

A Policy Roadmap for 24/7 Carbon-Free Energy

Executive Summary

In 2020, Google set its <u>most ambitious energy goal</u> to date: by 2030, we aim to operate entirely on carbon-free energy (CFE)—around the clock—at all of our data centers and offices.

When we <u>announced our goal</u>, we also identified three ways to advance toward it. First, we'll <u>develop new approaches</u> for buying clean energy and expand our purchases to a mix of technologies that can power our operations around the clock. Second, we'll <u>support the commercialization of next-generation clean energy technologies</u> and <u>develop smart solutions for managing electricity demand</u>. Finally, we'll advocate for policies to accelerate the decarbonization of electricity grids across the world.

This paper zeroes in on the policy front. We identify the policies that we believe are most critical to accelerating electricity grid decarbonization, informed by our experience as a large energy consumer and clean energy purchaser in many different markets around the world.

The policies discussed are grouped into three core areas:

- Rapidly Developing and Deploying Clean Energy Technologies
- Expanding and Reforming Markets to Value Carbon-Free Energy and Drive Innovation
- Empowering Energy Consumers

These three policy areas reinforce one another. The development and deployment of clean energy technologies will accelerate in the presence of more expansive electricity markets. Markets will enable greater levels of decarbonization if they are also coupled with complementary policies that reduce costs across a broad portfolio of technologies and build the infrastructure that enables greater integration. Empowering consumers, meanwhile, will encourage the development of new technologies, enhance market efficiency, lower costs, and sustain popular support for decarbonization policies. A complete list of the policy tools discussed in this paper can be found in the Appendix.



To drive the policy and market changes needed to tackle the climate challenge over the next decade, stakeholders across the energy ecosystem must organize around a common objective: the complete, rapid, and cost-effective decarbonization of electricity systems. This is why Google and our partners launched the global 24/7 Carbon-free Energy Compact—a set of commitments and actions from energy buyers, energy suppliers, governments, system operators, solutions providers, investors, and other organizations to advance 24/7 CFE.¹ We call on others to join us. New partnerships among diverse stakeholders will be critical to achieving policy change and decarbonizing global electricity grids at the pace and scale required.

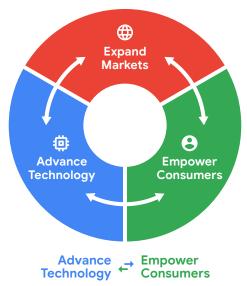
As Google advances toward our goal of 24/7 CFE by 2030, we are committed to working with others to advocate for clean energy policies that can enable 24/7 CFE for all.



A Policy Roadmap for 24/7 Carbon-Free Energy

Advance Expand Technology Markets

The development and deployment of clean energy technologies will advance more quickly with expansive electricity markets, and markets will enable greater levels of decarbonization if they are coupled with complementary technology policies.



Expand Empower Consumers

Open markets enable greater consumer participation, and empowering consumers enhances the efficiency of markets, leading to lower costs and more opportunities for decarbonization.

Advances in technology create new opportunities for consumers to drive decarbonization, which will also drive further innovation in technology and business models.

Advance Technology

- Rapidly and cost-effectively deploy commercialized clean energy technologies.
- Rapidly develop and commercialize next-generation clean energy technologies.
- Maintain existing carbon-free energy technologies on the grid.
- Speed the removal or replacement of carbon-emitting resources and limit investment in future carbonemitting resources.
- Develop and integrate the infrastructure required to cost-effectively deliver clean power.

Expand Markets

- Expand and integrate regional organized and competitive electricity markets, everywhere.
- Design markets to drive decarbonization.

Empower Consumers

- Create legal and regulatory access to cost-effective clean energy.
- Require transparent, granular energy data and make it easily accessible.
- Design regulatory structures to incentivize consumer participation in the energy transition.



Introduction

In 2020, Google set its <u>most ambitious energy goal</u> to date: by 2030, we aim to operate entirely on carbon-free energy (CFE)—around the clock—at all of our data centers and offices. This means matching each hour of our electricity consumption with carbon-free electricity sources on every grid where we operate. This represents the latest step on our decarbonization journey and builds on over a decade of work to advance decarbonization in our operations and through our products and services.

We became carbon neutral in 2007. In 2017, we were the first major company to match 100% of our annual operational electricity consumption with renewable energy purchases, and we've committed to achieving net-zero emissions across our entire value chain by 2030. Due to the rapid advancements underway in clean energy technology, we believe it's now possible to completely decarbonize our operational electricity consumption by the end of this decade.

We're also working to empower others to decarbonize through our core products and services. For over a decade, Nest thermostats have helped automate energy savings and guided consumers toward more efficient energy use—leading to a cumulative savings of over 80,000 GWh.² Nest is now helping consumers shift their energy use to when the electricity grid is cleanest and supporting clean energy on behalf of customers with Nest Renew. Google's Environmental Insights Explorer platform calculates rooftop solar energy potential and provides cities across the world with access to information about building and transportation emissions to enable them to develop climate action plans. Google has also made a commitment to help 1 billion people live more sustainably through our core products.

Google's work on energy is motivated by a core insight: if the world is to successfully tackle the urgent challenge of climate change, we must rapidly decarbonize the world's energy systems. The electricity sector is the linchpin of this effort, as it is both a significant contributor to global carbon emissions and a way to drive decarbonization of other parts of the economy, such as buildings and transportation, through electrification. Electricity is also the largest source of Google's operational carbon emissions, and is core to our ability to deliver our products and services to billions of users around the world through our data centers. That's why we've set a goal to fully decarbonize our own electricity demand by 2030; by taking on this challenge in our own operations, we hope to demonstrate and highlight the types of strategies and approaches that can speed the decarbonization of the electricity system as a whole.



As we laid out in our 2020 paper, our roadmap to 24/7 CFE is built on three major pillars. First, we'll develop new approaches for buying clean energy and expand our purchases to a mix of technologies that can power our operations around the clock. Second, we'll support the commercialization of next-generation clean energy technologies and develop smart solutions for managing electricity demand. Finally, we will develop partnerships and advocate for policies that accelerate electricity decarbonization across the globe. This pillar is, in fact, the most important. To achieve carbon-free electricity grids, we must do more than just purchase clean energy. We can multiply our impact by working to create and advance the tools, partnerships, and policy frameworks that allow all energy consumers to achieve 24/7 CFE. As one initial step in September 2021 at the United Nations High-level Dialogue on Energy, we and our partners launched the global 24/7 Carbon-free Energy Compact—a set of commitments and actions from energy buyers, energy suppliers, governments, system operators, solutions providers, investors, and other organizations to advance 24/7 CFE. We call on others to join this movement.

Among other commitments, Compact signatories commit to publicly advocating and supporting energy policies that accelerate the decarbonization of electricity grids. This paper details Google's vision, informed by over a decade of experience as a large electricity consumer operating in markets across the world, for how policy can help enable 24/7 CFE for everyone and hasten the creation of carbon-free electricity grids.

Our experience as a large energy consumer and clean energy buyer has taught us a number of important lessons. We learned that innovative carbon-free energy technologies are being developed across the globe, but greater support for R&D, commercialization, and deployment is critical to bringing them to scale. We learned that many of today's electricity market structures are ill-equipped to drive clean energy deployment and demand optimization at the scale and pace required. And we learned that customers need better tools to understand their carbon impact and more effectively engage in the clean energy transition.

We learned that renewable energy technologies like wind and solar will be key contributors to grid decarbonization, but limiting our toolkit to these technologies alone could mean that we overbuild electricity systems, increase system costs, and rely on carbon-emitting generation for longer than is necessary. This is why we are targeting a diverse portfolio of carbon-free energy options—including not only variable renewables, but also energy storage and flexibility technologies, and firm carbon-free energy technologies—which can most rapidly and cost-effectively decarbonize electricity grids.⁵



Above all, we learned that setting the right goal matters. The core focus of our collective efforts should be the complete, rapid, and cost-effective decarbonization of electricity systems. Matching 100% of our global, annual electricity demand with renewables was an important milestone for our own corporate purchasing, but 100% RE alone will not decarbonize entire grids. While we have been 100% renewable since 2017, we still rely on inefficient, costly, carbon-intensive power much of the time. With 24/7 CFE, we are committing to decarbonize our electricity demand at all hours and in all regions. Recent research confirms that this approach can drive deeper emissions reductions and accelerate the transformation of electricity systems. However, 24/7 CFE is not possible for Google or anyone without global policy and market changes.

While advances in technology have made deep decarbonization of electricity systems possible, the speed and cost-effectiveness of the transition will ultimately be determined by public policy. This paper provides a roadmap for how policymakers can accelerate the decarbonization of electricity systems as quickly and as cost-effectively as possible. These policies are focused on three key areas—advancing technology, expanding and enhancing markets, and empowering energy consumers.

As we advance toward our goal of 24/7 CFE by 2030, we are committed to working with others and using our voice to advocate for clean energy policies that can enable 24/7 CFE for all energy consumers. Working together, we can decarbonize electricity grids at the scale and pace required to mitigate the worst impacts of climate change.



Public Policies to Accelerate Electricity Grid Decarbonization

In this paper, we identify three core focus areas for policymakers to consider in order to accelerate the transition to a cost-effective, inclusive, and carbon-free electricity system. These are technology, markets, and consumer empowerment. It is critical to advance policies in each of these areas simultaneously, as they each reinforce each other to drive the clean energy transition.

Decarbonization is, at its core, a technological challenge. We must rapidly develop and deploy clean energy technologies and associated infrastructure to replace carbon-emitting infrastructure. The development and deployment of clean energy technologies will advance more quickly with expansive electricity markets that value carbon-free energy and drive innovation so that these technologies can achieve significant scale. Markets will drive deeper decarbonization if they are coupled with technology policies that drive down the costs of a broad portfolio of technologies and invest in the infrastructure that enables greater integration. The evolution of clean energy technologies presents an immense opportunity for energy consumers, large and small, to catalyze the transformation to a zero-carbon electricity system. Empowering energy consumers can advance new technologies, make markets more efficient, reduce costs, and enhance the benefits of the clean energy transition. This section discusses these three key policy areas and the policy tools needed to make progress in each. A complete list of the policy tools discussed in this paper can be found in the Appendix to this paper.



1. Rapidly Developing and Deploying Clean Energy Technologies

Spurred by decades of public and private investment that enabled economies of scale and technological innovation, solar and wind power experienced dramatic cost declines. This created an opportunity for these technologies to play a key role in decarbonizing electricity systems. Lithium-ion battery storage is following a similar path of cost reduction as manufacturing scales and more systems are deployed.

Solar, wind, and lithium-ion batteries, coupled with the significant contribution from other technologies like hydropower, geothermal, and nuclear power, make it possible to reliably and cost-effectively achieve high shares of clean energy on many electricity grids. These technologies enabled us to achieve high percentages of hourly carbon-free energy matching at some of our data center sites. In 2020, five of our data center sites around the world



achieved 90% carbon-free energy on an hourly basis. In Finland, for example, our wind energy power purchase agreements (PPAs) combined with renewable energy and nuclear power from the grid enabled us to achieve 94% carbon-free electricity on an hourly basis. In Denmark, home to our newest European data center, our PPAs for solar PV, combined with significant amounts of renewable electricity from the Danish grid, have enabled us to reach 90% hourly carbon-free energy there.

However, moving electricity grids to 100% clean energy will require other technology options that are costlier and less mature today. In systems with high shares of variable renewable energy, firm carbon-free energy technologies, advanced energy storage systems, and interregional transmission will be needed to reliably serve load during seasonal gaps in renewable energy production. New software and computational tools will be needed to better understand real-time energy flows and better keep the grid in balance.¹⁰

In some regions, it will be extremely difficult to deploy significant quantities of renewable energy cost-effectively. Singapore offers an instructive case. The island nation, which is home to three of our data centers, has one of the lowest clean energy percentages in our portfolio, with only 4% of our hourly electricity use coming from carbon-free energy sources. Due to land scarcity and less-than-ideal renewable resources, it will be challenging to take renewable energy technologies like wind and solar to the level required to significantly decarbonize the national electricity grid. Other technology options will likely be needed, such as firm, dispatchable carbon-free generation, carbon capture technologies, or greater cross-border transmission links to zero-carbon generation sources.

More broadly, a growing body of research indicates that we will need many different kinds of carbon-free energy technologies to rapidly, reliably, and cost-effectively decarbonize the electricity sector. A portfolio approach is therefore essential, and policy should be structured to value the contribution of all carbon-free energy and enabling technologies, each of which can play a role in the decarbonized electricity system of the future.



To drive the technology transition needed to decarbonize the electricity system, policymakers should prioritize five areas:

- a. Rapidly and cost-effectively deploy commercialized clean energy technologies via policies like clean electricity standards, investment incentives, and auctions.
- b. Rapidly develop and commercialize next-generation clean energy technologies by significantly increasing spending on energy research, development, and demonstration (RD&D) and orienting deployment incentives toward cutting-edge technologies.¹²
- c. Maintain existing carbon-free energy technologies, such as existing hydro and nuclear facilities, and plan for the repowering of carbon-free assets.
- d. Speed the removal and replacement of carbon-emitting resources and limit investment in future carbon-emitting resources.
- e. Develop and integrate the infrastructure required to cost-effectively deliver clean power.

Each of these areas is explored further below.

a. Rapidly and cost-effectively deploy commercialized clean energy technologies

To successfully decarbonize electricity systems, we will need to dramatically increase the rate of clean energy deployment. Fully decarbonizing the U.S. electricity system, for example, will require annual additions of clean energy capacity that are many multiples of historical records. The International Energy Agency (IEA) has calculated that putting the global economy on the path to net-zero emissions by 2050 would require over 1,000 GW of new wind and solar to be deployed every year starting in 2030, a 400% increase over today's annual rates of deployment.

Strong clean energy targets or standards are important tools to support this objective. The European Commission has proposed a goal to bring renewable energy to 40% of its energy mix by 2030, and in the United States, the Biden Administration is targeting a 100% carbon-free electricity sector by 2035. These frameworks set a direction for policy and provide investor confidence, encouraging the growth of clean energy industries.



Statutory requirements for clean electricity generation can drive significant clean energy deployment. A number of states in the United States have implemented technology-inclusive clean electricity standards (CES), which require an increasing share of electricity to be generated by clean energy sources. Such policies create predictable demand for clean energy over time. The U.S. Congress should build on this state-level progress and pass a federal clean electricity standard to accelerate the deployment of clean energy across the country. To drive the deployment of clean energy in Europe, the EU should require member states to set target dates and clear trajectories for the complete decarbonization of their electricity supply as part of their National Energy and Climate Plans. Governments in Asia, Latin America, and other regions of the world should also set ambitious decarbonization targets with clear timelines and specific actions and policies to achieve them.

Policymakers should also use **investment incentives** to accelerate clean energy deployment. The U.S. federal government has long used tax incentives and grants to offset some of the above-market cost of clean energy technologies. These policy tools, along with the clean energy standards mentioned above, created markets that enabled historic cost declines and scale-up of wind and solar power technologies. Policymakers should consider the following elements to structure incentives to most cost-effectively accelerate decarbonization. First, incentives should prioritize support for technologies—such as energy storage and high-voltage transmission—that are critical to integrating variable renewable energy resources. Second, incentives should be equally available for all carbon-free energy technologies. Finally, policymakers should provide enhanced support for next-generation technologies and tailor that support to drive continued innovation and cost reductions.

While investment incentives can help reduce the cost of above-market clean energy technologies, **competitive procurement** processes are important to deploying those technologies cost-effectively. This is particularly important in vertically integrated electricity systems where electricity supply and delivery are controlled by a single monopoly utility and there are no wholesale markets to facilitate competition. Electric utilities often use competitive, resource-agnostic requests for proposals (RFPs) to meet identified resource needs and achieve clean energy targets. To ensure rigor in project evaluation, RFPs should be independently and transparently administered. Competitive procurement mechanisms can also ensure that state and federal clean electricity standards are met at the lowest cost.



Many governments in Europe and elsewhere hold competitive auctions for clean energy. This has benefits compared to administratively-determined fixed price subsidies like feed-in tariffs, still in place in a number of countries around the world. In markets where the cost of clean energy is already competitive with wholesale market rates, feed-in tariffs keep the price of clean energy artificially high and limit its deployment based on government budgets rather than consumer demand. Auctions should be designed to maximize competition and deliver the most cost-effective portfolio of carbon-free resources for electricity consumers. By supporting an auction system that derives market-based pricing from supply and demand, governments can catalyze additional demand for clean energy from private industry. This will also free up public funds to support nascent next-generation CFE technologies instead of a non-market-based feed-in tariff.

Governments can also drive the deployment of new clean energy sources through their own **public procurement**. Public entities at all levels are increasingly setting clean energy purchasing goals to offset their energy consumption. They should shift their focus to purchasing around-the-clock clean power on their local or regional grids to maximize their impact. The U.S. government, for instance, has committed to purchasing 24/7 carbon-free electricity for federal facilities by 2030.²² A number of cities have adopted a similar goal.²³ Governments at all levels should consider setting 24/7 CFE targets. These procurement policies will accelerate the deployment of existing technologies and help commercialize next-generation ones.

b. Rapidly develop and commercialize next-generation clean energy technologies

While rapidly scaling today's clean energy technologies, we must also develop and commercialize new ones needed to decarbonize the electricity system and the broader economy. According to the IEA, 35% of the economy-wide emissions reductions needed by 2050 will come from technologies currently at the prototype or demonstration phase, and a further 40% rely on technologies not yet commercially deployed on a mass-market scale. ²⁴ Just as public policy and public investment catalyzed the development of technologies like solar and wind energy, so too must the public sector invest to ensure that the world has an adequate pipeline of next-generation energy technologies to confront the climate challenge. For the electricity sector, these include next-generation geothermal, clean hydrogen, advanced nuclear, carbon capture and storage (CCS), and long-duration energy storage technologies, among others.



To begin with, governments across the world should **dramatically boost funding for energy research, development, and demonstration (RD&D)**. As critical as energy is to the rest of the economy, it receives significantly less R&D investment than other societal priorities. Energy R&D represents less than 5% of overall public R&D spending globally and receives five times less R&D funding than health and defense among OECD member countries. As part of Mission Innovation, a global initiative to accelerate the pace of clean energy innovation, 25 governments committed to double public investment in clean energy innovation over five years. Countries should achieve this target and go beyond. In the United States, the budgets of key innovation agencies like ARPA-E and energy research programs throughout the federal government should be dramatically expanded. Similarly, the European Union should expand funding and support for clean energy research and innovation programs like Horizon Europe and the Innovation Fund.

Governments should also **provide financing support** and other risk mitigation mechanisms to help lower the cost of capital for innovative technologies. Public loan guarantees supported the construction of the first large-scale solar power plants and encouraged the private sector to invest in further scaling the industry. Similar tools are needed today to commercialize and scale up advanced clean energy technologies, such as electrolyzers to produce zero-carbon hydrogen, carbon capture and storage technologies, long-duration energy storage, and advanced nuclear reactors.

c. Maintain existing carbon-free energy technologies on the grid

In order to decarbonize the electricity system as rapidly as possible while maintaining reliability, we must recognize the value of the technologies already on the grid that provide significant quantities of emission-free energy. Hydropower and nuclear power produce the largest and second-largest share of low-carbon power generation globally, at 43% and 26%, respectively. Nuclear power's share is higher still in the United States and Europe, where it provides approximately 50% and 40% of clean electricity, respectively. Many existing zero-carbon energy plants across the world are at risk of shutting down, even if they could continue operating safely for decades longer. The loss of such large quantities of carbon-free electricity will increase carbon emissions and make the task of decarbonizing the electricity system more challenging.

Policymakers should thus focus on how they can **safely and cost-effectively extend the lives of existing carbon-free generation**, including nuclear, hydropower, and other carbon-free assets. To better recognize the carbon-free energy value of existing assets and maintain them on the grid, policymakers should pursue a number of policies, including



pricing carbon dioxide emissions and enacting technology-neutral clean electricity standards. In the absence of such technology-neutral policies, policymakers should consider credits that reflect the value of emissions that are reduced or avoided by the clean electricity these plants provide.³² In addition to extending the lives of existing assets, policymakers can also design strategies for repowering or otherwise increasing the output of existing assets that can boost the capacity and efficiency of clean energy technologies.³³

d. Speed the removal or replacement of carbon-emitting resources and limit investment in future carbon-emitting resources

In order to rapidly scale clean energy across electricity grids, we must actively reduce our reliance on carbon-emitting electricity generation and speed the removal or replacement of carbon-emitting assets. Simply adding new clean energy capacity to the grid will not guarantee that carbon-emitting assets will come off. We have learned this first-hand in lowa, where we purchase over 100% of our data centers' annual electricity requirements from wind projects serving the regional grid, but the coal plant down the road from our data center continues to operate. If we don't work to accelerate the removal of carbon-emitting assets, we risk overbuilding electricity systems, limiting the growth of clean energy and saddling consumers with significant costs. At the same time, we must also ensure that the communities and workers that have relied on these technologies for their livelihoods are able to participate meaningfully in the energy transition.

Reducing reliance on carbon-emitting fossil fuels will provide significant health and environmental benefits, particularly among vulnerable and underserved populations. Air pollution from the combustion of fossil fuels—in particular, coal—causes millions of premature deaths globally each year, and studies have found significant racial and socioeconomic disparities in the distribution of pollution from power plants in the United States. According to recent research, the reduction in air pollution associated with decarbonizing the U.S. economy would provide improved health and labor outcomes that outweigh the overall costs of the energy transition, even excluding consideration of carbon dioxide. Beyond the health benefits, a number of studies find that electricity system decarbonization can also lower electricity costs, create millions of jobs, increase energy security, and create significant savings for electricity consumers. 62

To speed the removal or replacement of carbon-emitting infrastructure, policymakers should focus on four areas. First, they should **set clear time lines for the complete phase-out of coal-fired power generation** and employ new tools and processes to accelerate this phase-out. Coal-fired power plants are the single largest source of global carbon emissions



and a hazard to human health in surrounding communities. The economic case for moving beyond coal in the electricity sector is clear, but regulatory barriers often prevent retirements even when plants are uneconomic. Policymakers should examine how amendments to traditional asset financing, such as **debt securitization and early depreciation**, can accelerate the retirement of coal assets while reducing the financial burden on ratepayers. Multilateral funding mechanisms can also help accelerate coal retirements in countries that lack adequate resources to finance this shift. These tools should be used to lower costs for ratepayers and should be paired with policies that support communities impacted by retirements and invest in new carbon-free resources to replace retiring assets.

Second, policymakers and regulators should avoid investment in unabated gas generation where it is unnecessary, and require, over time, that all gas generation is retrofitted with carbon capture and storage technologies or adapted to run on zero-carbon fuels. While new gas capacity may look attractive on a short-term basis, these assets and their supporting grid infrastructure have an expected lifetime that spans decades and may become the financial burden of ratepayers far into the future. To avoid the risk of potential lock-in of gas infrastructure, policymakers should critically evaluate any new gas build, as well as supporting infrastructure, taking into account feasible carbon-free alternatives, expected changes in electricity demand, investment in transmission infrastructure, and local policy objectives for decarbonization.

Third, policymakers should seek to repurpose existing fossil fuel infrastructure to accelerate the deployment of carbon-free energy technologies. Existing coal plants are already adjacent to transmission lines and electrical substations and are zoned for industrial applications, making them strong candidate sites for the deployment of CFE technologies. In Jackson County, Alabama, for example, we constructed a data center at the site of a retired coal-fired power plant and signed agreements to supply it with hundreds of megawatts of new-to-the-grid renewable energy. Existing natural gas infrastructure can be repurposed to carry zero-emissions hydrogen for both industrial and power-sector applications. And some of the advanced drilling techniques that have been deployed for fossil fuel extraction are being used to develop carbon-free resources like next-generation geothermal power. Policymakers should create plans to repurpose today's fossil fuel infrastructure to build the carbon-free economy of tomorrow.

Finally, policymakers should support communities that have historically relied on the production and use of fossil fuels for their livelihoods and enable them to participate meaningfully in the creation of a new energy economy. While the clean energy transition will bring many benefits, policymakers can ensure those benefits are broadly shared through active and targeted policy measures. These include investment incentives for projects in



communities impacted by the transition, public investments in training and skill building, and designing policy based on inclusive community-based consultations to ensure policy outcomes are equitable for all affected communities. 43 We are actively seeking opportunities to repurpose existing infrastructure and support this community and workforce transition.

e. Develop and integrate the infrastructure required to cost-effectively deliver clean power

Electricity transmission infrastructure, particularly high-voltage lines, will be key to rapid and cost-effective electricity system decarbonization. Transmission enables low-cost clean electricity to be generated in remote locations and delivered across long distances to large demand centers. It also enables the expansion and integration of regional electricity markets and is key to ensuring the reliability and resilience of the electricity system against the impacts of climate change. Demand for electricity is expected to increase significantly as the electrification of buildings, transport, and industry accelerates. Studies consistently find that cost-effectively electrifying while simultaneously decarbonizing the electricity system will require massively expanding the size of today's transmission systems. 44 Yet today's electricity transmission grid planning, interconnection, and cost allocation processes fall well short of the mark to support the pace and scale of grid decarbonization required over the coming decades.

Policymakers should focus on four core areas. First, they should **remove barriers** that delay and increase the costs of permitting and developing electricity transmission infrastructure. This includes streamlining permitting of transmission infrastructure, as well as updating generator interconnection and cost allocation processes to reflect the system benefits that carbon-free generators create.

Second, policymakers should proactively plan for the grid of the future rather than making minor updates to the grid of the past. This means **requiring holistic national**, **regional and interregional transmission planning** to ensure that investments are made in projects that most cost-effectively meet the needs of a decarbonized electricity system. Today's processes are too often incremental and reactive, focused on narrow and costly upgrades rather than long-term regional network solutions that are lower cost and more reliable. To address this, policymakers should strengthen national planning authorities, create regional planning authorities, and provide dedicated funding for regional and interregional transmission infrastructure. Reforms to transmission planning should be done in concert with reforms to create and enhance regional wholesale electricity markets, discussed further in the next section.



Third, policymakers should also incentivize operating practices and investments in grid-enhancing technologies that facilitate the efficient use of the existing system. While much more transmission infrastructure is needed, existing systems can be optimized by maximizing transmission capacity across regions or borders and deploying technologies to optimize the carrying capacity of lines and reduce congestion.47

Finally, while expanding transmission infrastructure is key to accelerating decarbonization, investments are also needed in distribution grid systems to accommodate greater deployment of distributed energy resources (DERs). Energy consumers are increasingly becoming active participants in the energy transition through electrification and distributed generation. Research indicates that co-optimizing transmission and distribution systems can lead to an overall reduction in electricity system costs while supporting decarbonization.48 Policymakers should require integrated distribution system planning processes that take full account of DERs and demand-side flexibility potential and are co-optimized with transmission planning to reduce overall costs and accelerate decarbonization. Section three of this paper discusses how policymakers can empower energy consumers to play a catalytic role in the transformation to a carbon-free electricity system.



② 2. Expand and Reform Markets to Value Carbon-Free Energy and Drive Innovation

Google operates within many different electricity systems around the world with different regulatory structures. These include vertically integrated market structures with generation and electricity service provided by one monopoly utility; wholesale market structures that use competitive forces to organize investment in and real-time operation of the electricity system; and fully liberalized markets with competition in generation and retail electricity service. While no one market structure is organized perfectly, we have found that some structures are more effective than others in enabling cost-effective carbon-free energy deployment while maintaining reliability. In particular, independent, regional, and competitive electricity markets operating flexibly within integrated transmission systems are the best way to reliably increase the deployment of clean energy onto the grid while reducing costs overall for consumers.49



a. Expand and integrate regional organized and competitive electricity markets, everywhere

Regional competitive electricity markets, when designed and governed appropriately, are the quickest way to cost-effectively decarbonize the grid, drive and scale innovative solutions, and unlock the full economic potential of the clean energy transition. Competitive electricity markets improve the efficiency and lower the cost of power systems through least-cost economic dispatch, efficient generator entry and exit incentives, enhanced transmission planning, and lower aggregate reserve requirements. They also enhance the reliability and flexibility of the power system by allowing grid operators to optimize a diverse set of supply and demand resources across geographies. Competitive electricity markets also improve customer access to new technologies and increase private investment in the clean energy transition.

These markets have brought significant benefits to electricity customers in the form of lower costs, lower carbon emissions, and more clean energy. In the United States, studies estimate the electricity cost savings associated with competitive markets at billions of dollars annually. Experienced by competitive wholesale electricity markets have also reduced their emissions faster over the last two decades than non-market regions and experienced the fastest deployment of clean energy.

Competitive wholesale markets provide buyers with the opportunity to purchase or invest in clean energy, driving down costs for all customers. In the United States, roughly 80% of bilateral corporate clean power purchase agreements have occurred in competitive wholesale markets. These purchases by companies have accelerated the dramatic cost declines in renewable energy and helped speed clean energy adoption by others. By contrast, the Southeastern United States, which lacks a regional, competitive wholesale market for generation, offers some of the highest retail electricity bills in the country, and has been slow to adopt clean energy. In Europe, progressive market liberalization and enhanced market integration have delivered several billions of euros per year in economic benefits to Europe's electricity consumers. Without wholesale markets, it is more challenging for customers to invest in the clean energy transition and drive clean energy deployment and innovation across the globe.



Our own experience as a purchaser of clean energy demonstrates these benefits. Across our global data center fleet, we have the greatest access to clean power options in competitive marketplaces. The first way to repurpose electricity systems for a carbon-free future is thus clear—organized and competitive wholesale electricity markets should be the norm everywhere.

In the United States, this means that all areas of the country should transition to organized wholesale power markets operated by independent Regional Transmission Organizations (RTOs), including in the Western and Southeastern United States, which do not benefit from these markets today. Existing RTO markets should also expand and integrate further. Policymakers and regulators should open proceedings to examine how the expansion and integration of wholesale markets can reduce costs, increase clean energy deployment, and improve resilience. Regulators should also pursue efforts that support joint dispatch arrangements between grids to more cost-effectively and reliably meet resource needs. The expansion, integration, and harmonization of wholesale markets can also increase the value of investments in critical transmission infrastructure.

In Europe, most countries have adopted competitive markets for electricity generation and retail service and have increasingly integrated their electricity markets with neighboring countries. However, barriers remain to a fully integrated and liquid Pan-European electricity market that could maximize these benefits. These include insufficient cross-border transmission capacity, uncoordinated national capacity and balancing markets, and prices that often do not reflect structural congestion on the grid. To address these issues, policymakers should move to greater regional coordination across transmission system development, operation, and electricity reserve procurement. They should enforce current requirements that at least 70% of transmission capacity be made available for cross-zonal trade and develop new models that support cross-zonal needs when determining resource builds. Financial incentives for greater coordination are one tool to support this. ⁵⁷ Finally, policymakers should also promote a greater role for regional power exchanges like Nordpool, which have been shown to support liquidity and price transparency. ⁵⁸

Many countries in Asia, where only 18% of electricity demand operates under fully competitive wholesale markets, could also benefit from greater regional coordination and integration of electricity markets. Research shows that new transmission infrastructure and increased regional trading are key enablers of renewable energy integration across the ASEAN region. A number of projects have been proposed to improve infrastructure links and power trading among Southeast Asian nations. The ASEAN Power Grid project, which would improve infrastructure links and power trading among a number of Southeast Asian nations, is a good step in this direction.



As state, regional, and national governments pursue targets to decarbonize their electricity systems, robust, competitive wholesale electricity markets will be critical to achieving these goals reliably and cost-effectively.

b. Design markets to drive decarbonization

Most of today's power grids and market structures were designed for a single purpose: to carry electricity from a relatively small number of large, centralized power plants to passive customers. As low-cost clean energy continues to scale, this paradigm is shifting quickly. The decarbonized power system of the future will be served by a much more diverse and geographically distributed set of generation resources on both the transmission and distribution system and will feature the active participation of electricity customers of all sizes. The clean energy transition will also change the price dynamics of today's markets. Most electricity markets are organized around generators' production costs, which are directly tied to fuel prices and fuel availability. The marginal cost is the signal that determines which generators are dispatched. As zero-marginal-cost clean energy resources come to predominate the generation mix, however, policymakers and market operators must rethink how markets are organized to optimize the use of new technologies and drive decarbonization. They should begin by focusing on the following areas of reform.

First, policymakers should move markets away from a model that encourages oversupply of generation capacity to meet resource and reliability needs and towards a model of integrated flexible supply and demand. This means appropriately compensating supply and demand flexibility and dispatchability (such as by placing a greater emphasis on scarcity pricing); facilitating efficient long-term procurement (such as through standardized contracts and organized markets); and by competitive procurement of reliability resources from carbon-free technologies. Redefining reliability in terms of flexibility can create new value streams that will help the financeability and integration of clean energy resources, as well spur investment in the right grid supporting technologies. Integrated transmission and distribution system planning, discussed in the prior section, goes hand in hand with these market reforms.

Second, policymakers must also **create opportunities for all carbon-free energy technologies to provide services beyond energy**. In most markets today, variable clean energy resources like wind and solar, as well as supporting technologies like battery storage, are not utilized or compensated for the full suite of grid services they provide (such as



operating reserves, regulation, fast frequency response, reactive power, and other ancillary services). 64 This will enable a transition away from a 'one-size-fits-all' capacity model for reliability and improve the financeability of new clean energy technologies.

Third, policymakers should eliminate any market and regulatory structures that allow utilities with captive ratepayers to commit and dispatch units uneconomically. To enhance the benefits of competition and ensure that new clean energy technologies can compete against legacy infrastructure, electric utilities should not be able to unduly favor their owned generating assets, as has occurred even in some competitive wholesale markets.

Fourth, market reform must bridge the gap between wholesale and retail market signals. Meeting decarbonization goals cost effectively will require significant contributions from demand-side resources. As policymakers design markets to value flexibility and support the integration of such resources at the wholesale level, they must also make sure these market signals transfer to customers and aggregators at the retail level, where significant demand-side potential remains underutilized. Policymakers should start with supporting diverse customer electricity pricing models, including time-varying electricity rates, and should build fair compensation models for individuals and third-party aggregators. This topic is explored further in the next section of this paper related to empowering energy consumers.

Finally, markets should explicitly incorporate long-term decarbonization into their design, operations, and planning. As a first step, policymakers should impose a price on power-sector carbon emissions to ensure that market prices reflect the value of emissions reductions provided by carbon-free energy sources. Policymakers could also explicitly direct market operators and regulators to take decarbonization objectives into account in the design of short-term and long-term markets. For example, they could create a regional competitive procurement mechanism as a compliance option for clean energy mandates. Markets designed for long-term decarbonization should also provide opportunities for the deployment of innovative but above-market-cost clean energy technologies and should be compatible with policies supporting existing clean energy facilities that are at risk of early retirement.





3. Empower Energy Consumers

While governments and utilities are setting goals to decarbonize their electricity systems, many companies and consumers want to move even faster. Energy consumers, large and small, from corporations to cities, can play an important role in driving the growth of clean energy industries, as well as creating new markets for innovative clean energy technologies. Yet government policies often create barriers to direct clean energy purchasing that could otherwise contribute significantly to decarbonizing the electricity system. In addition, consumers today generally lack the information necessary to purchase clean energy in a way that's cost-effective and maximizes their impact on decarbonization.

Google believes that every energy consumer, from the local restaurant, to data centers, to you in your home, should have an easy and cost-effective pathway to accessing clean energy. That's why we have helped found organizations dedicated to increasing companies' access to clean energy, like the Clean Energy Buyers Association (CEBA) in the United States and Re-Source in Europe. We're also developing technologies and tools to help residential energy consumers participate more effectively in the clean energy transition. For example, Project Sunroof allows anyone to quickly and easily understand the solar energy potential of their rooftop and connect to solar energy providers. Google Nest partners with dozens of utilities to provide energy and cost savings to consumers through demand response and is now helping consumers reduce carbon emissions through energy consumption shifts and investment in carbon-targeted clean energy projects.

Empowering energy consumers can reduce emissions, encourage utilities and regulators to accelerate their own plans for decarbonization, and lead to greater innovation in technology and clean energy business models. But to unleash the power of consumers to drive decarbonization, a number of gaps must be addressed.

a. Create legal and regulatory access to cost-effective clean energy

Consumer access to clean energy varies considerably across the world. According to the IEA, competitive retail electricity markets, where customers can most directly choose the source of their electricity, represent just 22% of global electricity demand. In the United States, access varies by region. A company like Google can directly purchase clean energy in areas with competitive wholesale electricity markets, but in other regions must go through the incumbent electric utility, which limits options and increases costs. In many emerging



markets, direct purchase or installation of clean energy is restricted altogether. And smaller customers often face even more obstacles, leading to unequal access to clean energy across customer classes and socio-economic groups.

Policymakers and regulators around the world should harness, not limit, consumer demand for clean energy. The opportunity is massive. In 2021, non-utility companies signed agreements to purchase over 31,000 MW of clean energy across the world, a new global record. Google has long worked to create opportunities for consumers to buy clean energy. In Georgia, we helped create a new customer program through our utility to add new solar energy to the grid. In Taiwan, we worked with other companies and the government to amend the country's Electricity Act, such that any organization can now directly contract for renewable energy. The policy change enabled Google's first Taiwanese solar project, as well clean energy purchases by other companies—including the world's largest-ever PPA for wind power.

Yet barriers to cost-effective access to clean energy remain. Take the same examples cited above. The Georgia customer renewable energy program is a good first step but is priced at a premium to the cost of the underlying clean energy and is limited by the decisions of the incumbent electric utility and its regulator, rather than driven by the much-larger customer demand for clean energy (the program is limited to certain customer classes and the total size is capped). Reforming the law in Taiwan was key to providing access to clean energy for the first time, but the government still keeps prices for renewable energy artificially high via its feed-in tariff system and other regulations, which blunts consumer demand for clean energy.

To enable legal access to clean energy, policymakers should **develop and enshrine legal frameworks that permit the direct purchasing of clean energy** by businesses and consumers, from distributed generation to utility-scale procurement. The best way to do this is to develop well-functioning competitive electricity markets, but supportive regulatory frameworks are important as well. The European Union provides a laudable example by requiring all Member States to identify and remove regulatory and administrative barriers to renewable PPAs, as well as establishing frameworks to empower consumers to generate and consume clean electricity. To make ensure that access to clean energy is cost-effective, policymakers should **move away from policies that keep the price of carbon-free energy artificially high** and toward policies that harness competition to drive cost reductions.



b. Require transparent, granular energy data and make it easily accessible

As Google has advanced toward our 24/7 CFE goal, we have encountered a persistent challenge: access to reliable electricity data. In order to measure our progress and plan for the future, we need access to hourly data about our own electricity consumption, the electricity we purchase, and the sources of electricity on the grid. This information is available in some regions, though there are often data gaps and issues with quality. In many places, consumers cannot easily access their own hourly electricity use data, and there is sparsely available and often inconsistent data on the hourly carbon intensity of electricity grids.⁷⁴

Enabling access to hourly real-time and historical electricity data can allow more companies to set 24/7 clean energy goals and empower all consumers to contribute to the decarbonization of the electricity grid. This kind of data can inform decision-making, such as energy consumers shifting the time (and, in some cases, the location) of their energy consumption to align with carbon-free generation. Google recently used the energy data we've begun to collect in exactly this way, as we developed a first-of-its-kind system that can shift flexible computing tasks at our data centers across time and space to better align with lower-carbon hours on the grid.

Some countries are making progress in providing actionable data. With respect to electricity grid data, the ENTSO-E Transparency Platform, mandated by European law, provides a common set of data relating to electricity generation, transport, and consumption for EU member states. In the United States, the Energy Information Administration (EIA) has launched an Hourly Electric Grid Monitor that provides generation data at an hourly resolution by individual balancing authority. Yet both systems rely on data provided by balancing authorities or transmission operators, which can be prone to gaps and errors. Moreover, the process for receiving this data from generators is not harmonized, and ENTSO-E and EIA lack the resources and the authority to ensure rigorous data quality.

Policymakers should require transparent disclosure of real-time and historical electricity data by electricity generators and system operators, put in place systems to address data quality and harmonization, and ensure such data is easily accessible by businesses and consumers. Such data should include information about hourly electricity grid mix and grid emissions. Electric utilities or electricity providers should also be required to provide customers access to their own hourly consumption data in real time. International collaboration can also help to enable standardized, widespread access to energy data across the globe. For instance, the International Energy Agency (IEA), which collects energy data



from member governments, can help by standardizing these datasets and making them publicly available. In 2021, Google.org provided a €1,000,000 grant to electricityMap, a leading provider of granular data on electricity and carbon intensity, that will help bring new data to the platform and make electricity data more accessible. Access to this sort of data will improve energy system models and forecasting capabilities, lead to higher-impact energy purchasing or consumption decisions, and will support better electricity market design.

In addition to data disclosure requirements, we also need systems to track and certify clean energy use at an hourly level, which will help enable purchasing decisions that drive faster emissions reductions across the grid. Today, a number of companies and organizations claim to be "powered by" renewable energy, yet in reality continue to consume grid power that includes a mix of clean and carbon-based energy sources. Matching consumption annually with 100% renewable energy is not equivalent to operating 24/7 carbon free, and more accurate tracking of the electricity grid mix is needed to better substantiate carbon and clean energy claims. ⁷⁶ Policymakers should support the development of clean energy certificate systems that provide greater granularity, starting at the hourly level. Existing "energy attribute certificates" (EACs), such as renewable electricity certificates (RECs) in the U.S. and guarantees of origin (GOs) in Europe, are typically issued monthly, often only for electricity from renewable sources, and do not provide information about when a MWh of electricity was produced. EAC systems should expand to track hourly generation, be issued for all forms of electricity generation (so-called "full disclosure" or "all generation tracking"), and provide information about the carbon intensity of generation technologies."

There are a number of benefits to more granular time-based energy attribute certificates, or T-EACs. They can increase transparency and confidence in claims about "using" clean energy. As more organizations set 24/7 CFE goals, a T-EACs system would translate demand for around-the-clock clean electricity into higher prices that can incentivize technologies that can deliver in hours when CFE is less plentiful. Paired with information about the hourly carbon-intensity of the grid, a T-EACs system can spur clean energy purchasing decisions that lead to greater emissions reductions. Finally, T-EACs would facilitate aggregated hourly tracking of energy for which the environmental attribute has been retired by a specific party for their own claim. Removing privately-claimed clean energy from the grid mix would result in hourly residual grid mix data that would allow organizations to both avoid double counting and obtain a more accurate accounting of their emissions.



A number of organizations are working on this challenge. Google is working with Energinet, the Danish electricity transmission system operator, on a pilot that enables granular certificates from the Danish solar projects we have under contract. In the Midwest U.S., we now buy and retire certificates that include associated hourly data thanks to a partnership with EAC registry M-RETs. We are also a founding advisory board member of EnergyTag, an international organization creating a standard for granular certificates that could be used by any country to create their own hourly certification systems. Energy policymakers across the world should support the adoption of these systems in their own countries and provide financial incentives to scale and harmonize data resources so that they can be used to improve market design.

c. Design regulatory structures to incentivize consumer participation in the energy transition

The declining cost and increasing modularity of carbon-free energy technologies, in addition to the rapid proliferation of digital technologies, are creating new opportunities for consumers of all sizes to participate actively in the energy transition. Consumers in many countries can now generate, store, or sell their own clean electricity, as well as modify their demand to better align with clean energy production on the grid. At Google, we are working to make our own electricity demand more flexible, as well as building battery storage systems at our data centers to replace fossil fuel backup and provide local grid services. In many countries, however, outdated market design and regulatory barriers prevent consumers from maximizing their participation. Governments should create policy and regulatory space for innovation and design markets to enable new business models and technologies to emerge.

There are a number of areas where policymakers and regulators should move quickly to enhance consumers' contribution to electricity decarbonization. The first is harnessing the potential of demand-side management (DSM) and distributed energy resources (DERs). DSM and DERs have the potential to provide significant value, improve the efficiency of the electricity system, improve reliability, and enable greater use of clean electricity. Unfortunately, as disruptive entrants to the market, DSM and DERs often encounter regulatory and market barriers that prevent them from realizing their full value. Policymakers should ensure that customers who choose to invest in DSM and DER technologies do not face rate discrimination and are able to fully participate in markets for energy, capacity, and ancillary services with fair compensation. Dynamic rate designs are a key tool to enable this participation, as typical flat or fixed rate structures discourage such responsiveness in demand. Policymakers and regulators should require that suppliers offer dynamic rate options to consumers to provide more opportunities for participation of DSM resources.



On the supply side, distributed energy resources (DERs) like solar PV and storage can also play a significant role. In Germany, for instance, the majority of renewable energy is deployed at the distribution level. Distribution-level deployment has the added benefit of reducing the strain on transmission resources to carry generation to load and the associated line losses that occur on the bulk system. To enable the participation of DERs, policymakers should require that utilities and system operators integrate DERs into their procurement and planning processes, ensure that customer-sited resources are not penalized in their rates, and fairly remunerate DERs for the value they provide to the system. Planning the distribution grid to optimize the contribution of DERs toward achieving decarbonization objectives can also lower overall electricity system costs. Wholesale markets should also provide an opportunity for DERs to participate to the extent that they are technically able to do so. 44

Finally, policymakers should **put in place clear legal and regulatory frameworks for aggregation**, which will become more important as DSM and DERs proliferate. Aggregation refers to the process of combining local sources of electricity demand or clean electricity supply, which can enable access to electricity markets for customers that would otherwise be too small to participate on their own. It can also lower clean energy costs by increasing economies of scale for consumers. Overall, governments should seek to increase, not limit, energy consumers' ability to participate actively in the clean energy transition. Doing so will add new clean power to the grid, improve system efficiency, and reduce emissions more quickly.



Conclusion

Only a few years ago, the idea of creating fully carbon-free electricity systems across the world would have seemed impossible. Yet today, it is possible to imagine a new paradigm. Carbon-free electricity sources are the cheapest in many markets across the globe, advanced clean energy technologies are making progress toward commercialization, and utilities and governments are pledging to fully decarbonize their electricity systems and broader economies. The electricity grid is the lifeblood of the modern economy, and this transition will mean not just mitigating the threat of climate change, but also building healthy, resilient, and economically prosperous communities across the globe.

While the rapid progress in carbon-free energy technology makes this transition possible, it is not inevitable, and it will be slower and more expensive than necessary without the right public policies to shape and accelerate it. In this paper, we have laid out the three areas of focus that we believe are particularly important if the world is to successfully decarbonize its electricity systems: advancing carbon-free energy and enabling technologies, redesigning markets to accelerate decarbonization, and empowering energy consumers to have greater impact. Structured well, these three areas reinforce each other to drive greater progress. The development and deployment of clean energy technologies will advance more quickly with expansive electricity markets that are optimized to enable them to achieve significant scale. Markets will drive greater levels of decarbonization if they are also coupled with complementary technology policies that drive down technology costs, advance a broad portfolio of technologies, and invest in the infrastructure that enables greater technology and market integration. Empowering consumers, meanwhile, will encourage the development of new technologies, enhance the efficiency of markets, and enable broad participation in the energy transition.

To drive the policy and market changes needed over the next decade, companies need to step up and get involved. Everyone has a stake in the policies and regulations that shape our electricity systems, and we must use our voices and organize around the common objective of complete, rapid, and cost-effective decarbonization. As we advance toward our goal of 24/7 CFE by 2030, we commit to working with others and advocating for clean energy policies that can enable 24/7 CFE for all energy consumers and decarbonize electricity grids at the scale and pace required to meet the scale of the world's climate challenge.



Appendix: Summary of Policy Recommendations

FOCUS AREA	POLICY GOALS	POLICY TOOLS
Advance Technology	Rapidly and cost-effectively deploy commercialized clean energy technologies	 Strong clean energy standards and targets Investment Incentives Competitive procurement Public procurement
	Rapidly develop and commercialize next-generation clean energy technologies	 Expanded RD&D Investment Public financing support Innovation-focused deployment incentives
	Maintain existing carbon-free energy technologies on the grid	 Extend lives of carbon-free assets Credits for carbon-free electricity Price carbon dioxide emissions Repower existing assets
	Speed the removal or replacement of carbon-emitting resources and limit investment in future carbon-emitting resources	 Set clear timelines for coal phase-out Debt securitization to accelerate coal retirement Avoid investment in unabated gas generation where unnecessary and, over time, require CCS or zero-carbon fuels for gas plants Repurpose existing fossil fuel infrastructure to accelerate the deployment of CFE Support communities that have historically relied on the production and use of fossil fuels for their livelihoods
	Develop and integrate the infrastructure required to cost-effectively deliver clean power	 Remove barriers to transmission infrastructure Holistic national, regional, and interregional transmission planning Incentivize investment in grid enhancing technologies and operating practices Take full account of distributed energy resources and demand flexibility in grid planning, and co-optimize transmission and distribution system planning



FOCUS AREA	POLICY GOALS	POLICY TOOLS
Expand Markets	Expand and integrate regional organized and competitive electricity markets, everywhere	 Create regional, organized, and competitive electricity markets where they don't exist today Encourage greater regional coordination on network planning and operation Develop stronger cross-border transmission links to enable greater energy trading
	Design markets to drive decarbonization	 Move from oversupply to flexibility model Allow CFE to provide services beyond energy Eliminate market and regulatory structures that allow for uneconomic dispatch Bridge the gap between wholesale and retail market signals Incorporate decarbonization into market design, operations, and planning
Empower Consumers	Create legal and regulatory access to cost-effective clean energy	 Legal framework for direct clean energy purchasing Move away from policies that keep the price of carbon-free energy artificially high
	Require transparent, granular energy data and make it easily accessible	 Require transparent energy data disclosure, ensure data quality, and make data easily accessible Create hourly certificate systems for all carbon-free electricity
	Design regulatory structures to incentivize consumer participation in the energy transition	 Enable full participation in DSM and DER Require dynamic rate designs to encourage responsive demand Require plans for optimizing DER contributions Remove barriers to aggregation



Endnotes

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- 1. For more information about the Compact and to get involved, visit www.gocarbonfree247.com.
- 2. https://nest.com/thermostats/real-savings/
- 3. J. D. Jenkins, M. Luke, and S. Thernstrom, Getting to Zero Carbon Emissions in the Electric Power Sector, Joule (2018).
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- 5. N. A. Sepulveda, J. D. Jenkins, F. J. de Sisternes, R. K. Lester, <u>The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation</u>, *Joule* (2018).
- <u>6</u>. Q. Xu, A. Manocha, N. Patankar, J. Jenkins, <u>System-level Impacts of 24/7 Carbon-free Electricity Procurement</u>, Princeton University Zero-carbon Energy Systems Research and Optimization (ZERO) Laboratory (2021).
- 7. Massive expansion of carbon-free energy technologies are also needed to meet the increasing energy needs of the 3.5 billion people around the world who lack access to reliable power today. For discussion of some of these challenges, see: J. Ayaburi, M. Bazilian, J. Kincer, T. Moss, Measuring "Reasonably Reliable" access to electricity services, The Electricity Journal (2020).
- <u>8</u>. From 2009 to 2021, costs for wind and solar power declined by 72% and 90%, respectively. See: <u>Lazard's Levelized Cost of Energy Analysis</u>, <u>Version 15.0</u> (2021).
- <u>9</u>. The volume-weighted average price for lithium-ion storage batteries has fallen from \$1,220/kWh in 2010 to \$132/kWh in 2021, a decline of nearly 90%. See: Bloomberg New Energy Finance, <u>2021 Lithium-lon Battery Price Survey</u> (2021).
- 10. Tapestry, Google X's moonshot for the electric grid, seeks to develop a single, virtualized view of the entire electricity system and the tools to run simulations for any location and at any time scale.
- 11. Sepulveda et al. (2018).
- 12. For the electricity sector, these include next-generation geothermal, clean hydrogen, advanced nuclear, carbon capture and storage (CCS), and various long-duration energy storage technologies, among others.
- 13. A landmark study by Princeton University finds that a total of 280 GW of new wind (3x current total installed capacity) and 300 GW of solar (4x current capacity) will need to be installed from 2021–2030 to be on a path to net-zero emissions by 2050 in the United States. See: E. Larson, C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan, Net-Zero America: Potential Pathways, Infrastructure, and Impacts (2021).
- 14. International Energy Agency. Net Zero by 2050: a Roadmap for the Global Energy Sector (2021).
- $\underline{15}$. The EU's $\underline{40\%}$ renewable energy target is part of its goal to reduce carbon emissions by 55% from 1990 levels by 2030, while the Biden Administration is targeting a 100% carbon pollution-free electricity sector by 2035 to achieve its greenhouse gas reduction goal of 50–52% below 2005 levels by 2030.
- 16. CES policies build on a successful history of state Renewable Portfolio Standards (RPS), which have been adopted by 29 states. Seven states have adopted clean electricity standards, which allow all carbon-free resources to contribute. For a full list, see: <u>U.S. State Electricity Portfolio Standards</u>, Center for Climate and Energy Solutions. Accessed December 20, 2020.



- <u>17</u>. A number of CES bills have been proposed in the United States Congress, each with somewhat different design details. See P. Picciano, K. Rennert, and D. Shawhan, Resources for the Future, <u>Two Key Design Parameters in Clean Electricity Standards</u> (2020).
- 18. National Energy and Climate Plans (NECPs) outline how each EU Member State will advance toward its clean energy and climate mitigation goals.
- 19. The Build Back Better Act currently being considered in the U.S. Congress creates a new technology-neutral tax incentive structure that would apply equally to all carbon-free energy generation technologies, in addition to standalone tax credits for energy storage and high-voltage transmission lines.
- <u>20</u>. One such example is the proposed <u>Energy Sector Innovation Credit</u> which would provide greater incentives for cutting-edge technologies and then phase down that support as technologies prove their commercial viability.
- <u>21</u>. J. D. Wilson, M. O'Boyle, R. Lehr, M. Detsky, <u>Making the Most of the Power Plant Market: Best Practices for All-Source Electric Generation Procurement</u>, Energy Innovation LLC (2020).
- 22. White House, Executive Order on Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability (2021).
- 23. The cities of Des Moines, Iowa, Ithaca, New York, and South Lake Tahoe, California have all adopted goals targeting 24/7 carbon-free energy, and are part of the United Nations' 24/7 Carbon-free Energy Compact.
- 24. International Energy Agency, ETP Clean Energy Technology Guide (2021). Accessed December 22, 2021.
- 25. International Energy Agency, Energy Technology Perspectives 2020—Special Report on Clean Energy Innovation (2020).
- 26. The Infrastructure Investment and Jobs Act (IIJA), signed into law in the United States in 2021, would more than double projected spending on energy research, development, and demonstration over the next 5 years. A recent report by the Columbia University Center on Global Energy Policy and the Information Technology and Innovation Foundation (ITIF) recommends that the federal government grow and sustain its investment in energy RD&D to \$25 billion annually by 2025. See: V. Sivaram, C. Cunliff, D. Hart, J. Friedmann, D. Sandalow, Energizing America: A Roadmap to Launch a National Energy Innovation Mission (2020).
- 27. The Department of Energy's Loan Programs Office provided low-cost finance to help build the first utility-scale solar projects in the United States and helped Tesla scale up their manufacturing. In Europe, the European Commission and Breakthrough Energy announced a partnership to use financial instruments and grants to mobilize the investment needed to demonstrate and scale up clean energy innovations, including green hydrogen, sustainable aviation fuels, direct air capture, and long-duration energy storage.
- 28. H. Ritchie, M. Roser, "Energy," (2020). Published online at OurWorldInData.org.
- 29. Global figures from International Energy Agency World Energy Outlook (2021); U.S. figures from U.S. Energy Information Administration, What is U.S. electricity generation by energy source (2021); EU figures from Eurostat, Nuclear Energy Statistics (2019).
- 30. The International Energy Agency estimates that advanced economies could lose 25% of their nuclear capacity by 2025 and as much as two-thirds by 2040. Plant closures could result in an additional 4 billion tons of CO₂ emissions. See: International Energy Agency, Nuclear Power in a Clean Energy System, (2019).
- 31. The International Energy Agency found that the cost of their World Energy Outlook Sustainable Development Scenario is significantly higher—\$1.6 trillion higher by 2040—without these extensions and that not extending plants would raise consumer electricity bills. See: International Energy Agency, Nuclear Power in a Clean Energy System (2019).
- 32. The United States Infrastructure Investment and Jobs Act (IIJA) created a new program to provide financial support to nuclear power stations struggling to remain competitive in wholesale electricity markets in order to prevent their early retirement.



- 33. Repowering of wind farms can increase the amount of electricity that is generated, even if the number of total wind turbines is reduced. Similarly, repowering hydropower assets can provide more carbon-free electricity using existing dams. Nuclear power plants have also consistently increased their generation over time through power uprates, which has led to thousands of MW of additional clean energy added to the grid.
- <u>34</u>. Recent research estimates that fossil fuels contribute to 3.61 million excess deaths per year. See: J. Lelieveld, K. Klingmüller, A. Pozzer, R. T. Burnett, A. Haines, V. Ramanathan, <u>Effects of fossil fuel and total anthropogenic emission removal on public health and climate</u>, Proceedings of the National Academy of Sciences (2019).
- 35. In the United States, it has been estimated that keeping to a 2°C pathway would prevent roughly 4.5 million premature deaths, about 3.5 million hospitalizations, and emergency room visits, and approximately 300 million lost workdays in the U.S. See: Drew Shindell, <u>Health and Economic Benefits of a 2°C Climate Policy</u>, Testimony to the House Committee on Oversight and Reform (2020).
- 36. An analysis by the Rocky Mountain Institute, the Carbon Tracker Initiative, and the Sierra Club finds that it's cheaper today to build new renewable energy capacity, including battery storage than to continue operating 39 percent of the world's existing coal capacity. See: Rocky Mountain Institute, How to Retire Early: Making Accelerated Coal Phaseout Feasible and Just (2020).
- <u>37</u>. M. Bazilian, B. Handler, and K. Auth, <u>How public funders can help take coal offline ahead of schedule: three financial options</u>, Energy for Growth Hub (2021).
- <u>38</u>. As one example, the Climate Investment Funds <u>Accelerating Coal Transition Investment Program</u> provides multilateral finance and technical assistance to developing countries to support their transition away from coal power and toward carbon-free energy sources.
- <u>39</u>. According to one estimate, nearly \$16 billion in investment in gas-fired assets could be stranded in the U.S. and Europe if they are closed on the timeline required to achieve net-zero emissions by 2050 in those economies. See: Carbon Tracker, <u>Put Gas on Standby</u> (2021).
- 40. The advanced nuclear company Terrapower announced plans to build its first plant at the site of a retiring coal plant in Wyoming, a state that generates 90% of its electricity from fossil fuels. A report by Good Energy Collective identified 80 similar sites across the United States that could be good candidates to consider advanced nuclear power as a replacement technology for coal. See: J. Toth, J. Lovering, and S. Baker, Opportunities for Coal Communities Through Nuclear Energy: An Early Look (2021).
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- <u>42</u>. Last year, Google signed the first-ever corporate agreement for a next-generation geothermal energy project that uses advanced drilling techniques to unlock a new class of clean energy resources. See: Google, <u>With new geothermal project</u>, it's full steam ahead for 24/7 carbon-free energy, Google Keyword Blog (2021).
- <u>43</u>. The IEA has provided a set of 12 key recommendations for policymakers as they design clean energy policies. See: International Energy Agency, <u>Recommendations of the Global Commission on People-Centred Clean Energy Transitions</u> (2021).
- <u>44</u>. Decarbonizing the U.S. economy by 2050 would require an electricity transmission system approximately 3 times larger than exists today. See: Larson et al. <u>Net-Zero America</u>: <u>Potential Pathways</u>, <u>Infrastructure</u>, <u>and Impacts</u> (2021).
- 45. See J. Pfeifenberger, R. Gramlich, K. Spokas, M. Goggin, J. Hagerty, J. Caspary, J. Tsoukalis, J. Schneider, Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs (2021).



- 46. The European Union's Trans-European Networks for Energy (TEN-E) policy provides a model for strategic infrastructure planning. The policy identifies priority corridors to link the energy infrastructure of different EU countries and commits preferential funding along with accelerated planning and permitting for infrastructure projects within these corridors. A similar approach can be adopted in the United States through the designation of National Interest Electric Transmission Corridors (NIETCs) and strategic use of public-private partnership projects to develop critical pieces of a nationally integrated transmission network capable of transferring large amounts of power across diverse geographic regions. See: A. Zevin, S. Walsh, J. Gundlach, I. Carey, Building a New Grid Without New Legislation: A Path to Revitalizing Federal Transmission Authorities (2020).
- <u>47</u>. One recent report found that such "grid-enhancing technologies" could save \$5 billion a year by boosting renewable energy deployment in the United States. See: T. Tsuchida, S. Ross, A. Bigelow, <u>Unlocking the Queue</u> with <u>Grid-Enhancing Technologies</u>, <u>Brattle Group</u> (2021).
- 48. A recent study shows that co-optimization of the distribution and the transmission grid would lead to an overall reduction in electricity system costs on the path toward decarbonization of the United States' electricity system.

 See: C. Clack, A. Choukulkar, B. Cote, S. A. Mckee, Why Local Solar for All Costs Less: A New Roadmap for the Lowest Cost Grid, Vibrant Clean Energy, LLC (2020).
- <u>49</u>. In the United States, such markets have been organized under Independent System Operators (ISOs) or Regional Transmission Organizations (RTOs).
- <u>50</u>. For a discussion of how organized wholesale markets can best be designed to achieve these outcomes, see: Clean Energy Buyers Association, <u>Organized Wholesale Market Design Principles</u> (2020).
- 51. Analyses have found that competitive markets lead to lower costs. One <u>study</u> found that retail prices in competitive states decreased by 8% from 2008 to 2016 while they increased by 15% in monopoly states. RTOs have also created savings for their market participants. In 2020, MISO provided \$3.1–3.9 billion in value (<u>study</u>); PJM's market operations produced savings of \$3.2–\$4 billion (<u>study</u>); and SPP has cumulatively saved market participants \$3.5 billion since its launch in 2014 (<u>study</u>).
- 52. J. D. Rhodes, L. L. Kiesling, F. T. Davidson, M. E. Webber, <u>Assessment of the Emissions Performance of Wholesale Electricity Markets</u> (2021).
- 53. Clean Energy Buyers Association (CEBA), CEBA Deal Tracker (2021).
- 54. American Council on Renewable Energy (ACORE), Energy Market Design and the Southeast United States (2021).
- <u>55</u>. European Union Agency for the Cooperation of Energy Regulators (ACER), <u>ACER Market Monitoring Report</u> <u>2020—Electricity Wholesale Market Volume</u> (2021).
- 56. According to one recent study, creating a regional transmission organization (RTO) in the southeast could save an estimated \$384 billion over the next 20 years and reduce CO₂ emissions by 40 percent over the same period. See: Energy Innovation LLC and Vibrant Clean Energy LLC, Economic and Clean Energy Benefits of Establishing a Southeast U.S. Competitive Wholesale Electricity Market (2020).
- 57. M. Mulder, Regulatory challenges to foster cross-border trade in electricity systems with increasing shares of renewables, Energy Post (2020).
- 58. P. Baker, M. Hogan, C. Kolokathis, <u>Realising the benefits of European market integration</u>, Regulatory Assistance Project (2018).
- 59. International Energy Agency, Electricity Market Report: 2020 Global overview: Prices (2020).
- 60. International Energy Agency, Establishing multilateral power trade in ASEAN (2019).
- 61. The <u>ASEAN Power Grid project</u> aims to connect the energy markets of its ten member nations and develop a common ASEAN policy on power interconnection and trade.



- <u>62</u>. A recent workshop collected a number of proposals on advancing long-term market design to support a decarbonized electricity system. See: World Resources Institute and Resources for the Future, <u>Market Design for the Clean Energy Transition: Advancing Long-Term Approaches</u> (2020).
- 63. This shift will allow policymakers to reexamine what the function of a capacity market should be in a highly diverse, increasingly integrated system and how to reduce reliance on oversupplied capacity markets for financeability. For regions where capacity is undersupplied and capacity markets are still needed, these policies can also help to create a new framework for reliability and resource adequacy that accurately accounts for the true reliability value of carbon-free resources and avoids overbuilding a system of uneconomic generation. For example, the United States Federal Regulatory Commission recently adopted Order No. 2222, which requires all organized markets to revise their market rules to allow for the full participation of distributed energy resources, including aggregations of such resources.
- <u>64</u>. For a discussion of some market barriers to carbon-free energy technologies, see M. Goggin, R. Gramlich, S. Shparber, A. Silverstein, <u>Customer Focused and Clean: Power Markets for the Future</u> (2018).
- <u>65</u>. Analyses have found (and operational data has confirmed) that some utilities run their own coal plants (self-schedule) uneconomically, leading to unnecessary carbon emissions and higher costs for ratepayers. See: J. Daniel, <u>The Coal Bailout Nobody is Talking About</u>, Union of Concerned Scientists (2018).
- <u>66</u>. One idea that has been proposed is to create a forward market for clean energy that could be implemented within regional electricity markets. See: S. Newell, K. Spees, <u>How States, Cities, and Customers Can Harness</u>
 <u>Competitive Markets to Meet Ambitious Carbon Goals: Through a Forward Market for Clean Energy Attributes,</u>
 The Brattle Group (2019).
- <u>67</u>. Large energy buyers, in particular, can have expanded decarbonization impact by engaging in transformative procurement strategies. See: L. Bird, E. O'Shaughnessy, N. Hutchinson, <u>Actions Large Energy Buyers can Take to Transform and Decarbonize the Grid: Procurement Practices for Achieving 100% Carbon Free Electricity</u>, World Resources Institute (2021).
- <u>68</u>. Nest's <u>Rush Hour Rewards</u> program partners with dozens of utilities representing 75 million homes, providing energy savings and demand curtailment. On average, Nest Learning Thermostats save 10–12% on heating and 15% on cooling and shift approximately 55% of AC usage on average during RHR events.
- 69. International Energy Agency, Electricity Market Report: 2020 Global overview: Prices (2020).
- 70. Bloomberg New Energy Finance (BNEF), Corporate Clean Energy Buying Tops 30 GW Mark in Record Year (2022).
- 71. Georgia Power, Commercial & Industrial Renewable Energy Development Initiative, accessed December 2021.
- 72. Google, Let the sunshine in: opening the market for more renewable energy in Asia, Google Keyword Blog (2019).
- 73. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, Article 15, Official Journal of the European Union (2018).
- 74. For a picture of the existing electricity data and gaps around the world, see electricitymap.org.
- 75. Today, IEA derives revenue from the data they collect, but this data could be provided freely and the revenue replaced by increased contributions from member states or other sources. See: M. Roser, H. Ritchie, The International Energy Agency publishes the detailed, global energy data we all need, but its funders force it behind paywalls. Let's ask them to change it, Our World in Data (2021).
- 76. J. A. de Chalendar and S. M. Benson, Why 100% Renewable Energy is Not Enough, Joule (2019). See also:
 M. C. Lott and B. Phillips, Advancing Corporate Procurement of Zero-Carbon Electricity in the United States:
 Moving from RE100 to ZC100, Columbia University (2021).
- 77. Google is working with partners across the world to enable time-based energy attribute certificates (T-EACs).
 See: Google, <u>A timely new approach to certifying clean energy</u>, Google Cloud Blog (2021).



- 78. Energinet, Energy Origin (2022).
- 79. B. Gerber, A Path to Supporting Data-Driven Renewable Energy Markets, M-RETS (2021).
- 80. www.energytag.org
- <u>81</u>. DSM can include formal demand response programs where customers are paid for avoiding grid-based energy use at certain times or price-responsive demand, where customers change their energy usage in response to fluctuations in energy prices.
- 82. B. Bayer, P. Matschoss, H. Thomas, A. Marian, <u>The German experience with integrating photovoltaic systems into the low-voltage grids</u>, *Renewable Energy* (2018).
- 83. C. Clack et al. Why Local Solar for All Costs Less: A New Roadmap for the Lowest Cost Grid, Vibrant Clean Energy, LLC (2020).
- 84. The United States Federal Regulatory Commission recently adopted <u>Order No. 2222</u>, which requires all organized markets to revise their market rules to allow for the full participation of DERs and DER aggregation.