A CLOSER LOOK

USING DIGITALIZATION TO ACHIEVE DECARBONIZATION GOALS

C2ES CLIMATE INNOVATION 2050

by

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Achieving net-zero emissions will require large scale change across all sectors of the economy, and efforts to drive this transition are intensifying. Over the past several years, through the Climate Innovation 2050 initiative, the Center for Climate and Energy Solutions (C2ES) has engaged closely with leading companies across diverse sectors to examine challenges and solutions to decarbonizing the U.S. economy by 2050. As we laid out in *Getting to Zero: A U.S. Climate Agenda*, reaching net-zero will require this large-scale change, but it will also require us to address a number of discrete and urgent challenges. To inform policymakers considering these near- and long-term questions, C2ES launched a series of "*Closer Look*" briefs to investigate important facets of the decarbonization challenge, focusing on key technologies, critical policy instruments, and cross-sectoral challenges. These briefs will explore policy implications and outline key steps needed to reach net-zero by mid-century.

EXECUTIVE SUMMARY

Digital technologies—such as sensors, networked devices, and data analytics—are already changing how energy is used and consumed across the economy. As digitalization expands, it is creating new opportunities to optimize energy use and decrease greenhouse gas emissions. Opportunities in key sectors include the following:

- **Power:** Digitalization can improve the grid's ability to integrate more variable renewable energy, create an interconnected grid with multi-directional power flow, and expand the use of demand response strategies (including smart charging of electric vehicles).
- **Transportation:** In addition to enabling electric vehicles to provide flexible load and storage resources for the power grid, digitalization of transportation can improve fuel efficiency (e.g., through route optimization) and enable autonomous driving systems.
- **Buildings:** Digitalization of buildings—such as through energy management systems, smart heating and cooling systems, and connected appliances and

equipment—can improve the comfort of occupants while reducing energy use.

- **Industry:** "Smart manufacturing" approaches can optimize energy and resource use, improve supply chain management, and allow for differentiation of products based on environmental attributes.
- **Oil & gas:** Digitalization in the oil and gas sector can help with preventative maintenance, detect and reduce emission leaks, and improve the sector's environmental footprint.
- **Agriculture:** "Smart farming" approaches can reduce emissions-producing inputs (e.g., fertilizers) and water use, better manage livestock production and animal health, enable urban and vertical farming, and improve accounting of carbon sequestration.

Realizing the decarbonization potential of digitalization, however, will require grappling with a number of informational, usage, financial, regulatory, technical, infrastructure, security, and privacy challenges. These include lack of knowledge and capacity, high upfront capital costs, outdated regulatory models, lack of interoperable standards, the current semiconductor supply crunch, limited access to broadband, cybersecurity vulnerabilities, and concerns about compromised privacy and proprietary business information.

These challenges are not insurmountable, and a range of policies at all levels of government could help. Policies to enable climate-beneficial digitalization across the economy include:

- **Investing in research, development, demonstration, and deployment**, including appropriations for the digitalization demonstrations authorized in the Energy Act of 2020;
- **Driving deployment through government procurement**, including requiring agencies to procure digital solutions, document the related energy efficiencies and cost savings, and publicize the lessons learned;
- **Enhancing understanding of digital technologies**, including by incorporating these technologies in agency outreach activities and by developing real-time measurement and verification protocols for systems-level efficiencies in buildings, industry, power, transportation, and agriculture and land use;
- **Developing interoperable standards and communications protocols** between devices and systems; and
- **Investing in digital infrastructure**, such as semiconductors and broadband.

INTRODUCTION

Digital technologies and innovation can play a significant role in spurring economic growth and reducing greenhouse gas emissions. As digital technologies become more ubiquitous, they are fundamentally changing how energy is used and consumed. Digitalization—the application of digital technologies (e.g., sensors, networked devices, cloud data storage, analytics) to physical equipment and systems—enables systems-based approaches to reducing energy use and carbon emissions across the economy, including in the power, transportation, buildings, industry, and agriculture sectors. A systems-based approach considers the interaction of various equipment, controls, and operations within and across systems to optimize collective performance. Fundamentally, digitalization is about collecting more and higher quality data about the physical world using sensors, analyzing data with algorithms or artificial intelligence (AI), and turning the resulting information into actions that can help increase productivity and efficiency.[1] Digital technologies are already being deployed across power grids, transportation networks, industrial facilities, buildings, and beyond, and as their deployment increases, so too does their potential to grow the economy and accelerate decarbonization.

Digitalization is projected to have a positive economic impact of $3.9 trillion to $11.1 trillion by 2025.[2] Investments in digitalization can also help decarbonize the economy in numerous ways. For example, digital technologies can improve wind and solar generation forecasts and help the grid maximize these resources. Digital technologies can also help enable communications between electricity generators and consumers and implement flexible demand response strategies to better align use with resources. Additionally, electric vehicle (EV) charging can be optimized using digital technologies, helping the grid to operate more efficiently with less total power required. Likewise, digital devices can provide system operators with information that enables two-way power flows. These examples only scratch the surface of digitalization's potential to improve efficiency, transform how electricity is generated and used, better manage much greater quantities of variable renewable electricity, expand demand response approaches, and increase electrification of buildings, transportation, and industry.

Digitalization is increasingly seen as a key driver for decarbonization across the economy. The majority staff report of the House Select Committee on the Climate Crisis found that, "As electrification of the economy increases, digitalization and artificial intelligence could dramatically increase the efficiency and performance of energy systems."[3] Similarly, the European Commission found that "digital technologies are a critical enabler for attaining the sustainability goals of the [European Green Deal] in many different sectors."[4]

This brief takes a closer look at key opportunities for adopting digital solutions across the economy to help meet long-term decarbonization goals, improve efficiency, and boost economic growth. It then reviews some of the informational, usage, financial, regulatory, technical, infrastructure, security, and privacy barriers to achieving the climate benefits of digitalization across economic sectors. The brief concludes with recommendations for policies and other government actions to help realize the potential of digitalization in decarbonization.

BOX 1: The Information and Communications Technology Sector's Footprint

Digitalization could enable large emissions reductions across the economy, but it is important to recognize that the technologies that make digitalization possible also use energy and have a carbon footprint.[1]

The exponential growth of networked devices and data storage has raised concerns about the potential increase in energy use (and thus emissions) in the information and communications technology (ICT) sector. Broadband expansion could enable even more of this growth. The ICT sector made up about 1.4 percent of global emissions in 2015.[2] Though the amount of data and internet traffic has grown exponentially, energy consumption of data centers has remained relatively flat due to design and hardware efficiency improvements.[3] In addition, technology companies are increasingly purchasing or generating renewable electricity, which could further limit emissions from the ICT sector. Nonetheless, additional actions and technologies could help drive further decarbonization in the ICT sector. For example, dispatchable data centers could shift computing tasks (e.g., data analysis, machine learning) to periods when low- or zero-carbon electricity is more widely available.[4] Likewise, placing computing resources between networked devices and "cloud" data centers—a practice known as fog computing or edge computing—could not only improve the response time for real-time data but also reduce energy use by analyzing and storing data closer to the networked devices.[5]

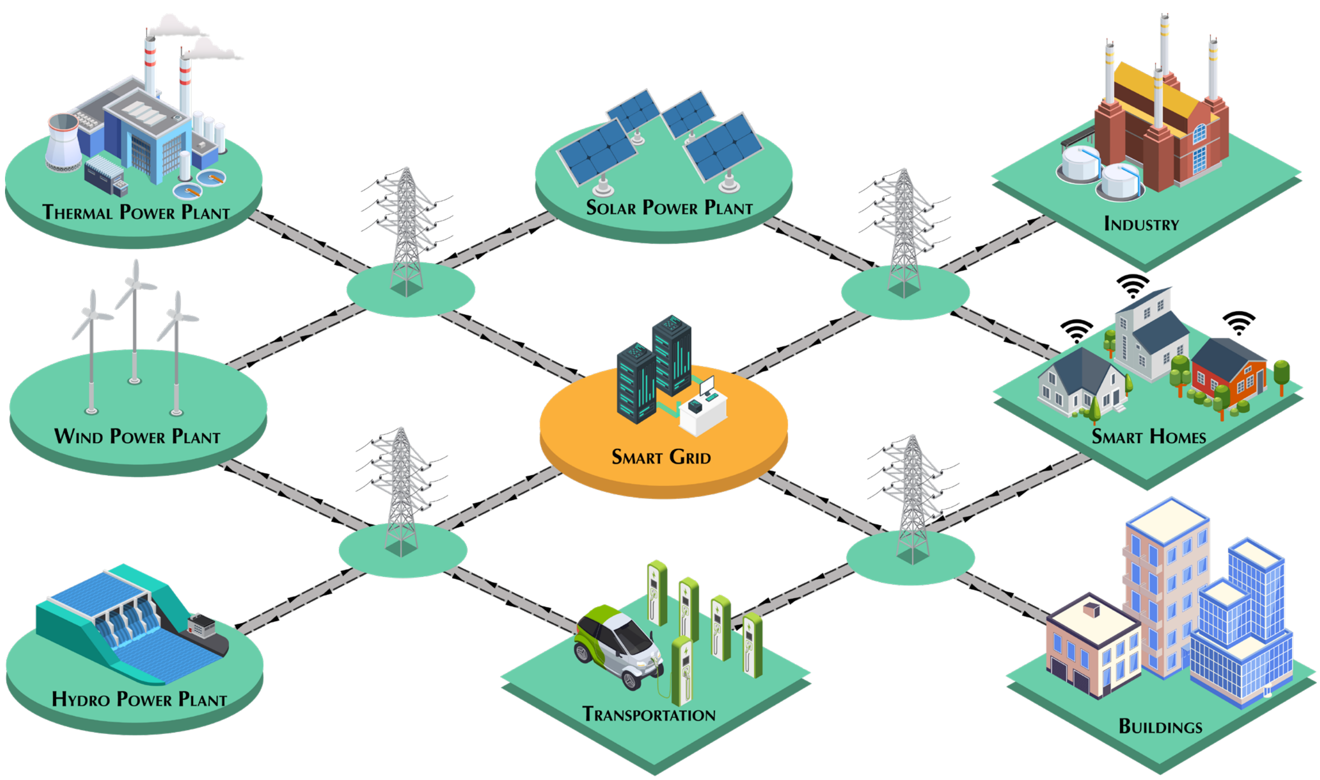
OPPORTUNITIES FOR DIGITAL DECARBONIZATION

Like all sectors, the information, communication, and technology (ICT) has as an energy and climate "footprint." However, through the use of digitalization, ICT solutions can also enable significant emission reductions in other sectors, referred to as a "handprint."[5] The systems-based approaches enabled by digital technologies are creating new opportunities to optimize energy use and decrease emissions. A 2015 study found that digital technologies could help reduce global greenhouse gas emissions up to 15 percent by 2030.[6] This section highlights some of the greatest opportunities for digitalization to reduce emissions in key sectors of the economy.

POWER

Digitalization of the electricity system is transforming how power is generated, distributed, and used. The traditional electricity system was designed for one-way power flow from large, centralized power plants, which is transmitted long distances on high-voltage power lines; individual substations step down that power, and lower-voltage distribution networks deliver power to homes and businesses. Digital technologies are helping to upend the traditional model in some key ways, accelerating the decarbonization of the power system and enabling the power system to serve as the backbone for decarbonizing

FIGURE 1: Digital transformation of the energy system



Note: Pre-digital electricity systems were defined by the unidirectional flow of power from power plants to end users. Digital technologies are transforming the system to allow for multidirectional flows (both electricity and data/communications), more distributed generation, and better integration. This is creating new opportunities to reduce energy use and emissions.

Source: George Kamiya, "Digitalization & Energy" (Webinar, Systems Thinking: Getting the Most out of Intelligent Efficiency, *2018).*

the rest of the economy. (See **Figure 1**) Digital technologies are helping drive decarbonization by:

- **Improving the grid's ability to integrate more variable renewable energy.** Increasing wind and solar power generation introduces more variability, which increases the need for digital technologies (e.g., substation automation, distribution automation, grid monitoring technologies and applications) to help integrate them without affecting reliability. Coupled with data from large wind and solar farms, weather forecasts, and energy usage data, these digital technologies could help grid operators more accurately forecast and manage variable renewable supply across wide geographic areas, improve management of energy demand in real-time, and optimize the use of energy storage, further improving reliability.[7]
- **Creating an interconnected grid with multi-directional power flow.** At the distribution level, solar rooftops, electric vehicle charging, and microgrids are introducing two-way power flows, requiring infrastructure upgrades to support more active electricity "prosumers" (i.e., who both produce and consume electricity). As more distributed resources come online with two-way power flows, digitalized distribution substations enable additional solutions that can help grid operators match supply with demand in novel and efficient ways, such as by leveraging the stored energy of a multitude of EV batteries with vehicle-to-grid (V2G) technologies to help balance intermittency issues, mitigate future peak load challenges, and ensure reliability. For example, Intel is working with Dell, VMWare, Southern California Edison, and Salt River Project to demonstrate how smaller and more efficient digital substations can enable bidirectional communication between customers and utilities (and can enable greater integration of distributed renewable energy resources).[8]
- **Expanding the use of demand response strategies, including smart charging of electric vehicles.** Demand response can help decarbonize the power sector by shifting or reducing electricity demand to match supply, which can then reduce the need for additional infrastructure and power plants. This will be particularly important as electrification in other sectors increases power demand. Digital technologies (such as smart meters, communication networks, and data management systems) can improve energy efficiency and expand the use of flexible demand response programs. For example, smart EV charging programs could leverage vehicle telematics and an interconnected grid to make EVs into smart, flexible load—shifting EV charging times to periods of high renewable energy generation and low electricity demand—thereby reducing the need to build additional electricity generation capacity to charge electric vehicles. The International Energy Agency (IEA) found that if 500 million EVs are deployed by 2040, it would require 300 gigawatts (GW) of electricity capacity for standard charging, whereas smart charging could reduce that to 190 GW, saving $280 billion in new electricity infrastructure.[9]

TRANSPORTATION

In addition to enabling EVs to provide flexible load and storage resources for the power grid, digitalization of transportation through the application of sensors, data analytics, and communication technologies has improved fuel efficiency through route optimization, lowered maintenance costs through telematics and improved fleet management, and safety features enhanced through new technologies.[10] From 2012 to 2017, the market for intelligent transportation systems in the United States nearly doubled.[11]

As vehicles and transportation infrastructure become more connected, digitalization could potentially reshape road transportation through advances in autonomous driving technologies.[12] One study projects the autonomous passenger vehicle market could be worth $7 trillion in 2050.[13] The interaction of autonomous vehicles, electrification, and transportation-as-a-service (e.g., ridesharing) could improve mobility and safety and reduce fuel use and related emissions. Realizing these environmental benefits will be contingent upon having the right alignment of technology, regulation, and infrastructure.[14]

BUILDINGS

Digitalization of buildings—such as through energy management systems, smart heating and cooling systems, and connected appliances and equipment—can improve the comfort of occupants while reducing energy use.[15] For example, AECOM found that widespread deployment of data analytics and building technologies (e.g., smart thermostats, other sensing equipment) across 120 commercial energy projects in Chicago and Detroit produced $60 million worth of kilowatt-hour reductions. These digital technologies are delivering significant energy savings through persistent monitoring and optimization of buildings' energy management systems.[16] The U.S. Department of Energy anticipates building monitoring and control technologies could save 1.7 quadrillion British thermal units (BTUs) in 2030 and 3.6 quadrillion BTUs in 2050.[17]

INDUSTRY

Digitalization of industry has enabled "smart manufacturing" approaches—such as additive (3-D) printing, robotics, and artificial intelligence and automation technologies—that can optimize energy and resource use, maintenance, production, and supply chain management. For example, LafargeHolcim's "Plants of Tomorrow" initiative utilizes automation, robotics, AI, predictive maintenance, and digital twins (i.e., virtual replicas of physical objects or systems that are used for simulations) to make cement production safer, improve productivity, and reduce energy usage and costs. The four-year "Plants of Tomorrow" initiative, launched in 2019, is expected to improve plant operational efficiency by 15 to 20 percent and help lower the carbon intensity of cement.[18]

Digital technologies can also improve upon the existing measurement, reporting, and verification (MRV) systems that are used across the economy to assess compliance with energy efficiency, emission reduction, and clean procurement goals and requirements. Digital MRV could improve supply chain management and tracking in numerous ways, including by: securely collecting, storing, and sharing energy and environmental data in real time; improving the speed and accuracy of regulatory reporting; lowering reporting and verification costs; and increasing interoperability across systems. Digital MRV could provide mechanisms by which products can be differentiated based on environmental attributes such as carbon content, enabling greater consumer demand for these low-carbon products (e.g., to align procurement decisions with sustainability and climate goals) and incentivizing industry to produce more of them.[19] For example, Xpansiv CBL Holding Group (XCHG) has developed a digital platform that collects real-time production data, uses AI to analyze and contextualize the raw data, and uses distributed ledger (i.e., blockchain) technologies to create a "Digital Feedstock" that allows commodities to be differentiated based on environmental attributes (e.g., greenhouse gas intensity, water use, land disturbance).[20]

OIL & GAS

Digitalization in the oil and gas sector, such as through sensors and analytics, can help with preventative maintenance, detect emission leaks across the value chain, and improve the reliability of pipelines. Digital technologies—such as sensors, drones, and data analytics—can help with remote monitoring and automated responses to detect and reduce methane emissions leaks.[21] More broadly, digitalization is creating new opportunities to reduce the environmental footprint of the oil and gas sector. In August 2020, 15 companies across economic sectors—including BP, Equinor, Intel, and Shell—formed the Open Footprint Forum to develop open and vendor-neutral industry standards for measuring and reporting of environmental footprint data, starting with greenhouse gas emissions data.[22] Open, consistent, and interoperable standards will allow companies to link various systems to measure and verify their environmental footprint across the supply chain to help them find ways of reducing their emissions.

AGRICULTURE

Digitalization of agriculture has enabled "smart farming" approaches that can increase productivity and help food production become more sustainable.[23] The integration of digital technologies—such as GPS-enabled precision agriculture technologies, sensors, and data analytics—have optimized farming systems to more efficiently meet the needs of individual fields and crops while reducing emissions-producing inputs (e.g., fertilizers) and water use.[24] Smart farming technologies can also help manage livestock production and animal health through improved health monitoring and precision feeding; healthier animals and reduced mortality, in turn, would allow for meeting the world's food demand with fewer animals, thereby reducing emissions from enteric fermentation and manure.[25] For example, Cargill and Cainthus have developed a bovine facial recognition technology that can identify each cow in a herd and, combined with machine learning, recognize changes in a cow's appearance to determine whether a cow is sick or is not eating or drinking enough; this system can enable more robust and automated animal care.[26] In addition, digital technologies are enabling urban and vertical farming, where the use of LEDs, sensors, and automation can create an environment where crops could be grown closer to consumers, year-round, in a way that is more resilient to a changing climate.

Beyond reducing emissions, digitalization also creates the potential for agriculture to benefit more from its ability to remove and sequester carbon dioxide from the atmosphere. Digital MRV systems that are interoperable with smart farming technologies could create new, more valuable carbon market opportunities for farmers by collecting, storing, and sharing real-time environmental data to provide a credible, accurate accounting of nature-based carbon sequestration projects.

CHALLENGES TO ECONOMY-WIDE DIGITAL DECARBONIZATION

In order to realize the full decarbonization potential of digitalization, a number of challenges, including informational, usage, financial, regulatory, technical, infrastructure, security, and privacy, that will have to be addressed.

INFORMATIONAL

Digitalization's potential may be limited due to lack of knowledge and technical expertise on the part of those who could be deploying and utilizing digital technologies. For example, small- and medium-sized companies, building owners and operators, and other potential implementors may have some knowledge of digitalization but may lack the internal capacity needed to deploy and effectively utilize it in their operations.[27] If they do deploy digital tools, they might only use the tools in ways that fall far short of their full potential and capabilities, such as manually inputting data versus setting up automatic data entry, failing to leverage the information generated from data and analysis, or only using a basic set of the tools' features. A related challenge is the need for digital tools to facilitate usage of these systems and minimize data input and analysis from non-technical experts.

Moreover, potential implementors may have greater familiarity with individual technologies than with systems-based approaches to digitalization. For example, energy savings from smart thermostats are well documented and increasingly understood, but more work is needed to document and build familiarity with the energy savings that are possible from building management systems of smart devices that include smart thermostats.

USAGE

While digitalization has the potential to help decarbonize the economy, digital technologies are not inherently clean and will not inevitably reduce emissions. The potential climate impact of digital technologies can be positive or negative depending on the ways those technologies and the systems they integrate into are managed, the sectors they are deployed in, whether their use causes a rebound effect that increases overall energy use and associated emissions, and much more. For example, digital technologies can improve efficiency and advance the deployment of non-emitting energy sources, as described earlier, but they can be equally effective in improving the efficiency of energy sources that are extracted and combusted. Looking at a different example, deployment of autonomous vehicles could either be positive or negative for decarbonization efforts, depending on policy responses, the types of technologies and practices used, and whether the increased efficiencies and reduced costs of travel lead to a rebound effect and increase total vehicle miles traveled.[28] It is important to recognize the range of uncertainty in outcomes and to develop policy responses to steer digitalization applications toward the lowest-carbon deployment of these solutions.

FINANCIAL

The deployment and utilization of digital technologies may be limited due to costs. Upfront capital may not be available for digitalization projects, even for those with a relatively short payback period. Companies may not have the capital to purchase these technologies and services without additional financial incentives. For example, new digitalized farming equipment and services may be cost prohibitive for small- and medium-sized farms without additional financial incentives to encourage adoption. Organizational accounting and budgeting practices could also limit investments in energy-saving opportunities if they only account for the upfront cost and not the total cost savings that accrue over the life of the project. An additional hurdle to deployment may be split incentives between the "principal," who benefits from the technology (e.g., building occupant or operations department), and the "agent," who pays for the technology (e.g., building owner or financial department). A principal may want to minimize the total cost of the technology or increase comfort level or productivity, while an agent may want to minimize the upfront costs of new technologies. These split incentives could create organizational barriers to the adoption and deployment of digital technologies.[29]

Beyond immediate deployment, there are also a number of reasons why companies may underinvest in research, development, and demonstration (RD&D) of digital technologies that could reduce emissions. For instance, companies are generally unable to capture the full economic benefits of RD&D due to knowledge spillover effects; in other words, a company that develops a new digital technology, or is an early adopter, may incur all the costs of integrating that technology without being able to exclude others from benefiting from the knowledge of the new technology. A lack of certainty around federal climate and clean energy policies may also discourage new investments in decarbonization technologies. As a practical matter, the scale and scope of RD&D needed for certain technologies cannot be taken on by one company or industry. As the largest funder of basic research, the U.S. government's support will be essential for maintaining domestic leadership in digital technologies.[30]

REGULATORY

State public utility commissions could intentionally or unintentionally disincentivize digitalization in the power sector.[31] Traditional cost-of-service regulation models tend to reward utilities for capital investments in new physical infrastructure instead of for minimizing capital expenditures through operational improvements, such as the kinds that digital technologies make possible.[32] In addition, utilities that pursue investments in digitalization may have a hard time justifying these investments with state utility commissions that may be unfamiliar with or unconvinced of their benefits. In particular, it may be harder to measure the system-wide benefits of digitalization—the benefits would potentially have to account for generation, transmission, distribution, operations, and end use—than the energy savings from a single piece of equipment. Furthermore, public utility commissions may prefer or have a bias toward more established solutions (i.e., wires) over innovative alternatives such as digitally-enabled demand response; deployment of non-wires alternatives has been greatest in states like California and New York that have adopted specific programs to incentivize them.[33]

TECHNICAL

Digitalization involves deployment of lots of different technologies, and there will be some clear technical challenges involved in realizing digitalization's decarbonization potential. For example, as noted earlier, V2G technologies could allow EVs to charge from the grid and provide power back to the grid when it can help balance the system, but realizing these opportunities requires vehicles to be designed and enabled for bidirectional charging. Currently, very few light- and medium-duty vehicles can use V2G charging, though there are pilot programs in various states exploring the V2G potential of electric school buses.[34] There are also technical challenges related to battery degradation resulting from increased charging cycles from V2G use. Increased battery degradation could negatively impact driving range of EVs, require frequent battery charging, and reduce the lifespan of the battery. Addressing battery charging and degradation issues will be critical for adoption of V2G technologies. In addition, conflicting technical standards for bidirectional charging will need to be resolved before V2G-equipped vehicles or charging stations are allowed to connect to the grid in any widescale fashion. The Combined Charging System—a widespread EV charging standard—is currently establishing a range of V2G standards, which could help enable much greater participation; more complete standards are expected by 2025, and products could follow soon afterward.

More broadly, the lack of interoperable standards for different data formats, technologies, and applications could serve as a barrier to the effective use of a range of digital solutions. Closed or proprietary standards could limit innovation and technology development to a select group of manufacturers and could lead to the creation of competing standards from different manufacturers with limited interoperability. An open set of technology standards and communications protocols—adopted internationally—would allow for technologies from different manufacturers to communicate with each other to enable more effective, more widespread digitalization. International standards would also allow U.S. products to be sold and utilized abroad. In addition, realizing the potential of digital monitoring, reporting, and verification protocols to enable supply chain decarbonization would require interoperability between different supply chain management systems. Allowing data to be entered and shared across global supply chains that span myriad countries, vendors, and organizations will be crucial to ensuring the accurate accounting of emissions data.[35] Standardized protocols will also be needed for MRV related to the energy savings of systems-based approaches to efficiency. MRV protocols exist for different equipment and controls, but more work is needed to develop protocols that will document and report on the "systems" energy savings resulting from a combination of equipment, operations, controls, and accessories.

SUPPLY CHAIN SECURITY

Semiconductors (also known as integrated circuits, microchips, or computer chips) are essential building blocks of electronic devices and are fundamental to digitalization. Unexpected increases in demand for consumer electronics and appliances during the COVID-19 pandemic and limited excess manufacturing capability have led to a global chip shortage that has hampered production across industries, most noticeably in automobile manufacturing.[36] The semiconductor supply crunch could last for some time and has brought renewed attention to the need to build and modernize domestic semiconducting manufacturing capabilities. All the while, the U.S. share of global semiconductor manufacturing capacity fell to 12 percent in 2019, down from 37 percent in 1990, and is projected to decline to 10 percent by 2030.[37]

ACCESS TO RELIABLE BROADBAND

Broadband infrastructure represents another hurdle to expanded digitalization. Access to reliable, high-speed internet has proven invaluable during the COVID-19 pandemic, allowing people to work, learn, receive medical attention, connect with family, and much more while sheltering in place. Deployment of new connected digital technologies to reduce energy use and emissions across the economy likewise requires wide availability of reliable, high-speed broadband.[38] The pandemic, however, has brought into clearer focus the digital divide between those who have high-quality broadband and those who do not have access due to lack of infrastructure or affordability. As of 2021, 28 percent of rural Americans, 43 percent of low-income households, and roughly 32 percent of racial minorities do not have access to broadband services at home.[39] When it comes to affordability, 54 percent of Hispanic users and 36 percent of Black users worry about paying for their home internet service, a similar percentage as those who worry about paying their cellphone bill.[40] Limited access to broadband is a major impediment to job creation, economic development, and deployment of digital technologies, particularly in remote rural areas.[41]

CYBERSECURITY

Digitalization, by increasing the number of networked devices, raises serious issues related to cybersecurity. Having more devices connected online increases the risk of cyberattacks not only to connected devices, but also to the system writ large. Successful cyberattacks can have sweeping impacts, as illustrated by the May 2021 ransomware attack on the Colonial Pipeline—the largest refined products pipeline in the United States—which disrupted fuel delivery across the eastern and southern United States and exposed the need to improve the cybersecurity of critical infrastructure.[42] The power sector is already a frequent target of cyberattacks, and further digitalization could create new pathways to take down the power system.[43] Concerns about increased vulnerability and decreased resilience and reliability could hinder the deployment of digital technologies if not addressed. Full prevention of all cyberattacks is almost impossible, but a variety of measures can help reduce the risk profile for connected devices and limit the impacts of potential attacks.[44] For example, information sharing among power companies, the government, device manufacturers, and security researchers could help raise awareness and enhance coordinated efforts to defend against cyberattacks. Interoperable standards could also make it easier to identify and fix security vulnerabilities.[45]

PRIVACY

Digitalization can help us better understand energy use and identify ways to further reduce emissions, but increased data gathering and analysis at the household or facility level could also compromise privacy or disclose proprietary business information. For example, data from a smart meter and appliances could indicate when someone is home and what they are doing. This data could be linked to other personal information databases to develop an in-depth consumer profile, influence a personal credit score, or for other intrusive purposes. Energy and emissions data from businesses could likewise be used to reveal proprietary business operations and practices. Concerns about privacy, like those about security, could slow the pace of digitalization if not addressed. In an effort to quell privacy concerns, both residential and commercial data could be aggregated to protect privacy and prevent the disclosure of proprietary information. How the data is protected, who owns it, and how much information should be shared with other parties are also key data security and privacy questions.

POLICY ACTIONS FOR SCALING DIGITALIZATION

None of the challenges identified in the previous section are insurmountable. While no single policy can address all of these challenges, governments at all levels can take steps to enable climate-beneficial digitalization across the economy. Several of these policies are described more below. (Policies to address cybersecurity and data privacy concerns are outside the scope of this brief on digital decarbonization, but policymakers will need to pursue solutions in those areas as well.)

INVESTING IN RESEARCH, DEVELOPMENT, DEMONSTRATION, AND DEPLOYMENT

The Energy Policy Act of 2020—enacted as part of the Consolidated Appropriations Act of 2021—authorized investments in a range of key technological sectors, including digitalization. Congress should fund these investments in research, development, demonstration, and deployment and ensure robust support for efforts to enable systems-based efficiency and decarbonization through digitalization.[46] These efforts could include transmission and distribution, V2G integrations, smart manufacturing technologies, artificial intelligence, and telecommunications.

Congress should also provide financial incentives for states and localities to deploy intelligent transportation technologies that can improve public transportation and safety, reduce traffic congestion, and reduce vehicle miles traveled. In addition, the U.S. Department of Energy (DOE) should assess the digital preparedness of the building and industrial sectors and provide financial and technical assistance to help small- and medium-sized businesses deploy and utilize digitalization.

DRIVING DEPLOYMENT THROUGH PROCUREMENT

All levels of government—federal, state, and local—should lead by example and move toward requiring agencies to procure digital solutions, document the related energy efficiencies and cost savings, and publicize the lessons learned.[47]

For instance, government agencies should pursue a coordinated smart buildings strategy to deploy digital technologies that will improve operational efficiency and reduce energy costs and greenhouse gas emissions. Best practices should be documented and shared with building managers and engineers, as well as with the general public. In implementing a smart buildings strategy, agencies should leverage energy savings performance contracts (ESPCs), which would allow government agencies to implement energy savings and facility improvements without an upfront cost to taxpayers, as energy service companies (ESCOs) would be paid back through the energy savings. In order to maximize return on investment, energy conservation measures under an ESPC should be broadened to include systems-based efficiency and distributed energy services.

Government agencies should also use their facilities and vehicle fleets as digitalization testbeds for innovative or underutilized products that are just reaching commercialization. This could build on efforts such as the U.S. General Services Administration's Proving Ground program, which evaluates new building technologies in real-world operations and recommends deployment of the most promising technologies across federal facilities.[48] Congress should provide additional funding for the program to enable it to evaluate more projects and deploy more technologies across public buildings.

In addition, government agencies should use digital MRV technologies to help track, identify, and understand their supply chain greenhouse gas emissions. As agencies seek to meet directives requiring them to purchase goods and services with lower greenhouse gas emissions and smaller environmental footprints, requiring digital MRV could help ensure that the procured products and services are verifiably clean.[49] Agency use and validation of digital MRV can also help facilitate its broader use and foster increased uptake across organizations seeking to reduce their supply chain climate impacts.

ENHANCING UNDERSTANDING OF DIGITAL TECHNOLOGIES

Congress should provide additional funding to federal agencies to help increase technical understanding of digital solutions, including by incorporating these technologies in agency outreach activities. For instance, the U.S. Department of Agriculture (USDA) should add precision agriculture to the scope of its cooperative research and extension services. The Department of Energy should likewise be directed to share knowledge and best practices about digitalization with small- and medium-sized businesses.

In addition, a key to unlocking the potential of digitalization is quantifying its systems-based performance so that companies, state public utility commissions, and other stakeholders can better understand relevant use cases, the financial benefits, and associated emissions reductions of adopting digital solutions. Congress should direct DOE and other federal agencies to provide financial and technical assistance to develop real-time measurement and verification protocols for systems-level efficiencies in buildings, industry, power, transportation, and agriculture and land use. Development of these protocols could foster deployment of digital solutions and could empower consumers to make better choices on their energy and resource use.

DEVELOPING INTEROPERABLE STANDARDS AND PROTOCOLS

As connected devices and management systems proliferate, relevant federal agencies and the National Institute of Standards and Technology should work with stakeholders to develop and promote interoperable standards and communication protocols between devices and systems. DOE and the U.S. Environmental Protection Agency (EPA) should also update model building energy codes and efficiency standards to encourage systems-based efficiency and the use of interoperable communication protocols.

INVESTING IN DIGITAL INFRASTRUCTURE

Given the central role of semiconductors and the importance of improving the resilience of critical supply chains, the Administration and Congress should take immediate actions to incentivize the building and modernization of domestic manufacturing and to invest in research and design of new semiconductor technologies.[50] Congress should fully fund the semiconductor manufacturing and research provisions that were adopted in the Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Act (passed as part of the National Defense Authorization Act for Fiscal Year 2021).[51] Congress should also provide an investment tax credit or accelerated depreciation for capital expenditures related to building or modernizing semiconductor manufacturing facilities located in the United States.

Additionally, Congress should increase funding for programs such as the USDA's Rural Development Broadband ReConnect Program to help expand high-speed broadband accessibility and affordability in underserved and unserved areas.[52] Internet service providers who receive these funds should be required to offer an affordable service plan to every consumer. Moreover, Congress should authorize $80 billion to be awarded through competitive bidding systems to deploy high-speed broadband in unserved areas.[53] Congress should also increase funding and improve upon programs that help expand broadband access for low-income households. For instance, the Federal Communications Commission's Lifeline program could allow households to have two connections (e.g., one mobile and one fixed broadband) and designate cable operators—key providers of home broadband—as "Eligible Telecommunications Carriers." Granting this certification would allow cable operators to offer discounts on services to low-income customers.[54] Government agencies can also assist in these efforts. Congress should appropriate any revenues from wireless

BOX 2: Improving the accessibility of climate and environmental data

Digital technologies could help improve understanding of and responses to climate change. Congress should increase funding to improve the quality of climate-related observations, sensors, and networks, as well as emissions- and energy-related datasets. Agencies such as the Federal Emergency Management Agency (FEMA), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA) should develop and provide downscaled, high-quality, consistent data that is publicly available to help enhance local understanding of climate risks.

EPA should also modernize the national air quality monitoring system to better meet the informational needs of air quality managers, researchers, and the public.[6] This could include deploying low-cost air quality sensors to supplement traditional air quality monitoring stations, particularly in disadvantaged communities experiencing local air quality issues.[7]

In addition, the White House should direct federal agencies to inventory climate- and energy-related datasets, ensure they are in an open, machine-readable format, publish the datasets as close to real-time as possible, and make them publicly available. Moreover, as demand for government data increases, there should be a corresponding increase in funding for agencies' web and data hosting capacities.

telecommunication installation leases on federal property into programs that address digital equity.

In addition, it will be critically important to ensure that 5G wireless networks—which will enhance mobile broadband usage, connect network devices that enable digitalization, and create new economic opportunities—are widely deployed and universally available so as not to further exacerbate digital inequity in underserved and unserved areas.[55] Congress should provide funding and a short-term tax credit or accelerated depreciation for capital expenditures related to 5G and fiber investments in low- and medium-income communities and underserved rural communities. Congress should also encourage providers who receive these benefits to promote capacity-sharing partnerships between utilities and service providers to encourage both community broadband access and grid modernization.

More broadly, to accelerate grid modernization with digital technologies, Congress should provide funding through programs such as DOE's State Energy Program for the development and deployment of a digitally connected power grid that is more efficient, resilient, and secure. State public utility commissions and the Federal Energy Regulatory Commission should also encourage the deployment of performance-enhancing digital technologies in the power sector, such as substation modernization projects.

To ensure emissions reductions continue in the ICT sector, Congress should direct DOE and EPA to further develop minimum efficiency standards for network devices, systems, and data centers. DOE should also fund RD&D efforts to help design and implement fog computing resources that can use less energy than cloud computing.

CONCLUSION

The application of digital technologies to physical equipment could enable a systems-based approach that could significantly reduce energy use and carbon emissions across the economy. While digitalization is increasingly seen as a key driver for decarbonization, there are a number of informational, usage, financial, regulatory, technical, infrastructure, security, and privacy barriers to achieving digital technologies' full potential. Realizing the potential of digitalization's role in decarbonization will require policies to increase investments in research, development, demonstration, deployment, infrastructure, and technical outreach and analysis, as well as government leadership by example.

Other Climate Innovation 2050 Resources:

Getting to Zero: A U.S. Climate Agenda
https://www.c2es.org/document/getting-to-zero-a-u-s-climate-agenda/

Pathways to 2050: Scenarios for Decarbonizing the U.S. Economy
https://www.c2es.org/document/pathways-to-2050-scenarios-for-decarbonizing-the-u-s-economy/

Restoring the Economy with Climate Solutions: Recommendations to Congress
https://www.c2es.org/document/restoring-the-economy-with-climate-solutions-recommendations-to-congress/

Climate Policy Priorities for the New Administration and Congress
https://www.c2es.org/document/climate-policy-priorities-for-the-new-administration-and-congress/

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FIGURES/TABLES/BOX HIGHLIGHT

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