow more conscious of their ecological footprints, many are insisting on more sustainable practices from businesses and increased transparency about their purchases.[2]

And as companies across a range of sectors adopt climate change goals, they're creating demand for more renewable energy, low-emissions transportation, and high-quality carbon offsets.[3]

This paper will explore factors to accelerate this low-carbon future for the power sector, examining policies that can best support that objective, new financing mechanisms to expedite commercialization of new technologies, and which technologies may most quickly address the challenges of intermittency.



Laying the policy groundwork

Governments and multi-lateral institutions have a key role in facilitating the energy transition both as "market maker" to support development of new technologies, and to establish a framework which helps mitigate risk—be it price risk or regulatory risk—that may impact private capital investing in new business models. The financing of low-carbon initiatives has been woven inextricably into the fabric of policymaking, with levers ranging from tax credits for electric vehicle (EV) purchases and research and development funding for battery technology, to subsidies for carbon capture and wind farms.

Given the breadth of policy activity worldwide—from the Paris Agreement to the efforts of individual municipalities—it is of course not possible to highlight every example of successful policy implementation. Furthermore, many policy successes are specific to the system and market in which they are implemented, meaning that while lessons can be extrapolated from these successes, it may be difficult to replicate policy in a different country or context. Nevertheless, bearing in mind this regional specificity, it is worth calling out some innovative policy successes.

The European Commission has adopted a package of proposals ("Fit for 55") to make the European Union's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. Achieving these emission reductions in the next decade is crucial to Europe's objective: becoming the world's first climate-neutral continent by 2050.

The package of proposals combines application of emissions trading to new sectors and a tightening of the existing EU Emissions Trading System, and also promotes increased use of renewable energy and greater energy efficiency. With regard to transportation, the proposals include a faster roll-out of low emission transport modes and the infrastructure and fuels to support them. Finally, the package addresses new taxation policies, measures to prevent carbon leakage, and tools to preserve and grow European natural carbon sinks.

Australia has moved ahead with renewables implementation, and South Australia in particular has seen success, moving from 100% of its power generation coming from fossil fuels as recently as 2006 to 60% from renewables today.[4] Behind that state's successes lies the federal government's Renewable Energy Targets (RET), a program designed to reduce emissions of greenhouse gases in the electricity sector and encourage the generation of electricity from sustainable and renewable sources.

RET, introduced in 2001, works on two levels. The large-scale scheme incentivizes investment in renewable energy power stations by legislating demand for large-scale generation certificates (LGCs). One LGC can be created for each megawatt-hour of eligible renewable electricity produced. LGCs can be sold to electricity retailers that buy and surrender the LGCs to the national Clean Energy Regulator to demonstrate their compliance with the scheme's annual targets. In turn, the LGCs provide the power station with additional revenue beyond the sale of the electricity generated.

The small-scale scheme works in parallel, providing incentives for households and businesses to install rooftop solar panels, solar water heaters, and small wind or hydro systems.[5] Combined with state-based feed-in-tariffs (FiTs), the schemes have led to strong rooftop solar growth with a national average of 29% as of March 2021.[6] Despite potential political impediments, the large-scale scheme has been a striking success, reaching its targets more than a year early.[7]

Turning to India, there is still heavy dependence on coal-fired power stations, but the country is winning plaudits for its aggressive carbon-reduction plans.[8] India committed to a renewable-led generation capacity program via its Nationally Determined Commitment (NDC) under the Paris Agreement. Under its NDC it committed to increase the share of non-fossil fuels to 40% of the total electricity generation capacity and to reduce the emission intensity of the economy by 33% to 35% by 2030. It has recently committed to raise its renewable capacity to 350 GW by 2030. This intent translated into gradually increasing Renewable Portfolio Obligation targets for electricity distribution utilities and a centralized auction framework for utility scale renewables, which has led to a sharp increase in renewables deployment, primarily in the private sector.

India case study

India's Renewable Energy (RE) Policy stemmed from its National Action Plan for Climate Change released in 2010, where the National Solar Mission was one of the nine missions devised as pathways to reduce India's climate change impact. Originally, India had a target under the National Solar Mission of 20 GW of Solar by 2020, which in 2017 was scaled up to 100 GW of solar by 2022, in addition to another 60 GW of Wind by 2022.[9]

Of particular note is the Greening the Grid (GTG) program developed as part of the U.S.-India Strategic Clean Energy Partnership. The GTG-Renewable Integration and Sustainable Energy (RISE) initiative includes a series of pilots demonstrating how new technologies and methods can support RE deployment nationwide. For example, a coal flexing pilot used quick-ramp coal plants as flexible base load to support greater variable RE integration. Another pilot tested whether minimal retrofits could enable remote and automatic generation (AGC) control of two hydroelectric plants and a solar plant. Results showed that AGC can tap secondary reserves to facilitate grid operations with RE variability.[10]

In Vietnam, the government has successfully implemented a system to encourage private partnership via creation of a power purchase agreement designed specifically to help multinational corporations operating in the country reduce their carbon footprint and meet their sustainability goals. The government has also worked with USAID to establish two Vietnam Low Emission Energy Programs (V-LEEP I and V-LEEP II). Initiated in 2020, V-LEEP II aims to help design, finance, build, and operate 2,000 megawatts (MW) of renewable energy sources and is expected to advance Vietnam's clean energy transition in four ways through 2025:[11]

1. Deploy advanced clean energy systems by mobilizing private sector investment
2. Improve energy sector performance, specifically renewable energy integration and dispatch
3. Increase competition in a market-based energy sector
4. Foster innovation, incubation, and inclusion in the energy sector

There are common attributes to these policy initiatives: incentivizing more renewables generation and building additional demand for renewable power. However, each case has unique elements: in Australia a second stream of revenue was created for renewables producers through the large-scale generation certificates. In India, market signals have been part of the solution through the creation of auction markets. And in Vietnam, the incentives were tailored to a particular customer segment, multinational corporations looking to reduce their carbon footprint.

As new technologies and energy transition evolve, regulators from around the world are honing their approaches and policies. To promote innovation, some energy regulators are also testing new models in sandboxes. Sandboxes are controlled environments to trial new products, services and business models in a real-world environment without some of the usual rules applying. These new approaches are intended to help regulators better understand new technologies and work with industry players to develop appropriate rules and regulations for new environments.

UK case study

In the UK, Ofgem, Great Britain's independent energy regulator uses a sandbox approach to encourage innovation.[12] Trials are run in which some rules have been temporarily suspended for designated period and defined customer base. The results of the trial are taken into account during policy development.

Some examples of this program include:

- A "matching" scheme to connect renewable energy providers to non-residential customers. Through the program they can enter into direct contracts.
- Chargepoint infrastructure price discovery trial to understand how to enable higher EV usage for customers who need to charge on the street instead of their own garage.[13]

Acknowledging the challenges

However, not all policy is effective. Policy efforts may be confounded by regional specifics or complexities, in which a policy that suits one sector or market is not easily implemented in another. Another common obstacle is the failure to address cost or competitiveness concerns of investors. The examples below explore some of these complexities.

Carbon taxes and emissions trading

Carbon taxes and emissions trading mechanisms create a carbon "price," by pricing emissions in order to incentivize emissions reductions. Policies around carbon pricing and carbon trading mechanisms have proven complex to implement. In some cases, this is due to incomplete implementation, in which some sectors are covered and others are not. For example, there is not a comprehensive and homogeneous carbon mechanism that covers all countries and all emitting sectors. Carbon pricing is a bit of patchwork in terms of geographies and sectors. For example, ETS only covers Europe and certain sectors (currently there is a proposal to be extended to other sectors such as transport). Furthermore, Europe has announced the proposal to create a carbon border mechanism.[14]

Other emissions trading scheme issues, such as insufficiently stringent caps, excessive allocations of allowances, and price volatility are policy design issues that can be relatively easy to resolve. Recently, China implemented a carbon emissions trading mechanism based on a cap and trade model but which differs from others in that it focuses on reducing the intensity of emissions generation rather than absolute emissions. Thus, the system incentivizes reduction of emissions intensity of energy generation. The benefit of this system is that it allows for the growth in energy demand which China is experiencing, while incentivizing electricity production to be delivered in lower emissions ways.[15]

Retiring fossil generation

The timing of retiring fossil generation while adding substantial renewables capacity is proving a challenge, which in some cases is exacerbated by the lack of a clear road map for addressing transition costs to asset owners. India, by contrast, is developing a national roadmap to flexibly operate coal plants and compensate operators for the additional flexing costs incurred with plants are more quickly and frequently ramped up and down to support renewables integration.[16]

But in other markets this has proven more difficult. In the US one challenge is that most of the US coal fleet (>75%) is in regulated markets where policy is designed such that customers pay for the undepreciated balances on utilities' coal investments.[17] In competitive power markets, private companies are in a similar position. Accelerated depreciation has been the preferred approach thus far because it's quick and shareholder-friendly, though it could involve rate increases. But other options exist. For example, around half of US states have legislatively authorized securitization, which allows utilities to refinance by issuing ratepayer-backed bonds to cover undepreciated coal plant balances.[18] This frees up low-cost capital to reinvest in capital-intensive clean technology replacements that could grow regulated utilities' rate base and earnings. This approach can also help with workforce transition, securing funds to help transition communities that may lose jobs and revenue from the coal plant closures. Federal policymakers could further support these efforts by offering similar financing mechanisms via DOE, in addition to loans, and/or debt forgiveness.

Another pressing issue is how governments incentivize fossil fuel decommissioning (and even not commissioning new units) in regions with lower access to resources, such as India, Africa or South East Asia. Governments and public finance institutions can accelerate coal phaseout through an integrated three-part approach: (1) refinancing to help fund coal transition and save customers money on day one, (2) reinvesting in clean energy, and (3) providing transition financing for workers and communities.[19]

For instance, South Africa's Eskom has put in place the Just Transition Transaction plan to allow early decommissioning of coal power plants and ensure the workers' economic rehabilitation in affected regions.[20] As part of this strategy, Eskom recently revealed plans to shut down 8GW–12 GW of coal-fired generation by 2031.[21] In addition, Eskom has announced the launch of a pilot program allowing businesses to buy renewable energy from the utility.[22]

Incorporating market mechanisms

Another policy challenge lies in appropriately incentivizing market mechanisms—knowing when market signals will be more effective than policy implementation. For example, development of ancillary services is often provided by base load coal units at low or no cost, and so the market has not "valued" these services, yet they are essential to system reliability. Consequently, commercialization of new technologies in this space can lag because these services have not been appropriately valued by the market even as gas and coal generation retire. So, the question arises of how policy could help assign value to these services, and yet leave the market and private sector to actually build the market based on price signals.

Understanding the finance-policy link

The role of successful policy should be to mitigate the risks investors face such as regulatory, price, technology and project risk, and to drive towards sustainability and to help ensure a safe energy supply. In particular, the private sector's appetite for investment depends in part on the predictability and stability of policy over the long-term. One way in which policy can shape investment strategies is through influencing project costs, often via subsidies or incentives. Examples of this would include tax benefits, such as the investment tax credits ("ITC") and production tax credits ("PTC") introduced in the US.

The Biden administration aims to extend the ITC and PTC for 10 years for clean energy generation and expand them to storage. The extension and expansion could continue to boost investment in these technologies. However, one issue with the tax credits is that they are indirect, i.e. renewable developers often need to partner with tax equity. However, this angle is being addressed in recent changes to the 45Q tax provisions in the US, which may help reduce costs of carbon capture, utilization and storage and now include new provisions to make a greater impact on costs. Congress also aims to extend the $1 per gallon blenders tax credit for biodiesel and renewable diesel through 2025, which is set to expire at the end of 2022. The extension can boost consumer access to clean, low-carbon fuel.

In the Netherlands, the government has been able to hold Europe's first subsidy-free tenders for offshore wind in the North Sea, without a guaranteed feed-in tariff or financial help from the government.

The Dutch government reduces project risk to investors by providing critical data to investors (wind profiles, seismic data) and guaranteeing the license and network connections in the tender process.[23]

Additionally, the Dutch government ran the cables to shore and guaranteed their operability. Meanwhile, increases in turbine size (10MW in Hollandse Kust Zuid project) have helped increase the economic viability of the projects by increasing the generation output.[24]

Turning to Australia, the Australian Renewable Energy Agency (ARENA) provides grants to non-commercial projects--much of which are now going into hydrogen. This serves to drive down project costs, flatten the technology cost curve and encourage knowledge sharing. For example, initial hydrogen projects funded were small, at 1 MW. Next the program funded 10 MW projects, and has grown to 50MW scale, which is more commercially viable. ARENA works in tandem with the Australian Clean Energy Finance Corporation, which provides mainly debt financing, but also some equity. The interface between these organizations has been efficient and effective at supporting new projects. In addition, the planned Certificate of Origin scheme to measure and track emissions from hydrogen production can be instrumental in Australia's clean hydrogen industry.[25]

In Europe, the Next Generation EU funds provide a post-COVID stimulus package ($1 trillion) in which 40% of the funds are directed to energy transition initiatives. Around 30% of the EU funds have to be invested in projects and initiatives that contribute to the fight against climate change, the highest share ever of a European budget.[26]

The need for creative financing

Policies can help engender creative financing needed to address gaps in the market.

Community based funding

Community behind-the-meter (BTM) solar involves a community of small investors pooling funds to support local energy production, where a business or other discrete entity generates its own electricity and does not tap into the grid. In Australia, for example, community BTM solar has been compared to crowdfunding holding promise as a highly scalable financing model.[27]

Crowdfunding of renewables

By broadening the pool of potential investors to people with as little as a few dollars to invest in relatively low-risk projects with steady returns, crowdfunding platforms can help close renewables financing gaps.[28] Locally funded renewables projects can benefit from more community support, while new technologies such as blockchain are providing the transactional speed and security required to enable global crowdfunding.[29]

Cross border cooperation and financing

In certain projects stakeholder management and consultation is underway for multiple donors and partners. For example, multilateral organizations are working with Namibia and Botswana to jointly develop a 2.5 GW solar effort.[30] Similarly, in the South East Asian Mekong Region—the US and the Japanese governments are working together on the Japan-US-Mekong Power Partnership (JUMPP) to drive power security in the region and increase the reach of available financing.[31]

Technology agnostic funding

In Australia, Victoria ran a tender for a 300 MW battery, but with a technology-agnostic approach to expedite commercialization. The process was agnostic regarding battery chemistry—and the goal was to solve for storage. Another interesting financing model is the development of grid-scale battery projects financed from private sector market participants without government funding. For instance, Lumea kicked off the process to construct the country's first privately funded large scale battery without any government support by 2022.[32]

The contracts for difference (CfDs) auction model

Projects are paid the difference between a reference wholesale electricity price and a fixed "strike price" for the electricity generated over a given period. During this period projects either receive a subsidy if the strike price is higher than the wholesale price, or in the reverse case, developers pay the difference to the government. This mechanism has seen strike prices fall so dramatically that UK offshore wind auctioned in September 2019 are on track to be "negative subsidy" projects, and cheaper than operating existing natural gas plants by 2023.[33]

Technologies moving faster to achieve the energy transition

Policy levers will likely be needed to galvanize innovation to solve some of the most intractable problems. Topping that list will likely be modernizing utilities to adjust to intermittent renewable generation. In emerging economies, electricity demand will continue to grow with increased industrialization, improvement in the standard of living and electrification of additional sectors. Contending with these growth challenges with modern, flexible, and smart grid systems could be a significant challenge as existing systems need to be transformed significantly to remain reliable under the influx of variable renewable energy and increasing deployment of behind-the-meter energy sources and devices. The technologies being commercialized to address this issue are worth a closer look. Although wind and solar installations are certainly the public face of renewables, the future of the energy sector may depend on a widening mix of other technologies that address the intermittency issue.

Storage

Storage is likely the single most important technology to integrate renewables and address grid bottlenecks, as the surge of renewables will require energy storage and demand response to enhance system flexibility. In fact, the global storage market in 2020 surpassed a record 27 GWh, up 51% from the previous year. Furthermore, it's estimated that the global market will grow more than 27 times in MWh terms by 2030.[34] As renewable penetration crosses the "last 20%" threshold, integration challenges become much greater.

Significant overbuilding and curtailment of renewables may occur absent seasonal storage enabling the capture of excess renewable production. Lithium-ion battery technology, the majority of storage additions currently, can competitively provide 4-hour grid storage and is continuing to experience rapidly falling costs, increased density, and other material and chemical advances, but other options are emerging. Demand response programs are one option which is expected to have a greater role as renewable penetration increases.[35]

Hybridization

Hybridization can help integrate renewables by firming their variable output so that they can operate more like conventional, dispatchable power plants. For example, floating offshore wind platforms with complementary tidal, wave, and ocean thermal energy generation, as well as floating solar generation and hydrogen production, can ramp up the latter technologies when the wind slackens, or conversely, store excess wind production to prevent curtailment. By co-locating and/or coordinating the operations of energy generation, storage, and conversion technologies, developers can also save on equipment, interconnection, permitting, and transaction costs, and capture more market value and financial incentives in favorable markets, such as states with capacity markets.[36] Co-located solar and storage projects have gained prominence, especially in key regions such as the Southwest US, California and Renewable Energy Zones in New South Wales.[37]

Hybridization is likely to help sustain the momentum for advances in various kinds of long-term storage including compressed air, aqueous air and flow batteries, and thermal storage technologies such as molten salt, and gravity-based storage. Their prospects seem bright in markets like Chile, which has an atypical geographical footprint that compounds supply-demand mismatches, and an enabling regulatory environment to meet ambitious decarbonization targets. Chile is seeking to convert its coal plants to Carnot batteries, wherein molten salt thermal storage can power steam turbines at a comparable cost to lithium-ion batteries, and to pair its run-of-the river hydro with flow batteries at three times the cost savings of lithium-ion batteries. Compressed-air energy storage is proposed where fossil plants are closing or in lieu of replacing transmission, and liquid air energy storage at the intersection of the electrical and mining sectors. Market reform to value flexible generation and storage, and to reward storage technologies for providing grid inertia could help accelerate deployment.[38]

Carbon capture

Carbon capture and sequestration ("CCS") could yet prove a useful interim technology to extend the life of fossil plants while greatly decreasing their carbon emissions. However, currently the costs of implementing CCS in the power sector remain very high, and in some cases even higher than building new renewable generation. But new interest in this technology from other sectors and additional government focus and support may yet help this technology further penetrate the power sector. The IEA reports that after years of declining investment in carbon capture, utilization and storage ("CCUS"), plans for at least 30 new integrated CCUS facilities have been announced since 2017. Sixteen of those projects are now in advanced planning stages, with investments almost double those made in projects commissioned since 2010. If all 30-plus projects were to go forward, global CO_2 capture capacity would more than triple, to about 130 million tons per year.[39]

Most CCUS initiatives – and investments – are in the US and Europe, but the momentum is truly international, with activity in Mexico, Japan, Saudi Arabia, Australia, and elsewhere. For instance, the US federal government is funding a dedicated CCUS research program. In late 2020, the US Department of Energy awarded US $72 million to support the development and advancement of carbon capture technologies.[40] Australia is proposing to include carbon credits produced from CCUS as a part of the government scheme for Australian Carbon Credit Units (ACCUs).[41]

One storage project that is moving rapidly is Porthos in the Netherlands.[42] (The name is an acronym for "Port of Rotterdam CO_2 Transport Hub and Offshore Storage.") The objective is to store CO_2 emitted by Dutch industrial companies in depleted gas fields under the North Sea; the system is expected to be operational by 2024. Developed by state-owned companies and oil and gas consortium, the future clients of Porthos will now receive subsidy support from the Dutch government.[43] But that subsidy support is planned to decrease as the carbon price rises, increasing the economic competitiveness of the project.

In northeast England, the Net Zero Teesside project aims to deliver the United Kingdom's first zero-carbon industrial cluster by decarbonizing a local network of businesses as early as 2030.[44] In Norway, the Northern Lights project, under development by Equinor and two oil majors is picking up speed.[45] In North America, ExxonMobil is planning a large scale CCUS project that would capture CO_2 from refineries and industrial plants along the Houston Ship Channel and store it offshore.[46] Occidental's Oxy Low Carbon Ventures is building the world's first large-scale direct air capture (DAC) in Texas to remove carbon dioxide from the atmosphere and pump it deep underground forever.[47]

However, amid this renewed interest, CCS adoption for power sector applications is still moving slowly for a number of reasons:

- Cost and financing gap: A significant financing gap remains in the US despite the 45Q tax credit for the capture and disposal, injection, or utilization of at least 500,000 metric tons of CO_2 annually from power generation (value is $35/metric ton CO_2 if the carbon is used for enhanced oil recovery and $50 if sequestered; construction must begin by 2024). In many cases new-build renewables cost less today than retrofitting coal and gas plants with CCS.
- Performance gap: DOE-backed and funded projects have fallen short: the country's only commercially operational CCS project was mothballed last year after failing to meet CO_2 capture, enhanced oil recovery (EOR) and economic viability targets.
- Infrastructural constraints: Infrastructure to sell and transport captured carbon for utilization in other industries is undeveloped.
- Incomplete carbon abatement: carbon capture does not fully abate emissions—current potential is up to 90% depending on the particular technology used.[48]

European natural sinks strategy

The proposal of the European Regulation on Land Use, Forestry and Agriculture sets an overall EU target for carbon removals by natural sinks, equivalent to 310 million tonnes of CO_2 emissions by 2030. National targets will require Member States to care for and expand their carbon sinks to meet this target. The EU Forest Strategy aims to improve the quality, quantity, and resilience of EU forests. It supports foresters and the forest-based bioeconomy while keeping harvesting and biomass use sustainable, preserving biodiversity, and setting out a plan to plant three billion trees across Europe by 2030.[49]

Green hydrogen

The growing interest in green hydrogen not only for power generation and energy storage, but also for heating, transport, and industrial use, has propelled this technology forward. This cross sectoral approach may expedite its commercialization and adoption. For example, countries such as Australia and the Netherlands have encouraged development of hubs which would allow different off-takers with different demand profiles to boost the utilization of the plant.[50]

Decarbonized hydrogen can be used as a fuel for power generation, to provide load balancing for intermittent renewables. However, it would be necessary to retrofit installed combined cycle gas turbines to accept a blend above 5%, or turbines could be used that could run on 100% hydrogen, producing zero carbon emissions. Converting natural gas pipelines to carry a blend of natural gas and hydrogen may require modifications to the existing pipeline infrastructure. Current regulations in the US limit the share of hydrogen that can be blended in natural gas pipelines to under 4% (including pilots). Based on current global practices, this share could be increased to 10% in transmission pipelines and potentially higher in distribution pipelines.[51] A market may be developing for pure hydrogen, as pilot projects such as the Intermountain Power Plant in Utah begin replacing fossil fuels with green hydrogen.[52]

In addition to these technological advances, there are two additional drivers motivating investment in hydrogen. First, countries see hydrogen as a way to develop their own business and to gain a newfound energy independence and are willing to put funds towards research and development. Second, as renewable electricity capacity grows and costs continue to fall, production of green hydrogen is more realistic at an LCOE of power below $20MWh. A groundbreaking PPA in the US demonstrates the viability of aligning significant wind resources with green hydrogen production: a hydrogen developer recently signed a 345 MW PPA to power a new 30-ton green hydrogen plant with wind power.[53]

One of the most encouraging moves on the demand side is Japan's started goal of having hydrogen be a power source sufficient to produce the output of more than 30 nuclear reactors by 2030.[54] The Australian Renewable Energy Agency (ARENA) is providing federal funding to support R&D in renewable hydrogen production, storage and use for energy to help drive down costs and increase efficiencies of production and distribution. Some of the funded projects are focused on commercial-scale deployments of larger electrolyzers (10 to 40 MW) and feasibility studies on electrolyzers producing more than 100 MW—developments that could yield substantial scale economies.

In Europe, sizeable hydrogen projects are moving ahead. An example is NorthH2, a consortium of energy companies that is developing Europe's largest green hydrogen project.[55] (Deloitte is conducting the feasibility study that will support a final investment decision in 2024.)[56] The objective is to use offshore wind power and a large onshore electrolyzer to generate as much as four GW of green hydrogen by 2030, and to scale up to 10-plus GW by 2040 for a reduction of up to 10 megatons of carbon emissions annually.

Digitalization can solve integration challenges

Digitalization will likely be central to solving the challenges of integrating renewables. Information and communications technologies such as big data, virtual power plants, demand response technologies, smart grids, internet of things, artificial intelligence (AI), and blockchain can help create a more flexible and efficient electricity system. Smart meters communicate real time data about power demand and generation, making it easier to balance them. AI can predict supply and demand peaks and forecast weather and renewable output more precisely. Cloud-based IT systems control pools of distributed energy resources in virtual power plants that can reduce load or provide supply when needed. And blockchain technology could facilitate peer-to-peer trading, adding more of the flexibility required to integrate variable renewables. For instance, Jemena Electricity Network in Victoria worked with Deloitte and AWS to build the Jemena AWS (JAWS) platform to deliver valuable insights from its 500 billion data points from smart meters to help customers make better energy decisions.[57]

Conclusion

Moving to a lower-carbon energy system presents a tremendous challenge, and effective policy levers will likely be needed to expedite commercialization of new technologies and to help incentivize investment in these areas. Policy has a key role to play in mitigating risks faced by investors and impacting project costs. Leveraging cross-sectoral learnings and regional best practices can be critical. For technologies such as CCS and some long-term storage applications, use cases and pilot projects in the oil sector or the industrial sector could help drive cost declines and facilitate uptake. And not only cross-sector, but also cross-border collaboration could defray project costs and accelerate project timetables.

While in the medium- to long-term, the benefits in moving to a lower-carbon energy system outweigh the costs of this transition, in the short run, some climate policies could impact households and micro-enterprises. The design of energy policies should fairly spread the costs of tackling and adapting to climate change. Against this backdrop, companies will likely continue to focus on safety, reliability, and efficiency, increasingly relying on digital technologies to provide the agility needed in order to adopt new technologies and business models and navigate the transition.

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Endnotes

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